

ADA271931

WL-TR-92-4060

CHARACTERIZATION OF EA9396 EPOXY RESIN  
FOR COMPOSITE REPAIR APPLICATIONS

D. Robert Askins

University of Dayton Research Institute  
300 College Park Avenue  
Dayton, Ohio 45469

October 1991

Interim Technical Report for Period November 1988 - May 1991

Approved for public release; distribution is unlimited.

MATERIALS DIRECTORATE  
WRIGHT LABORATORY  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6533



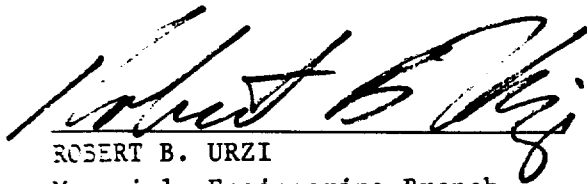
THIS DOCUMENT CONTAINED  
BLANK PAGES THAT HAVE  
BEEN DELETED

## NOTICE

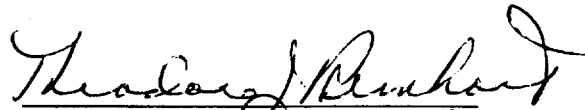
When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented information that may in any way be related thereto.

This report is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.



ROBERT B. URZI  
Materials Engineering Branch  
Systems Support Division  
Materials Directorate



THEODORE J. REINHART, Chief  
Materials Engineering Branch  
Systems Support Division  
Materials Directorate



THOMAS D. COOPER, Chief  
Systems Support Division  
Materials Directorate

If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization, please notify WL/MLSE, WPAFB, OH, 45433-6533 to help us maintain a current mailing list.

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                          |                                                         | Form Approved<br>OMB No 0704-0188                                                 |                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------|
| <small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                          |                                                         |                                                                                   |                                                                  |
| 1. AGENCY USE ONLY (Leave blank)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                          | 2. REPORT DATE<br>October 1991                          |                                                                                   | 3. REPORT TYPE AND DATES COVERED<br>Interim; 11/01/88 - 05/31/91 |
| 4. TITLE AND SUBTITLE<br>CHARACTERIZATION OF EA9396 EPOXY RESIN FOR COMPOSITE REPAIR APPLICATIONS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                          |                                                         | 5. FUNDING NUMBERS<br>C F33615-89-C-5643<br>PE 62102<br>PR 2418<br>TA 04<br>WU 89 |                                                                  |
| 6. AUTHOR(S)<br><br>Robert Askins                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                          |                                                         |                                                                                   |                                                                  |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>University of Dayton Research Institute<br>300 College Park Avenue<br>Dayton, Ohio 45469-0130                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                          |                                                         | 8. PERFORMING ORGANIZATION REPORT NUMBER<br><br>UDR-TR-91-77                      |                                                                  |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>Materials Directorate, Wright Laboratory<br>WL/MLSE, ATTN: Mr. Robert Urzi (513-255-7483)<br>Air Force Systems Command<br>Wright-Patterson AFB, Ohio 45433-6533                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                          |                                                         | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER<br><br>WL-TR-92-4060               |                                                                  |
| 11. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                          |                                                         |                                                                                   |                                                                  |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br><br>Approved for public release; distribution is unlimited.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                          |                                                         | 12b. DISTRIBUTION CODE                                                            |                                                                  |
| 13. ABSTRACT (Maximum 200 words)<br><p>A program was completed to develop material property data for an epoxy resin system for aircraft repair applications. The epoxy resin was developed by Hysol and is designated EA9396. An extensive array of mechanical property data was generated for both glass and graphite reinforced laminates. Comparative properties of three resin lots were obtained. The effect of several processing and environmental variables on laminate properties was determined and the effect of long-term storage was established.</p> <p>All laminates prepared and tested during this program were cured with vacuum-bag pressure only. Mechanical tests were carried out at temperatures ranging from -65°F to 200°F on both dry and humidity-aged specimens. Processing variables that were studied included cure time and temperature, vacuum pressure level, resin impregnation procedure, alternate bagging schemes, alternate bleeder materials, and alternate resin/reinforcement ratios. Environmental variables that were studied included, in addition to humidity-aging, elevated temperature exposure and exposure to a high-intensity heat-pulse.</p> <p style="text-align: right;">(Continued on attached page)</p> |                                                          |                                                         |                                                                                   |                                                                  |
| 14. SUBJECT TERMS<br><br>(See attached page)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                          |                                                         | 15. NUMBER OF PAGES<br>500                                                        |                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                          |                                                         | 16. PRICE CODE                                                                    |                                                                  |
| 17. SECURITY CLASSIFICATION OF REPORT<br>UNCLASSIFIED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 18. SECURITY CLASSIFICATION OF THIS PAGE<br>UNCLASSIFIED | 19. SECURITY CLASSIFICATION OF ABSTRACT<br>UNCLASSIFIED | 20. LIMITATION OF ABSTRACT<br>UNLIMITED                                           |                                                                  |

13. ABSTRACT (Concluded)

Test results indicated that the neat EA9396 resin system absorbed about 9 percent water by weight during humidity aging and that its glass-transition temperature decreased from around 176°C (349°F) to around 107°C (225°F) as a result of moisture absorption for a 200°F/45-minute cure. Storage at temperatures ranging from 72°F to 120°F for up to 24 months had no adverse effect on achievable interlaminar shear strength. Pot/work life of the resin was only slightly shorter after 18 months than it was for fresh resin and exceeded 90 minutes at 72°F and 40 minutes at 100°F. Mechanical properties were very consistent from batch-to-batch. The absorption of moisture significantly lowered most mechanical properties, particularly with glass reinforcement.

14. SUBJECT TERMS (Concluded)

|             |               |                      |
|-------------|---------------|----------------------|
| Epoxy       | Tg            | Glass                |
| Two-Part    | Bearing       | Graphite             |
| Repair      | Dry           | Elevated Temperature |
| Composite   | Wet           | Vacuum Bag           |
| Wet Layup   | Storage Life  | Humidity Aging       |
| Properties  | Pot Life      | Processing           |
| Mechanical  | Laminate      | Temperature          |
| Physical    | Honeycomb     | Pressure             |
| Tensile     | Sandwich      | Thermal Flash        |
| Compressive | Reinforcement | Cure                 |
| Shear       |               |                      |



## PREFACE

This report covers the work performed during the period from November 1988 to May 1991 under Air Force Contract Nos. F33615-86-C-5031 and F33615-89-C-5643, Project 7381. The work was administered under the direction of the Systems Support Division of the Air Force Materials Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. William Purcell (WL/MLSE) was the Program Project Engineer.

The Principal Investigator on this program was D. Robert Askins. The major portion of the laboratory work was conducted by Messrs. L. Dee Pike, Jr., Gary Andrews, and Don Byrge.

This report was submitted by the author in October 1991. The contractor's report number is UDR-TR-91-77.

DTIC QUALITY INSPECTED 8

|                    |                                            |
|--------------------|--------------------------------------------|
| Accession For      |                                            |
| NTIS GRA&I         | <input checked="checked" type="checkbox"/> |
| DTIC TAB           | <input type="checkbox"/>                   |
| Unannounced        | <input type="checkbox"/>                   |
| Justification      |                                            |
| By                 |                                            |
| Distribution/      |                                            |
| Availability Codes |                                            |
| Dist               | Avail and/or<br>Special                    |
| A-1                |                                            |

## TABLE OF CONTENTS

| <u>SECTION</u> |                                                                       | <u>PAGE</u> |
|----------------|-----------------------------------------------------------------------|-------------|
| 1              | INTRODUCTION                                                          | 1           |
| 2              | APPROACH                                                              | 2           |
| 2.1            | MATERIALS                                                             | 2           |
| 2.2            | EXPERIMENTAL DESIGN                                                   | 4           |
| 2.3            | TEST METHODS                                                          | 4           |
| 2.3.1          | Interlaminar Shear                                                    | 8           |
| 2.3.2          | Glass Transition Temperature                                          | 8           |
| 2.3.3          | Bearing Strength                                                      | 9           |
| 2.3.4          | Viscosity                                                             | 9           |
| 2.3.5          | Viscosity Curing Profile                                              | 9           |
| 2.3.6          | Differential Scanning Calorimetry (DSC)                               | 9           |
| 2.3.7          | Fourier Transform Infrared (FTIR)<br>Spectroscopy                     | 10          |
| 2.3.8          | High Pressure Liquid Chromatography (HPLC)                            | 10          |
| 2.4            | PROCESSING PROCEDURES                                                 | 11          |
| 3              | DISCUSSION OF RESULTS                                                 | 12          |
| 3.1            | LAMINATE PHYSICAL PROPERTIES                                          | 12          |
| 3.2            | BATCH-TO-BATCH MECHANICAL PROPERTY<br>COMPARISONS                     | 14          |
| 3.2.1          | Tension                                                               | 14          |
| 3.2.2          | Compression                                                           | 14          |
| 3.2.3          | Inplane Shear                                                         | 14          |
| 3.2.4          | Interlaminar Shear                                                    | 14          |
| 3.3            | GLASS TRANSITION TEMPERATURE                                          | 31          |
| 3.4            | BEARING STRENGTH                                                      | 31          |
| 3.5            | EFFECT OF NONBASELINE CURE/<br>PROCESSING CONDITIONS                  | 31          |
| 3.5.1          | Effect of Cure Temperature on Degree of<br>Cure by DSC                | 35          |
| 3.5.2          | Effect of Cure Time and Temperature on<br>Interlaminar Shear Strength | 40          |
| 3.5.3          | Effect of Cure Vacuum Pressure on<br>Interlaminar Shear Strength      | 40          |
| 3.6            | RESIN POT/WORK LIFE                                                   | 40          |
| 3.7            | EFFECT OF STORAGE TIME AND TEMPERATURE                                | 43          |
| 3.8            | EFFECT OF FIBER CONTENT                                               | 55          |

## TABLE OF CONTENTS (Continued)

| <u>SECTION</u>        |                                                             | <u>PAGE</u> |
|-----------------------|-------------------------------------------------------------|-------------|
| 3.9                   | ALTERNATE IMPREGNATION AND BAGGING<br>SCHEMES               | 58          |
| 3.9.1                 | Alternate Ply Impregnation Procedure                        | 58          |
| 3.9.2                 | Alternative Bleeder Materials                               | 61          |
| 3.9.3                 | Alternative Bagging Schemes                                 | 61          |
| 3.10                  | HONEYCOMB SANDWICH BEHAVIOR                                 | 66          |
| 3.10.1                | Effect of Skin Cocuring on Edgewise<br>Compression Behavior | 66          |
| 3.10.2                | Effect of Fillet Size on Flatwise<br>Tensile Strength       | 69          |
| 3.11                  | EFFECT OF SIZING ON GLASS FABRIC<br>LAMINATES               | 72          |
| 3.12                  | EFFECT OF NON-BASELINE ENVIRONMENTAL<br>EXPOSURE            | 74          |
| 3.12.1                | Elevated Temperature Exposure                               | 74          |
| 3.12.2                | Exposure to Thermal Pulse                                   | 74          |
| 4                     | CONCLUSIONS                                                 | 81          |
| 5                     | REFERENCES                                                  | 82          |
| <br><u>APPENDICES</u> |                                                             |             |
| A                     | STANDARD LAMINATE PROCESSING PROCEDURE                      | A-1         |
| B                     | NONSTANDARD LAMINATE PROCESSING<br>PROCEDURES               | B-1         |
| B.1                   | NONSTANDARD CURE TIME/TEMPERATURE                           | B-1         |
| B.2                   | NONSTANDARD CURE VACUUM PRESSURES                           | B-1         |
| B.3                   | NONSTANDARD FIBER CONTENT                                   | B-1         |
| B.4                   | NONSTANDARD PLY IMPREGNATION<br>PROCEDURES                  | B-2         |
| B.5                   | NONSTANDARD BLEEDER MATERIAL                                | B-3         |
| B.6                   | NONSTANDARD BAGGING SCHEMES                                 | B-3         |
| C                     | LAMINATE PHYSICAL PROPERTIES                                | C-1         |
| D                     | INDIVIDUAL SPECIMEN TENSION PROPERTIES,<br>BASELINE         | D-1         |

## TABLE OF CONTENTS (Continued)

| <u>SECTION</u>                                                                                                      | <u>PAGE</u> |
|---------------------------------------------------------------------------------------------------------------------|-------------|
| <u>APPENDICES</u>                                                                                                   |             |
| E      INDIVIDUAL SPECIMEN COMPRESSION PROPERTIES,<br>BASELINE                                                      | E-1         |
| F      INDIVIDUAL SPECIMEN $\pm 45^\circ$ TENSION/INPLANE<br>SHEAR PROPERTIES, BASELINE                             | F-1         |
| G      INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR<br>PROPERTIES, BASELINE                                               | G-1         |
| H      INDIVIDUAL SPECIMEN BEARING PROPERTIES,<br>BASELINE                                                          | H-1         |
| I      INDIVIDUAL SPECIMEN GLASS TRANSITION<br>TEMPERATURE MEASUREMENTS                                             | I-1         |
| J      INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR<br>STRENGTHS, EFFECT OF CURE TIME/TEMPERATURE/<br>PRESSURE VARIATIONS | J-1         |
| K      INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR<br>STRENGTH, EFFECT OF EXPOSURE TO 177°C (350°F)                      | K-1         |
| L      INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR<br>STRENGTH, EFFECT OF RESIN/FIBER CONTENT                            | L-1         |
| M      INDIVIDUAL SPECIMEN PROPERTIES, EFFECT OF<br>STORAGE TIME AND TEMPERATURE                                    | M-1         |
| M.1    HPLC SPECTRA                                                                                                 | M-1         |
| M.2    BROOKFIELD VISCOSITY MEASUREMENTS                                                                            | M-1         |
| M.3    HEAT OF REACTION TESTS (DSC)                                                                                 | M-2         |
| M.4    FTIR SPECTRA                                                                                                 | M-2         |
| M.5    RHEOMETRIC VISCOSITY PROFILES                                                                                | M-2         |
| M.6    INTERLAMINAR SHEAR STRENGTH                                                                                  | M-3         |
| N      INDIVIDUAL SPECIMEN HONEYCOMB FLATWISE<br>TENSILE PROPERTIES, EFFECT OF ADHESIVE<br>FILLET SIZE              | N-1         |

## TABLE OF CONTENTS (Concluded)

| <u>SECTION</u>    |                                                                                                                                     | <u>PAGE</u> |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------|-------------|
| <u>APPENDICES</u> |                                                                                                                                     |             |
| O                 | INDIVIDUAL SPECIMEN HONEYCOMB SANDWICH<br>EDGEWISE COMPRESSION PROPERTIES, EFFECT OF<br>COCURING VS. SECONDARY BONDING              | O-1         |
| P                 | INDIVIDUAL SPECIMEN COMPRESSION PROPERTIES,<br>EFFECT OF THERMAL PULSE                                                              | P-1         |
| Q                 | INDIVIDUAL SPECIMEN MECHANICAL PROPERTIES,<br>EFFECT OF SILANE SIZING ON ENVIRONMENTAL<br>DEGRADATION OF GLASS REINFORCED LAMINATES | Q-1         |
| R                 | COMPUTATION OF BLEEDER ABSORPTIVITY                                                                                                 | R-1         |

## LIST OF FIGURES

| <u>FIGURE</u> |                                                                                                       | <u>PAGE</u> |
|---------------|-------------------------------------------------------------------------------------------------------|-------------|
| 1             | Typical DMA Cure with Tg Value                                                                        | 33          |
| 2             | Typical Dynamic and Isothermal Heat Release Test Results for Curing of EA9396                         | 37          |
| 3             | Dynamic DSC Residual Heat Release Test for Postcuring of EA9396 After Isothermal Cure at 82°C (180°F) | 38          |
| 4             | HPLC Spectra of EA9396, Part A                                                                        | 45          |
| 5             | FTIR Spectra of EA9396, Part A                                                                        | 47          |
| 6             | FTIR Spectra of EA9396, Part B                                                                        | 48          |
| 7             | Rheometrics Viscosity Cure Profile for Fresh EA9396 Resin                                             | 49          |
| 8             | Heat Release Test Results for Fresh EA9396 Resin                                                      | 51          |
| 9             | Comparison of Cocured and Secondarily Bonded Honeycomb Sandwich Skins                                 | 67          |
| 10            | Effect of Adhesive on Fillet Size and Flatwise Tensile Strength of Sandwich Constructions             | 73          |
| A.1           | Typical Vacuum Bag Lay-up Scheme for Curing EA9396 Composite Laminates                                | A-7         |
| A.2           | Heat-Up Curve for Laminate Cure                                                                       | A-8         |
| B.1           | Nonstandard Vacuum Bag Lay-up Scheme with Perforated Bleeder/Breather Barrier Film                    | B-9         |
| B.2           | Nonstandard Vacuum Bag Lay-up Using Double-Bag Scheme                                                 | B-10        |
| I.1           | Determination of Tg for Specimen 1-2, Batch 1, Dry Condition                                          | I-3         |
| I.2           | Determination of Tg for Specimen 1-4, Batch 1, Dry Condition                                          | I-4         |
| I.3           | Determination of Tg for Specimen 1-6, Batch 1, Dry Condition                                          | I-5         |

## LIST OF FIGURES (Continued)

| <u>FIGURE</u> |                                                              | <u>PAGE</u> |
|---------------|--------------------------------------------------------------|-------------|
| I.4           | Determination of Tg for Specimen 2-2, Batch 2, Dry Condition | I-6         |
| I.5           | Determination of Tg for Specimen 2-4, Batch 2, Dry Condition | I-7         |
| I.6           | Determination of Tg for Specimen 2-6, Batch 2, Dry Condition | I-8         |
| I.7           | Determination of Tg for Specimen 3-2, Batch 3, Dry Condition | I-9         |
| I.8           | Determination of Tg for Specimen 3-4, Batch 3, Dry Condition | I-10        |
| I.9           | Determination of Tg for Specimen 3-6, Batch 3, Dry Condition | I-11        |
| I.10          | Determination of Tg for Specimen 1-1, Batch 1, Wet Condition | I-12        |
| I.11          | Determination of Tg for Specimen 1-3, Batch 1, Wet Condition | I-13        |
| I.12          | Determination of Tg for Specimen 1-5, Batch 1, Wet Condition | I-14        |
| I.13          | Determination of Tg for Specimen 2-1, Batch 2, Wet Condition | I-15        |
| I.14          | Determination of Tg for Specimen 2-3, Batch 2, Wet Condition | I-16        |
| I.15          | Determination of Tg for Specimen 2-5, Batch 2, Wet Condition | I-17        |
| I.16          | Determination of Tg for Specimen 3-1, Batch 3, Wet Condition | I-18        |
| I.17          | Determination of Tg for Specimen 3-3, Batch 3, Wet Condition | I-19        |
| I.18          | Determination of Tg for Specimen 3-5, Batch 3, Wet Condition | I-20        |
| M.1           | Initial HPLC Spectra for EA9396 Parts A and B                | M-26        |
| M.2           | HPLC Spectra for EA9396, Part A After 1 Month Storage        | M-27        |
| M.3           | HPLC Spectra for EA9396, Part A After 6 Months Storage       | M-28        |
| M.4           | HPLC Spectra for EA9396, Part A After 12 Months Storage      | M-29        |
| M.5           | HPLC Spectra for EA9396, Part A After 18 Months Storage      | M-30        |
| M.6           | HPLC Spectra for EA9396, Part A After 24 Months Storage      | M-31        |

# LIST OF FIGURES (Continued)

| <u>FIGURE</u> |                                                                       | <u>PAGE</u> |
|---------------|-----------------------------------------------------------------------|-------------|
| M.7           | Heat Release Curve for EA9396 Stored at 22°C (72°F)<br>for 1 Month    | M-32        |
| M.8           | Heat Release Curve for EA9396 Stored at 38°C (100°F)<br>for 1 Month   | M-33        |
| M.9           | Heat Release Curve for EA9396 Stored at 49°C (120°F)<br>for 1 Month   | M-34        |
| M.10          | Heat Release Curve for EA9396 Stored at 22°C (72°F)<br>for 3 Months   | M-35        |
| M.11          | Heat Release Curve for EA9396 Stored at 22°C (72°F)<br>for 6 Months   | M-36        |
| M.12          | Heat Release Curve for EA9396 Stored at 38°C (100°F)<br>for 6 Months  | M-37        |
| M.13          | Heat Release Curve for EA9396 Stored at 49°C (120°F)<br>for 6 Months  | M-38        |
| M.14          | Heat Release Curve for EA9396 Stored at 22°C (72°F)<br>for 12 Months  | M-39        |
| M.15          | Heat Release Curve for EA9396 Stored at 38°C (100°F)<br>for 12 Months | M-40        |
| M.16          | Heat Release Curve for EA9396 Stored at 49°C (120°F)<br>for 12 Months | M-41        |
| M.17          | Heat Release Curve for EA9396 Stored at 22°C (72°F)<br>for 18 Months  | M-42        |
| M.18          | Heat Release Curve for EA9396 Stored at 38°C (100°F)<br>for 18 Months | M-43        |
| M.19          | Heat Release Curve for EA9396 Stored at 49°C (120°F)<br>for 18 Months | M-44        |
| M.20          | Heat Release Curve for EA9396 Stored at 22°C (72°F)<br>for 24 Months  | M-45        |



## LIST OF FIGURES (Continued)

| <b><u>FIGURE</u></b> |                                                                       | <b><u>PAGE</u></b> |
|----------------------|-----------------------------------------------------------------------|--------------------|
| M.21                 | Heat Release Curve for EA9396 Stored at 38°C (100°F) for 24 Months    | M-46               |
| M.22                 | Heat Release Curve for EA9396 Stored at 49°C (120°F) for 24 Months    | M-47               |
| M.23                 | FTIR Spectra for EA9396, Part A, Initial                              | M-48               |
| M.24                 | FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 1 Month   | M-49               |
| M.25                 | FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 1 Month   | M-50               |
| M.26                 | FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 3 Months   | M-51               |
| M.27                 | FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 6 Months   | M-52               |
| M.28                 | FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 6 Months  | M-53               |
| M.29                 | FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 6 Months  | M-54               |
| M.30                 | FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 12 Months  | M-55               |
| M.31                 | FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 12 Months | M-56               |
| M.32                 | FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 12 Months | M-57               |
| M.33                 | FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 18 Months  | M-58               |
| M.34                 | FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 18 Months | M-59               |

# LIST OF FIGURES (Continued)

| <u>FIGURE</u> |                                                                       | <u>PAGE</u> |
|---------------|-----------------------------------------------------------------------|-------------|
| M.35          | FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 18 Months | M-60        |
| M.36          | FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 24 Months  | M-61        |
| M.37          | FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 24 Months | M-62        |
| M.38          | FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 24 Months | M-63        |
| M.39          | FTIR Spectra for EA9396, Part B, Initial                              | M-64        |
| M.40          | FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 1 Month   | M-65        |
| M.41          | FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 1 Month   | M-66        |
| M.42          | FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 3 Months   | M-67        |
| M.43          | FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 6 Months   | M-68        |
| M.44          | FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 6 Months  | M-69        |
| M.45          | FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 6 Months  | M-70        |
| M.46          | FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 12 Months  | M-71        |
| M.47          | FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 12 Months | M-72        |
| M.48          | FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 12 Months | M-73        |

## LIST OF FIGURES (Continued)

| <u>FIGURE</u> |                                                                               | <u>PAGE</u> |
|---------------|-------------------------------------------------------------------------------|-------------|
| M.49          | FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 18 Months          | M-74        |
| M.50          | FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 18 Months         | M-75        |
| M.51          | FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 18 Months         | M-76        |
| M.52          | FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 24 Months          | M-77        |
| M.53          | FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 24 Months         | M-78        |
| M.54          | FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 24 Months         | M-79        |
| M.55          | Viscosity Cure Profile for EA9396, Initial                                    | M-80        |
| M.56          | Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 1 Month  | M-81        |
| M.57          | Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 1 Month   | M-82        |
| M.58          | Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 3 Month   | M-83        |
| M.59          | Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 6 Months  | M-84        |
| M.60          | Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 6 Months | M-85        |
| M.61          | Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 6 Months | M-86        |
| M.62          | Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 12 Months | M-87        |

## LIST OF FIGURES (Concluded)

| <u>FIGURE</u> |                                                                                | <u>PAGE</u> |
|---------------|--------------------------------------------------------------------------------|-------------|
| M.63          | Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 12 Months | M-88        |
| M.64          | Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 12 Months | M-89        |
| M.65          | Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 18 Months  | M-90        |
| M.66          | Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 18 Months | M-91        |
| M.67          | Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 18 Months | M-92        |
| M.68          | Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 24 Months  | M-93        |
| M.69          | Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 24 Months | M-94        |
| M.70          | Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 24 Months | M-95        |
| O.1           | Types of Failure Modes Observed in Edgewise Compression Tests                  | O-2         |
| Q.1           | Failure Location of Tensile Specimens That Failed Inside Tab Area              | Q-11        |

## LIST OF TABLES

| <b><u>TABLE</u></b> |                                                                                                                                                  | <b><u>PAGE</u></b> |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| 1                   | Glass and Graphite Fabric Reinforcement Description                                                                                              | 3                  |
| 2                   | Test Matrix for Batch-to-Batch Comparisons and Baseline Mechanical Property Data                                                                 | 5                  |
| 3                   | Summary of Supplemental Tests to Determine Specific Materials Properties and the Effects of Processing and Environmental Variables on Properties | 6                  |
| 4                   | Physical Properties Summary for Laminates Prepared with Baseline Processing Procedure                                                            | 13                 |
| 5                   | Baseline Longitudinal (Warp) Tensile Properties of Glass Reinforced E-7781/EA9396 Composite Material                                             | 15                 |
| 6                   | Baseline Transverse (Fill) Tensile Properties of Glass Reinforced E-7781/EA9396 Composite Material                                               | 16                 |
| 7                   | Baseline Transverse (Fill) Tensile Properties of Glass Reinforced E-7781/EA9396 Composite Material                                               | 17                 |
| 8                   | Baseline Longitudinal (Warp) Tensile Properties of Graphite Reinforced T300-W133/EA9396 Composite Material                                       | 18                 |
| 9                   | Baseline Transverse (Fill) Tensile Properties of Graphite Reinforced T300-W133/EA9396 Composite Material                                         | 19                 |
| 10                  | Baseline Transverse (Fill) Tensile Properties of Graphite Reinforced T300-W133/EA9396 Composite Material                                         | 20                 |
| 11                  | Baseline Longitudinal (Warp) Compressive Properties of Glass Reinforced E-7781/EA9396 Composite Material                                         | 21                 |
| 12                  | Baseline Transverse (Fill) Compressive Properties of Glass Reinforced E-7781/EA9396 Composite Material                                           | 22                 |
| 13                  | Baseline Transverse (Fill) Compressive Properties of Glass Reinforced E-7781/EA9396 Composite Material                                           | 23                 |
| 14                  | Baseline Longitudinal (Warp) Compressive Properties of Graphite Reinforced T300-W133/EA9396 Composite Material                                   | 24                 |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                              | <u>PAGE</u> |
|--------------|--------------------------------------------------------------------------------------------------------------|-------------|
| 15           | Baseline Transverse (Fill) Compressive Properties of Graphite Reinforced T300-W133/EA9396 Composite Material | 25          |
| 16           | Baseline Transverse (Fill) Compressive Properties of Graphite Reinforced T300-W133/EA9396 Composite Material | 26          |
| 17           | Baseline In-Plane Shear Properties of Glass Reinforced E-7781/EA9396 Composite Material                      | 27          |
| 18           | Baseline In-Plane Shear Properties of Glass Reinforced E-7781/EA9396 Composite Material                      | 28          |
| 19           | Baseline In-Plane Shear Properties of Graphite Reinforced T300-W133/EA9396 Composite Material                | 29          |
| 20           | Baseline In-Plane Shear Properties of Graphite Reinforced T300-W133/EA9396 Composite Material                | 30          |
| 21           | Baseline Interlaminar Shear Properties of EA9396 Composite Laminates                                         | 32          |
| 22           | Glass Transition Temperature of EA9396 Neat Resin Castings                                                   | 34          |
| 23           | Room Temperature Bearing Strength of EA9396 Composite Material                                               | 34          |
| 24           | Effect of Temperature on Cure Exotherm Behavior of EA9396 Neat Resin                                         | 36          |
| 25           | Effect of Cure Temperature on Interlaminar Shear Strength of Graphite Reinforced EA9396 Laminates            | 41          |
| 26           | Effect of Cure Pressure on Laminate Physical Characteristics and Interlaminar Shear Strength                 | 42          |
| 27           | Pot Life Observations for 200-Gram Batch of EA9396                                                           | 44          |
| 28           | Work Life Observations of 12-Ply Graphite Laminate Impregnated with EA9396 A/B Resin                         | 44          |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                                          | <u>PAGE</u> |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| 29           | Effect of Long-Term Storage at Elevated Temperature on the Curing Viscosity Profile Characteristics of EA9396                                            | 50          |
| 30           | Effect of Long-Term Storage at Elevated Temperature on the Calorimetric Cure Characteristics of EA9396                                                   | 52          |
| 31           | Effect of Long-Term Storage at Elevated Temperature on the Viscosity of EA9396, Part A                                                                   | 53          |
| 32           | Effect of Long-Term Storage at Elevated Temperature on Achievable Interlaminar Shear Strength of Graphite-Reinforced T300-W133/EA9396 Composite Material | 54          |
| 33           | Effect of Resin/Fiber Content on Interlaminar Shear Strength of EA9396 Composite Laminates                                                               | 56          |
| 34           | Effect of Resin/Fiber Content on 22°C (72°F), Dry Compressive Properties of EA9396 Laminates                                                             | 57          |
| 35           | Physical Properties Summary of Laminates Prepared with Variant Processing Procedures                                                                     | 60          |
| 36           | Physical Properties Summary of Laminates Prepared with Alternative Bleeder Material                                                                      | 62          |
| 37           | Effect of Perforated Film Processing Modification on Laminate Properties                                                                                 | 64          |
| 38           | Effect of Double-Bag Processing Modification on Laminate Properties                                                                                      | 65          |
| 39           | Effect of Skin Bonding Approach on Edgewise Compression Strength                                                                                         | 70          |
| 40           | Effect of Adhesive Application Rate on Flatwise Tensile Strength of Honeycomb Sandwich                                                                   | 71          |
| 41           | Longitudinal (Warp) Tensile Properties of A1100-Sized Glass Reinforced E-7781/EA9396 Composite Material                                                  | 75          |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                         | <u>PAGE</u> |
|--------------|-------------------------------------------------------------------------------------------------------------------------|-------------|
| 42           | In-Plane Shear Properties of A1100-Sized Glass Reinforced E-7781/EA9396 Composite Material                              | 75          |
| 43           | Interlaminar Shear Properties of A1100-Sized Glass Reinforced E-7781/EA9396 Composite Material                          | 76          |
| 44           | Effect of 177°C (350°F) Cure Cycles on Interlaminar Shear Strength of EA9396 Composite Laminates                        | 77          |
| 45           | Effect of Radiant Thermal Pulse on Compression Strength of Glass-Reinforced E-7781/EA9396 Composite Material            | 78          |
| 46           | Effect of Radiant Thermal Pulse on Compression Strength of Graphite-Reinforced T300-W133/EA9396 Composite Material      | 79          |
| A.1          | Laminate Thicknesses and Dimensions                                                                                     | A-5         |
| A.2          | EA9396 Baseline Laminate Fabrication Parameters                                                                         | A-6         |
| B.1          | Laminates Cured at Nonstandard Times/Temperatures                                                                       | B-6         |
| B.2          | Laminates Cured Under Nonstandard Vacuum Pressure                                                                       | B-6         |
| B.3          | Laminates Prepared with Nonstandard Bleeder Ply in Resin Ratios                                                         | B-7         |
| B.4          | Laminates Made with Nonstandard Bleeder Material                                                                        | B-8         |
| C.1          | Physical Properties of T300-W133 Graphite Fabric Reinforced Laminates                                                   | C-2         |
| C.2          | Physical Properties of E-7781 Glass Fabric Reinforced Laminates                                                         | C-5         |
| D.1          | Individual Specimen Tensile Test Results, Baseline Tests, Glass Reinforcement, Batch 1, Warp Direction, 22°C (72°F) Dry | D-2         |
| D.2          | Individual Specimen Tensile Test Results, Baseline Tests, Glass Reinforcement, Batch 2, Warp Direction, 22°C (72°F) Dry | D-3         |



# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                              | <u>PAGE</u> |
|--------------|------------------------------------------------------------------------------------------------------------------------------|-------------|
| D.3          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Warp Direction, 22°C (72°F) Dry   | D-4         |
| D.4          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Warp Direction, 22°C (72°F) Wet   | D-5         |
| D.5          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Warp Direction, 22°C (72°F) Wet   | D-6         |
| D.6          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Warp Direction, 22°C (72°F) Wet   | D-7         |
| D.7          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Fill Direction, -54°C (-65°F) Dry | D-8         |
| D.8          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Fill Direction, -54°C (-65°F) Dry | D-9         |
| D.9          | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Fill Direction, -54°C (-65°F) Dry | D-10        |
| D.10         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Fill Direction, 22°C (72°F) Dry   | D-11        |
| D.11         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Fill Direction, 22°C (72°F) Dry   | D-12        |
| D.12         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Fill Direction, 22°C (72°F) Dry   | D-13        |
| D.13         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Fill Direction, 93°C (200°F) Dry  | D-14        |
| D.14         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Fill Direction, 93°C (200°F) Dry  | D-15        |
| D.15         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Fill Direction, 93°C (200°F) Dry  | D-16        |
| D.16         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Fill Direction, -54°C (-65°F) Wet | D-17        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                  | <u>PAGE</u> |
|--------------|----------------------------------------------------------------------------------------------------------------------------------|-------------|
| D.17         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Fill Direction, -54°C (-65°F) Wet     | D-18        |
| D.18         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Fill Direction, -54°C (-65°F) Wet     | D-19        |
| D.19         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Fill Direction, 22°C (72°F) Wet       | D-20        |
| D.20         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Fill Direction, 22°C (72°F) Wet       | D-21        |
| D.21         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Fill Direction, 22°C (72°F) Wet       | D-22        |
| D.22         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 1, Fill Direction, 93°C (200°F) Wet      | D-23        |
| D.23         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 2, Fill Direction, 93°C (200°F) Wet      | D-24        |
| D.24         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Glass Reinforcement, Batch 3, Fill Direction, 93°C (200°F) Wet      | D-25        |
| D.25         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 1, Warp Direction,<br>22°C (72°F) Dry | D-26        |
| D.26         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 2, Warp Direction,<br>22°C (72°F) Dry | D-27        |
| D.27         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 3, Warp Direction,<br>22°C (72°F) Dry | D-28        |
| D.28         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 1, Warp Direction,<br>22°C (72°F) Wet | D-29        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                              | <u>PAGE</u> |
|--------------|------------------------------------------------------------------------------------------------------------------------------|-------------|
| D.29         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, Warp Direction, 22°C (72°F) Wet   | D-30        |
| D.30         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, Warp Direction, 22°C (72°F) Wet   | D-31        |
| D.31         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, Fill Direction, -54°C (-65°F) Dry | D-32        |
| D.32         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, Fill Direction, -54°C (-65°F) Dry | D-33        |
| D.33         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, Fill Direction, -54°C (-65°F) Dry | D-34        |
| D.34         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, Fill Direction, 22°C (72°F) Dry   | D-35        |
| D.35         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, Fill Direction, 22°C (72°F) Dry   | D-36        |
| D.36         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, Fill Direction, 22°C (72°F) Dry   | D-37        |
| D.37         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, Fill Direction, 93°C (200°F) Dry  | D-38        |
| D.38         | Individual Specimen Tensile Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, Fill Direction, 93°C (200°F) Dry  | D-39        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                    | <u>PAGE</u> |
|--------------|------------------------------------------------------------------------------------------------------------------------------------|-------------|
| D.39         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 3, Fill Direction,<br>93°C (200°F) Dry  | D-40        |
| D.40         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 1, Fill Direction,<br>-54°C (-65°F) Wet | D-41        |
| D.41         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 2, Fill Direction,<br>-54°C (-65°F) Wet | D-42        |
| D.42         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 3, Fill Direction,<br>-54°C (-65°F) Wet | D-43        |
| D.43         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 1, Fill Direction,<br>22°C (72°F) Wet   | D-44        |
| D.44         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 2, Fill Direction,<br>22°C (72°F) Wet   | D-45        |
| D.45         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 3, Fill Direction,<br>22°C (72°F) Wet   | D-46        |
| D.46         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 1, Fill Direction,<br>93°C (200°F) Wet  | D-47        |
| D.47         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 2, Fill Direction,<br>93°C (200°F) Wet  | D-48        |
| D.48         | Individual Specimen Tensile Test Results, Baseline Tests,<br>Graphite Reinforcement, Batch 3, Fill Direction,<br>93°C (200°F) Wet  | D-49        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                               | <u>PAGE</u> |
|--------------|-------------------------------------------------------------------------------------------------------------------------------|-------------|
| E.1          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Warp Direction, Batch 1, 22°C (72°F) Dry   | E-2         |
| E.2          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Warp Direction, Batch 2, 22°C (72°F) Dry   | E-3         |
| E.3          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Warp Direction, Batch 3, 22°C (72°F) Dry   | E-4         |
| E.4          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Warp Direction, Batch 1, 22°C (72°F) Wet   | E-5         |
| E.5          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Warp Direction, Batch 2, 22°C (72°F) Wet   | E-6         |
| E.6          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Warp Direction, Batch 3, 22°C (72°F) Wet   | E-7         |
| E.7          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 1, -54°C (-65°F) Dry | E-8         |
| E.8          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 2, -54°C (-65°F) Dry | E-9         |
| E.9          | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 3, -54°C (-65°F) Dry | E-10        |
| E.10         | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 1, 22°C (72°F) Dry   | E-11        |
| E.11         | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 2, 22°C (72°F) Dry   | E-12        |
| E.12         | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 3, 22°C (72°F) Dry   | E-13        |
| E.13         | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 1, 93°C (200°F) Dry  | E-14        |
| E.14         | Individual Specimen Compression Test Results, Baseline Tests, Glass Reinforcement, Fill Direction, Batch 2, 93°C (200°F) Dry  | E-15        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                      | <u>PAGE</u> |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------|
| E.15         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 3, 93°C (200°F) Dry      | E-16        |
| E.16         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 1, -54°C (-65°F) Wet     | E-17        |
| E.17         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 2, -54°C (-65°F) Wet     | E-18        |
| E.18         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 3, -54°C (-65°F) Wet     | E-19        |
| E.19         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 1, 22°C (72°F) Wet       | E-20        |
| E.20         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 3, 22°C (72°F) Wet       | E-21        |
| E.21         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 1, 93°C (200°F) Wet      | E-22        |
| E.22         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 2, 93°C (200°F) Wet      | E-23        |
| E.23         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 2, 93°C (200°F) Wet      | E-24        |
| E.24         | Individual Specimen Compression Test Results, Baseline Tests,<br>Glass Reinforcement, Fill Direction, Batch 3, 93°C (200°F) Wet      | E-25        |
| E.25         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Warp Direction, Batch 1,<br>22°C (72°F) Dry | E-26        |
| E.26         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Warp Direction, Batch 2,<br>22°C (72°F) Dry | E-27        |
| E.27         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Warp Direction, Batch 3,<br>22°C (72°F) Dry | E-28        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                  | <u>PAGE</u> |
|--------------|----------------------------------------------------------------------------------------------------------------------------------|-------------|
| E.28         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Warp Direction, Batch 1, 22°C (72°F) Wet   | E-29        |
| E.29         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Warp Direction, Batch 2, 22°C (72°F) Wet   | E-30        |
| E.30         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Warp Direction, Batch 3, 22°C (72°F) Wet   | E-31        |
| E.31         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 1, -54°C (-65°F) Dry | E-32        |
| E.32         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 2, -54°C (-65°F) Dry | E-33        |
| E.33         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 3, -54°C (-65°F) Dry | E-34        |
| E.34         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 1, 22°C (72°F) Dry   | E-35        |
| E.35         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 2, 22°C (72°F) Dry   | E-36        |
| E.36         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 3, 22°C (72°F) Dry   | E-37        |
| E.37         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 1, 93°C (200°F) Dry  | E-38        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                        | <u>PAGE</u> |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------|-------------|
| E.38         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 2,<br>93°C (200°F) Dry  | E-39        |
| E.39         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 3,<br>93°C (200°F) Dry  | E-40        |
| E.40         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 1,<br>-54°C (-65°F) Wet | E-41        |
| E.41         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 2,<br>-54°C (-65°F) Wet | E-42        |
| E.42         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 3,<br>-54°C (-65°F) Wet | E-43        |
| E.43         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 1,<br>22°C (72°F) Wet   | E-44        |
| E.44         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 2,<br>22°C (72°F) Wet   | E-45        |
| E.45         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 3,<br>22°C (72°F) Wet   | E-46        |
| E.46         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 1,<br>93°C (200°F) Wet  | E-47        |
| E.47         | Individual Specimen Compression Test Results, Baseline Tests,<br>Graphite Reinforcement, Fill Direction, Batch 2,<br>93°C (200°F) Wet  | E-48        |



# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                 | <u>PAGE</u> |
|--------------|---------------------------------------------------------------------------------------------------------------------------------|-------------|
| E.48         | Individual Specimen Compression Test Results, Baseline Tests, Graphite Reinforcement, Fill Direction, Batch 3, 93°C (200°F) Wet | E-49        |
| F.1          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, -54°C (-65°F) Dry                 | F-2         |
| F.2          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, -54°C (-65°F) Dry                 | F-3         |
| F.3          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, -54°C (-65°F) Dry                 | F-4         |
| F.4          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 22°C (72°F) Dry                   | F-5         |
| F.5          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 22°C (72°F) Dry                   | F-6         |
| F.6          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 22°C (72°F) Dry                   | F-7         |
| F.7          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 93°C (200°F) Dry                  | F-8         |
| F.8          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 93°C (200°F) Dry                  | F-9         |
| F.9          | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 93°C (200°F) Dry                  | F-10        |
| F.10         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, -54°C (-65°F) Wet                 | F-11        |
| F.11         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, -54°C (-65°F) Wet                 | F-12        |
| F.12         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, -54°C (-65°F) Wet                 | F-13        |
| F.13         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 22°C (72°F) Wet                   | F-14        |

# LIST OF TABLES (Continued)

| <b><u>TABLE</u></b> |                                                                                                                    | <b><u>PAGE</u></b> |
|---------------------|--------------------------------------------------------------------------------------------------------------------|--------------------|
| F.14                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 22°C (72°F) Wet      | F-15               |
| F.15                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 22°C (72°F) Wet      | F-16               |
| F.16                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 93°C (200°F) Wet     | F-17               |
| F.17                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 93°C (200°F) Wet     | F-18               |
| F.18                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 93°C (200°F) Wet     | F-19               |
| F.19                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, -54°C (-65°F) Dry | F-20               |
| F.20                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, -54°C (-65°F) Dry | F-21               |
| F.21                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, -54°C (-65°F) Dry | F-22               |
| F.22                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 22°C (72°F) Dry   | F-23               |
| F.23                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 22°C (72°F) Dry   | F-24               |
| F.24                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 22°C (72°F) Dry   | F-25               |
| F.25                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 93°C (200°F) Dry  | F-26               |
| F.26                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 93°C (200°F) Dry  | F-27               |
| F.27                | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 93°C (200°F) Dry  | F-28               |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                    | <u>PAGE</u> |
|--------------|--------------------------------------------------------------------------------------------------------------------|-------------|
| F.28         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, -54°C (-65°F) Wet | F-29        |
| F.29         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, -54°C (-65°F) Wet | F-30        |
| F.30         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, -54°C (-65°F) Wet | F-31        |
| F.31         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 22°C (72°F) Wet   | F-32        |
| F.32         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 22°C (72°F) Wet   | F-33        |
| F.33         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 22°C (72°F) Wet   | F-34        |
| F.34         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 93°C (200°F) Wet  | F-35        |
| F.35         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 93°C (200°F) Wet  | F-36        |
| F.36         | Individual Specimen Inplane Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 93°C (200°F) Wet  | F-37        |
| G.1          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 22°C (72°F) Dry | G-2         |
| G.2          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 22°C (72°F) Dry | G-3         |
| G.3          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 22°C (72°F) Dry | G-4         |
| G.4          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 22°C (72°F) Wet | G-5         |
| G.5          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 22°C (72°F) Wet | G-6         |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                        | <u>PAGE</u> |
|--------------|------------------------------------------------------------------------------------------------------------------------|-------------|
| G.6          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 22°C (72°F) Wet     | G-7         |
| G.7          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 1, 93°C (200°F) Wet    | G-8         |
| G.8          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 2, 93°C (200°F) Wet    | G-9         |
| G.9          | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Glass Reinforcement, Batch 3, 93°C (200°F) Wet    | G-10        |
| G.10         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 22°C (72°F) Dry  | G-11        |
| G.11         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 22°C (72°F) Dry  | G-12        |
| G.12         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 22°C (72°F) Dry  | G-13        |
| G.13         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 22°C (72°F) Wet  | G-14        |
| G.14         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 22°C (72°F) Wet  | G-15        |
| G.15         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 22°C (72°F) Wet  | G-16        |
| G.16         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 1, 93°C (200°F) Wet | G-17        |
| G.17         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 2, 93°C (200°F) Wet | G-18        |
| G.18         | Individual Specimen Interlaminar Shear Test Results, Baseline Tests, Graphite Reinforcement, Batch 3, 93°C (200°F) Wet | G-19        |
| H.1          | Individual Specimen Bolt-Bearing Test Results, Glass Reinforcement, Dry Condition                                      | H-2         |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                | <u>PAGE</u> |
|--------------|--------------------------------------------------------------------------------------------------------------------------------|-------------|
| H.2          | Individual Specimen Bolt-Bearing Test Results,<br>Glass Reinforcement, Wet Condition                                           | H-3         |
| H.3          | Individual Specimen Bolt-Bearing Test Results,<br>Graphite Reinforcement, Dry Condition                                        | H-4         |
| H.4          | Individual Specimen Bolt-Bearing Test Results,<br>Graphite Reinforcement, Wet Condition                                        | H-5         |
| I.1          | Individual Specimen Glass Transition Temperature                                                                               | I-2         |
| J.1          | Effect of Vacuum Pressure on Interlaminar Shear Strength<br>of Glass Reinforced EA9396 Composite Laminates                     | J-2         |
| J.2          | Interlaminar Shear Strength of Graphite Reinforced EA9396<br>Composite Laminates Cured 45 Minutes at 107°C (225°F)             | J-3         |
| J.3          | Interlaminar Shear Strength of Graphite Reinforced EA9396<br>Composite Laminates Cured 30 Minutes at 93°C (200°F)              | J-4         |
| J.4          | Interlaminar Shear Strength of Graphite Reinforced EA9396<br>Composite Laminates Cured 30 Minutes at 82°C (180°F)              | J-5         |
| J.5          | Interlaminar Shear Strength of Graphite Reinforced EA9396<br>Composite Laminates Cured 45 Minutes at 79°C (175°F)              | J-6         |
| J.6          | Interlaminar Shear Strength of Graphite Reinforced EA9396<br>Composite Laminates Cured 7 Days at 22°C (72°F)                   | J-7         |
| K.1          | Effect of Elevated Temperature Exposure on Interlaminar<br>Shear Strength of Glass Reinforced EA9396 Composite<br>Laminates    | K-2         |
| K.2          | Effect of Elevated Temperature Exposure on Interlaminar<br>Shear Strength of Graphite Reinforced EA9396 Composite<br>Laminates | K-3         |
| L.1          | Effect of Fiber Content on Interlaminar Shear Strength of<br>Glass Reinforced EA9396 Composite Laminates                       | L-2         |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                          | <u>PAGE</u> |
|--------------|----------------------------------------------------------------------------------------------------------|-------------|
| L.2          | Effect of Fiber Content on Interlaminar Shear Strength of Glass Reinforced EA9396 Composite Laminates    | L-3         |
| L.3          | Effect of Fiber Content on Interlaminar Shear Strength of Glass Reinforced EA9396 Composite Laminates    | L-4         |
| L.4          | Effect of Fiber Content on Interlaminar Shear Strength of Glass Reinforced EA9396 Composite Laminates    | L-5         |
| L.5          | Effect of Fiber Content on Interlaminar Shear Strength of Glass Reinforced EA9396 Composite Laminates    | L-6         |
| L.6          | Effect of Fiber Content on Interlaminar Shear Strength of Glass Reinforced EA9396 Composite Laminates    | L-7         |
| L.7          | Effect of Fiber Content on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminates | L-8         |
| L.8          | Effect of Fiber Content on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminates | L-9         |
| L.9          | Effect of Fiber Content on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminates | L-10        |
| L.10         | Effect of Fiber Content on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminates | L-11        |
| L.11         | Effect of Fiber Content on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminates | L-12        |
| L.12         | Effect of Fiber Content on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminates | L-13        |
| L.13         | Effect of Fiber Content on Compression Strength of Glass Reinforced EA9396 Composite Laminates           | L-14        |
| L.13         | Effect of Fiber Content on Compression Strength of Glass Reinforced EA9396 Composite Laminates           | L-14        |
| L.14         | Effect of Fiber Content on Compression Strength of Glass Reinforced EA9396 Composite Laminates           | L-15        |

## LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                      | <u>PAGE</u> |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------|
| L.15         | Effect of Fiber Content on Compression Strength of Graphite Reinforced EA9396 Composite Laminates                                    | L-16        |
| L.16         | Effect of Fiber Content on Compression Strength of Graphite Reinforced EA9396 Composite Laminates                                    | L-17        |
| M.1          | HPLC Test Parameters and Results                                                                                                     | M-4         |
| M.2          | Brookfield Viscosity Measurements on EA9396 as a Function of Storage Time at Various Temperatures                                    | M-5         |
| M.3          | Effect of Long-Term Storage on Heat Release During Cure                                                                              | M-6         |
| M.4          | Effect of Resin Storage for 1 Month at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate   | M-7         |
| M.5          | Effect of Resin Storage for 1 Month at 38°C (100°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-8         |
| M.6          | Effect of Resin Storage for 1 Month at 49°C (120°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-9         |
| M.7          | Effect of Resin Storage for 3 Months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-10        |
| M.8          | Effect of Resin Storage for 6 Months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-11        |
| M.9          | Effect of Resin Storage for 6 Months at 38°C (100°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-12        |
| M.10         | Effect of Resin Storage for 6 Months at 49°C (120°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-13        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                       | <u>PAGE</u> |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------|-------------|
| M.11         | Effect of Resin Storage for 12 Months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-14        |
| M.12         | Effect of Resin Storage for 12 Months at 38°C (100°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-15        |
| M.13         | Effect of Resin Storage for 12 Months at 49°C (120°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-16        |
| M.14         | Effect of Resin Storage for 18 Months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-17        |
| M.15         | Effect of Resin Storage for 18 Months at 38°C (200°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-18        |
| M.16         | Effect of Resin Storage for 18 Months at 49°C (120°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-19        |
| M.17         | Effect of Resin Storage for 24 Months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-20        |
| M.18         | Effect of Resin Storage for 24 Months at 38°C (100°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-21        |
| M.19         | Effect of Resin Storage for 24 Months at 49°C (120°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-22        |
| M.20         | Effect of Resin Storage for 43 Months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-23        |



# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                                       | <u>PAGE</u> |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------|-------------|
| M.21         | Effect of Resin Storage for 43 Months at 38°C (100°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate | M-24        |
| M.22         | Effect of Resin Storage for 50 months at 22°C (72°F) on Interlaminar Shear Strength of Graphite Reinforced EA9396 Composite Laminate  | M-25        |
| N.1          | Flatwise Tensile Strength of Honeycomb Sandwich With No Supplemental Adhesive                                                         | N-2         |
| N.2          | Flatwise Tensile Strength of Honeycomb Sandwich With Moderate Adhesive Layer Along Top Skin                                           | N-3         |
| N.3          | Flatwise Tensile Strength of Honeycomb Sandwich With Light Adhesive Layer Along Both Skins                                            | N-4         |
| N.4          | Flatwise Tensile Strength of Honeycomb Sandwich With Moderate Adhesive Layer Along Both Skins                                         | N-5         |
| N.5          | Flatwise Tensile Strength of Honeycomb Sandwich With Heavy Adhesive Layer Along Both Skins                                            | N-6         |
| O.1          | Edgewise Compression Strength of Cocured Honeycomb Sandwich With Light Core and Graphite Reinforced Skins                             | O-3         |
| O.2          | Edgewise Compression Strength of Secondarily Bonded Honeycomb Sandwich With Light Core and Graphite Reinforced Skins                  | O-4         |
| O.3          | Edgewise Compression Strength of Cocured Honeycomb Sandwich With Heavy Core and Graphite Reinforced Skins                             | O-5         |
| O.4          | Edgewise Compression Strength of Secondarily Bonded Honeycomb Sandwich With Heavy Core and Graphite Reinforced Skins                  | O-6         |
| O.5          | Edgewise Compression Strength of Cocured Honeycomb Sandwich With Light Core and Glass Reinforced Skins                                | O-7         |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                       | <u>PAGE</u> |
|--------------|-----------------------------------------------------------------------------------------------------------------------|-------------|
| O.6          | Edgewise Compression Strength of Seccondarily Bonded Honeycomb Sandwich With Light Core and Glass Reinforced Skins    | O-8         |
| P.1          | Room Temperature Dry Compression Strength of Glass Reinforced Specimens That Were Not Subjected to a Thermal Pulse    | P-2         |
| P.2          | Room Temperature Dry Compression Strength of Glass Reinforced Specimens That Were Subjected to a Thermal Pulse        | P-3         |
| P.3          | Elevated Temperature Dry Compression Strength of Glass Reinforced Specimens That Were Subjected to a Thermal Pulse    | P-4         |
| P.4          | Low Temperature Wet Compression Strength of Glass Reinforced Specimens That Were Subjected to a Thermal Pulse         | P-5         |
| P.5          | Room Temperature Wet Compression Strength of Glass Reinforced Specimens That Were Not Subjected to a Thermal Pulse    | P-6         |
| P.6          | Room Temperature Wet Compression Strength of Glass Reinforced Specimens That Were Subjected to a Thermal Pulse        | P-7         |
| P.7          | Elevated Temperature Wet Compression Strength of Glass Reinforced Specimens That Were Subjected to a Thermal Pulse    | P-8         |
| P.8          | Room Temperature Dry Compression Strength of Graphite Reinforced Specimens That Were Not Subjected to a Thermal Pulse | P-9         |
| P.9          | Room Temperature Dry Compression Strength of Graphite Reinforced Specimens That Were Subjected to a Thermal Pulse     | P-10        |

# LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                         | <u>PAGE</u> |
|--------------|-------------------------------------------------------------------------------------------------------------------------|-------------|
| P.10         | Elevated Temperature Dry Compression Strength of Graphite Reinforced Specimens That Were Subjected to a Thermal Pulse   | P-11        |
| P.11         | Low Temperature Wet Compression Strength of Graphite Reinforced Specimens That Were Subjected to a Thermal Pulse        | P-12        |
| P.12         | Room Temperature Wet Compression Strength of Graphite Reinforced Specimens That Were Not Subjected to a Thermal Pulse   | P-13        |
| P.13         | Room Temperature Wet Compression Strength of Graphite Reinforced Specimens That Were Subjected to a Thermal Pulse       | P-14        |
| Q.1          | Room Temperature Dry Tensile Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement            | Q-2         |
| Q.2          | Room Temperature Wet Tensile Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement            | Q-3         |
| Q.3          | Elevated Temperature Wet Tensile Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement        | Q-4         |
| Q.4          | Room Temperature Dry Inplane Shear Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement      | Q-5         |
| Q.5          | Room Temperature Wet Inplane Shear Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement      | Q-6         |
| Q.6          | Elevated Temperature Wet Inplane Shear Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement  | Q-7         |
| Q.7          | Room Temperature Dry Interlaminar Shear Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement | Q-8         |

## LIST OF TABLES (Continued)

| <u>TABLE</u> |                                                                                                                             | <u>PAGE</u> |
|--------------|-----------------------------------------------------------------------------------------------------------------------------|-------------|
| Q.8          | Room Temperature Wet Interlaminar Shear Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement     | Q-9         |
| Q.9          | Elevated Temperature Wet Interlaminar Shear Properties of EA9396 Laminates Reinforced With Silane Sized Glass Reinforcement | Q-10        |

## SECTION 1

### INTRODUCTION

With the increased application of fiber-reinforced, resin-matrix composite materials in aircraft structure, the need for effective repair materials and procedures has led to a great deal of activity over the past 5-10 years. Some of this has focused on the development of equipment and procedures for repair while others have resulted in the development of new materials for use in repair.

Because of limitations in available equipment and the need for rapid turnaround in field repair scenarios, the techniques and materials used in repair differ from those employed in original construction. These considerations imposed a number of constraints on both the materials and procedures employed in this program. Some of these include, but are not limited to, the following:

- The material should have a long storage life at ambient temperatures ranging up to 120°F. This generally precludes the use of prepreg material and leads to two-part resin systems.
- The material should be curable at temperatures below the boiling point of water. This is desired so that any residual moisture absorbed in the substrate to which the repair is being applied does not catastrophically volatilize during cure and cause blistering, debonding, or excessive bondline porosity.
- The material should have a reasonably long pot life (approximately 1 hour) while being curable in a relatively short period (1 hour or less).
- The material should not lose a large proportion of its mechanical strength under hot/wet conditions.
- Only vacuum pressure will be available to provide compaction during cure.

An initial series of materials screening tests were carried out on several candidate materials that were identified by a review of vendor literature and direct vendor contact. The result of that screening test effort was a selection of one material for more comprehensive characterization. The investigation reported here dealt with the characterization of that material. The goal of this work was to develop a mechanical and physical property database for EA9396 glass and graphite fabricate laminates that would enable aircraft repairs to be designed using these materials.

## SECTION 2 APPROACH

The materials used during this investigation are described in Section 2.1. Section 2.2 discusses and describes the mechanical and physical test methods that were employed and the experimental design that was followed. Section 2.3 discusses the processing procedures employed to fabricate both the baseline laminates, which represented the bulk of the panels, as well as those fabricated by procedures that varied from the baseline process.

### 2.1 MATERIALS

The principal material of interest in the investigation reported here was a wet-layup epoxy resin manufactured by Dexter-Hysol designated EA9396. This is an unfilled, low viscosity, two-part system. It was obtained in both gallon and quart kit forms directly from Dexter-Hysol. Three different batches of EA9396, produced in August, September and October of 1988, respectively, were supplied. The baseline property measurements (to be discussed in Section 2.2) employed all three of these resin batches in order to generate batch-to-batch comparisons. In addition to the baseline properties, many supplemental tests were also performed to assess the effects of various processing, reinforcement, and environmental variables on resulting properties. Batch-to-batch comparisons were not generated for these supplemental tests. Rather, these tests employed resin from only one of the three batches.

Laminate mechanical properties were generated for both glass and graphite fabric reinforced composite panels. The specific types of fabric used in these laminates are detailed in Table 1. Both of these were balanced 8-harness satin (8HS) style fabrics. The ply orientation of each laminate was such that the warp yarns of every ply ran in the same direction. Since 8HS fabric has a "top" side that consists of predominantly one yarn direction, and a "bottom" side that consists predominantly of the perpendicular yarn direction, the up/down orientation of the plies was reversed at the laminate midplane so that all plies above the midplane were oriented in the "up" direction while all plies below the midplane were oriented "down." In the data tables to follow in this report the "warp" direction is synonymous with the longitudinal or 0° direction, while the "fill" direction is synonymous with the transverse or 90° direction.

**TABLE 1**  
**GLASS AND GRAPHITE FABRIC REINFORCEMENT DESCRIPTION**

| Characteristic              | Glass Fabric                                    | Graphite Fabric                                  |
|-----------------------------|-------------------------------------------------|--------------------------------------------------|
| Fiber Type                  | E-Glass                                         | Toray T300, 3K                                   |
| Fiber Sizing                | F-16 (Volan-A- type)<br>538 (Silane type)       | UC 309 (epoxy compatible)                        |
| Weave Style                 | 7781                                            | W133 (8HS)                                       |
| Fabric Width                | 100 cm (39.5 in)                                | 107 cm (42 in)                                   |
| Fabric Weight               | 295 gm/m <sup>2</sup> (8.7 oz/yd <sup>2</sup> ) | 366 gm/m <sup>2</sup> (10.8 oz/yd <sup>2</sup> ) |
| Nominal Cured Ply Thickness | 0.2 mm (0.008 in)                               | 0.37 mm (0.0145 in)                              |
| Fiber Specific Gravity      | 2.54                                            | 1.78                                             |
| Nominal Fiber Properties    |                                                 |                                                  |
| Tensile Strength            | 3445 MPa (500 Ksi)                              | 3734 MPa (542 Ksi)                               |
| Young's Modulus             | 72 GPa (10.5 Msi)                               | 235 GPa (34.1 Msi)                               |
| Elongation                  | 4.8%                                            | 1.6%                                             |
| Source                      | Hexcel (1)<br>Burlington (2)                    | ICI Fiberite                                     |

(1) F-16 (Volan-A) sized fabric.

(2) 538 (Silane) sized fabric.

## 2.2 EXPERIMENTAL DESIGN

Seven different properties were measured on all three resin batches. These are referred to here as the baseline property measurements. Six of these seven were mechanical properties and the seventh was glass transition temperature. Table 2 lists the test matrix and test methods used for the baseline property measurements. This test matrix was repeated for both the glass and graphite fabric reinforcement and for each of the three resin batches. The glass transition tests were performed on unreinforced neat resin samples.

The baseline material properties derived from the test matrix presented in Table 2 provide a comprehensive database for repair design purposes. It incorporates the effects of different batches, reinforcement type, temperature, and dry-wet variables. The material properties generated from this test matrix represent the basic design needs.

In addition to the baseline properties listed in Table 2, numerous other supplemental tests were carried out to determine the effect of various processing and environmental variables on resulting properties. Only one batch of resin was used for these tests, and the results were compared to the baseline values, where appropriate, to assess the effect of the respective processing or environmental condition. Table 3 lists these supplemental, nonbaseline tests.

## 2.3 TEST METHODS

Nearly all of the testing conducted during this effort was performed in accordance with standard ASTM test procedures. The specific ASTM methods employed are listed in Tables 2 and 3 and are not discussed further here. The remainder of the tests were also performed in accordance with generally accepted laboratory procedures. Since, however, these are not as readily referenced as ASTM procedures, each of these non-ASTM procedures is briefly discussed in the following sections.

All specimens that were tested at other than room temperature in the dry condition were allowed to equilibrate for 20 minutes before loading was started. In order to minimize specimen dryout, testing of moisture conditioned specimens was started 4 minutes after the specimen was installed in the test fixture and the chamber door closed.



TABLE 2

**TEST MATRIX FOR BATCH-TO-BATCH COMPARISONS AND BASELINE  
MECHANICAL PROPERTY DATA**

| Property                              | Properties Measured(1)                           | Test Method             | Replicates Per Batch at Each<br>Test Condition Below |      |         |       |            |
|---------------------------------------|--------------------------------------------------|-------------------------|------------------------------------------------------|------|---------|-------|------------|
|                                       |                                                  |                         | Dry                                                  |      | Wet (2) |       |            |
|                                       |                                                  |                         | -65°F                                                | 72°F | 200°F   | -65°F | 72°F 200°F |
| Longitudinal<br>(Warp) Tension        | $F_{tu}$ , $\epsilon_{ult}$ , $E_t$ , $\nu_{12}$ | ASTM D3039              | 0                                                    | 5    | 0       | 0     | 5 0        |
| Transverse (Fill)<br>Tension          | $F_{tu}$ , $\epsilon_{ult}$ , $E_t$ , $\nu_{12}$ | ASTM D3039              | 5                                                    | 5    | 5       | 5     | 5 5        |
| Longitudinal<br>(Warp)<br>Compression | $F_{cu}$ , $\epsilon_{ult}$ , $E_c$              | ASTM D3410B             | 0                                                    | 5    | 0       | 0     | 5 0        |
| Transverse (Fill)<br>Compression      | $F_{cu}$ , $\epsilon_{ult}$ , $E_c$              | ASTM D3410B             | 5                                                    | 5    | 5       | 5     | 5 5        |
| 45° Tension/<br>Inplane Shear         | $F_{ipsu}$ , $E_t$ , $G$ , $\nu_{12}$            | ASTM D3518              | 5                                                    | 5    | 5       | 5     | 5 5        |
| Interlaminar<br>Shear                 | $F_{ils}$                                        | Four-Point<br>Shear (3) | 0                                                    | 5    | 0       | 0     | 5 5        |
| Glass Transition<br>Temp.             | $T_g$                                            | DMA (4)                 | 3 (5)                                                |      |         |       | 3 (5)      |

NOTES: (1) Poisson's ratio was only measured on two specimens from each set of five in the tensile tests.

(2) Wet = tested at indicated test temperature after wet aging to saturation at 60°C (140°F)/100% R.H.

(3) See Reference 1 and Section 2.3.1.

(4) DMA = Dynamic Mechanical Analysis.

(5) Glass Transition tests are not run at 22°C (72°F). The specimens are heated from 22°C (72°F) to above  $T_g$  at a constant heating rate.

TABLE 3

SUMMARY OF SUPPLEMENTAL TESTS TO DETERMINE  
SPECIFIC MATERIALS PROPERTIES AND THE  
EFFECTS OF PROCESSING AND ENVIRONMENTAL  
VARIABLES ON PROPERTIES (1)

| <u>Variable of Concern</u>                           | <u>Type of Tests Conducted</u>                      | <u>Test Method</u>                                   |
|------------------------------------------------------|-----------------------------------------------------|------------------------------------------------------|
| Effect of Maximum Cure Temperature on Degree of Cure | DSC (2)                                             |                                                      |
| Cure Time and Temperature                            | Interlaminar Shear                                  | Four-Point Shear (5)                                 |
| Cure Pressure                                        | Laminate Physical Properties and Interlaminar Shear | ASTM D3171, D792, D2584, D2734, Four-Point Shear (5) |
| Bearing Strength                                     | MIL-HDBK-17B Bearing Strength                       | MIL-HDBK-17B                                         |
| Effect of 350°F Exposure                             | Interlaminar Shear                                  | Four-Point Shear (5)                                 |
| Effect of Resin Content                              | Interlaminar Shear and Compression                  | Four-Point Shear (5)<br>ASTM D3410B                  |
| Effect of Storage Time and Temperature               | Interlaminar Shear                                  | Four-Point Shear (5)                                 |
|                                                      | Viscosity                                           | ASTM D2393                                           |
|                                                      | Viscosity Curing Profile                            | Rheometrics RSA II                                   |
|                                                      | DSC (2)                                             | ---                                                  |
|                                                      | FTIR (3)                                            | ---                                                  |
|                                                      | HPLC (4)                                            | ---                                                  |
| Effect of Temperature on Pot Life                    | Manual/Visual Assessment                            | N.A.                                                 |
| Effect of Adhesive Fillet Size on Honeycomb Sandwich | Flatwise Tension                                    | ASTM D297                                            |

TABLE 3 (Concluded)

SUMMARY OF SUPPLEMENTAL TESTS TO DETERMINE  
SPECIFIC MATERIALS PROPERTIES AND THE  
EFFECTS OF PROCESSING AND ENVIRONMENTAL  
VARIABLES ON PROPERTIES (1)

| <u>Variable of Concern</u>                                      | <u>Type of Tests Conducted</u>                 | <u>Test Method</u>                               |
|-----------------------------------------------------------------|------------------------------------------------|--------------------------------------------------|
| Effect of Skin Processing<br>Technique on Honeycomb<br>Sandwich | Edgewise Compression                           | ASTM C364                                        |
| Effect of Thermal Flash                                         | Compression                                    | ASTM D3410B                                      |
| Effect of Alternate<br>Impregnation and Bagging<br>Schemes      | Physical Properties                            | ASTM D792, D3171,<br>D2584, D2734                |
| Effect of A1100 Sizing on<br>Wet-Strength Retention             | Tension<br>Inplane Shear<br>Interlaminar Shear | ASTM D3039<br>ASTM D3518<br>Four-Point Shear (5) |

## NOTES:

- (1) Only one resin batch used for these tests.
- (2) Dynamic Scanning Calorimetry.
- (3) Fourier Transform Infrared Spectroscopy.
- (4) High Pressure Liquid Chromatography.
- (5) See Reference 1 and Section 2.3.1.

### 2.3.1 Interlaminar Shear

The most common test for interlaminar shear strength of composite laminates is the short beam shear (SBS) test of ASTM D2344. While this procedure calls for specimens 6.4 mm (0.25 inch) thick, most short beam shear tests on composite materials do not meet this requirement. The specimens are more commonly only around 3.2 mm (0.125 inch) or less thick. The typical result of such a test is that while a number for apparent interlaminar shear strength is generated, the failure mode is seldom interlaminar shear. An alternative test, referred to as Four-Point Shear (FPS), has been proposed and has been demonstrated as more likely to produce true and consistent interlaminar shear failure modes (Ref. 1). As a consequence of the advantages of the FPS test over the SBS test, the FPS test was used in this investigation to generate interlaminar shear data.

The FPS test is a modified version of the flexure test described in ASTM D790, Method II, Procedure B. In order to ensure an interlaminar failure mode, however, the support span is reduced to half the span used in flexural testing. Thus, the FPS tests carried out in this investigation were conducted at support span to specimen thickness ratios of 8 to 1 for the glass reinforced specimens and 16 to 1 for the graphite reinforced specimens.

### 2.3.2 Glass Transition Temperature

Glass transition temperature ( $T_g$ ) can be determined by means of differential scanning calorimetry (DSC), thermomechanical analysis (TMA), and dynamic mechanical analysis (DMA). In DSC, the  $T_g$  is determined from the position of the shift in the baseline on a plot of heat release vs. temperature. The  $T_g$  values obtained with DSC are consistently lower (by 20-40°C) than those obtained with either TMA or DMA. In TMA, the  $T_g$  is determined from the location of change in slope of a plot of change in specimen length vs. temperature. The  $T_g$  values obtained from TMA are usually within 0-10°C of the value obtained with DMA. In DMA, the  $T_g$  is determined from the position of the peak in either the loss modulus ( $E''$ ) vs. temperature curve or the  $\tan \delta$  vs. temperature curve. The  $T_g$  values from the  $\tan \delta$  curve are always higher than those from the loss modulus curve.

In this investigation the Tg values were determined on neat EA9396 cast resin samples by means of the loss modulus curve in a DMA test. The test was carried out at a heating rate of 0.5°C/min.

### 2.3.3 Bearing Strength

Although this test was not carried out in accordance with an ASTM standard, it was in accordance with the standard procedure for bearing strength presented in MIL-HDBK-17B (Ref. 2).

### 2.3.4 Viscosity

Viscosity of the uncured resin was measured in general accordance with ASTM Method D2393 using a Brookfield RVF Viscometer. All measurements were carried out at 22±2°C (72±4°F).

### 2.3.5 Viscosity Curing Profile

A viscosity curing profile is a continuous measure of polymer viscosity during polymerization (cure). While the procedure can be carried out for any time-temperature history, it is usually performed by heating the test sample at a constant rate until cure is complete. This procedure was used for this investigation. Resin samples were tested in a Rheometrics Solids Analyzer (RSA II) at a heating rate of 1°C/minute and a frequency of 1 Hz. The sample was contained in a parallel plate configuration and both dynamic ( $\eta'$ ) and loss ( $\eta''$ ) viscosities were continuously recorded throughout the test. The dynamic viscosity ( $\eta'$ ) was used as an indication of the resin viscosity behavior.

### 2.3.6 Differential Scanning Calorimetry (DSC)

A DSC test measures the heat released by a test sample as its temperature is raised. As the sample undergoes polymerization, the heat released during the polymerization process is reflected as the area under the hump of the heat release vs. temperature curve. If a sample is only partially polymerized, only part of the heat of polymerization will be released and the area under the curve will be correspondingly reduced. Thus, the heat release during a DSC test can be used as a measure of degree of cure.

The DSC tests carried out in this investigation were performed on a DuPont 9900 instrument in accordance with generally accepted thermal analysis techniques. Sample sizes were 5 mg.

### 2.3.7 Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectroscopy is a widely use and standard analytical procedure that can be used to identify the presence or absence of different chemical groups. FTIR analysis in this study were performed with a Nicolet 200XD Transform Infrared Spectrometer. These tests were performed on uncured resin samples after various periods of storage to determine whether chemical changes occurred. The resin sample was simply spread onto a salt crystal for mounting in the spectrometer.

### 2.3.8 High Pressure Liquid Chromatography (HPLC)

HPLC is also a widely used and generally well standardized procedure that separates multicomponent formulations into their constituent parts. The separation occurs because different components have different transit times through chromatography columns. These differences arise because of differences in molecular size and relative attraction to the column packing material.

In this program, samples were prepared for HPLC analysis by dissolving in dioxane to a concentration of 1% by weight and filtering through a 0.5-micron PTFE filter to remove insolubles. The gradient profile used during the HPLC test is listed below. The flow rate during analysis was 0.5 ml/minute.

| <u>Time (minutes)</u> | <u>% Water</u> | <u>% Dioxane</u> |
|-----------------------|----------------|------------------|
| 1                     | 50             | 50               |
| 10                    | 50             | 50               |
| 40                    | 30             | 70               |
| 50                    | 30             | 70               |

The analyses were carried out on a Hewlett-Packard Model 1090 instrument with a reverse phase C-18 ZORBOX ODS column (250 x 4.6 mm) and a UV detector.

## 2.4 PROCESSING PROCEDURES

The "Standard" laminate processing procedure is described in detail in Appendix A, and the various "non-Standard" procedures are described in Appendix B.

We must note that this effort was not to develop or use the precise repair processing procedure that might be used in actual on-aircraft repair with these materials. Rather, a laboratory procedure was employed that was both convenient and that produced laminate quality comparable to what would be expected in repair scenarios.

All of the laminates prepared during this investigation were prepared by wet-layup hand-impregnation procedures. Most of the laminates were prepared in the same manner, by what will be referred to as the "Standard" procedure. This includes all of the baseline laminates (Table 2) and many of the supplemental laminates (Table 3). The processing procedures used for the remainder of the supplemental laminates (Table 3) differed from the "Standard" procedure in a variety of ways, depending on the particular variable being investigated. Examples of such differences include a difference in cure temperature, cure pressure, resin/reinforcement ratio, bagging scheme, or ply impregnation procedure. A detailed step-by-step description of the "standard" procedure is presented in Appendix A, along with the rationale for certain of the procedural details.

The amount of resin used to impregnate the reinforcing fabric was about 50% more than the amount remaining in the laminate after cure, with the excess bled out the top of the ply stack. The quantity of resin used to impregnate the reinforcing fabric was determined as a ratio to the amount of reinforcement being impregnated. In the case of the laminates used in this program, the resin was not apportioned equally to each ply of reinforcement. Rather, every other ply was impregnated. This approach was adopted for two reasons. First, it considerably shortened the time required to complete the wet-layup, thereby eliminating potential pot life problems. Secondly, it permitted much more resin to be distributed onto and worked into a ply. This made it much easier to uniformly spread and impregnate a ply. The alternating dry plies were laid atop each wet impregnated ply and manually tamped down so that in short order it was uniformly wetted by resin from the preceding plies. The laminates were cured in an air circulating oven for 45 minutes at 93°C (200°F) under vacuum pressure. The vacuum level applied to the vacuum bag was typically ~635 mm (25 inches) Hg.

## SECTION 3

### DISCUSSION OF RESULTS

As would be surmised from the tests outlined in Table 2, a very substantial quantity of mechanical property data was generated during this program. The majority of these data represent baseline tensile, compressive, inplane and interlaminar shear properties that were determined on three different resin batches. In addition to these baseline data, additional data, as outlined in Table 3, were generated on only a single resin batch for a variety of different properties and processing or environmental exposure variations.

The following sections (3.1 through 3.12) discuss these various test results item by item. In these sections, all the data presented in either tabular or graphical form represent average values. Individual specimen data are presented in Appendices C-Q.

#### 3.1 LAMINATE PHYSICAL PROPERTIES

The physical properties of nearly every laminate fabricated during this program were determined. These included specific gravity (D792), cured ply thickness, fiber content, resin content, and void content (D2734). In the case of the glass reinforced laminates, the fiber and resin contents were determined with an ignition loss procedure (D2584), while in the case of the graphite reinforced laminates, an acid digestion procedure (D3171, procedure A) was used. Table 4 presents a summary of the laminate physical property data for all the laminates prepared with the baseline fabrication procedure. Appendix C presents individual panel data. The physical properties of laminates fabricated by procedures that deviated from the baseline processing procedure may have been different or equivalent to those listed in Table 4. depending on the nature of the processing deviation. These will be noted as appropriate in the following sections.

It is apparent from the data in Table 4 that the laminate quality produced by the standard baseline processing procedure described in Appendix A was very consistent. While the void contents of these laminates was consistently in the vicinity of 5% by volume, it must be remembered that this was for a vacuum bag cure. While no mechanical property data were generated in this program on autoclave cured laminates, some were prepared in this manner for another project and were essentially void free as a result of the positive pressure during cure instead of vacuum pressure.



TABLE 4

PHYSICAL PROPERTIES SUMMARY FOR LAMINATES PREPARED WITH  
BASELINE PROCESSING PROCEDURE (1)

| Type of Laminate            | Specific Gravity |      | Ply Thickness<br>(10 <sup>-3</sup> inch) |      | Fiber Content<br>(% by vol) |      | Resin Content<br>(% by wt.) |      | Void Content<br>(% by vol.) |      |
|-----------------------------|------------------|------|------------------------------------------|------|-----------------------------|------|-----------------------------|------|-----------------------------|------|
|                             | Avg.             | S.D. | Avg.                                     | S.D. | Avg.                        | S.D. | Avg.                        | S.D. | Avg.                        | S.D. |
| T300-W133(Gr)/EA9396<br>(2) | 1.48             | 0.01 | 15.1                                     | 0.3  | 55.8                        | 1.0  | 33.9                        | 1.3  | 4.7                         | 0.8  |
| "E" - 7781(GI)/EA9396 (2)   | 1.91             | 0.03 | 8.5                                      | 0.2  | 55.0                        | 1.5  | 26.6                        | 1.4  | 5.0                         | 1.1  |

(1) The baseline processing procedure is detailed in Appendix A.

(2) Values based on 23 baseline laminates.

## 3.2 BATCH-TO-BATCH MECHANICAL PROPERTY COMPARISONS

The following four subsections present and discuss the results from the batch-to-batch mechanical property comparisons in tension, compression, inplane shear, and interlaminar shear. Table 2 listed the test matrices for these tests and indicated the data that was obtained. All of the laminates used for these tests were prepared in accordance with the standard processing procedures described in Appendix A. The data from these tests are considered as the "baseline" properties and are so referred to in later sections and tables of this report.

### 3.2.1 Tension

Tension tests were carried out in both the longitudinal (warp) and transverse (fill) directions for both reinforcements (graphite and glass fabric) and all three resin batches. Tables 5-10 summarize the tensile data from the baseline tests. While it is evident from the data in these tables that there are no appreciable differences evident between the three batches of resin, the effect of temperature and moisture are very apparent.

### 3.2.2 Compression

Compression tests were carried out in both the longitudinal (warp) and transverse (fill) directions for both reinforcements (graphite and glass fabric) and all three resin batches. Tables 11-16 summarize the compression data from the baseline tests. As with the tensile data, it is evident that there are no appreciable differences evident between the three batches of resin.

### 3.2.3 Inplane Shear

Inplane shear tests were carried out on both reinforcements (graphite and glass fabric) and all three resin batches. Tables 17-20 summarize the inplane shear data from the baseline tests. As with the tensile and compression data, no appreciable batch-to-batch differences are evident in the inplane shear data.

### 3.2.4 Interlaminar Shear

Interlaminar shear tests were carried out on both reinforcements (graphite and glass fabric) and all three resin batches. Interlaminar shear tests, however, were not performed for as many of the test conditions as was the case for tension, compression,

TABLE 5  
BASELINE LONGITUDINAL (WARP) TENSILE PROPERTIES OF  
GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test Condition       | Resin Batch No.       | SI Units                |                       | U.S. Units              |                                       | Ultimate Strain (10 <sup>-6</sup> ) | Poisson's Ratio   |
|----------------------|-----------------------|-------------------------|-----------------------|-------------------------|---------------------------------------|-------------------------------------|-------------------|
|                      |                       | Ultimate Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strength (psi) | Tensile Modulus (10 <sup>6</sup> psi) |                                     |                   |
| 22°C (72°F), DRY     | 1 - Avg.<br>Std. Dev. | 356.7<br>16.6           | 24.82<br>0.58         | 51,740<br>2,140         | 3.600<br>0.084                        | 17,481<br>973                       | 0.121<br>---      |
|                      | 2 - Avg.<br>Std. Dev. | 368.5<br>23.5           | 25.37<br>0.61         | 53,440<br>3,410         | 3.680<br>0.088                        | 18,512<br>2,039                     | 0.110<br>---      |
|                      | 3 - Avg.<br>Std. Dev. | 345.4<br>5.2            | 24.70<br>0.56         | 50,090<br>750           | 3.583<br>0.081                        | 17,238<br>559                       | 0.114<br>---      |
| 22°C (72°F), WET (2) | 1 - Avg.<br>Std. Dev. | 113.1<br>5.6            | 21.94<br>0.66         | 16,400<br>810           | 3.182<br>0.095                        | 5,283<br>438                        | 0.073(3)<br>0.012 |
|                      | 2 - Avg.<br>Std. Dev. | 106.3<br>9.2            | 22.57<br>0.46         | 15,420<br>1,330         | 3.273<br>0.067                        | 4,795<br>484                        | 0.092<br>---      |
|                      | 3 - Avg.<br>Std. Dev. | 119.5<br>6.7            | 23.70<br>0.42         | 17,330<br>970           | 3.437<br>0.061                        | 5,213<br>328                        | 0.092<br>---      |

NOTES:

1. All average values represent five specimens except Poisson's ratio, which only represents two specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.
3. Average of three specimens.

TABLE 6  
BASELINE TRANSVERSE (FILL) TENSILE PROPERTIES OF  
GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test Condition       | Resin Batch No.       | SI Units                |                       | U.S. Units              |                                       | Ultimate Strain (10 <sup>-6</sup> ) | Poisson's Ratio  |
|----------------------|-----------------------|-------------------------|-----------------------|-------------------------|---------------------------------------|-------------------------------------|------------------|
|                      |                       | Ultimate Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strength (psi) | Tensile Modulus (10 <sup>6</sup> psi) |                                     |                  |
| -54°C (-65°F)<br>DRY | 1 - Avg.<br>Std. Dev. | 526.4<br>19.9           | 29.25<br>0.30         | 76,350<br>2,890         | 4.243<br>0.043                        | 23,133+(2)<br>3,304                 | 0.153<br>---     |
|                      | 2 - Avg.<br>Std. Dev. | 476.8<br>69.2           | 28.99<br>1.81         | 69,150<br>10,040        | 4.205<br>0.263                        | 18,159+(2)<br>4,975                 | 0.155(3)<br>0.22 |
|                      | 3 - Avg.<br>Std. Dev. | 484.8<br>7.6            | 28.36<br>0.83         | 70,320<br>1,100         | 4.113<br>0.120                        | 20,419+(2)<br>6,511                 | 0.155<br>---     |
| 22°C (72°F),<br>DRY  | 1 - Avg.<br>Std. Dev. | 367.8<br>32.8           | 27.04<br>1.33         | 53,340<br>4,750         | 3.922<br>0.193                        | 17,052<br>1,489                     | 0.124<br>---     |
|                      | 2 - Avg.<br>Std. Dev. | 368.1<br>16.8           | 24.42<br>0.67         | 53,390<br>2,430         | 3.542<br>0.097                        | 18,450<br>1,324                     | 0.128<br>---     |
|                      | 3 - Avg.<br>Std. Dev. | 386.7<br>14.2           | 24.44<br>0.70         | 56,080<br>2,060         | 3.545<br>0.102                        | 20,766+(2)<br>2,945                 | 0.130<br>---     |
| 93°C (200°F)<br>DRY  | 1 - Avg.<br>Std. Dev. | 321.0<br>18.3           | 24.46<br>0.68         | 46,550<br>2,660         | 3.547<br>0.099                        | 15,198<br>824                       | 0.116<br>---     |
|                      | 2 - Avg.<br>Std. Dev. | 312.2<br>12.6           | 24.24<br>0.68         | 45,280<br>1,830         | 3.515<br>0.099                        | 14,895<br>551                       | 0.095<br>---     |
|                      | 3 - Avg.<br>Std. Dev. | 301.9<br>29.2           | 24.25<br>0.80         | 43,790<br>4,230         | 3.517<br>0.116                        | 13,005+(2)<br>2,268                 | 0.094<br>---     |

NOTES:

1. All average values represent five specimens except Poisson's ratio, which only represents two specimens unless otherwise noted.
2. Where + sign follows an average value, strain gage failed before specimen fracture on one or more specimens.
3. Average of three specimens.

TABLE 7

**BASELINE TRANSVERSE (FILL) TENSILE PROPERTIES OF  
GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)**

| Test<br>Condition(2) | Resin<br>Batch No.    | SI Units                      |                             | U.S. Units                    |                                             | Poisson's<br>Ratio |
|----------------------|-----------------------|-------------------------------|-----------------------------|-------------------------------|---------------------------------------------|--------------------|
|                      |                       | Ultimate<br>Strength<br>(MPa) | Tensile<br>Modulus<br>(GPa) | Ultimate<br>Strength<br>(psi) | Tensile<br>Modulus<br>(10 <sup>6</sup> psi) |                    |
| -54°C (-65°F)<br>WET | 1 - Avg.<br>Std. Dev. | 134.7<br>19.2                 | 26.75<br>0.54               | 19,530<br>2,780               | 3.880<br>0.078                              | 0.143<br>---       |
|                      | 2 - Avg.<br>Std. Dev. | 156.6<br>15.4                 | 25.95<br>1.42               | 22,720<br>2,230               | 3.764<br>0.206                              | 0.117<br>---       |
|                      | 3 - Avg.<br>Std. Dev. | 147.5<br>14.7                 | 26.03<br>0.66               | 21,390<br>2,130               | 3.775<br>0.095                              | 0.145<br>---       |
| 22°C (72°F),<br>WET  | 1 - Avg.<br>Std. Dev. | 129.3<br>7.3                  | 22.49<br>0.62               | 18,750<br>1,060               | 3.262<br>0.090                              | 0.097<br>---       |
|                      | 2 - Avg.<br>Std. Dev. | 112.7<br>4.4                  | 22.07<br>0.78               | 16,350<br>640                 | 3.201(3)<br>0.113                           | 0.016<br>---       |
|                      | 3 - Avg.<br>Std. Dev. | 120.9<br>10.9                 | 22.01<br>0.23               | 17,530<br>1,580               | 3.192<br>0.033                              | 0.086<br>---       |
| 93°C (200°F)<br>WET  | 1 - Avg.<br>Std. Dev. | 93.8<br>4.0                   | 19.80<br>0.38               | 13,610<br>580                 | 2.872<br>0.055                              | 0.048<br>---       |
|                      | 2 - Avg.<br>Std. Dev. | 93.2<br>9.1                   | 22.32<br>2.83               | 13,520<br>1,320               | 3.237<br>0.411                              | 0.101<br>---       |
|                      | 3 - Avg.<br>Std. Dev. | 93.1<br>7.2                   | 20.08<br>2.65               | 13,500<br>1,040               | 2.912<br>0.385                              | 0.087<br>---       |

**NOTES:**

1. All average values represent five specimens except Poisson's ratio, which only represents two specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.
3. Average of three specimens.

TABLE 8  
BASELINE LONGITUDINAL (WARP) TENSILE PROPERTIES OF  
GRAPHITE REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition(2)    | Resin Batch No.       | SI Units                |                       | U.S. Units              |                                       | Ultimate Strain (10 <sup>-6</sup> ) | Poisson's Ratio   |
|----------------------|-----------------------|-------------------------|-----------------------|-------------------------|---------------------------------------|-------------------------------------|-------------------|
|                      |                       | Ultimate Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strength (psi) | Tensile Modulus (10 <sup>6</sup> psi) |                                     |                   |
| 22°C (72°F), DRY     | 1 - Avg.<br>Std. Dev. | 567.4<br>32.5           | 57.78<br>2.60         | 82,300<br>4,710         | 8.380<br>0.377                        | 8,911<br>568                        | 0.053<br>---      |
|                      | 2 - Avg.<br>Std. Dev. | 561.0<br>29.7           | 56.43<br>2.39         | 81,370<br>4,310         | 8.184<br>0.346                        | 7,507<br>835                        | 0.053(3)<br>0.013 |
|                      | 3 - Avg.<br>Std. Dev. | 539.4<br>44.1           | 59.03<br>2.83         | 78,230<br>6,400         | 8.562<br>0.410                        | 7,060<br>1,020                      | 0.073<br>---      |
| 22°C (72°F), WET (2) | 1 - Avg.<br>Std. Dev. | 597.6<br>40.2           | 62.40<br>1.46         | 86,670<br>5,830         | 9.050<br>0.212                        | 9,618<br>603                        | 0.029<br>---      |
|                      | 2 - Avg.<br>Std. Dev. | 562.3<br>34.2           | 59.58<br>1.62         | 81,560<br>4,960         | 8.642<br>0.235                        | 9,277<br>472                        | 0.041<br>---      |
|                      | 3 - Avg.<br>Std. Dev. | 596.3<br>23.2           | 60.52<br>1.94         | 86,480<br>3,370         | 8.777<br>0.282                        | 9,831<br>365                        | 0.041<br>---      |

NOTES:

1. All average values represent five specimens except Poisson's ratio, which only represents two specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.
3. Average of three specimens.

TABLE 9  
BASELINE TRANSVERSE (FILL) TENSILE PROPERTIES OF  
GRAPHITE REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition(2)    | Resin Batch No.       | SI Units                |                       | U.S. Units              |                                       | Ultimate Strain (10 <sup>-6</sup> ) | Poisson's Ratio   |
|----------------------|-----------------------|-------------------------|-----------------------|-------------------------|---------------------------------------|-------------------------------------|-------------------|
|                      |                       | Ultimate Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strength (psi) | Tensile Modulus (10 <sup>6</sup> psi) |                                     |                   |
| -54°C (-65°F)<br>DRY | 1 - Avg.<br>Std. Dev. | 642.5<br>30.8           | 62.79<br>0.30         | 93,190<br>4,460         | 9.107<br>0.043                        | 10,239<br>395                       | 0.060(2)<br>0.008 |
|                      | 2 - Avg.<br>Std. Dev. | 619.4<br>66.8           | 63.63<br>4.62         | 89,830<br>9,690         | 9.229<br>0.670                        | 9,283<br>530                        | 0.048<br>---      |
|                      | 3 - Avg.<br>Std. Dev. | 611.4<br>20.1           | 65.77<br>1.94         | 88,680<br>2,910         | 9.540<br>0.281                        | 9,208<br>428                        | 0.053<br>---      |
| 22°C (72°F),<br>DRY  | 1 - Avg.<br>Std. Dev. | 663.8<br>26.0           | 57.07<br>1.78         | 96,280<br>3,770         | 8.278<br>0.258                        | 11,157<br>493                       | 0.048(2)<br>0.001 |
|                      | 2 - Avg.<br>Std. Dev. | 687.1<br>12.7           | 60.60<br>1.37         | 99,660(2)<br>1,840      | 8.790(2)<br>0.199                     | 11,228(2)<br>355                    | 0.063(2)<br>0.009 |
|                      | 3 - Avg.<br>Std. Dev. | 619.1<br>10.9           | 61.96<br>0.23         | 89,800(3)<br>1,580      | 8.987(3)<br>0.033                     | 9,431(3)<br>1,136                   | 0.044(4)<br>---   |
| 93°C (200°F)<br>DRY  | 1 - Avg.<br>Std. Dev. | 455.3<br>37.3           | 57.23<br>2.67         | 66,030<br>5,410         | 8.301<br>0.387                        | 7,827<br>785                        | 0.037<br>---      |
|                      | 2 - Avg.<br>Std. Dev. | 539.0<br>70.5           | 59.27<br>2.92         | 78,170<br>10,230        | 8.596<br>0.424                        | 8,940<br>992                        | 0.053<br>---      |
|                      | 3 - Avg.<br>Std. Dev. | 567.1<br>36.8           | 62.30<br>0.90         | 82,250<br>5,340         | 9.038<br>0.130                        | 8,993<br>494                        | 0.082<br>---      |

NOTES:

1. All average values represent five specimens except Poisson's ratio, which only represents two specimens unless otherwise noted.
2. Average of three specimens.
3. Average of four specimens.
4. Single specimen.

TABLE 10  
BASELINE TRANSVERSE (FILL) TENSILE PROPERTIES OF  
GRAPHITE REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition(2)   | Resin Batch No.       | SI Units                |                       | U.S. Units              |                                       | Ultimate Strain (10 <sup>-6</sup> ) | Poisson's Ratio   |
|---------------------|-----------------------|-------------------------|-----------------------|-------------------------|---------------------------------------|-------------------------------------|-------------------|
|                     |                       | Ultimate Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strength (psi) | Tensile Modulus (10 <sup>6</sup> psi) |                                     |                   |
| -54°C(-65°F)<br>WET | 1 - Avg.<br>Std. Dev. | 671.3<br>30.0           | 64.70<br>2.54         | 97,370<br>4,350         | 9.384<br>0.369                        | 9,760<br>1,540                      | 0.046<br>---      |
|                     | 2 - Avg.<br>Std. Dev. | 650.7<br>58.8           | 65.57<br>1.05         | 94,380<br>8,530         | 9.510<br>0.153                        | 9,662<br>1,017                      | 0.046<br>---      |
|                     | 3 - Avg.<br>Std. Dev. | 677.2<br>50.2           | 66.60<br>3.28         | 98,220<br>7,280         | 9.659<br>0.475                        | 10,058<br>459                       | 0.068<br>---      |
| 22°C (72°F),<br>WET | 1 - Avg.<br>Std. Dev. | 572.2<br>72.5           | 59.48<br>1.81         | 82,990<br>10,520        | 8.627<br>0.262                        | 9,526<br>972                        | 0.037<br>---      |
|                     | 2 - Avg.<br>Std. Dev. | 619.6<br>48.8           | 60.63<br>4.04         | 89,860<br>7,080         | 8.794<br>0.586                        | 10,264<br>872                       | 0.046<br>---      |
|                     | 3 - Avg.<br>Std. Dev. | 619.1<br>38.7           | 60.54<br>1.36         | 89,790<br>5,620         | 8.780<br>0.197                        | 10,286<br>657                       | 0.056<br>---      |
| 93°C (200°F)<br>WET | 1 - Avg.<br>Std. Dev. | 448.2<br>41.2           | 54.85<br>4.85         | 65,010<br>5,980         | 7.956<br>0.703                        | 7,058<br>2,348                      | 0.034(3)<br>0.018 |
|                     | 2 - Avg.<br>Std. Dev. | 434.9<br>16.1           | 55.72<br>4.83         | 63,080<br>2,340         | 8.082<br>0.701                        | 8,164<br>1,556                      | 0.049(4)<br>0.010 |
|                     | 3 - Avg.<br>Std. Dev. | 445.8<br>28.7           | 54.63<br>4.02         | 64,660(5)<br>4,160      | 7.923(5)<br>0.583                     | 6,979(5)<br>1,308                   | 0.067(3)<br>0.018 |

- NOTES: 1. All average values represent five specimens except Poisson's ratio, which only represents two specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.
3. Average of three specimens.
4. Average of four specimens.
5. Average of five specimens.



TABLE 11  
BASELINE LONGITUDINAL (WARP) COMPRESSIVE PROPERTIES  
OF GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test Condition (2)    | Resin Batch No. | SI Units                |                           | U.S. Units              |                                           | Ultimate Strain (10 <sup>-6</sup> ) |
|-----------------------|-----------------|-------------------------|---------------------------|-------------------------|-------------------------------------------|-------------------------------------|
|                       |                 | Ultimate Strength (MPa) | Compressive Modulus (GPa) | Ultimate Strength (psi) | Compressive Modulus (10 <sup>6</sup> psi) |                                     |
| 22°C (72°F), DRY      | 1 - Avg.        | 336.5                   | 25.06                     | 48,800                  | 3.635                                     | 15,086                              |
|                       | Std. Dev.       | 25.8                    | 2.30                      | 3,740                   | 0.334                                     | 2,573                               |
|                       | 2 - Avg.        | 343.4                   | 25.68                     | 49,800                  | 3.724                                     | 13,359                              |
|                       | Std. Dev.       | 23.7                    | 1.36                      | 3,440                   | 0.197                                     | 1,198                               |
|                       | 3 - Avg.        | 346.9                   | 25.45                     | 50,310                  | 3.691                                     | 15,600                              |
|                       | Std. Dev.       | 9.9                     | 0.83                      | 1,430                   | 0.120                                     | 926                                 |
| 22°C (72°F), WET (2)  | 1 - Avg.        | 163.9                   | 21.17                     | 23,770                  | 3.070                                     | 8,540                               |
|                       | Std. Dev.       | 27.4                    | 2.05                      | 3,970                   | 0.298                                     | 1,300                               |
|                       | 3 - Avg.        | 175.5                   | 23.57                     | 25,450                  | 3.419                                     | 7,742                               |
|                       | Std. Dev.       | 13.0                    | 2.41                      | 1,880                   | 0.350                                     | 1,864                               |
| 93°C (200°F), WET (3) | 2 - Avg.        | 95.6                    | 95.56                     | 13,860                  | 3.049                                     | 5,229                               |
|                       | Std. Dev.       | 11.4                    | 1.39                      | 1,660                   | 0.202                                     | 896                                 |

NOTES:

1. All average values represent five specimens.
2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.
3. Tested at incorrect temperature. Should have been tested at 22°C (72°F).

TABLE 12  
BASELINE TRANSVERSE (FILL) COMPRESSIVE PROPERTIES  
OF GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test Condition (2) | Resin Batch No.       | SI Units                |                           | U.S. Units              |                                           | Ultimate Strain (10 <sup>-6</sup> ) |
|--------------------|-----------------------|-------------------------|---------------------------|-------------------------|-------------------------------------------|-------------------------------------|
|                    |                       | Ultimate Strength (MPa) | Compressive Modulus (GPa) | Ultimate Strength (psi) | Compressive Modulus (10 <sup>6</sup> psi) |                                     |
| -54°C (-65°F), DRY | 1 - Avg.<br>Std. Dev. | 442.2<br>32.1           | 27.67<br>0.68             | 64,140<br>4,650         | 4.013<br>0.099                            | 17,511<br>1,604                     |
|                    | 2 - Avg.<br>Std. Dev. | 397.0<br>9.8            | 28.87<br>2.39             | 57,580<br>1,420         | 4.187<br>0.346                            | 14,622<br>953                       |
|                    | 3 - Avg.<br>Std. Dev. | 480.9<br>26.2           | 29.99<br>0.63             | 69,750<br>3,800         | 4.350<br>0.092                            | 18,121<br>1,761                     |
| 22°C (72°F), DRY   | 1 - Avg.<br>Std. Dev. | 287.4<br>23.6           | 26.12<br>0.95             | 41,690<br>3,420         | 3.788<br>0.138                            | 11,670<br>2,118                     |
|                    | 2 - Avg.<br>Std. Dev. | 269.4<br>20.8           | 24.75<br>1.34             | 39,080<br>3,020         | 3.590<br>0.195                            | 11,725<br>2,050                     |
|                    | 3 - Avg.<br>Std. Dev. | 287.9<br>18.3           | 24.80<br>2.41             | 41,760<br>2,660         | 3.597<br>0.349                            | 12,246<br>3,323                     |
| 93°C (200°F), DRY  | 1 - Avg.<br>Std. Dev. | 192.7(2)<br>---         | 23.93(2)<br>---           | 27,950(2)<br>---        | 3.471(2)<br>---                           | 9,240(2)<br>---                     |
|                    | 2 - Avg.<br>Std. Dev. | 172.6<br>11.1           | 23.12<br>1.91             | 25,040<br>1,610         | 3.353<br>0.277                            | 7,450<br>1,077                      |
|                    | 3 - Avg.<br>Std. Dev. | 230.5<br>16.5           | 24.97<br>1.56             | 33,430<br>2,390         | 3.622<br>0.226                            | 9,625<br>1,876                      |

NOTES:

1. All average values represent five specimens unless otherwise noted.
2. Average of two specimens.

TABLE 13  
BASELINE TRANSVERSE (FILL) COMPRESSIVE PROPERTIES  
OF GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test Condition (2)    | Resin Batch No.             | SI Units                |                           | U.S. Units              |                                           |
|-----------------------|-----------------------------|-------------------------|---------------------------|-------------------------|-------------------------------------------|
|                       |                             | Ultimate Strength (MPa) | Compressive Modulus (GPa) | Ultimate Strength (psi) | Compressive Modulus (10 <sup>6</sup> psi) |
| -54°C (-65°F),<br>WET | 1 - Avg.<br>Std. Dev.       | 319.5<br>29.6           | 28.38<br>1.06             | 46,340<br>4,300         | 4.116<br>0.154                            |
|                       | 2 - Avg.<br>Std. Dev.       | 297.8<br>27.1           | 26.75<br>2.36             | 43,190<br>3,930         | 3.881<br>0.342                            |
|                       | 3 - Avg.<br>Std. Dev.       | 344.7<br>24.8           | 29.14<br>1.48             | 49,990<br>3,600         | 4.227<br>0.215                            |
| 22°C (72°F),<br>WET   | 1 - Avg.<br>Std. Dev.       | 147.8<br>16.8           | 22.82<br>0.40             | 21,440<br>2,430         | 3.310<br>0.058                            |
|                       | 3 - Avg.<br>Std. Dev.       | 177.1<br>12.7           | 24.93<br>3.72             | 25,680<br>1,840         | 3.616<br>0.539                            |
| 93°C (200°F),<br>WET  | 1 - Avg.<br>Std. Dev.       | 95.5<br>7.6             | 22.31<br>2.23             | 13,850<br>1,100         | 3.236<br>0.323                            |
|                       | 2 - Avg.<br>Std. Dev.       | 91.4<br>11.7            | 19.33<br>2.73             | 13,260<br>1,700         | 2.803<br>0.396                            |
|                       | 2 - Avg.(4)<br>Std. Dev.(4) | 88.3<br>6.9             | 14.35<br>2.12             | 12,800<br>680           | 3.060<br>0.308                            |
|                       | 3 - Avg.<br>Std. Dev.       | 119.8<br>7.0            | 22.57<br>4.21             | 17,370(3)<br>1,020      | 3.273(3)<br>0.610                         |
|                       |                             |                         |                           |                         | Ultimate Strain (10 <sup>-6</sup> )       |
| -54°C (-65°F),<br>WET | 1 - Avg.<br>Std. Dev.       |                         |                           |                         | 12,196<br>1,686                           |
|                       | 2 - Avg.<br>Std. Dev.       |                         |                           |                         | 11,330<br>1,090                           |
|                       | 3 - Avg.<br>Std. Dev.       |                         |                           |                         | 13,633<br>1,424                           |
| 22°C (72°F),<br>WET   | 1 - Avg.<br>Std. Dev.       |                         |                           |                         | 7,384<br>1,929                            |
|                       | 3 - Avg.<br>Std. Dev.       |                         |                           |                         | 8,214<br>815                              |
| 93°C (200°F),<br>WET  | 1 - Avg.<br>Std. Dev.       |                         |                           |                         | 4,493<br>521                              |
|                       | 2 - Avg.<br>Std. Dev.       |                         |                           |                         | 4,809<br>1,335                            |
|                       | 2 - Avg.(4)<br>Std. Dev.(4) |                         |                           |                         | 4,156<br>836                              |
|                       | 3 - Avg.<br>Std. Dev.       |                         |                           |                         | 4,727(3)<br>1,459                         |

NOTES: 1. All average values represent five specimens unless otherwise noted.

2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.

3. Average of four specimens.

4. Tested inadvertently at 93°C (200°F) WET condition. Should have been tested at 22°C (72°F) WET condition.

TABLE 14

BASELINE LONGITUDINAL (WARP) COMPRESSIVE PROPERTIES  
OF GRAPHITE REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition (2)   | Resin Batch No.       | SI Units                |                           | U.S. Units              |                                           | Ultimate Strain (10 <sup>-6</sup> ) |
|----------------------|-----------------------|-------------------------|---------------------------|-------------------------|-------------------------------------------|-------------------------------------|
|                      |                       | Ultimate Strength (MPa) | Compressive Modulus (GPa) | Ultimate Strength (psi) | Compressive Modulus (10 <sup>6</sup> psi) |                                     |
| 22°C (72°F), DRY     | 1 - Avg.<br>Std. Dev. | 456.9(3)<br>65.3        | 52.88(3)<br>7.99          | 66,270(3)<br>9,470      | 7.670(3)<br>1.159                         | 9,627(3)<br>2,860                   |
|                      | 2 - Avg.<br>Std. Dev. | 496.8<br>33.2           | 60.23<br>7.83             | 72,060<br>4,810         | 8.735<br>1.135                            | 8,062<br>1,534                      |
|                      | 3 - Avg.<br>Std. Dev. | 481.8(4)<br>21.0        | 57.18(4)<br>11.79         | 69,880(4)<br>3,050      | 8.290(4)<br>1.711                         | 9,532+(4,5)<br>3,334                |
| 22°C (72°F), WET (2) | 1 - Avg.<br>Std. Dev. | 396.5<br>61.4           | 51.71<br>4.07             | 57,510<br>8,910         | 7.502<br>0.590                            | 8,313<br>2,664                      |
|                      | 2 - Avg.<br>Std. Dev. | 369.9<br>20.8           | 54.87<br>8.27             | 53,650<br>3,010         | 7.958<br>1.200                            | 7,397<br>1,794                      |
|                      | 3 - Avg.<br>Std. Dev. | 347.6<br>14.8           | 52.78<br>9.39             | 50,410<br>2,150         | 7.655<br>1.362                            | 7,807<br>2,045                      |

## NOTES:

1. All average values represent five specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F), 100% R.H. until saturated.
3. Average of three specimens.
4. Average of four specimens.
5. Where + sign follows an average value, strain gage failed before specimen fracture on one or more specimens.

TABLE 15  
BASELINE TRANSVERSE (FILL) COMPRESSIVE PROPERTIES  
OF GRAPHITE REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition        | Resin Batch No.       | SI Units                |                           | U.S. Units              |                                           | Ultimate Strain (10 <sup>-6</sup> ) |
|-----------------------|-----------------------|-------------------------|---------------------------|-------------------------|-------------------------------------------|-------------------------------------|
|                       |                       | Ultimate Strength (MPa) | Compressive Modulus (GPa) | Ultimate Strength (psi) | Compressive Modulus (10 <sup>6</sup> psi) |                                     |
| -54°C (-65°F),<br>DRY | 1 - Avg.<br>Std. Dev. | 592.5<br>32.7           | 69.49(2)<br>7.78          | 85,930<br>4,740         | 9.499(2)<br>1.128                         | 9,993(2)<br>1,680                   |
|                       | 2 - Avg.<br>Std. Dev. | 531.0<br>41.6           | 56.09(2)<br>3.26          | 77,010<br>6,030         | 8.135(2)<br>0.473                         | 11,615(2)<br>2,264                  |
|                       | 3 - Avg.<br>Std. Dev. | 596.5<br>43.7           | 54.38<br>2.96             | 86,520<br>6,340         | 7.887<br>0.429                            | 13,047<br>888                       |
| 22°C (72°F),<br>DRY   | 1 - Avg.<br>Std. Dev. | 414.2<br>32.3           | 51.51<br>6.83             | 60,080<br>4,680         | 7.471<br>0.990                            | 7,919<br>872                        |
|                       | 2 - Avg.<br>Std. Dev. | 410.1(2)<br>37.3        | 57.38(2)<br>5.08          | 59,480(2)<br>5,410      | 8.322(2)<br>0.737                         | 8,148(2)<br>1,714                   |
|                       | 3 - Avg.<br>Std. Dev. | 434.6<br>20.8           | 54.34<br>4.72             | 63,030<br>3,010         | 7.882<br>0.685                            | 8,698<br>3,423                      |
| 93°C (200°F),<br>DRY  | 1 - Avg.<br>Std. Dev. | 300.2<br>10.7           | 55.93<br>5.24             | 43,540<br>1,550         | 8.112<br>0.760                            | 5,342<br>1,055                      |
|                       | 2 - Avg.<br>Std. Dev. | 257.1<br>16.5           | 56.29<br>9.18             | 37,290<br>2,400         | 8.164<br>1.331                            | 4,511<br>980                        |
|                       | 3 - Avg.<br>Std. Dev. | 279.1<br>11.3           | 52.22<br>1.88             | 40,480<br>1,640         | 7.574<br>0.273                            | 6,217<br>853                        |

NOTES:

1. All average values represent five specimens unless otherwise noted.
2. Average of four specimens.

TABLE 16  
BASELINE TRANSVERSE (FILL) COMPRESSIVE PROPERTIES  
OF GRAPHITE REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition        | Resin Batch No.       | SI Units                |                           | U.S. Units              |                                           | Ultimate Strain (10 <sup>-6</sup> ) |
|-----------------------|-----------------------|-------------------------|---------------------------|-------------------------|-------------------------------------------|-------------------------------------|
|                       |                       | Ultimate Strength (MPa) | Compressive Modulus (GPa) | Ultimate Strength (psi) | Compressive Modulus (10 <sup>6</sup> psi) |                                     |
| -54°C (-65°F),<br>WET | 1 - Avg.<br>Std. Dev. | 544.1<br>34.1           | 63.28<br>4.64             | 78,920<br>4,950         | 9.179<br>0.673                            | 10,090<br>2,806                     |
|                       | 2 - Avg.<br>Std. Dev. | 514.1<br>31.5           | 59.32<br>1.42             | 74,560<br>4,570         | 8.604<br>0.206                            | 10,476<br>1,383                     |
|                       | 3 - Avg.<br>Std. Dev. | 534.3<br>51.4           | 59.32<br>3.14             | 77,500<br>7,460         | 8.604<br>0.456                            | 9,337<br>2,256                      |
| 22°C (72°F),<br>WET   | 1 - Avg.<br>Std. Dev. | 365.8<br>32.3           | 61.49<br>1.91             | 53,060<br>4,680         | 8.918<br>0.277                            | 5,893<br>848                        |
|                       | 2 - Avg.<br>Std. Dev. | 338.3<br>12.1           | 53.43<br>7.74             | 49,070<br>1,760         | 7.749<br>1.123                            | 7,366<br>3,156                      |
|                       | 3 - Avg.<br>Std. Dev. | 344.6<br>32.3           | 55.50<br>3.55             | 49,980<br>4,690         | 8.049<br>0.515                            | 6,754<br>1,256                      |
| 93°C (200°F),<br>WET  | 1 - Avg.<br>Std. Dev. | 168.0(3)<br>21.9        | 66.89(3)<br>5.58          | 24,370(3)<br>3,170      | 9.701(3)<br>0.810                         | 2,485(3)<br>421                     |
|                       | 2 - Avg.<br>Std. Dev. | 190.4<br>33.9           | 56.16<br>4.72             | 27,610<br>4,910         | 8.146<br>0.685                            | 3,783<br>1,064                      |
|                       | 3 - Avg.<br>Std. Dev. | 222.3(3)<br>23.4        | 58.57(3)<br>6.29          | 32,240(3)<br>3,400      | 8.495(3)<br>0.912                         | 3,950(3)<br>704                     |

NOTES:

1. All average values represent five specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F), 100% R.H. until saturated.
3. Average of four specimens.

TABLE 17  
BASELINE IN-PLANE SHEAR PROPERTIES OF GLASS  
REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test<br>Condition(2)  | Resin<br>Batch No.   | SI Units                        |                                 |                                          | U.S. Units                      |                                                 |                                                          |
|-----------------------|----------------------|---------------------------------|---------------------------------|------------------------------------------|---------------------------------|-------------------------------------------------|----------------------------------------------------------|
|                       |                      | In-Plane<br>Shear<br>Str. (MPa) | In-Plane<br>Shear Mod.<br>(GPa) | $\pm 45^\circ$ Tens.<br>Modulus<br>(GPa) | In-Plane<br>Shear<br>Str. (MPa) | In-Plane<br>Shear Mod.<br>(10 <sup>6</sup> psi) | $\pm 45^\circ$ Tens.<br>Modulus<br>(10 <sup>6</sup> psi) |
| -54°C (-65°F),<br>DRY | 1 - Avg.<br>Std.Dev. | 114.9(2)<br>19.4                | 7.39<br>0.83                    | 20.95<br>2.23                            | 16,670(2)<br>2,820              | 1.072(2)<br>0.120                               | 3.038(2)<br>0.323                                        |
|                       | 2 - Avg.<br>Std.Dev. | 118.3(3)<br>15.9                | 6.93(3)<br>0.75                 | 19.71(3)<br>2.48                         | 17,160(3)<br>2,300              | 1.005(3)<br>0.109                               | 2.858(3)<br>0.360                                        |
|                       | 3 - Avg.<br>Std.Dev. | 115.6<br>16.0                   | 7.01<br>0.68                    | 19.62<br>2.45                            | 16,770<br>2,320                 | 1.016<br>0.098                                  | 2.845<br>0.356                                           |
| 22°C (72°F),<br>DRY   | 1 - Avg.<br>Std.Dev. | 78.2(2)<br>9.9                  | 5.94(2)<br>0.38                 | 17.25(2)<br>1.21                         | 11,340(2)<br>1,430              | 0.861(2)<br>0.055                               | 2.502(2)<br>0.176                                        |
|                       | 2 - Avg.<br>Std.Dev. | 80.7(4)<br>4.5                  | 4.99(4)<br>0.46                 | 14.28(4)<br>1.40                         | 11,710(4)<br>813                | 0.723(4)<br>0.066                               | 2.071(4)<br>0.203                                        |
|                       | 3 - Avg.<br>Std.Dev. | 76.9<br>7.2                     | 4.91<br>0.32                    | 13.86<br>1.14                            | 11,150<br>1,050                 | 0.712<br>0.047                                  | 2.010<br>0.166                                           |
| 93°C (200°F)<br>DRY   | 1 - Avg.<br>Std.Dev. | 48.7(2)<br>9.2                  | 3.08(2)<br>0.54                 | 10.23(2)<br>1.50                         | 7,060(2)<br>1,330               | 0.446(2)<br>0.079                               | 1.484(2)<br>0.217                                        |
|                       | 2 - Avg.<br>Std.Dev. | 47.9(2)<br>5.4                  | 3.09(2)<br>0.24                 | 9.73(2)<br>0.80                          | 6,940(2)<br>790                 | 0.448(2)<br>0.035                               | 1.411(2)<br>0.116                                        |
|                       | 3 - Avg.<br>Std.Dev. | 51.2<br>9.5                     | 3.38<br>0.37                    | 11.01<br>1.17                            | 7,420<br>1,380                  | 0.490<br>0.054                                  | 1.597<br>0.169                                           |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | $\pm 45^\circ$<br>Poisson's<br>Ratio                     |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.418(2)<br>0.033                                        |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.420(3)<br>0.036                                        |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.397<br>0.043                                           |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.449(2)<br>0.029                                        |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.433(4)<br>0.079                                        |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.411<br>0.037                                           |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.676(2)<br>0.087                                        |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.577(2)<br>0.091                                        |
|                       |                      |                                 |                                 |                                          |                                 |                                                 | 0.631<br>0.047                                           |

NOTES:

1. All average values represent five specimens unless otherwise noted.
2. Average of seven specimens.
3. Average of six specimens.
4. Average of eleven specimens.

TABLE 18  
BASELINE IN-PLANE SHEAR PROPERTIES OF GLASS  
REINFORCED E-7781/EA9396 COMPOSITE MATERIAL (1)

| Test Condition(2)                                                      | Resin Batch No.   | SI Units                  |                           |                                    | U.S. Units                                |                                                    |                                |
|------------------------------------------------------------------------|-------------------|---------------------------|---------------------------|------------------------------------|-------------------------------------------|----------------------------------------------------|--------------------------------|
|                                                                        |                   | In-Plane Shear Str. (MPa) | In-Plane Shear Mod. (GPa) | $\pm 45^\circ$ Tens. Modulus (GPa) | In-Plane Shear Mod. (10 <sup>6</sup> psi) | $\pm 45^\circ$ Tens. Modulus (10 <sup>6</sup> psi) | $\pm 45^\circ$ Poisson's Ratio |
| -54°C (-65°F), WET                                                     | 1 - Avg. Std.Dev. | 60.3(3)<br>9.5            | 6.41(3)<br>0.24           | 18.91(3)<br>0.79                   | 8,740(3)<br>1,380                         | 0.930(3)<br>0.035                                  | 2.743(3)<br>0.115              |
|                                                                        | 2 - Avg. Std.Dev. | 57.7<br>7.3               | 5.30<br>0.68              | 15.89<br>1.14                      | 8,370<br>1,060                            | 0.769<br>0.099                                     | 2.305<br>0.166                 |
|                                                                        | 3 - Avg. Std.Dev. | 57.3<br>6.0               | 6.01<br>0.64              | 18.01<br>1.83                      | 8,310<br>870                              | 0.873<br>0.093                                     | 2.612<br>0.266                 |
| 22°C (72°F), WET                                                       | 1 - Avg. Std.Dev. | 37.0(3)<br>5.1            | 3.30(3)<br>0.34           | 10.60(3)<br>1.09                   | 5,370(3)<br>740                           | 0.479(3)<br>0.050                                  | 1.537(3)<br>0.158              |
|                                                                        | 2 - Avg. Std.Dev. | 37.9<br>2.8               | 3.04<br>0.66              | 9.63<br>1.32                       | 5,490<br>400                              | 0.441<br>0.096                                     | 1.396<br>0.192                 |
|                                                                        | 3 - Avg. Std.Dev. | 39.1<br>5.4               | 3.84<br>0.52              | 12.77<br>1.68                      | 5,670<br>790                              | 0.557<br>0.076                                     | 1.852<br>0.244                 |
| 93°C (200°F) WET                                                       | 1 - Avg. Std.Dev. | 18.7(4)<br>3.3            | 1.61(4)<br>0.42           | 5.58(4)<br>0.84                    | 2,710(4)<br>480                           | 0.234(4)<br>0.061                                  | 0.809(4)<br>0.122              |
|                                                                        | 2 - Avg. Std.Dev. | 19.3<br>0.9               | 1.34<br>0.28              | 4.87<br>0.86                       | 2,800<br>130                              | 0.194<br>0.041                                     | 0.706<br>0.125                 |
|                                                                        | 3 - Avg. Std.Dev. | 18.6<br>2.6               | 2.08<br>0.72              | 7.52<br>2.23                       | 2,700<br>370                              | 0.301<br>0.104                                     | 1.091<br>0.323                 |
| NOTES:                                                                 |                   |                           |                           |                                    |                                           |                                                    |                                |
| 1. All average values represent five specimens unless otherwise noted. |                   |                           |                           |                                    |                                           |                                                    |                                |
| 2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.           |                   |                           |                           |                                    |                                           |                                                    |                                |
| 3. Average of eight specimens.                                         |                   |                           |                           |                                    |                                           |                                                    |                                |
| 4. Average of seven specimens.                                         |                   |                           |                           |                                    |                                           |                                                    |                                |



TABLE 19  
BASELINE IN-PLANE SHEAR PROPERTIES OF GRAPHITE  
REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test<br>Condition(2) | Resin<br>Batch No.   | SI Units                        |                                 |                                | U.S. Units                      |                                                 |                                                | +45°<br>Poisson's<br>Ratio |
|----------------------|----------------------|---------------------------------|---------------------------------|--------------------------------|---------------------------------|-------------------------------------------------|------------------------------------------------|----------------------------|
|                      |                      | In-Plane<br>Shear<br>Str. (MPa) | In-Plane<br>Shear Mod.<br>(GPa) | +45° Tens.<br>Modulus<br>(GPa) | In-Plane<br>Shear<br>Str. (MPa) | In-Plane<br>Shear Mod.<br>(10 <sup>6</sup> psi) | +45° Tens.<br>Modulus<br>(10 <sup>6</sup> psi) |                            |
| -54°C(-65°F),<br>DRY | 1 - Avg.<br>Std.Dev. | 125.1<br>16.8                   | 5.50<br>0.67                    | 18.91<br>2.00                  | 18,140<br>2,440                 | 0.797<br>0.097                                  | 2.742<br>0.290                                 | 0.723<br>0.052             |
|                      | 2 - Avg.<br>Std.Dev. | 120.5<br>8.8                    | 5.79<br>0.53                    | 19.38<br>1.85                  | 17,480<br>1,270                 | 0.839<br>0.077                                  | 2.811<br>0.269                                 | 0.674<br>0.037             |
|                      | 3 - Avg.<br>Std.Dev. | 134.8<br>4.3                    | 5.86<br>0.34                    | 20.31<br>1.61                  | 19,550<br>620                   | 0.850<br>0.050                                  | 2.945<br>0.233                                 | 0.731<br>0.056             |
| 22°C (72°F),<br>DRY  | 1 - Avg.<br>Std.Dev. | 89.3<br>9.8                     | 3.99<br>0.57                    | 14.30<br>2.13                  | 12,950<br>1,420                 | 0.579<br>0.083                                  | 2.074<br>0.309                                 | 0.791<br>0.060             |
|                      | 2 - Avg.<br>Std.Dev. | 81.9<br>3.4                     | 4.28<br>0.44                    | 14.67<br>0.96                  | 11,880<br>500                   | 0.621<br>0.064                                  | 2.128<br>0.140                                 | 0.721<br>0.087             |
|                      | 3 - Avg.<br>Std.Dev. | 93.9<br>8.5                     | 4.43<br>0.32                    | 15.25<br>1.43                  | 13,620<br>1,230                 | 0.642<br>0.047                                  | 2.211<br>0.208                                 | 0.724<br>0.147             |
| 93°C (200°F)<br>DRY  | 1 - Avg.<br>Std.Dev. | 53.5<br>7.4                     | 2.62<br>0.21                    | 9.92<br>0.84                   | 7,760<br>1,080                  | 0.380<br>0.031                                  | 1.439<br>0.122                                 | 0.894<br>0.053             |
|                      | 2 - Avg.<br>Std.Dev. | 52.6<br>3.7                     | 3.18<br>0.68                    | 11.34<br>1.93                  | 7,630<br>540                    | 0.461<br>0.098                                  | 1.645<br>0.280                                 | 0.799<br>0.093             |
|                      | 3 - Avg.<br>Std.Dev. | 55.6<br>4.1                     | 2.74<br>0.24                    | 10.12<br>1.13                  | 8,060<br>600                    | 0.398<br>0.035                                  | 1.468<br>0.164                                 | 0.840<br>0.081             |

NOTES: 1. All average values represent five specimens unless otherwise noted.

TABLE 20  
BASELINE IN-PLANE SHEAR PROPERTIES OF GRAPHITE  
REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL (1)

| Test Condition(2)    | Resin Batch No.      | SI Units                  |                           |                          | U.S. Units                |                                           |                                          | ±45° Poisson's Ratio |
|----------------------|----------------------|---------------------------|---------------------------|--------------------------|---------------------------|-------------------------------------------|------------------------------------------|----------------------|
|                      |                      | In-Plane Shear Str. (MPa) | In-Plane Shear Mod. (GPa) | ±45° Tens. Modulus (GPa) | In-Plane Shear Str. (MPa) | In-Plane Shear Mod. (10 <sup>6</sup> psi) | ±45° Tens. Modulus (10 <sup>6</sup> psi) |                      |
| -54°C(-65°F),<br>WET | 1 - Avg.<br>Std.Dev. | 112.4<br>17.4             | 5.96<br>0.19              | 19.98<br>1.60            | 16,300<br>2,520           | 0.865<br>0.028                            | 2.897<br>0.232                           | 0.673<br>0.093       |
|                      | 2 - Avg.<br>Std.Dev. | 116.1<br>10.6             | 6.37<br>0.82              | 21.26<br>2.85            | 16,830<br>1,540           | 0.924<br>0.119                            | 3.083<br>0.414                           | 0.669<br>0.052       |
|                      | 3 - Avg.<br>Std.Dev. | 119.2<br>14.8             | 4.89<br>0.43              | 17.52<br>1.79            | 17,280<br>2,140           | 0.709<br>0.063                            | 2.541<br>0.260                           | 0.791<br>0.070       |
| 22°C (72°F),<br>WET  | 1 - Avg.<br>Std.Dev. | 68.7<br>9.3               | 3.39<br>0.31              | 11.74<br>1.10            | 9,970<br>1,350            | 0.492<br>0.045                            | 1.702<br>0.159                           | 0.729<br>0.083       |
|                      | 2 - Avg.<br>Std.Dev. | 70.5<br>9.4               | 4.21<br>0.89              | 14.92<br>3.12            | 10,230<br>1,370           | 0.610<br>0.129                            | 2.163<br>0.453                           | 0.779<br>0.128       |
|                      | 3 - Avg.<br>Std.Dev. | 77.1<br>6.7               | 3.61<br>0.41              | 13.46<br>1.29            | 11,180<br>970             | 0.524<br>0.060                            | 1.952<br>0.187                           | 0.869<br>0.108       |
| 93°C (200°F)<br>WET  | 1 - Avg.<br>Std.Dev. | 31.2<br>4.3               | 1.70<br>0.41              | 5.97<br>1.42             | 4,520<br>630              | 0.247<br>0.059                            | 0.866<br>0.206                           | 0.755<br>0.124       |
|                      | 2 - Avg.<br>Std.Dev. | 30.8<br>3.5               | 1.85<br>0.86              | 6.82<br>2.83             | 4,470<br>500              | 0.268<br>0.124                            | 0.989<br>0.410                           | 0.873<br>0.186       |
|                      | 3 - Avg.<br>Std.Dev. | 30.9<br>3.3               | 1.57<br>0.28              | 6.59<br>0.83             | 4,480<br>480              | 0.228<br>0.040                            | 0.956<br>0.120                           | 1.074<br>0.142       |

NOTES:

1. All average values represent five specimens unless otherwise noted.
2. WET = wet aged at 60°C (140°F)/100% R.H. until saturated.

and inplane shear. Table 21 summarizes the interlaminar shear data from the baseline tests. Again, all three resin batches produced very similar property levels.

### 3.3 GLASS TRANSITION TEMPERATURE

As noted in Section 2.3.2 and Table 2, Tg measurements were carried out on neat resin samples for both dry and wet conditions by means of a DMA test. Figure 1 illustrates a typical DMA test result, and the Tg value determined from the analysis is indicated in the figure. Table 22 summarizes the Tg data from the baseline tests. It is apparent from the data in Table 22 that the batch-to-batch Tg values are in excellent agreement and also that absorbed moisture significantly reduces the Tg of EA9396.

An additional Tg test was performed on a neat EA9396 resin sample that was cured at a lower temperature and for a shorter time than the standard cure condition. This value is also listed in Table 22 for comparison. The reduced Tg value for this shorter, lower temperature cure suggests that cure is incomplete and this corroborates the results from the cure studies that are discussed in Sections 3.5.1 and 3.5.2.

### 3.4 BEARING STRENGTH

Bearing strength tests were performed on only one of the three resin batches. All of the laminates used for bearing strength tests were prepared and cured in accordance with the standard baseline processing procedures, detailed in Appendix A. Bearing strength tests were carried out on both reinforcements (graphite and glass fabric) and in both the wet and dry condition although only at room temperature. Table 23 summarizes the bearing test data. It is evident from these data that absorbed moisture significantly reduces bearing strength.

### 3.5 EFFECT OF NONBASELINE CURE/PROCESSING CONDITIONS

The baseline cure condition used in this program was a vacuum bag cure at 93°C (200°F) for 45 minutes. Alternative conditions that were used included curing at both lower and higher temperatures, lower and higher cure vacuum levels than the baseline 635 mm (25 in) Hg, and cure times other than 45 minutes. Laminates processed at these alternative conditions were tested for interlaminar shear strength to assess the effect of the alternative cure. In addition, a number of differential scanning calorimetry (DSC) measurements were made for different cure temperatures and cure histories.

TABLE 21  
BASELINE INTERLAMINAR SHEAR PROPERTIES OF  
EA9396 COMPOSITE LAMINATES

| Reinforcement Type | Resin Batch Number | Test Condition(3) | SI Units                                |                | U.S. Units                              |                | Weight Gain During Aging (%) |
|--------------------|--------------------|-------------------|-----------------------------------------|----------------|-----------------------------------------|----------------|------------------------------|
|                    |                    |                   | Interlaminar Shear Strength (1,2) (MPa) | Avg. Std. Dev. | Interlaminar Shear Strength (1,2) (psi) | Avg. Std. Dev. |                              |
| "E"-7781 Glass     | 1                  | 22°C(72°F) Dry    | 40.03                                   | 1.68           | 5806                                    | 244            | N.A.                         |
|                    | 2                  | 22°C(72°F) Dry    | 38.27                                   | 1.22           | 5551                                    | 177            | N.A.                         |
|                    | 3                  | 22°C(72°F) Dry    | 37.97                                   | 1.64           | 5507                                    | 238            | N.A.                         |
|                    | 1                  | 22°C(72°F) Wet    | 18.66                                   | 0.37           | 2706                                    | 53             | 2.32                         |
|                    | 2                  | 22°C(72°F) Wet    | 20.74                                   | 0.85           | 3008                                    | 124            | 2.10                         |
|                    | 3                  | 22°C(72°F) Wet    | 22.17                                   | 0.35           | 3216                                    | 51             | 2.09                         |
|                    | 1                  | 93°C(200°F) Wet   | 9.25                                    | 0.50           | 1342                                    | 73             | 2.24                         |
|                    | 2                  | 93°C(200°F) Wet   | 13.25                                   | 0.57           | 1922                                    | 82             | 2.09                         |
|                    | 3                  | 93°C(200°F) Wet   | 12.93                                   | 0.52           | 1875                                    | 75             | 2.11                         |
| T300-W133 Graphite | 1                  | 22°C(72°F) Dry    | 39.06                                   | 2.78           | 5665                                    | 403            | N.A.                         |
|                    | 2                  | 22°C(72°F) Dry    | 39.82                                   | 4.55           | 5776                                    | 660            | N.A.                         |
|                    | 3                  | 22°C(72°F) Dry    | 38.94                                   | 2.35           | 5648                                    | 341            | N.A.                         |
|                    | 1                  | 22°C(72°F) Wet    | 32.74                                   | 15.82          | 4748                                    | 409            | 2.19                         |
|                    | 2                  | 22°C(72°F) Wet    | 32.63                                   | 6.96           | 4733                                    | 180            | 2.32                         |
|                    | 3                  | 22°C(72°F) Wet    | 31.78                                   | 4.14           | 4609                                    | 107            | 2.24                         |
|                    | 1                  | 93°C(200°F) Wet   | 14.21                                   | 1.19           | 2061                                    | 173            | 2.22                         |
|                    | 2                  | 93°C(200°F) Wet   | 15.51                                   | 0.48           | 2250                                    | 69             | 2.32                         |
|                    | 3                  | 93°C(200°F) Wet   | 18.73                                   | 0.97           | 2716                                    | 140            | 2.24                         |

NOTES:

1. Four-point shear. Graphite tests at 16:1 span-thickness ratio, Glass tests at 8:1.
2. Warp direction of fabric is running in length direction of specimens.
3. WET = wet aged at 60°C (140°F)/95-100% R.H. until saturated.

Sample : EA 9396 2-2 DRY  
 Size : 22.70 x 13.30 x 1.85 mm  
 Method : DMA-STEP 2°  
 Comment: STEP 2°C  
 File : E, RUN1893.01  
 Operator: GALASKA  
 Run Date: 06/13/89 18:05

# DMA

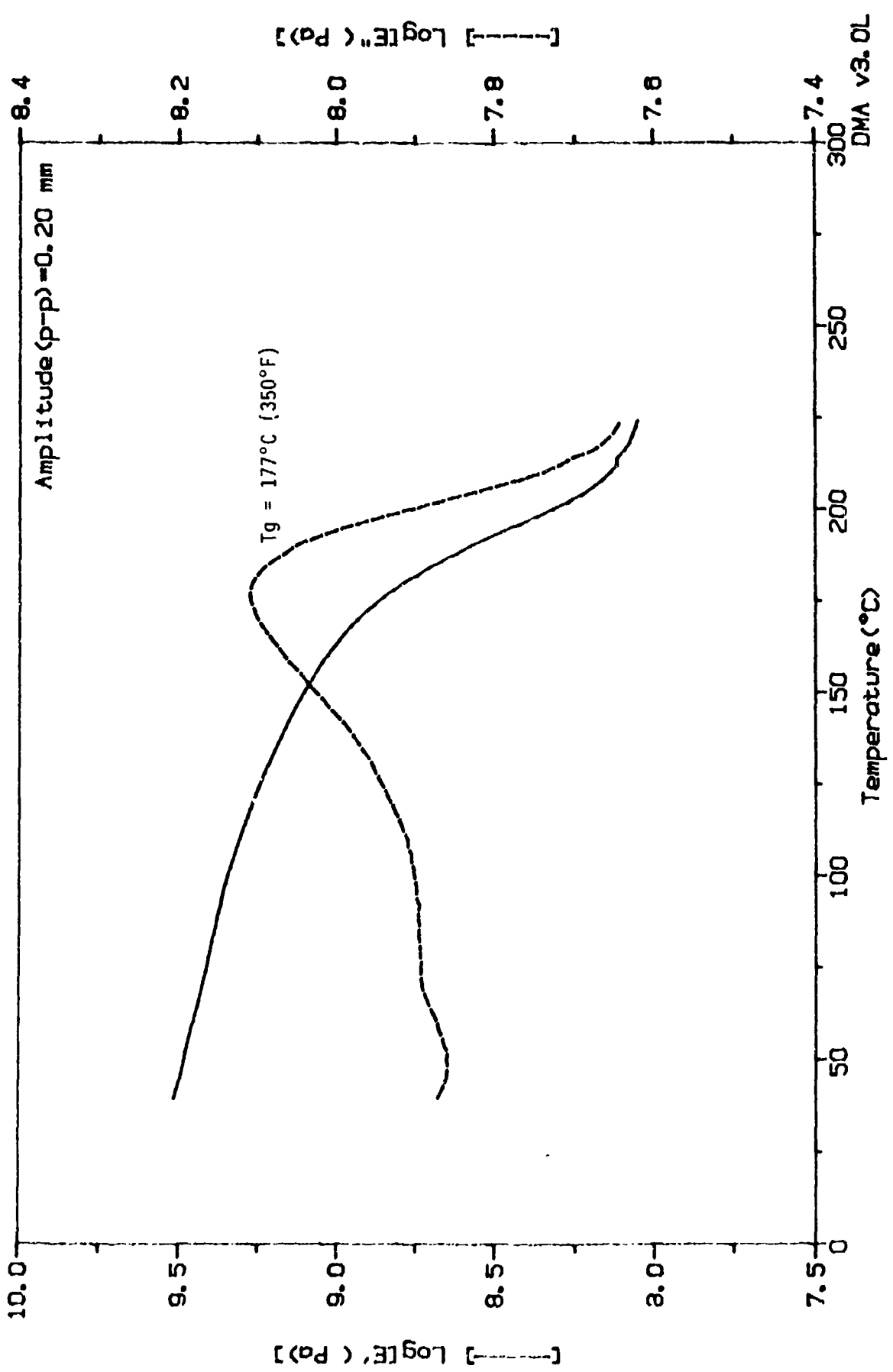


Figure 1. Typical DMA Cure With T<sub>g</sub> Value.

TABLE 22

GLASS TRANSITION TEMPERATURE OF EA9396  
NEAT RESIN CASTINGS (1)

| Resin Batch<br>Number | Test Condition | Tg (2) |      | Weight Gain<br>During Aging (%) |
|-----------------------|----------------|--------|------|---------------------------------|
|                       |                | (°C)   | (°F) |                                 |
| 1 - Avg.              | Dry            | 175    | 347  | N.A.                            |
| 2 - Avg.              | Dry            | 176    | 349  | N.A.                            |
| 3 - Avg.              | Dry            | 177    | 350  | N.A.                            |
| 1 - Avg.              | Wet (3)        | 106    | 223  | 9.1                             |
| 2 - Avg.              | Wet (3)        | 108    | 226  | 8.7                             |
| 3 - Avg.              | Wet (3)        | 107    | 225  | 8.8                             |
| NA (4)                | Dry            | 149    | 300  | N.A.                            |

(1) Castings cured 45 minutes at 93°C (200°F) unless otherwise noted.

(2) Listed values represent averages of three test samples from each resin batch.

(3) Wet = Aging at 60°C (140°F), 95-100% R.H. until saturated.

(4) Casting cured 30 minutes at 82°C (180°F).

TABLE 23

ROOM TEMPERATURE BEARING STRENGTH OF EA9396  
COMPOSITE MATERIAL

| Reinforcement         | Aging Condition | Bearing Strength @ |                             |
|-----------------------|-----------------|--------------------|-----------------------------|
|                       |                 | 4% Elong. (ksi)    | Max. Bearing Strength (ksi) |
| E-7781 Glass          | None(dry)       | 42.4               | 54.9                        |
|                       | Wet (1)         | 21.6               | 35.1                        |
| T300-W133<br>Graphite | None (dry)      | 58.3               | 71.3                        |
|                       | Wet (1)         | 33.7               | 89.0                        |

(1) Wet aged at 60°C (140°F), 95-100% RH until saturated.

### 3.5.1 Effect of Cure Temperature on Degree of Cure by DSC

Both isothermal and dynamic DSC measurements were made on neat uncured EA9396 resin samples. Table 24 summarizes the data obtained from these tests. Figure 2 illustrates typical dynamic and isothermal DSC test scans. Heat released as a result of the polymerization (or cure) reaction causes the plotted curve to rise above the baseline. The area under this curve corresponds to the total heat released during the curing reaction. In the two curves illustrated in Figure 2, the total heat released was 535.1 J/gm for the case of the dynamic scan and 479.3 J/gm for the case of the isothermal scan. The higher heat release value for the dynamic test implies that the sample was more completely cured during this test than in the isothermal test. This is a logical result since the sample was heated to a substantially higher maximum temperature in the dynamic test ( $>200^{\circ}\text{C}$  ( $>392^{\circ}\text{F}$ )) than in the isothermal test ( $82^{\circ}\text{C}$  ( $180^{\circ}\text{F}$ )).

In the case of the isothermal tests, a second DSC test, carried out in the dynamic mode at  $2^{\circ}\text{C}/\text{minute}$ , was performed on each sample to determine residual exotherm. Figure 3 illustrates a dynamic DSC test result from which residual exotherm, or heat release during postcure, was obtained.

The first two tests listed in Table 24, dynamic tests at  $10^{\circ}\text{C}/\text{minute}$  and  $1^{\circ}\text{C}/\text{minute}$ , respectively, were performed to establish the total exotherm (total heat release during cure) of the EA9396 resin and to determine whether heating rate caused significant differences in exotherm. From these tests, it appears that between 535 and 574 J/gm are released by EA9396 when it is completely cured. Following these tests, four isothermal tests were carried out over the temperature range of  $66\text{--}107^{\circ}\text{C}$  ( $150\text{--}225^{\circ}\text{F}$ ).

It is evident from the isothermal data that as the cure temperature increases, the degree of cure, as measured by the heat release, increases and the residual exotherm (or remaining cure that can be achieved) diminishes. Examination of the residual exotherm DSC curves are particularly interesting in that they demonstrate that the remainder of the cure still to be accomplished after the initial cure, does not begin until the temperature is considerably higher than the temperature at which the initial cure occurred. This is evident by comparing the curves in Figures 2b and 3. The data in Table 24 show that the postcure initiation temperature becomes progressively higher as the initial cure temperature is increased. Another point of interest from the data for the four isothermal tests in the center of Table 24 is that the sum of the heat released during

TABLE 24

EFFECT OF TEMPERATURE ON CURE EXOTHERM BEHAVIOR  
OF EA9396 NEAT RESIN

| DSC Run Type | Heating Rate (°C/min) | Cure(Hold) Temperature (°C) [°F] | Time to Complete Cure at Hold Temp. (min.) (1) | Heat Release During Cure (J/gm) | Cure State (%) (2) | Heat Release During Postcure (J/gm)(3) | Temperature at Which Postcure Initiates (°C) [°F] | Total Heat Release (J/gm) |
|--------------|-----------------------|----------------------------------|------------------------------------------------|---------------------------------|--------------------|----------------------------------------|---------------------------------------------------|---------------------------|
| Dynamic      | 10                    | — (4)                            | —                                              | 535                             | 100%               | —                                      | —                                                 | 535                       |
| Dynamic      | 1                     | — (4)                            | —                                              | 574                             | 100%               | —                                      | —                                                 | 574                       |
| Isothermal   | 2                     | (66)[150]                        | ~75                                            | 450                             | 83%                | 94                                     | (100)[212]                                        | 544                       |
| Isothermal   | 2                     | (82)[180]                        | ~40                                            | 479                             | 89%                | 57                                     | (110)[230]                                        | 536                       |
| Isothermal   | 2                     | (93)[200]                        | ~30                                            | 486                             | 91%                | 46                                     | (120)[248]                                        | 532                       |
| Isothermal   | 2                     | (107)[225]                       | ~10                                            | 496                             | 95%                | 27                                     | (130)[266]                                        | 522                       |
| Isothermal   | 2                     | (82)[180]                        | ~41                                            | 519                             | 89%                | 60(5)                                  | (107)[225]                                        | 579                       |
| Dynamic      | 10                    | — (4)                            | —                                              | —                               | 68%(est)(6)        | 170                                    | (69)[156]                                         | 535(est)(6)               |

(1) Time after reaching hold temperature.

(2) Heat released during cure ÷ total heat release.

(3) All values in this column determined in a dynamic, 2°C/min, DSC test.

(4) Temperature increased throughout cure until no further heat release evident. Test typically terminated in 225-300°C range.

(5) After the 82°C isothermal cure, the sample was held at 22°C for 7 days before the residual heat (of postcure) was measured in a dynamic DSC test.

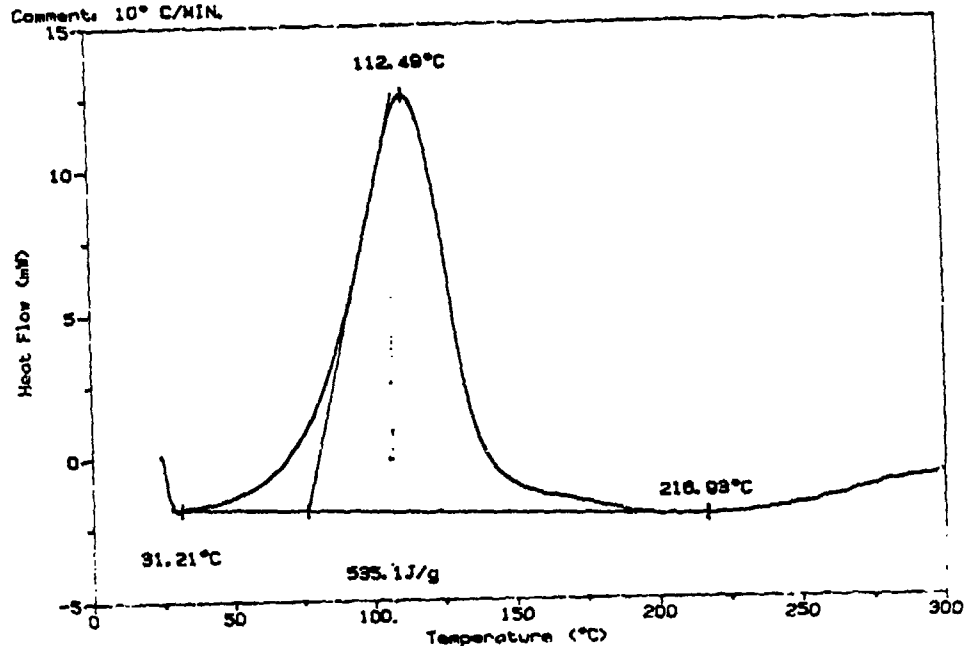
(6) Sample cured at 22°C for 7 days before residual heat (or postcure) was measured in a dynamic DSC test. Assumed a total heat release of 535 J/gm (equal to first test listed in table). Heat release during 7 day, 22°C cure assumed equal to 535 J/gm minus heat release during postcure.



Sample: EA 9396  
Size: 6.7940 mg

DSC

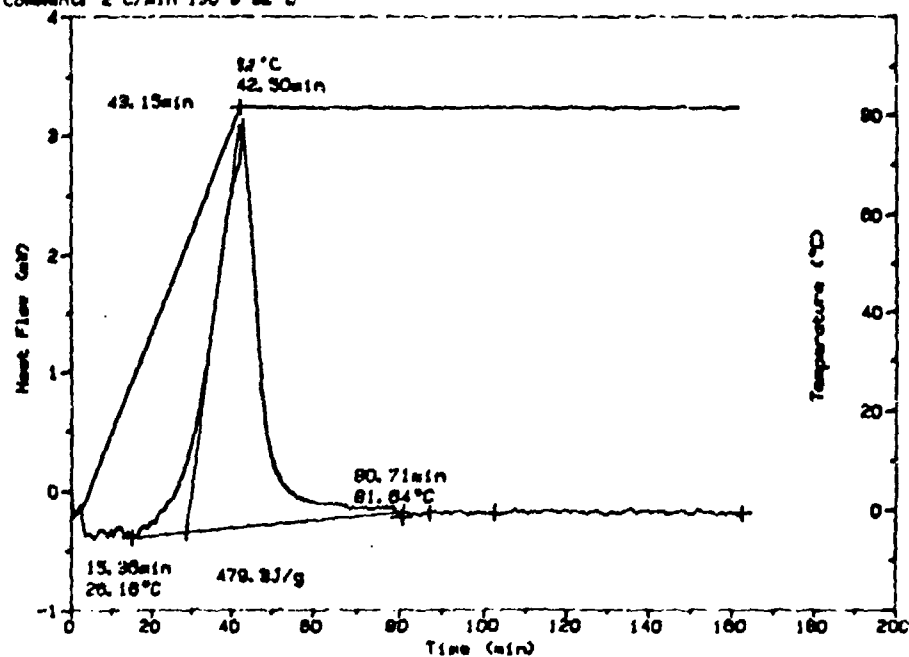
Comments: 10° C/MIN.



(a) Dynamic DSC Heat Release Test for Curing of EA9396.

Sample: EA 9396  
Size: 5.8700 mg  
Method: DSC-150 @ 82°C  
Comments: 2°C/min-150 @ 82°C

DSC



(b) Isothermal DSC Heat Release Test for Curing of EA9396 at 82°C (180°F).

Figure 2. Typical Dynamic and Isothermal Heat Release Test Results for Curing of EA9396.

Sample: EA 9396  
Size: 5.8700 mg

DSC

Comment: 10°C/min AFTER ISO @ 82°C

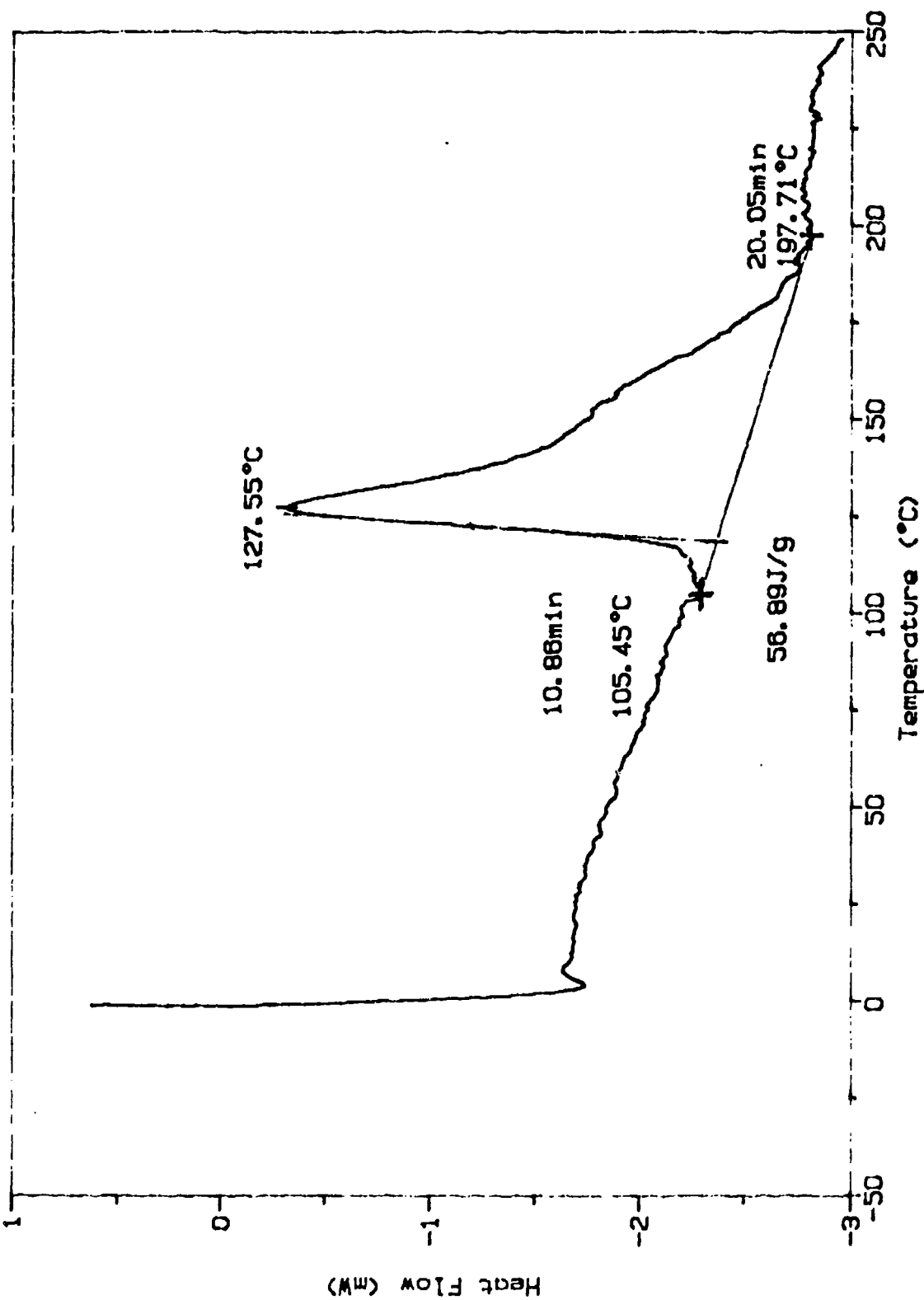


Figure 3. Dynamic DSC Residual Heat Release Test for Postcuring of EA9396 After Isothermal Cure at 82°C (180°F).

the cure and postcure ranges between 522 and 544 J/gm. These total heat release values are in excellent agreement with the total heat release values determined previously for the two dynamic tests.

The last two DSC tests that were conducted were aimed at determining:

- (a) whether an 82°C (180°F) cure, followed by a 7-day postcure at room temperature, would produce full cure, and
- (b) how much cure could be achieved in a 7-day cure at room temperature.

In the former instance, one would expect a dynamic residual exotherm test that was delayed 7 days after the initial 82°C (180°F) isothermal cure, to exhibit no additional heat release if cure had proceeded to completion during the intervening week at room temperature. In the latter case, the amount of residual exotherm remaining would provide a measure of how complete the cure was in the initial 7-day room temperature cure.

Note from the data in Table 24 that after an 82°C (180°F) cure, an additional 7 days at room temperature did not appear to produce any additional cure since only an additional 60 J/gm of exotherm was measured after the 7-day period.

The 7-day room temperature cure appeared to produce only about 68% of full cure since an additional 170 J/gm of exotherm was measured in a dynamic DSC test after the 7-day room temperature cure. This is consistent with the pattern observed in the other isothermal cure tests.

Based on these measurements, the baseline cure schedule of 45 minutes at 93°C (200°F) would appear to produce approximately 90% of the full cure in so far as heat release is concerned. Thus one would expect that extended subsequent exposure to temperatures above this level would drive the material to more complete cure. These results are consistent with the T<sub>g</sub> data discussed in Section 3.3, in which a shorter, lower temperature cure produced a lower T<sub>g</sub> than the standard cure, implying a lower degree of cure.

### 3.5.2 Effect of Cure Time and Temperature on Interlaminar Shear Strength

Graphite fabric reinforced laminates were impregnated and cured at various combinations of time and temperature and then tested for interlaminar shear strength. Table 25 presented the data obtained from these tests.

It is evident that for all of the cures carried out at 80°C (175°F) or higher, the room temperature dry shear strength is basically equivalent while it falls off somewhat for the reduced temperature cure. There appears to be a slight loss of wet shear strength levels for reduced cure temperatures but so long as the cure temperature remains at 80°C (175°F) or above, the loss is not much more than about 10%. The room temperature cure, on the other hand, results in a wet room temperature shear strength that is nearly 25% below that produced by the higher temperature cures.

### 3.5.3 Effect of Cure Vacuum Pressure on Interlaminar Shear Strength

Glass fabric reinforced laminates were impregnated and cured at the standard baseline cure condition of 45 minutes at 93°C (200°F) but at vacuum pressure levels both above and below the nominal 635 mm (25 in) Hg used with the baseline laminates. These laminates were then tested for interlaminar shear strength. Table 26 presents these test results, as well as the physical properties for each of these laminates. The physical property data show several logical trends. Specific gravity increases and ply thickness decreases with increasing cure vacuum level. The shear strength behavior appears to be independent of vacuum level until the vacuum level falls below 625 mm (25 in) Hg. At lower vacuum levels than this, the shear strength is noticeably lower. This may be, in part, a result of the fact that the void contents of the laminates cured under the reduced vacuum levels are higher than the normal 5% that occurs in the laminates cured under 635 mm (25 in) Hg vacuum.

## **3.6 RESIN POT/WORK LIFE**

Two different types of pot-life or work-life tests were carried out. The purpose of the first was to determine the time available before a freshly mixed resin batch advanced to gel. The purpose of the second was to determine the time available before an impregnated layup advanced so far that it was no longer workable.

In the first test, two 200-gram samples of EA9396 were mixed and placed in 22°C (72°F) and 38°C (100°F) environments while pot-life observations were recorded.

TABLE 25  
EFFECT OF CURE TEMPERATURE ON INTERLAMINAR  
SHEAR STRENGTH OF GRAPHITE REINFORCED  
EA9396 LAMINATES

| Cure Condition                                                                 | Interlaminar Shear Strength (psi) (2) |                      |                       |
|--------------------------------------------------------------------------------|---------------------------------------|----------------------|-----------------------|
|                                                                                | 22°C (72°F), Dry                      | 22°C (72°F), Wet (4) | 93°C (200°F), Wet (4) |
| 45 min. at 107°C<br>(225°F)                                                    | 6120                                  | 4540                 | ---                   |
| 45 min. at 93°C<br>(200°F) (3)                                                 | 5700                                  | 4700                 | 2340                  |
| 30 min. at 93°C<br>(200°F)                                                     | 6220                                  | 4430                 | 2270                  |
| 30 min. at 82°C<br>(180°F)                                                     | 6230                                  | 4340                 | 1900                  |
| 45 min. at 79.5°C<br>(175°F)                                                   | 5640                                  | 4020                 | ---                   |
| 7 days at 22°C (72°F)<br>plus additional 3 mos.<br>dry storage or wet<br>aging | 5010                                  | 3410                 | ---                   |

- (1) All cures were under nominally full vacuum pressure ~ 25 in. Hg).
- (2) Four-point shear test procedure.
- (3) This represents the baseline cure schedule used throughout the program.
- (4) Wet aged at 60°C (140°F), 95-100% R.H. till saturated.
- (5) Laminate under compacting vacuum bag pressure only during first few hours of 22°C (72°F) cure. Remaining 164 hrs. of cure at 22°C (72°F) under ambient conditions.

TABLE 26

EFFECT OF CURE PRESSURE ON LAMINATE PHYSICAL CHARACTERISTICS  
AND INTERLAMINAR SHEAR STRENGTH

| Cure Vacuum<br>Level<br>(in. Hg) | Specific<br>Gravity | Resin<br>Content<br>(% wt.) | Fiber<br>Content<br>(% vol.) | Void<br>Content<br>(% vol.) | Ply<br>Thickness<br>(mil) | Interlaminar<br>Shear<br>Strength<br>(psi) (1) |
|----------------------------------|---------------------|-----------------------------|------------------------------|-----------------------------|---------------------------|------------------------------------------------|
| 10                               | 1.87                | 28.6                        | 52.6                         | 5.4                         | 8.5                       | 4640                                           |
| 16                               | 1.88                | 25.6                        | 55.0                         | 7.1                         | 8.3                       | 5170                                           |
| 23                               | 1.91                | 24.4                        | 56.6                         | 6.7                         | 8.0                       | 4630                                           |
| 25 (2)                           | 1.91                | 26.6                        | 55.2                         | 5.1                         | 8.0                       | 5700                                           |
| 27                               | 1.94                | 26.2                        | 56.1                         | 3.9                         | 7.8                       | 5940                                           |

(1) Tests conducted at 72°F on dry specimens.

(2) Baseline laminates.

These pot-life measurements were repeated on samples from the same batch of resin after 20 months of storage at 4°C (40°F). Table 27 presents the results of these tests.

In the second test, two 12-ply graphite fabric reinforced laminates were impregnated with freshly mixed EA9396 resin and then placed in 22°C (72°F) to 38°C (100°F) environments while observations were recorded on the state of the matrix resin. Table 28 presents the results of these tests.

It is apparent from the data in Tables 27 and 28 that the pot/work life is markedly shortened by increasing the temperature from 22°C (72°F) to 38°C (100°F). In addition, the effect of long-term storage is to reduce the available pot life and especially to shorten the time between first noticeable exotherm and final kick-over. In spite of the shortened pot-life or work-life available after extended storage for the conditions examined, the available time is still probably sufficient to permit most repairs to be satisfactorily completed.

### 3.7 EFFECT OF STORAGE TIME AND TEMPERATURE

The purpose of these tests was to determine how the processability of the material changed and whether good mechanical property levels could still be achieved after extended resin storage at ambient and elevated temperature. The tests listed in Table 3 were periodically conducted over a 30-month storage period. Samples of both parts A and B of a single batch of the EA9396 resin system were placed in storage at room temperature, 38°C (100°F) and 49°C (120°F). The samples were stored in the cans they were received in from the vendor.

The HPLC, FTIR, DSC and Rheometrics viscosity profile measurements failed to reveal any significant changes in the resin system as a result of 24 months storage at any of the three storage temperatures. Figure 4 presents HPLC spectra for part A of the EA9396 system in the freshly received condition (~3 months after manufacture) and after 18 months of storage at 49°C (120°F), respectively. Both spectra were generated using the same test parameters. It is evident that no significant difference appears. The HPLC spectra for 24 months at all three storage temperatures indicated equivalent behavior. Since no components are present in Part B of the EA9396 system that produce significant features in an HPLC spectra, this test was not performed on Part B.

**TABLE 27**  
**POT LIFE OBSERVATIONS FOR 200-GRAM BATCH OF EA9396 (1)**

| Storage Condition | Test Temperature | Time to First<br>Notice of Exotherm<br>(min. after mixing) | Time to Boil/Gel (2)<br>(min. after mixing) |
|-------------------|------------------|------------------------------------------------------------|---------------------------------------------|
| Freshly Received  | 22°C (72°F)      | 105                                                        | 112/113                                     |
|                   | 39°C (100°F)     | 40                                                         | 60/61                                       |
| 20 months at      | 22°C (72°F)      | 90                                                         | 92/94                                       |
|                   | 38°C (100°F)     | 40                                                         | 42/43                                       |

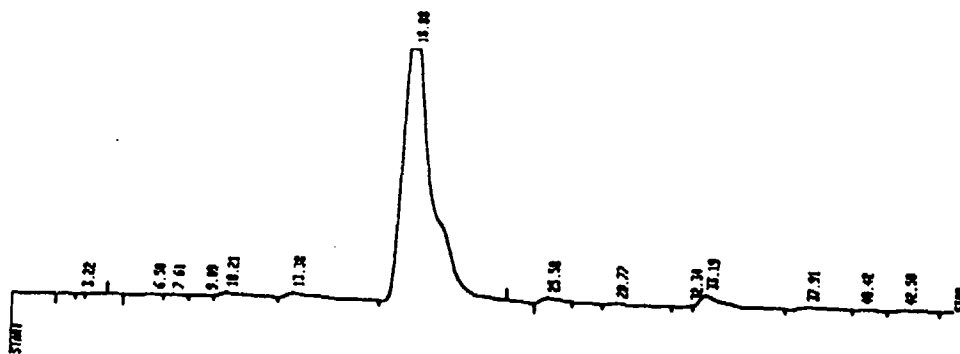
- (1) Times listed were measured from completion of mixing.  
 (2) At the first times indicated, the two samples were so hot that they were bubbling and smoking. Gel followed within a minute of this.

**TABLE 28**  
**WORK LIFE OBSERVATIONS OF 12-PLY GRAPHITE LAMINATE**  
**IMPREGNATED WITH EA9396 A/B RESIN (1)**

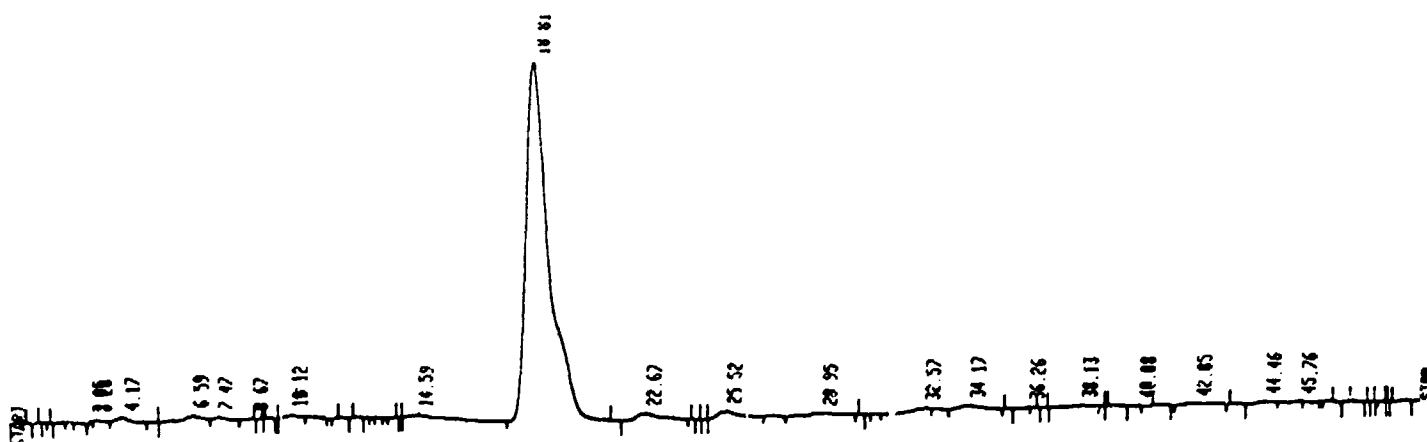
| Temperature<br>Environment | Maximum<br>Midplane<br>Temp. (2) | Time to<br>Become Tacky<br>(min) (3) | Time to Lose<br>Tack (min) (4) | Time at Which<br>Surface is no<br>Longer Indentable<br>(min) (5) |
|----------------------------|----------------------------------|--------------------------------------|--------------------------------|------------------------------------------------------------------|
| 22°C (72°F)                | 29°C (84°F)                      | ~60                                  | 210                            | 240                                                              |
| 38°C (100°F)               | 47°C<br>(116°F)                  | ~50                                  | 100                            | 100                                                              |

- (1) Times listed were measured from completion of laminate impregnation. Impregnation required approximately 15 minutes after completion of mixing.  
 (2) Midplane temperature recorded with imbedded thermocouple.  
 (3) Subjective judgement of when resin changes from thick syrupy state to a sticky, nonliquid state.  
 (4) Subjective judgement.  
 (5) Unable to make an impression on surface of laminate with a wooden tongue depressor and hand pressure.





(a) Fresh Resin.



(b) Resin Aged for Eighteen Months at 49°C (120°F).

Test Parameters: Resin dissolved in dioxane

Flow rate: 1 ml/min

Gradient Profile

| <u>Time (minutes)</u> | <u>% Water</u> | <u>% Dioxane</u> |
|-----------------------|----------------|------------------|
| 0                     | 50             | 50               |
| 10                    | 50             | 50               |
| 40                    | 30             | 70               |
| 50                    | 30             | 70               |

Figure 4. HPLC Spectra of EA9396, Part A.

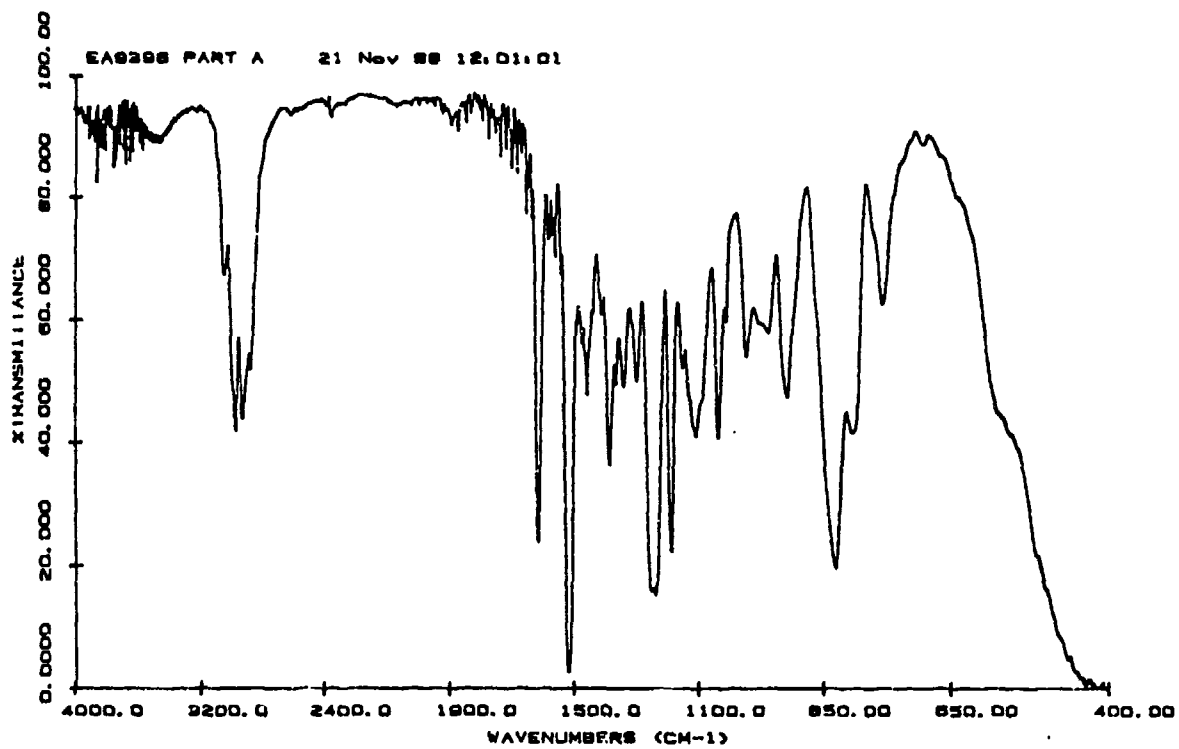
Figures 5 and 6 present FTIR spectra for both parts A and B in the fresh condition and after 24 months storage at 49°C (120°F). No significant changes between the fresh and 24-month aged material is apparent for either parts A or B.

Figure 7 presents a Rheometrics cure profile for fresh EA9396 material. Similar curves were obtained every 6 months for up to 24 months at each of the three storage temperatures. Table 29 lists key information extracted from each of these cure profiles. It is evident from the data in Table 29 that no changes are apparent as storage time increases.

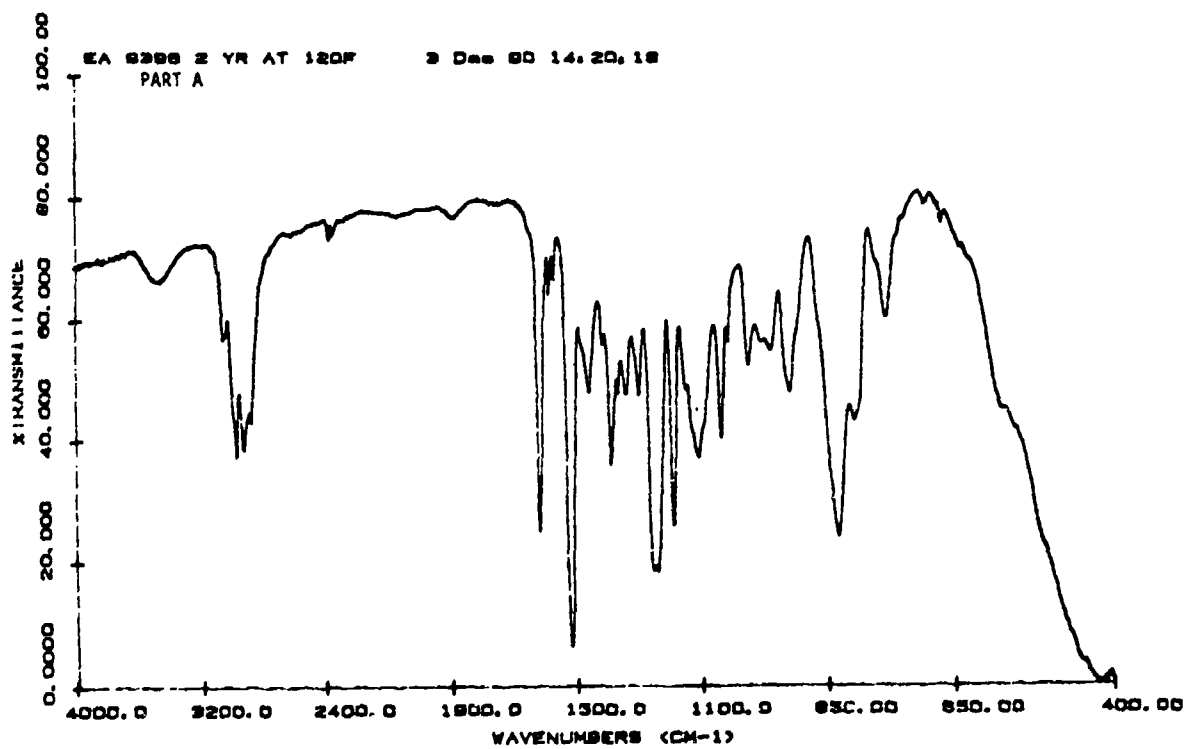
Figure 8 presents a DSC curve for fresh EA9396 material. Additional curves were generated every 6 months for up to 24 months at each of the three storage temperatures. Table 30 lists key information extracted from each of these DSC tests. As with the data from the cure profiles, no significant changes are apparent in the data of Table 30 as storage time increases.

The room temperature viscosity of parts A and B was also measured, using a Brookfield viscometer, as storage time increased. While the viscosity of the unmixed part B did not change during storage, part A did. Table 31 lists these changes. It is evident that at the 49°C (120°F) storage temperature viscosity starts to increase markedly after 12 months. After 30 months storage at 49°C (120°F), part A had become much too viscous to use at room temperature for wet layup impregnation of a laminate. After 36 months at 38°C (100°F), the viscosity of part A was still low enough to be processible by wet layup impregnation although the material was starting to show a marked viscosity increase. At the 22°C (72°F) storage condition, the resin was still usable after over four years.

In addition to the tests discussed above, the EA9396 resin samples that were in storage at the three different temperatures were also used to prepare graphite fabric reinforced laminates for interlaminar shear testing after various storage intervals. The interlaminar shear properties achievable from stored resin was not degraded at all so long as the viscosity remained low enough to permit wet layup impregnation of the reinforcement. In fact, it appears that an increased interlaminar shear strength is possible over time. Table 32 presents these data.

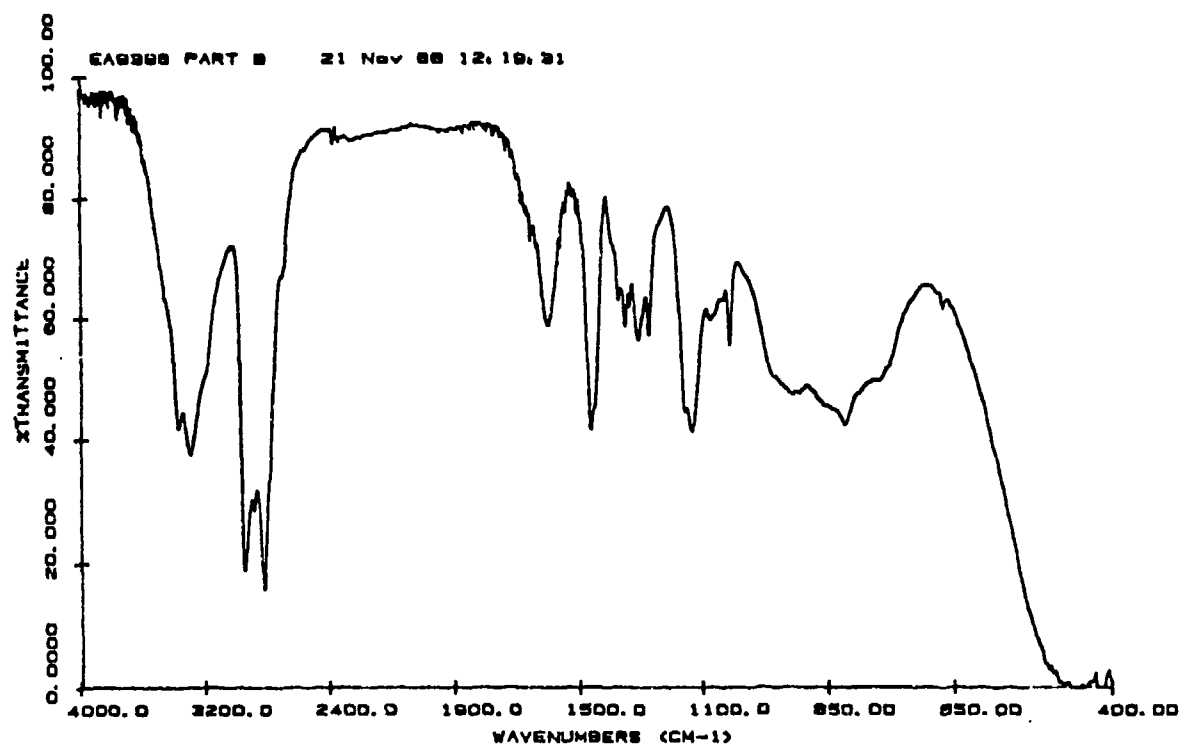


(a) Fresh Resin.

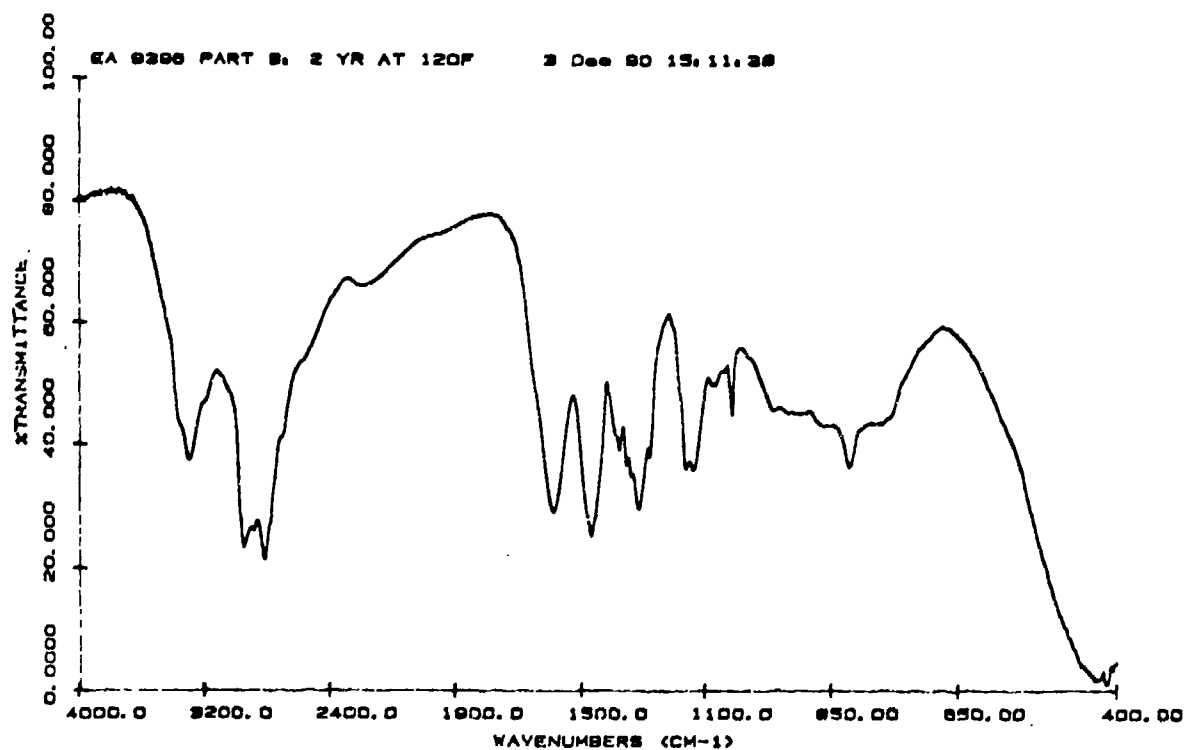


(b) Resin Aged for Two Years at 49°C (120°F).

Figure 5. FTIR Spectra of EA9396, Part A.



(a) Fresh Resin.



(b) Resin Aged For Two Years at 49 °C (120°F).

Figure 6. FTIR Spectra of EA9396, Part B.

# Initial testing of EA9396.

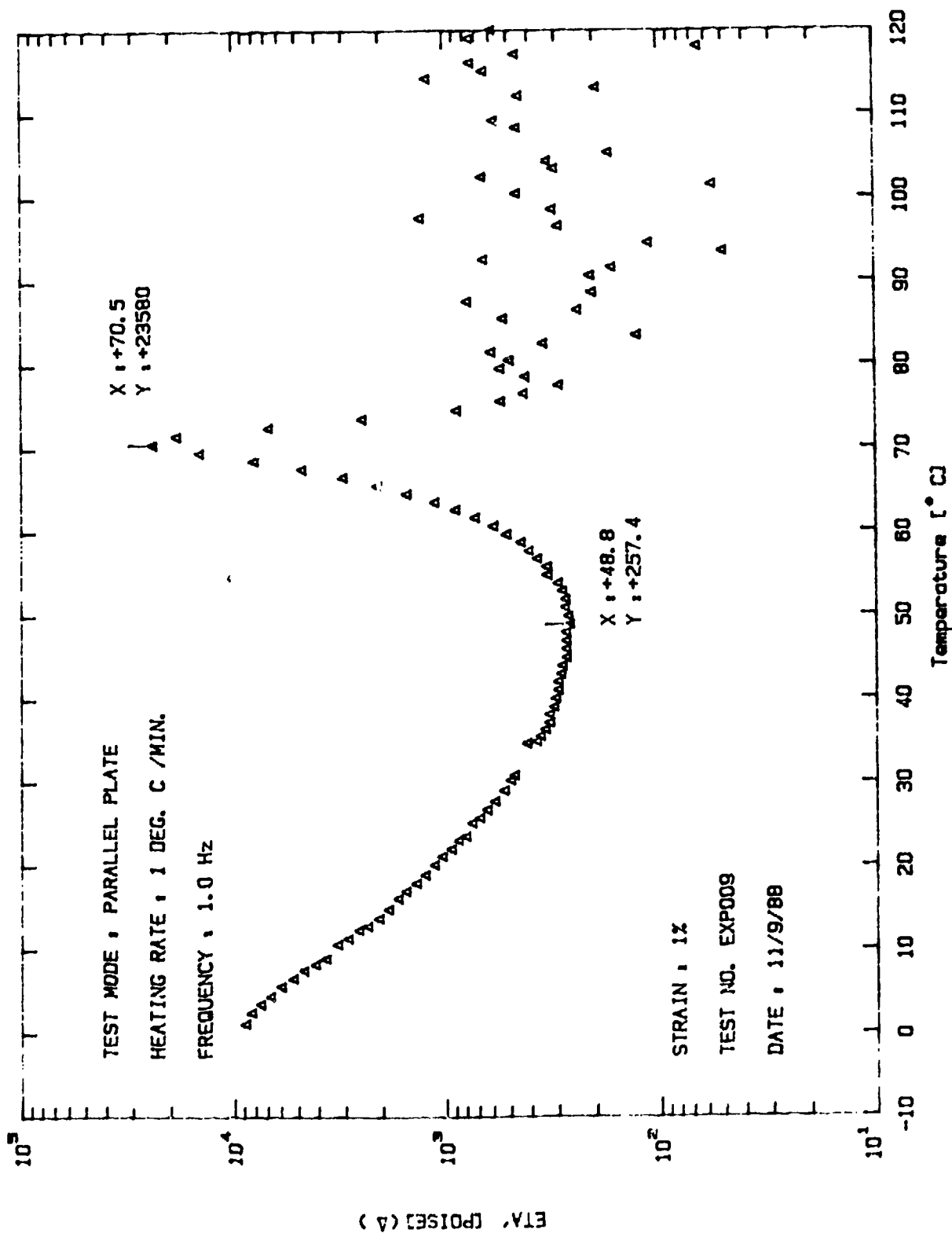


Figure 7. Rheometrics Viscosity Cure Profile for Fresh EA9396 Resin.

TABLE 29  
EFFECT OF LONG-TERM STORAGE AT ELEVATED TEMPERATURE ON  
THE CURING VISCOSITY PROFILE CHARACTERISTICS OF EA9396

| Storage Conditions           | Temperature at<br>Minimum Viscosity | Minimum Viscosity<br>(poise) | Gel Temperature<br>(°C) |
|------------------------------|-------------------------------------|------------------------------|-------------------------|
| Initial                      | 49                                  | ~257                         | 70.5                    |
| 1 month at 38°C<br>(100°F)   | 51                                  | ~150                         | 71.6                    |
| 1 month at 49°C<br>(120°F)   | 47                                  | ~150                         | 71.9                    |
| 3 months at 22°C<br>(72°F)   | 50                                  | ~40                          | 73.3                    |
| 6 months at 22°C<br>(72°F)   | 48                                  | ~110                         | 66.8                    |
| 6 months at 38°C<br>(100°F)  | 45                                  | ~110                         | 65.9                    |
| 6 months at 49°C<br>(120°F)  | 44                                  | ~200                         | 67.8                    |
| 12 months at 22°C<br>(72°F)  | 67                                  | ~149                         | 71.9                    |
| 12 months at 38°C<br>(100°F) | 66                                  | ~46                          | 72.6                    |
| 12 months at 49°C<br>(120°F) | 64                                  | ~64                          | 71.4                    |
| 18 months at 22°C<br>(72°F)  | 49                                  | ~54                          | 70.5                    |
| 18 months at 38°C<br>(100°F) | 47                                  | ~54                          | 68.4                    |
| 18 months at 49°C<br>(120°F) | 47                                  | ~127                         | 68.4                    |
| 24 months at 22°C<br>(72°F)  | 47                                  | ~60                          | 71.6                    |
| 24 months at 38°C<br>(100°F) | 50                                  | ~60                          | 71.6                    |
| 24 months at 49°C<br>(120°F) | 51                                  | ~120                         | 70.5                    |

NOTE: Test conducted on Rheometrics Solids Analyzer using a heating rate of 1°C (34°F)/minute.

Sample: EA 9398  
Size: 5.2460 mg

Comment: 10°C/min

DSC

File: DSC0334.01  
Operator: GALASKA  
Run Date: 12/19/88 13:50

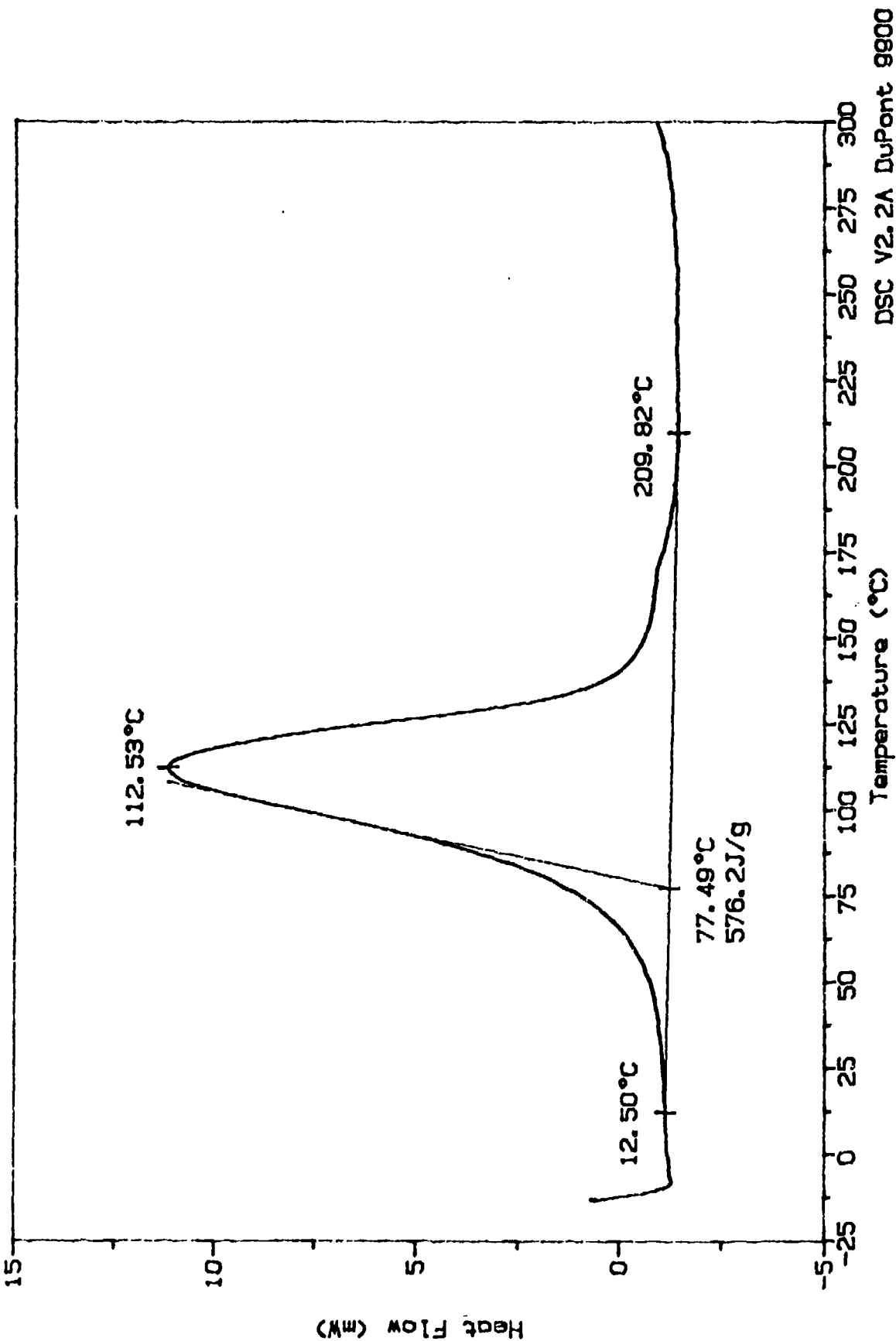


Figure 8. Heat Release Test Results for Fresh EA9396 Resin.

TABLE 30  
EFFECT OF LONG-TERM STORAGE AT ELEVATED TEMPERATURE ON  
THE CALORIMETRIC CURE CHARACTERISTICS OF EA9396

| Storage Conditions           | Temperature at<br>Reaction Peak (°C) | Total Heat of Cure<br>(J/gm) |
|------------------------------|--------------------------------------|------------------------------|
| Initial                      | 112.5                                | 576.2                        |
| 1 month at 38°C<br>(100°F)   | 115.2                                | 588.8                        |
| 1 month at 49°C<br>(120°F)   | 114.6                                | 576.4                        |
| 3 months at 22°C<br>(72°F)   | 115.0                                | 572.9                        |
| 6 months at 22°C<br>(72°F)   | 108.9                                | 633.8                        |
| 6 months at 38°C<br>(100°F)  | 110.9                                | 593.5                        |
| 6 months at 49°C<br>(120°F)  | 111.8                                | 624.6                        |
| 12 months at 22°C<br>(72°F)  | 112.8                                | 613.4                        |
| 12 months at 38°C<br>(100°F) | 114.3                                | 589.5                        |
| 12 months at 49°C<br>(120°F) | 112.6                                | 601.6                        |
| 18 months at 22°C<br>(72°F)  | 107.2                                | 615.4                        |
| 18 months at 38°C<br>(100°F) | 111.5                                | 564.6                        |
| 18 months at 49°C<br>(120°F) | 112.8                                | 586.8                        |
| 24 months at 22°C<br>(72°F)  | 114.1                                | 599.6                        |
| 24 months at 38°C<br>(100°F) | 115.1                                | 575.6                        |
| 24 months at 49°C<br>(120°F) | 114.1                                | 560.6                        |

NOTE: Dynamic DSC test at heating rate of 10°C/minute under nitrogen.



TABLE 31  
EFFECT OF LONG-TERM STORAGE AT ELEVATED  
TEMPERATURE ON THE VISCOSITY OF EA9396, PART A

| Storage Temperature | Storage Time (1)<br>(months) | Brookfield Viscosity of Part A |            |
|---------------------|------------------------------|--------------------------------|------------|
|                     |                              | (Pa-s)                         | (Poise)    |
| 22°C (72°F)         | Initial                      | 84                             | 840        |
|                     | 3                            | 92                             | 920        |
|                     | 6                            | 72                             | 720        |
|                     | 12                           | 72                             | 720        |
|                     | 18                           | 112                            | 1,120      |
|                     | 24                           | 82                             | 820        |
|                     | 30                           | 78                             | 780        |
|                     | 36                           | 80                             | 800        |
|                     | 43                           | 100                            | 1,000      |
|                     | 50                           | 100                            | 1,000      |
| 38°C (100°F)        | 1                            | 84                             | 840        |
|                     | 7                            | 84                             | 840        |
|                     | 12                           | 96                             | 960        |
|                     | 18                           | 108                            | 1,080      |
|                     | 24                           | 84                             | 840        |
|                     | 30                           | 234                            | 2,340      |
|                     | 36                           | 460                            | 4,600      |
|                     | 43                           | >2,000                         | >20,000(2) |
|                     | 50                           | ---                            | (3)        |
| 49°C (120°F)        | 1                            | 88                             | 880        |
|                     | 7                            | 88                             | 880        |
|                     | 12                           | 100                            | 1,000      |
|                     | 18                           | 263                            | 2,630      |
|                     | 21                           | 344                            | 3,440      |
|                     | 24                           | 650                            | 6,500      |
|                     | 30                           | >2,000                         | >20,000(2) |

NOTES:

1. Months after receipt of resin. Resin was manufactured three months before receipt.
2. Material no longer processible into laminates.
3. Hard crust on surface.

TABLE 32  
EFFECT OF LONG-TERM STORAGE AT ELEVATED TEMPERATURE  
ON ACHIEVABLE INTERLAMINAR SHEAR STRENGTH OF GRAPHITE-  
REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL

| Storage Temp. | Storage Time (2) (months) | Interlaminar Shear Strength (3) |       |         |       | Wt. Gain During Wet Aging(%) (4) |
|---------------|---------------------------|---------------------------------|-------|---------|-------|----------------------------------|
|               |                           | DRY                             |       | WET (4) |       |                                  |
|               |                           | (MPa)                           | (psi) | (MPa)   | (psi) |                                  |
| 22°C (72°F)   | Initial                   | 37.56                           | 5447  | 25.91   | 3758  | 3.91                             |
|               | 3                         | 38.27                           | 5515  | 31.46   | 4563  | 1.56 (5)                         |
|               | 6                         | 42.60                           | 6178  | 30.40   | 4409  | 2.68                             |
|               | 12                        | 36.94                           | 5357  | 29.95   | 4344  | 2.59                             |
|               | 18                        | 42.21                           | 6122  | 31.88   | 4624  | 2.65                             |
|               | 24                        | 46.28                           | 6712  | 32.00   | 4641  | 2.63                             |
|               | 43                        | 45.59                           | 6612  | 33.86   | 4910  | 2.86                             |
|               | 50                        | 43.76                           | 6347  | ---     | ---   | ---                              |
| 38°C (100°F)  | 1                         | 42.52                           | 6166  | 32.82   | 4759  | 2.70                             |
|               | 6                         | 42.77                           | 6202  | 32.31   | 4686  | 2.61                             |
|               | 12                        | 43.72                           | 6341  | 32.77   | 4752  | 2.54                             |
|               | 18                        | 44.32                           | 6427  | 35.80   | 5192  | 2.65                             |
|               | 24                        | 40.48                           | 5871  | 28.05   | 4068  | 2.80                             |
|               | 43                        | 45.59                           | 6612  | 33.48   | 4856  | 3.02                             |
| 49°C (120°F)  | 1                         | 39.29                           | 5698  | 29.83   | 4326  | 2.90                             |
|               | 6                         | 42.88                           | 6218  | 29.29   | 4247  | 2.79                             |
|               | 12                        | 42.52                           | 6167  | 26.08   | 3782  | 4.25                             |
|               | 18                        | 46.41                           | 6731  | 35.65   | 5170  | 2.65                             |
|               | 24                        | 43.15                           | 6257  | 31.59   | 4581  | 2.83                             |

NOTES:

1. EA9396 Parts A and B stored at temperature listed for time listed before resin was mixed and laminate prepared.
2. From date of receipt. Resin was manufactured 3 months before receipt.
3. All tests were conducted at 22°C (72°F). Dry values represent average of three specimens, wet values represent average of two specimens.
4. WET = specimens immersed in water at 60°C (140°F) until saturated before being tested unless otherwise noted.
5. Immersed in water at 22°C (72°F) until saturated before being tested.

In summary, it appears that the EA9396 resin system is very tolerant of long-term storage. It is still useable after 24 months storage at 49°C (120°F) and after over 50 months storage at a temperature of 22°C (72°F).

### 3.8 EFFECT OF FIBER CONTENT

Since field or depot repairs may be subject to greater inconsistency in control of processing parameters than was the case in a laboratory environment, several laminates were prepared with deliberately lower fiber contents than the baseline laminates. These were then tested for both interlaminar shear and compressive properties. Both glass and graphite fabric reinforced laminates were prepared with fiber contents ranging from the standard 55% by volume down to as low as 34% by volume. The low fiber content laminates were all cured by the same "standard cure cycle", described in step (m) of Appendix A, that was used for the baseline laminates. The differences in fiber content were achieved by changing the bleeder ply/laminate ply ratio used during cure and/or the ratio of resin to reinforcement used during impregnation (see Table A.2 in Appendix A). Two attempts were made to obtain higher than normal fiber content laminates. In one case, the bleeder ratio was increased by 50% and the resin ratio reduced by 5% from the standard. In the other case, the bleeder ratio was not changed but the resin ratio was reduced by 27% from the standard. In each case, the resulting laminate exhibited practically identical physical characteristics (fiber content, void content) to the baseline laminates. This implies that one is not likely to obtain much higher fiber contents than that exhibited by the baseline laminates regardless of processing variations encountered in the field. The same should not be said with regard to void content since it is likely that some processing variations would affect porosity. Reduced fiber contents, on the other hand, were achieved by simultaneously reducing the bleeder ratio and raising the resin ratio during impregnation. In the extreme cases, in which the lowest fiber contents were achieved, the bleeder was eliminated entirely while the resin ratio used during impregnation was increased to 150% and 180% of the standard ratio for graphite and glass reinforced laminates, respectively. Interlaminar shear and compression specimens were machined and tested from these reduced fiber content laminates. The data from these tests are presented in Tables 33 and 34.

Examination of the data in Table 33 reveals several points. First, it appears that the interlaminar shear strength is influenced by both fiber and void content. In the case of the glass reinforced laminates, the two lowest shear strengths were produced by laminates that had significantly lower fiber content and significantly higher void content

TABLE 33  
EFFECT OF RESIN/FIBER CONTENT ON INTERLAMINAR SHEAR  
STRENGTH OF EA9396 COMPOSITE LAMINATES

| Panel Number | Reinforcement Fabric | Laminate Physical Properties |                       |                      |                  | Interlaminar Shear Strength (1) |                    |                         |
|--------------|----------------------|------------------------------|-----------------------|----------------------|------------------|---------------------------------|--------------------|-------------------------|
|              |                      | Resin Content (% wt)         | Fiber Content (% vol) | Void Content (% vol) | Specific Gravity | 22°C(72°F), Dry                 | 22°C(72°F), Wet(2) | Shear Strength MPa(psi) |
| GL-31        | E-7781, Glass        | 26.2                         | 55.4                  | 5.0                  | 1.94             | 36.5(5290)                      | 2                  | 21.4(3110)              |
| GL-30        | "                    | 26.7                         | 54.3                  | 6.1                  | 1.89             | 38.2(5540)                      | 2                  | 21.9(3180)              |
| GL-13R(3)    | "                    | 26.5                         | 54.0                  | 6.9                  | 1.87             | 40.1(5810)                      | 5                  | 18.7(2710)              |
| GL-33        | "                    | 28.4                         | 52.3                  | 6.4                  | 1.86             | 37.8(5490)                      | 2                  | 20.5(2970)              |
| GL-10        | "                    | 35.2                         | 45.6                  | 4.7                  | 1.79             | 37.9(5500)                      | ---                | ---                     |
| GL-54        | "                    | 43.6                         | 35.8                  | 8.8                  | 1.62             | 33.2(4810)                      | ---                | ---                     |
| GL-53        | "                    | 45.6                         | 33.9                  | 9.3                  | 1.59             | 34.7(5030)                      | ---                | ---                     |
| GR-51        | T300-W133, Graphite  | 32.5                         | 55.8                  | 6.5                  | 1.47             | 40.5(5870)                      | 2                  | 29.5(4280)              |
| GR-52        | "                    | 33.6                         | 54.7                  | 6.4                  | 1.47             | 40.4(5860)                      | 2                  | 32.7(4740)              |
| GR-17(3)     | "                    | 35.6                         | 54.6                  | 4.0                  | 1.48             | 39.1(5670)                      | 5                  | 32.7(4750)              |
| GR-53        | "                    | 39.0                         | 50.1                  | 4.9                  | 1.46             | 43.6(6320)                      | 2                  | 34.2(4960)              |
| GR-54        | "                    | 39.0                         | 49.8                  | 4.7                  | 1.47             | 43.8(6350)                      | 2                  | 35.3(5120)              |
| GR-84        | "                    | 45.6                         | 42.3                  | 7.5                  | 1.39             | 31.4(4550)<br>(4)               | ---                | ---                     |
| GR-79        | "                    | 48.8                         | 40.5                  | 5.5                  | 1.41             | 33.5(4860)<br>(4)               | ---                | ---                     |

NOTES:

- (1) Four-point shear. Graphite tests at 16:1 span-thickness ratio, glass tests at 8:1 unless otherwise noted.
- (2) Wet = wet aged at 60°C (140°F), 95-100% R.H. until saturation.
- (3) Baseline panel data.
- (4) Tests carried out at 12:1 span-thickness ratio.

TABLE 34  
EFFECT OF RESIN/FIBER CONTENT ON 22°C (72°F), DRY  
COMPRESSIVE PROPERTIES OF EA9396 LAMINATES

| Panel Number | Reinforcement Fabric | Laminate Physical Properties |                       |                      |                  |                   | Laminate Mechanical Properties(1)                  |                                           |                                      |
|--------------|----------------------|------------------------------|-----------------------|----------------------|------------------|-------------------|----------------------------------------------------|-------------------------------------------|--------------------------------------|
|              |                      | Resin Content (% wt)         | Fiber Content (% vol) | Void Content (% vol) | Specific Gravity | Number Replicates | Ultimate Compr. Strength MPa (10 <sup>3</sup> psi) | Initial Modulus GPa (10 <sup>6</sup> psi) | Ult. Strain (10 <sup>-6</sup> in/in) |
| GL-53        | E-7781, Glass        | 45.6                         | 33.9                  | 9.3                  | 1.59             | 6                 | 238(34.52)                                         | 17.0(2.5)                                 | 14,070                               |
| GL-54        | "                    | 43.6                         | 35.8                  | 8.8                  | 1.62             | 6                 | 254(36.85)                                         | 18.7(2.7)                                 | 15,560                               |
| GL-7,8(2)    | "                    | 28.1                         | 53.7                  | 4.4                  | 1.90             | 5                 | 287(41.69)                                         | 26.1(3.8)                                 | 11,670                               |
| GL-9(2)      | "                    | 27.6                         | 53.8                  | 5.0                  | 1.84             | 5                 | 269(39.08)                                         | 24.7(3.6)                                 | 11,730                               |
| GL-10R(2)    | "                    | 30.4                         | 51.2                  | 4.0                  | 1.87             | 5                 | 288(41.80)                                         | 24.8(3.6)                                 | 12,250                               |
| GR-79        | T300-W133, Graphite  | 48.8                         | 40.5                  | 5.5                  | 1.41             | 6                 | 309(44.87)                                         | 37.3(5.4)                                 | 9,030                                |
| GR-84        | "                    | 45.6                         | 42.3                  | 7.5                  | 1.39             | ---               | 298(43.18)                                         | 37.6(5.4)                                 | 8,020                                |
| GR-13,14(2)  | "                    | 35.9                         | 54.6                  | 3.6                  | 1.48             | 5                 | 414(60.08)                                         | 51.5(7.5)                                 | 7,920                                |
| GR-15(2)     | "                    | 34.7                         | 55.5                  | 4.3                  | 1.48             | 5                 | 410(59.50)                                         | 57.4(8.3)                                 | 8,150                                |
| GR-16(2)     | "                    | 34.9                         | 54.9                  | 4.8                  | 1.47             | 5                 | 435(63.03)                                         | 54.3(7.9)                                 | 8,700                                |

NOTES:

- (1) All tests conducted at 22°C (72°F), dry condition in fill direction of fabric reinforcement.  
(2) Baseline panel data.

than the other five laminates. In the case of the graphite reinforced laminates, the two laminates with the lowest fiber content exhibited significantly lower shear strengths than the other five laminates. Similar behavior is observed in the case of the compressive properties, presented in Table 34. For both the glass and graphite reinforced laminates, the compressive strength is lowest for the laminates with low fiber content and high void content.

In summary, the shear and compression data in Tables 33 and 34 indicate that laminate strength is reduced with decreasing fiber content and increasing void content. For example, in Tables 33 and 34, panel numbers GL-53 and GL-54 had the lowest fiber contents and the highest void contents and also produced the lowest strengths. Similarly, panel GR-79 had the lowest fiber content and an intermediate void content and produced the second lowest strengths, while panel GR-84 had the second lowest fiber content and the highest void content and produced the lowest strengths. It also appears that the laminates that were deliberately prepared with low fiber contents generally had higher void contents than baseline laminates. This indicates that low fiber content (resin-rich) laminates should be avoided if optimum properties are desired.

### 3.9 ALTERNATE IMPREGNATION AND BAGGING SCHEMES

Appendix A describes the rationale behind the individual steps in the "standard processing procedure." This procedure was selected for use in the laboratory because it was convenient and because it produced laminate quality consistent with what would be expected in repair scenarios using a vacuum bag cure. A number of laminates were prepared during the program, however, by procedures that differed from the standard procedures. These differences were in the areas of ply impregnation procedures, bleeder material used, and bagging scheme employed. Each of the activities undertaken in these respective subject areas are discussed in the following sections.

#### 3.9.1 Alternate Ply Impregnation Procedure

It was recognized that repair technicians working in the field might elect to employ different processing procedures than were used here. In order to anticipate what these different procedures might be, and to determine their effects on resulting laminate quality, two variations from the standard ply impregnation procedure were investigated.

In the first, the resin was applied to every ply instead of every other ply as in the standard procedure. In the second, a lower ratio of resin to reinforcement was employed during the impregnation steps than in the standard procedure. Each of these variant procedures is described in detail in Appendix B but a brief summary of each is presented in the following paragraphs.

The first variant impregnation procedure involved applying resin to every reinforcement ply during the wet layup procedure instead of every other ply. The reason for doing this was to determine whether laminate quality (specifically, void content) would be adversely affected. Since only half as much resin was available to be applied and worked into each ply, it was thought that resin distribution might be less uniform and that more voids due to air entrapment might result. As in the "standard procedure," the total amount of resin used during impregnation represented a 50% excess over what was desired in the final laminate. The same amount was applied to every ply, including the first and last, as opposed to the resin distribution approach described in steps (e)-(j) of Appendix A. Other than this, all other steps were identical to those described in Appendix A.

The physical properties of specimens cut from this panel are presented in Table 35. Table 35 shows that while this laminate had a slightly higher void content than the baseline laminates made with the standard processing procedure (Table 4), the difference was within the range of the standard deviation of the baseline panels. The other physical properties are also very nearly equivalent to those exhibited by the baseline panels.

The second variant impregnation procedure involved using a smaller quantity of resin during impregnation of the reinforcement plies than the amount computed in step (c) of Appendix A. The reason for doing this was to determine whether equivalent laminate quality (specifically void content) could be achieved without bleeding excess resin out of the wet layup stack. Instead of the 50% excess used in the standard procedure, the amount used for this laminate represented 0% excess (nominally net resin content). Thus, the resin/reinforcement ratio employed for this laminate was only 0.370 gm resin/gm reinforcement instead of the 0.555 gms listed in Table A.2. The other difference was that since no excess resin was used, no bleeder plies were used during cure. Other than these two variations, all other steps were identical to those described in Appendix A.

TABLE 35  
PHYSICAL PROPERTIES SUMMARY OF LAMINATES  
PREPARED WITH VARIANT PROCESSING PROCEDURES

| Type of Laminate    | Processing Variation                               | Specific Gravity | Ply Thickness (mm) | Ply Thickness ( $10^{-3}$ inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
|---------------------|----------------------------------------------------|------------------|--------------------|---------------------------------|---------------------|---------------------|--------------------|
| E-7781 (GI)/EA 9396 | Every ply impregnated                              | 1.87             | 0.21               | 8.1                             | 52.6                | 28.4                | 5.9                |
| E-7781 (GI)/EA 9396 | Net resin used during impregnation and no bleeding | 1.85             | 0.20               | 7.9                             | 50.3                | 30.8                | 4.8                |



The physical properties of specimens cut from this panel are presented in Table 35. It is evident from these data that void content was not adversely affected by this alternative processing procedure. It does appear, however, that the panel was somewhat more resin-rich than the baseline panels made with bleeder plies during cure. This is probably because the amount of resin used was only nominally net resin content, not precisely net resin content.

Based on these two variations in resin impregnation procedures, it appears that essentially equivalent laminate quality can be achieved with a variety of procedures.

### 3.9.2 Alternative Bleeder Materials

All of the baseline laminates prepared during this program, as well as nearly all the other laminates prepared in accordance with the "Standard Laminate Processing Procedure," were bagged according to Figure A.1 using Mochburg CW 1850 bleeder, which had an area weight of 71 gm/m<sup>2</sup>. It was empirically determined that this bleeder material typically absorbed about three times its own weight of EA9396 resin during a cure cycle when used in the ply ratios listed in Table A.2. This was used as bleeder material only because it was readily available and because of prior experience with it. It was recognized, however, that in field repair scenarios, this particular bleeder material might not be available. Several laminates were, therefore, prepared using the same fabric material as bleeder as was used for reinforcement in the wet layup, specifically, the E-7781 glass and T300-W133 graphite fabrics described in Table 1. The absorptivity of these materials as bleeder was characterized, and the physical properties of the laminates made using them were determined to demonstrate equivalence to the baseline laminates made using the standard processing procedure. The procedure used to determine bleeder material absorptivity is described in Appendix R. Table 36 summarizes the results obtained for the laminates made with the glass and graphite fabric as bleeder material. Other than the bleeder material, these laminates were prepared in accordance with the standard procedure described in Appendix A.

### 3.9.3 Alternative Bagging Schemes

The standard laminate bagging scheme, illustrated in Figure A.1, was employed for the large majority of the laminates prepared in this program. Two alternative bagging schemes were investigated, however, in an effort to see if the void

TABLE 36

PHYSICAL PROPERTIES SUMMARY FOR LAMINATES  
PREPARED WITH ALTERNATIVE BLEEDER MATERIAL

| Type of Laminate      | Bleeder Material   | Bleeder Area Density (gm/m <sup>2</sup> ) | Bleeder/Laminate Ply Ratio | Bleeder Absorptivity(1) gm/gm (gm/m <sup>2</sup> ) | Laminate Physical Properties (2) |                                          |                     |                     |                    |
|-----------------------|--------------------|-------------------------------------------|----------------------------|----------------------------------------------------|----------------------------------|------------------------------------------|---------------------|---------------------|--------------------|
|                       |                    |                                           |                            |                                                    | Specific Gravity                 | Ply Thickness mm (10 <sup>-3</sup> inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
| E7781(GI)/EA9396      | E-7781 Glass       | 295                                       | 3/16                       | 0.41 (122)                                         | 1.84                             | 0.20 (7.8)                               | 50.0                | 30.7                | 5.6                |
| E7781(GI)/EA9396      | E-7781 Glass       | 295                                       | 2/8                        | 0.50 (148)                                         | 1.85                             | 0.21 (8.2)                               | 49.5                | 31.6                | 4.5                |
| E7781(GI)/EA9396      | E-7781 Glass       | 295                                       | 3/8                        | 0.41 (122)                                         | 1.89                             | 0.23 (8.9)                               | 52.5                | 29.2                | 4.2                |
| E7781(GI)/EA9396      | CW1850             | 71                                        | 2/8                        | 3.0 (213)                                          | 1.91                             | 0.20 (8.0)                               | 55.2                | 26.6                | 5.1                |
| T300-W133 (Gr)/EA9396 | T300-W133 Graphite | 366                                       | 3/12                       | 0.54 (198)                                         | 1.48                             | 0.37 (14.4)                              | 55.4                | 33.1                | 5.8                |
| T300-W133 (Gr)/EA9396 | T300-W133 Graphite | 366                                       | 3/8                        | 0.47 (172)                                         | 1.49                             | 0.39 (15.4)                              | 53.5                | 36.0                | 4.5                |
| T300-W133 (Gr)/EA9396 | CW1850             | 71                                        | 5/12                       | 3.0 (213)                                          | 1.48                             | 0.36 (14.3)                              | 55.8                | 33.6                | 4.9                |

(1) Grams resin absorbed per gram or per square meter of bleeder material.

(2) All laminates cured 45 minutes at 93°C (200°F) under vacuum bag pressure.

content could be reduced by means readily available to technicians carrying out field repairs.

The first variant was to perforate the normally nonporous barrier between the bleeder material and the breather material. The rationale for this was that this perforation permits the vacuum, when it is applied, to draw air out of the bleeder instead of forcing it into the layup. It was speculated that air might be trapped in the bleeder when the vacuum was applied because the caul plate would be pressed down so tightly that air escape paths would be shut off. The altered layup scheme is described in detail and illustrated in Appendix B. Instead of separating the bleeder material from the breather material with the two layers of nonporous teflon and a caul plate, the modified layup scheme consisted of a single layer of nonporous teflon film with a series of knife slits separating the two. A glass fabric reinforced laminate was prepared in this manner. Physical and interlaminar shear properties of this laminate were determined. Table 37 presents the data for this laminate and also for comparable baseline laminates. While the physical properties of the experimental laminate prepared with the perforated film procedure are slightly inferior to those exhibited by the laminates made with the baseline procedure, the interlaminar shear strength is about 15 percent higher. Since the higher void content of the experimental laminate is higher than that of the baseline laminates, one would normally expect the interlaminar shear properties to be lower. The only reason that can be offered to explain this is that the experimental laminate was made approximately 12 months after the baseline laminates. As was discussed in Section 3.7, interlaminar shear properties delivered by laminates made with 1 year old resin are higher than those delivered by laminates made with relatively fresh resin (by about 11% in the case of 22°C (72°F) dry tests -- see Table 32).

The second variant was to utilize a double-bag vacuum scheme rather than the single-bag scheme illustrated in Figure A.1. The rationale for this approach was that while the vacuum applied in the single bag scheme supposedly aids in drawing air and volatiles out of the laminate, the compaction of the layup resulting from the vacuum bag may pinch off escape paths and trap air and volatiles in the layup. The idea of the double bag scheme is to permit the layup to "breathe" even while under vacuum by reducing the compacting force during the early part of the cure cycle. The double bag layup scheme is described in detail and illustrated in Appendix B. A graphite fabric reinforced laminate was prepared using this double bag scheme and both physical and interlaminar shear properties of this laminate were determined. Table 38 presents these data for both this

TABLE 37  
EFFECT OF PERFORATED FILM PROCESSING MODIFICATION ON  
LAMINATE PROPERTIES

| Laminate Type      | Processing Procedure     | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Specific Gravity | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) | Interlaminar Shear Strength (1) (MPa) | Interlaminar Shear Strength (1) (Psi) |
|--------------------|--------------------------|--------------------|---------------------------------------|------------------|---------------------|---------------------|--------------------|---------------------------------------|---------------------------------------|
| E-7781 (GI)/EA9396 | Standard (App. A)        | 0.20               | 8.0                                   | 1.91             | 55.2                | 26.6                | 5.1                | 39.3                                  | 5700                                  |
| E-7781 (GI)/EA9396 | Perforated Film (App. B) | 0.19               | 7.6                                   | 1.86             | 52.8                | 27.6                | 6.7                | 45.2                                  | 6560                                  |

(1) All tests performed on dry, as-fabricated laminates at 22°C (72°F).

TABLE 38  
EFFECT OF DOUBLE-BAG PROCESSING MODIFICATION ON  
LAMINATE PROPERTIES

| Laminate Type         | Processing Procedure | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Specific Gravity | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) | Interlaminar Shear Strength (MPa) | Interlaminar Shear Strength (l) (Psi) |
|-----------------------|----------------------|--------------------|---------------------------------------|------------------|---------------------|---------------------|--------------------|-----------------------------------|---------------------------------------|
| T300-W133 (Gr)/EA9396 | Baseline (App. A)    | 0.36               | 14.3                                  | 1.48             | 55.8                | 33.6                | 4.9                | 39.3                              | 5700                                  |
| T300-W133 (Gr)/EA9396 | Double Bag (App. B)  | 0.39               | 15.2                                  | 1.48             | 55.0                | 33.6                | 5.9                | 43.4                              | 6300                                  |

(1) All tests performed on dry, as-fabricated laminates at 22°C (72°F).

laminate and also for comparable baseline laminates. While the physical properties of the experimental laminate prepared with the double-bag vacuum scheme are essentially equivalent to those exhibited by laminates made with the baseline procedure, the interlaminar shear strength values are about 10 percent higher. As noted for the laminate made with the perforated film (Table 37), the higher interlaminar shear strength listed in Table 38 for the double-bag laminate may well be attributable to the fact that the EA9396 resin used for this laminate was 13 months older than that used for the baseline laminates. Again, Table 32 shows that 1 year old resin produces an interlaminar shear strength about 11% higher than fresh resin.

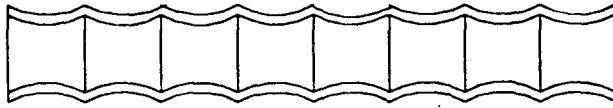
Based on the results of these two modified bagging schemes, it appears that both produced laminates that were essentially equivalent to those produced by the standard baseline processing procedure.

### 3.10 HONEYCOMB SANDWICH BEHAVIOR

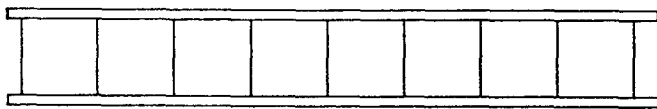
Two types of honeycomb sandwich specimens were made and tested, edgewise compression, and flatwise tension. The former type specimens were utilized to investigate whether skin dimpling, if it occurred, would reduce the edgewise compression strength. The latter type specimens were utilized to investigate the effects of adhesive fillet size on flatwise tensile strength. Both specimen types consisted of honeycomb core with composite skins bonded to the core with a layer of epoxy adhesive (EA9394 by Dexter Hysol). The honeycomb core was either  $126.5 \text{ Kg/m}^3$  ( $7.9 \text{ lb/ft}^3$ ) or  $91.3 \text{ Kg/m}^3$  ( $5.7 \text{ lb/ft}^3$ ) density material. Both cores were from Hexcel and were designated CRIII-1/4-5052-.004N-7.9 and CRIII-3/16-5052-.002-5.7, respectively. These two honeycomb sandwich investigations are discussed in detail in the following sections.

#### 3.10.1 Effect of Skin Cocuring on Edgewise Compression Behavior

When skin repairs are made on honeycomb core substrates, the skin is relatively thin, typically as few as only two plies in some cases. If the skin is cocured, under a compacting vacuum bag pressure, the cured skin may exhibit the imprint of the honeycomb substrate. This is called dimpling and results in a skin that is not flat, but is somewhat rippled, as illustrated in Figure 9. Since one failure mode in edgewise compression can consist of skin buckling, it was felt that if dimpling does occur during cocure, the resulting edgewise compression strength may be reduced from what it would be with straight, undimpled skins.



- (a) Dimpled skin (exaggerated) resulting from cocuring composite skin and adhesive under vacuum bag compaction.



- (b) Flat, undimpled skin resulting from precuring the composite skin on a flat tool and then bonding it to the core in a second step.

Figure 9. Comparison of Cocured and Secondarily Bonded Honeycomb Sandwich Skins.

This possibility was investigated by preparing honeycomb sandwich panels both by cocuring and by secondarily bonding flat composite skins to the core. When graphite fabric was used for the skin, each skin was two plies thick. When glass fabric was used, each skin was four plies thick, since the glass fabric plies were only about half as thick as the graphite plies. On all sandwich panels, an adhesive layer consisting of a ply of style 120 glass fabric impregnated with  $0.21 \text{ gm/cm}^2$  EA9394 paste adhesive was used to bond the skin to the core. This paste adhesive layer was used because the viscosity of the EA9396 resin used in the skins became so low during cure that satisfactory filleting along the honeycomb cell walls could not be achieved. Two different cores were used: one with a 6.35-mm (1/4-inch) cell size and one with a 4.76-mm (3/16-inch) cell size. It was felt that if skin dimpling indeed did occur and caused a reduction in edgewise compression strength, the effect would be greater for a larger cell size and lesser for a smaller cell size.

In the case of the cocured panels, the skins were impregnated in the standard manner, as described in Appendix A. The bottom skin rested on a flat tool surface while the upper skin was atop the core (and adhesive layer). The entire sandwich assembly was bagged in accordance with the layup illustrated in Figure A.1 except that no caul plate was used. The cure cycle was the same as that described in Appendix A.

In the case of the secondarily bonded panels, the two skins were prepared by the standard processing procedure described in Appendix A. These were then bonded to the core using a layer of EA9394 adhesive on a style 120 glass carrier fabric between each skin and the core. The two skins were lightly sanded and wiped with solvent prior to bonding to ensure a clean surface. The adhesive was cured for 1 hour at  $93^\circ\text{C}$  ( $200^\circ\text{F}$ ) under vacuum bag pressure.

The cocured panels were  $30.5 \times 30.5 \text{ cm}$  ( $12 \times 12 \text{ inches}$ ) and three specimens  $7.6 \times 22.9 \text{ cm}$  ( $3 \times 9 \text{ inches}$ ) were machined from each panel. The secondarily bonded specimens were prepared individually in a  $10.2 \times 25.4 \text{ cm}$  ( $4 \times 10 \text{ inch}$ ) dimension, then trimmed to the final specimen size. Individual specimens were secondarily bonded because it was found that secondary bonding of large panels resulted in disbonds. These were manifested as large blisters in the center of the panels. All specimens, whether cocured or secondarily bonded, were oriented such that the fill fibers in the fabric reinforced skins were in the length direction of the specimens.



Table 39 summarizes the results of the edgewise compression tests. As the data in Table 39 indicate, the cocured samples produced higher compression strengths than the secondarily bonded samples, by around 15-20%. All of the secondarily bonded samples failed by virtue of the skin debonding from the adhesive layer. All of the cocured samples exhibited compressive failure of one or both skins and no debonding of either skin from the adhesive layer. In addition to the failure modes described above, most of the samples made with the lower density core, regardless of the type skin/core bond, exhibited general buckling. No evidence of skin dimpling was observed on any of the cocured panels.

### 3.10.2 Effect of Fillet Size on Flatwise Tensile Strength

Several preliminary attempts were made to prepare honeycomb sandwich panels in which the EA9396 resin in the composite skins served simultaneously as the skin-to-core adhesive. This proved generally unsuccessful because the viscosity of the EA9396 resin became so low during cure that satisfactory filleting along the honeycomb cell walls could not be achieved along the upper skin. Suitable fillets did form on the lower skin because the resin from the upper skin ran down the cell walls and accumulated along the lower skin-to-core interface. As a consequence, it was found that suitable fillets, and a reasonable strength of the skin-to-core bond could only be achieved by the addition of a layer of paste adhesive between the skins and core. As noted earlier in Section 3.10.1, this paste adhesive layer consisted of a ply of style 120 glass scrim fabric impregnated with EA9394 epoxy adhesive. This adhesive is a filled version of the EA9396 resin system.

Since flatwise tensile strength of a sandwich construction is influenced by the size of the fillets that are formed, the purpose of the investigation described in this section was to determine how much the flatwise tensile strength is affected by various fillet sizes. Fillet size was varied by applying different amounts of adhesive to the style 120 glass scrim cloth.

Table 40 summarizes the results obtained in this study. It includes data for honeycomb panels made with no adhesive layer, with an adhesive layer along the top skin only, and with an adhesive layer of various weights along both skins. It is evident from the data in this table that the flatwise tensile strength increases as the amount of adhesive, and the accompanying fillet size, are increased. There is a dramatic increase in flatwise tensile strength as the amount of adhesive increases from zero to about

TABLE 39  
EFFECT OF SKIN BONDING APPROACH ON EDGEWISE COMPRESSION STRENGTH

| Skin Type (1)                | Core Density<br>(gm/m <sup>3</sup> )(lb/ft <sup>3</sup> ) | Type Bond (2) | Facing Stress at Failure (3)         |                                             | Failure Mode               |
|------------------------------|-----------------------------------------------------------|---------------|--------------------------------------|---------------------------------------------|----------------------------|
|                              |                                                           |               | Average<br>MPa (10 <sup>3</sup> psi) | Std. Deviation<br>MPa (10 <sup>3</sup> psi) |                            |
| T300-W133<br>Graphite, 2-ply | 115 (5.7)                                                 | Cocured       | 286 (41.5)                           | 47.8 (6.9)                                  | buckling, skin compression |
|                              |                                                           | Secondary     | 244 (35.3)                           | 38.5 (5.6)                                  | skin debonding             |
|                              | 160 (7.9)                                                 | Cocured       | 326 (47.2)                           | 15.7 (2.3)                                  | skin compression           |
|                              |                                                           | Secondary     | 271 (39.3)(4)                        | ---                                         | skin debonding             |
| E-7781 Glass, 4-ply          | 115 (5.7)                                                 | Cocured       | 294 (42.6)                           | 10.6 (1.5)                                  | buckling, skin compression |
|                              |                                                           | Secondary     | 252 (36.6)                           | 62.7 (9.1)                                  | buckling, skin debonding   |

(1) In both the cocure and secondary bonding processes a layer of EA9394 adhesive on a fiberglass scrim was used between the skins and the core to assure satisfactory filleting on both skins.

(2) Cocured = Skins cured and bonded to core simultaneously.

Secondary = Skins cured separately then bonded to core in a second operation.

(3) Values represent average of three specimens unless otherwise indicated. All tests at 22°C (72°F).

(4) Two specimens.

TABLE 40

EFFECT OF ADHESIVE APPLICATION RATE ON FLATWISE  
TENSILE STRENGTH OF HONEYCOMB SANDWICH

| Sandwich Description                            |                                                 |                                                                   | Fillet Size (2) |                  | Failure Mode (4)                          |       |         |                             |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------------------------|-----------------|------------------|-------------------------------------------|-------|---------|-----------------------------|
| Core                                            | Skin                                            | Adhesive Application Rate (1)                                     | Top Skin (mm)   | Bottom Skin (mm) | Flatwise Tensile Strength (3) (MPa) (psi) | A (%) | A/C (%) | A/S (%) S (%)               |
| CRIII-1/4-5052-.004N-7.9<br>2.54cm (1 in) thick | 2-ply T300-W133<br>Gr/EA9396<br>Comp. each face | None                                                              | 0.1-0.3         | 0.3-0.5          | 1.7 (248)                                 | 30    | 10      | 60 0<br>------(NOTE 5)----- |
| "                                               | "                                               | 0.21 gm/cm <sup>2</sup> adh.<br>between core and<br>top skin only | ~1.5            | 0.3-0.5          | 4.2 (607)                                 | 92    | 8       | 0 0<br>------(NOTE 6)-----  |
| "                                               | "                                               | 0.08 gm/cm <sup>2</sup> adh.<br>between core and<br>both skins    | ~0.5            | ~0.5             | 5.2 (751)                                 | 35    | 60      | 5 0                         |
| "                                               | "                                               | 0.21 gm/cm <sup>2</sup> adh.<br>between core and<br>both skins    | ~1.5            | ~1.5             | 5.8 (846)                                 | 10    | 50      | 40 0                        |
| "                                               | "                                               | 0.73 gm/cm <sup>2</sup> adh.<br>between core and<br>both skins    | 3.2-4.7         | 3.2-4.7          | 6.7 (980)                                 | 3     | 30      | 34 33                       |

## NOTES:

1. EA9394 adhesive on Style 120 glass resin cloth.
2. Estimated from microscopic examination of specimens after testing.
3. Average of three or four specimens. All tests performed at 22°C (72°F).
4. A = cohesive failure within the adhesive (between the base of the fillet and the adhesive layer)  
A/C = failure at fillet-to-core interface (bare cell wall)  
A/S = failure at adhesive to skin interface  
S = delamination of skin
5. Failure located between core and top skin.
6. Failure located between core and bottom skin.

0.08 gm/cm<sup>2</sup> along the skin-core interface. Above this weight of adhesive application, additional strength increases are achieved but at a much lower rate. Figure 10 illustrates the relationship between adhesive application rate and resulting flatwise tensile strength and the relationship between fillet size (or area of contact between adhesive and core cell walls) and adhesive application rate. With no adhesive at all, the fillets result solely from the EA9396 matrix resin in the sandwich skins, and the fillet size ranges from nearly zero along the upper skin (0.1-0.3 mm by visual estimate) to approximately 0.3-0.5 mm along the lower skin. In those cases where a layer of EA9394 adhesive was employed, the fillet sizes ranged from approximately 0.5 mm for an adhesive application rate of 0.08 gm/cm<sup>2</sup>, to 1.5 mm for a rate of 0.21 gm/cm<sup>2</sup>, and 4 mm for a rate of 0.73 gm/cm<sup>2</sup>.

While it is evident that flatwise tensile strength levels can be raised significantly by the use of large quantities of adhesive, and that without an adhesive layer the strength levels are quite low, a point of diminishing returns is reached at adhesive application rates in the vicinity of 0.1 gm/cm<sup>2</sup>. Above this level the increases in strength that can be achieved may not be worth the weight penalty that accompanies it.

### 3.11 EFFECT OF SIZING ON GLASS FABRIC LAMINATES

Except for the work reported in this section, all of the glass-reinforced laminates made and tested during this program had a Volan-A type fiber sizing. This fiber sizing was used because it is the most commonly used fiberglass sizing and is epoxy-compatible, even though it is not the most environmentally durable finish. It was felt that there was a high likelihood of Volan-sized glass fabric being used in repairs, and the data would therefore provide conservative numbers. The property levels delivered by glass-reinforced laminates made with Volan-A sized fiber were listed in the various tables in Section 3.2. It is evident from these data that very significant property losses are encountered as a result of moisture absorption. Because of this substantial moisture-induced property degradation, it was decided to prepare and test a limited quantity of glass-reinforced laminates that incorporated a silane sizing rather than the Volan-A type sizing.

Laminates using silane-sized glass fabric were prepared in the same manner as those for which property data are reported in Sections 3.2.1, 3.2.3, and 3.2.4. The standard processing procedure described in Appendix A was followed in the preparation of these silane-sized laminates. Tensile, inplane shear and interlaminar shear properties were generated from specimens machined from these laminates, and the results of these

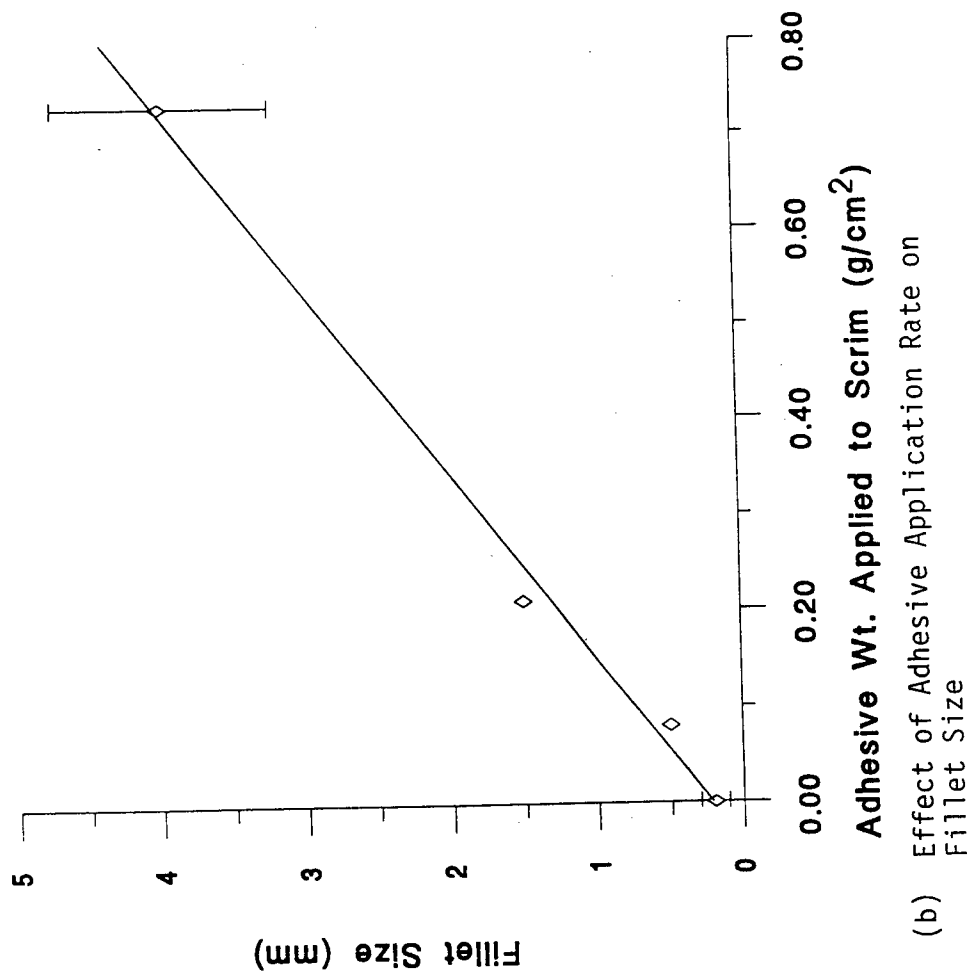
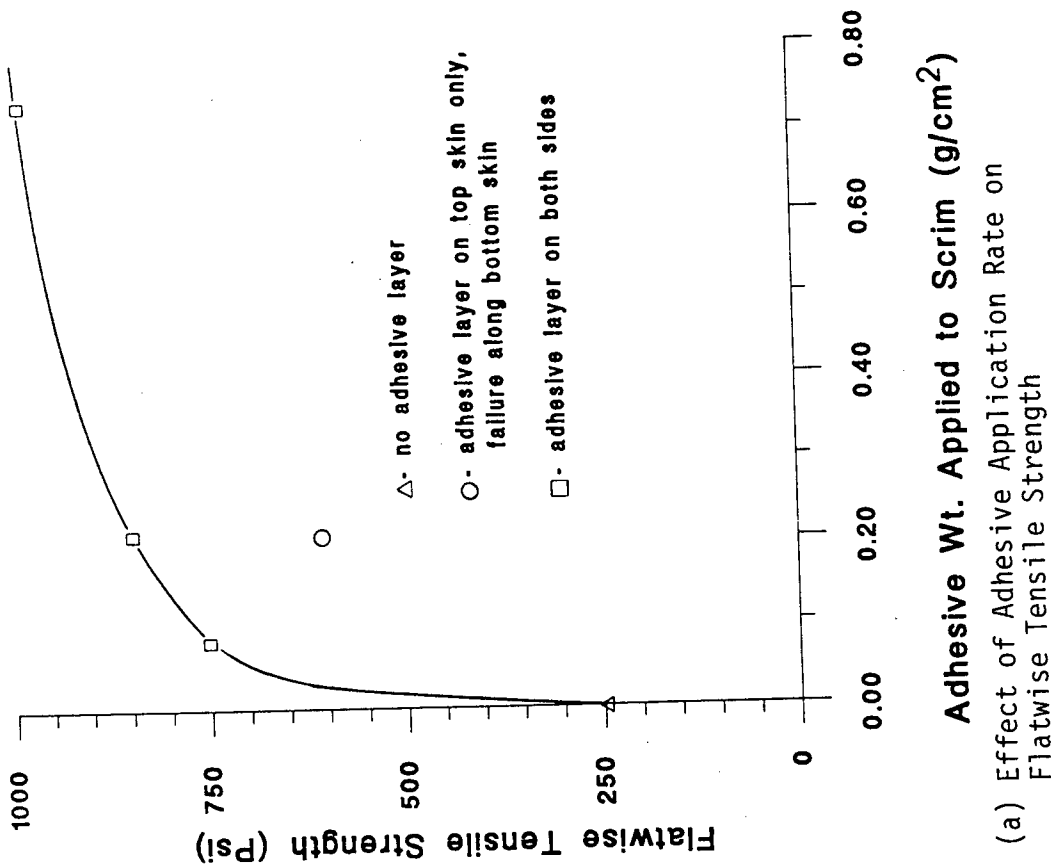


Figure 10. Effect of Adhesive on Fillet Size and Flatwise Tensile Strength of Sandwich Constructions.

tests are presented in Tables 41-43. It is apparent from these tables that the silane-sized fiber produces appreciably higher strength retention after wet aging than the Volan sizing.

### 3.12 EFFECT OF NONBASELINE ENVIRONMENTAL EXPOSURE

The baseline environmental exposure condition utilized during this investigation was a wet-aging exposure at conditions of 60°C (140°F)/100% R.H. until saturation was achieved. This was followed by mechanical testing at -54°C (-65°F), 22°C (72°F), or 93°C (200°F). Two nonbaseline types of environmental exposure were carried out, however, to assess durability of the repair material to various thermal environments. These are described in the following two sections.

#### 3.12.1 Elevated Temperature Exposure

The purpose of this test was to determine whether exposure to 177°C (350°F) was detrimental to composite mechanical properties, specifically interlaminar shear. This was of interest because a repair initially cured at 93°C (200°F) might, at some later date, be exposed to one or more 177°C (350°F) cure cycles. Two exposure levels, 2 hours and 16 hours at 177°C (350°F), were carried out. Interlaminar shear tests were conducted after these exposures and the results are presented in Table 44. No degradation is evident in the shear strength values for the glass reinforced material in spite of the visual darkening that was evident. In the case of the graphite reinforced material, the shear strengths after the 177°C (350°F) exposures are approximately 15% lower than the baseline shear strength levels.

#### 3.12.2 Exposure to Thermal Pulse

Both graphite and glass reinforced laminates were painted on one side with a standard aircraft paint scheme in a dark gray shade. Some of these painted laminates were humidity aged until saturated while some were stored in a desiccated environment. After completion of the environmental exposure, these laminates were exposed, on the painted side, to a thermal pulse by means of a quartz lamp bank. A Mach 0.7 air flow was maintained over the laminates during the thermal pulse and the laminates were not loaded.

After exposure to the pulse, the laminates were machined into compression specimens and tested for residual strength. Tables 45 and 46 present the

TABLE 41

LONGITUDINAL (WARP) TENSILE PROPERTIES OF A1100-SIZED  
GLASS REINFORCED E-7781/EA9396 COMPOSITE MATERIAL

| Test Condition       | Fiber Sizing | Test Direction | Ultimate Strength<br>(MPa) (psi) |        | Tensile Modulus<br>(GPa) (10 <sup>6</sup> psi) |      | Ult. Strain<br>(10 <sup>-6</sup> in/in) |
|----------------------|--------------|----------------|----------------------------------|--------|------------------------------------------------|------|-----------------------------------------|
| 22°C(72°F), Dry      | A1100        | Warp           | 280.8                            | 40,760 | 24.5                                           | 3.55 | 11,880                                  |
| 22°C (72°F), Wet(2)  | A1100        | Warp           | 246.5                            | 35,780 | 21.6                                           | 3.14 | 12,130                                  |
| 93°C (200°F), Wet(2) | A1100        | Warp           | 170.6                            | 24,760 | 18.8                                           | 2.73 | 9,520                                   |
| 22°C (72°F), Dry     | Volan (3)    | Warp           | 356.6                            | 51,750 | 24.9                                           | 3.62 | 17,740                                  |
| 22°C (72°F), Wet     | Volan (3)    | Warp           | 112.9                            | 16,390 | 22.7                                           | 3.30 | 5,100                                   |
| 22°C (72°F), Wet     | Volan (3)    | Fill           | 120.9                            | 17,540 | 23.9                                           | 3.47 | 5,410                                   |
| 93°C (200°F), Wet    | Volan (3)    | Fill           | 93.3                             | 13,540 | 20.7                                           | 3.01 | 4,470                                   |

- (1) All average values represent five specimens.  
 (2) WET = wet aged at 60°C (140°F)/100% R.H. until saturation.  
 (3) The Volan sized fiber panels represent the baseline data.

TABLE 42

IN-PLANE SHEAR PROPERTIES OF A1100-SIZED GLASS  
REINFORCED E-7781/EA9396 COMPOSITE MATERIAL

| Test Condition        | Fiber Sizing | In-Plane Shear Strength<br>(MPa) (psi) |        | In-Plane Shear Modulus<br>(GPa) (10 <sup>6</sup> psi) |       |
|-----------------------|--------------|----------------------------------------|--------|-------------------------------------------------------|-------|
| 22°C (72°F), Dry      | A1100        | 65.6                                   | 9,520  | 4.38                                                  | 0.635 |
| 22°C (72°F), Wet (2)  | A1100        | 44.1                                   | 6,400  | 2.60                                                  | 0.378 |
| 93°C (200°F), Wet (2) | A1100        | 25.8                                   | 3,740  | 0.90                                                  | 0.131 |
| 22°C (72°F), Dry      | Volan (3)    | 78.5                                   | 11,400 | 5.27                                                  | 0.765 |
| 22°C (72°F), Wet      | Volan (3)    | 38.0                                   | 5,510  | 3.39                                                  | 0.492 |
| 93°C (200°F), Wet     | Volan (3)    | 18.9                                   | 2,740  | 1.67                                                  | 0.243 |

- (1) All values represent average of five specimens.  
 (2) WET = wet aged at 60°C (140°F)/100% R.H. until saturated.  
 (3) The Volan sized fiber panels represent the baseline data.

TABLE 43

INTERLAMINAR SHEAR PROPERTIES OF A1100-SIZED GLASS  
REINFORCED E-7781/EA9396 COMPOSITE MATERIAL

| Test Condition           | Fiber Sizing | Interlaminar Shear Str. |       | Weight Gain      |
|--------------------------|--------------|-------------------------|-------|------------------|
|                          |              | (MPa)                   | (psi) | During Aging (%) |
| 22°C (72°F), Dry         | A1100        | 42.4                    | 6,150 | N.A.             |
| 22°C (72°F),<br>Wet (2)  | A1100        | 29.4                    | 4,260 | 2.69%            |
| 93°C (200°F),<br>Wet (2) | A1100        | 12.7                    | 1,840 | 2.68%            |
| 22°C (72°F), Dry         | Volan (3)    | 38.7                    | 5,620 | N.A.             |
| 22°C (72°F), Wet         | Volan (3)    | 20.5                    | 2,980 | 2.18%            |
| 93°C (200°F), Wet        | Volan (3)    | 11.8                    | 1,710 | 2.15%            |

- (1) All values represent average of five specimens. Four-point shear. Tested at 8:1 span-thickness ratio.
- (2) WET = wet aged at 60°C (140°F)/100% R.H. until saturation.
- (3) The volan sizing fiber panels represent the baseline data.



TABLE 44

EFFECT OF 177°C (350°F) CURE CYCLES ON INTERLAMINAR  
SHEAR STRENGTH OF EA9396 COMPOSITE LAMINATES

| Reinforcement<br>Type | Exposure<br>Condition                                             | Test<br>Condition | Shear Strength(1,2) |         | Weight Gain<br>During Aging<br>(%) |
|-----------------------|-------------------------------------------------------------------|-------------------|---------------------|---------|------------------------------------|
|                       |                                                                   |                   | (MPa)               | (psi)   |                                    |
| "E"-7781-Glass        | None (3)                                                          | 22°C (72°F),      | 38.7                | 5620    | N.A.                               |
|                       |                                                                   | Dry               |                     |         |                                    |
|                       |                                                                   | 93°C (200°F),     | 11.8                | 1710    | 2.15                               |
|                       | 2 hrs. @ 177°C<br>(350°F)                                         | Wet (4)           |                     |         |                                    |
|                       |                                                                   | 22°C (72°F),      | 38.9                | 5650    | N.A.                               |
|                       |                                                                   | Dry               |                     |         |                                    |
|                       |                                                                   | 93°C (200°F),     | 13.3                | 1930    | 2.04                               |
|                       | 16 hrs. @ 177°C<br>(350°F) (3 seg-<br>ments of 6 +<br>6 + 4 hrs)  | Wet (4)           |                     |         |                                    |
|                       |                                                                   | 22°C (72°F),      | 41.4                | 6010(5) | N.A.                               |
|                       |                                                                   | Dry               |                     |         |                                    |
| T300-W133<br>Graphite | None (3)                                                          | 93°C (200°F),     | 13.2                | 1920(5) | 2.25                               |
|                       |                                                                   | Wet (4)           |                     |         |                                    |
|                       |                                                                   | 22°C (72°F),      | 39.3                | 5700    | N.A.                               |
|                       | 2 hrs. @ 177°C<br>(350°F)                                         | Dry               |                     |         |                                    |
|                       |                                                                   | 93°C (200°F),     | 16.1                | 2340    | 2.20                               |
|                       |                                                                   | Wet (4)           |                     |         |                                    |
|                       | 16 hrs. @ 177°C<br>(350°F) (3 seg-<br>ments of 6 +<br>6 + 4 hrs.) | 22°C (72°F),      | 34.5                | 5000    | N.A.                               |
|                       |                                                                   | Dry               |                     |         |                                    |
|                       |                                                                   | 200°F, Wet (4)    | 13.7                | 1990    | 2.35                               |
|                       | 16 hrs. @ 177°C<br>(350°F) (3 seg-<br>ments of 6 +<br>6 + 4 hrs.) | 22°C (72°F),      | 36.2                | 5260    | N.A.                               |
|                       |                                                                   | Dry               |                     |         |                                    |
|                       |                                                                   | 93°C (200°F),     | 13.2                | 1920    | 2.35                               |
|                       |                                                                   | Wet (4)           |                     |         |                                    |

- (1) Four-point shear (Graphite tests at 16:1 span-thickness ratio Glass tests at 8:1).
- (2) Warp direction of fabric is running in length direction of specimens.
- (3) The shear strength values listed for the no exposure condition represent the baseline interlaminar shear strengths.
- (4) WET = aging at 60°C (140°F)/95-100% R.H. until saturated.
- (5) These glass reinforced specimens turned very noticeably darker after this exposure. This darkening could not be noticed on the black graphite reinforced specimens.

TABLE 45

EFFECT OF RADIANT THERMAL PULSE ON COMPRESSION STRENGTH  
OF GLASS-REINFORCED E-7781/EA9396 COMPOSITE MATERIAL

| Data Source (1)        | Test Condition (2)         | Compression Strength |           |
|------------------------|----------------------------|----------------------|-----------|
|                        |                            | (MPa)                | (psi)     |
| Baseline Panel Average | 22°C(72°F) Dry, No Pulse   | 281.6                | 40,840    |
| Test Panel             | 22°C(72°F) Dry, No Pulse   | 293.7                | 42,600(3) |
| Test Panel             | 22°C(72°F) Dry, Pulsed     | 283.4                | 41,100    |
| Baseline Panel Average | 93°C(200°F) Dry, No Pulse  | 200.1                | 29,020    |
| Test Panel             | 93°C(200°F) Dry, Pulsed    | 177.5                | 25,740    |
| Baseline Panel Average | -54°C(-65°F) Wet, No Pulse | 320.7                | 46,510    |
| Test Panel             | -54°C(-65°F) Wet, Pulsed   | 280.3                | 40,650    |
| Baseline Panel Average | 22°C(72°F) Wet, No Pulse   | 162.4                | 23,560    |
| Test Panel             | 22°C(72°F) Wet, No Pulse   | 159.2                | 23,090(4) |
| Test Panel             | 22°C(72°F) Wet, Pulsed     | 146.8                | 21,290    |
| Baseline Panel Average | 93°C(200°F) Wet, No Pulse  | 97.8                 | 14,180    |
| Test Panel             | 93°C(200°F) Wet, Pulsed    | 70.7                 | 10,250    |

## NOTES:

- Baseline panel average values from Tables 12 and 13. All test panel values represent an average of five specimens unless otherwise noted. Test panel, no pulse specimens were tested to demonstrate that the test panel was equivalent to the baseline panels.
- The listed temperature represents the temperature at which the compression test was conducted. DRY means that the specimens were in the dry condition when exposed to thermal pulse (if applicable) and also when tested in compression. WET means that the specimens had been exposed to 60°C (140°F)/100% R.H. wet aging until saturated prior to the thermal pulse exposure (if applicable) and also when tested in compression. The wet aged samples that were thermally pulsed were reaged after the pulse until resaturated before being compression tested.
- Average of two specimens.
- Average of four specimens.

TABLE 46

EFFECT OF RADIANT THERMAL PULSE ON COMPRESSION STRENGTH  
OF GRAPHITE-REINFORCED T300-W133/EA9396 COMPOSITE MATERIAL

| Data Source (1)        | Test Condition (2)         | Compression Strength |           |
|------------------------|----------------------------|----------------------|-----------|
|                        |                            | (MPa)                | (psi)     |
| Baseline Panel Average | 22°C(72°F) Dry, No Pulse   | 420.3                | 60,960    |
| Test Panel             | 22°C(72°F) Dry, No Pulse   | 448.2                | 65,000(3) |
| Test Panel             | 22°C(72°F) Dry, Pulsed     | 395.1                | 57,300    |
| Baseline Panel Average | 93°C(200°F) Dry, No Pulse  | 278.8                | 40,440    |
| Test Panel             | 93°C(200°F) Dry, Pulsed    | 297.4                | 43,130    |
| Baseline Panel Average | -54°C(-65°F) Wet, No Pulse | 530.8                | 76,990    |
| Test Panel             | -54°C(-65°F) Wet, Pulsed   | 495.5                | 71,860    |
| Baseline Panel Average | 22°C(72°F) Wet, No Pulse   | 349.6                | 50,700    |
| Test Panel             | 22°C(72°F) Wet, No Pulse   | 314.6                | 45,630(4) |
| Test Panel             | 22°C(72°F) Wet, Pulsed     | 315.1                | 45,690    |

## NOTES:

1. Baseline panel average values from Tables 15 and 16. All test panel values represent an average of five specimens unless otherwise noted. Test panel, no pulse specimens were tested to demonstrate that the test panel was equivalent to the baseline panels.
2. The listed temperature represents the temperature at which the compression test was conducted. DRY means that the specimens were in the dry condition when exposed to thermal pulse (if applicable) and also when tested in compression. WET means that the specimens had been exposed to 60°C (140°F)/100% R.H. wet aging until saturated prior to the thermal pulse exposure (if applicable) and also when tested in compression. The wet aged samples that were thermally pulsed were reaged after the pulse until resaturated before being compression tested.
3. Average of two specimens.
4. Average of four specimens.

results of these tests. The data in these tables indicate that the laminates used in the thermal pulse tests were equivalent to the baseline laminates in the unpulsed condition and that exposure to a thermal pulse resulted in relatively small decreases in compression strength.

## SECTION 4

### CONCLUSIONS

Based on the results obtained during the test program described in this report, the following conclusions were drawn.

- Reproducible composite mechanical and physical property levels can be achieved using the wet-layup impregnation and vacuum-bag curing procedures described here.
- With vacuum-bag cure pressure, the void content of cured composites is in the vicinity of 5% by volume.
- Batch-to-batch property values are quite consistent and reproducible.
- Significant reductions in composite property levels occur with increasing temperature over the range of -65°F to 200°F.
- The property levels of EA9396 composites reinforced with a Volan-A sized glass fabric are significantly reduced when the composites become moisture saturated. A silane-type sizing on the glass reinforcement provides markedly better wet strength retention than the Volan-A type sizing and nearly equivalent to that of the graphite reinforced composites.
- Measurements made during this program indicate that nominally complete cure and peak property levels can only be achieved with elevated temperature (180°F and up) curing.
- The EA9396 resin system has a reasonable pot and work life at temperatures up to 100°F for use in repair.
- The EA9396 resin system appears to have good storage stability, even at elevated temperature.
- Exposure of EA9396 composites to simulated 350°F cure cycles had no adverse effect on mechanical properties.
- A high heat flux thermal pulse did not cause a major degradation in compressive strength levels.

## SECTION 5

### REFERENCES

1. Browning, C.E., Abrams, F.L., and Whitney, J.M., "A Four-Point Shear Test for Graphite/Epoxy Composites," Composite Materials: Quality Assurance and Processing, ASTM STP 7979, C.E. Browning, Ed., American Society for Testing and Materials, 1983, pp. 54-74.
2. MIL-HDBK-178, Polymer Matrix Composites, Vol. 1, Ch. 7, 29 February, 1988.

## APPENDIX A

### STANDARD LAMINATE PROCESSING PROCEDURE

Most of the laminates prepared during this investigation were made by a procedure designated the "Standard Procedure." This "Standard" laminate processing procedure is described below, first in a general stepwise listing of the procedure, and then in a more detailed description of each step. The general step-by-step procedure consisted of the following.

- (a) Cut fabric (total number of plies =  $P$ ).
- (b) Weigh or measure the total area of all the plies cut in step (a).
- (c) Compute total amount of resin needed to impregnate fabric cut in step (a), (see Table A.2).
- (d) Weigh out and mix the total amount of resin needed. This is in the ratio of 100 parts A to 30 parts B by weight. A few grams extra should be allowed since some resin will adhere to sides of mixing container (total weight of mixed resin =  $W$ ).
- (e) Lay down first two plies of fabric, one atop the other.
- (f) Weigh out an amount of mixed resin equal to  $2.5 W/P$ . Pour this resin on top of the second ply and manually spread it over the entire surface as uniformly as possible.
- (g) Lay down two more plies on top of the two in steps (e) and (f). Manually tamp these down so that the resin applied in step (f) is soaking into these two new plies.
- (h) Weigh out an amount of mixed resin equal to  $2 W/P$ . Pour this resin on top of the last ply and manually spread it over the entire surface as uniformly as possible.
- (i) Do steps (g) and (h) a total of  $P-4/2$  times.
- (j) Lay down the last two plies of fabric on top of the previously impregnated plies.
- (k) Lay down an amount of mixed resin equal to  $1.5 W/P$ . Pour this resin on top of the last ply and manually spread it over the entire surface as uniformly as possible.
- (l) Bag the layup in general accordance with Figure A.1.
- (m) Cure the laminate in accordance with the standard cure cycle.

Each of the steps listed above, and the relevant rationale is described in detail below.

(a) The graphite (W133) and glass (7781) fabrics were cut to the size needed for the laminate being made. In this investigation, laminate sizes varied depending on the type and number of specimens that were required from the laminate. Table A.1 lists the thicknesses and dimensions used for the laminates prepared in this investigation.

(b) The amount of fabric used for each laminate was weighed. Alternatively, if a scale is not available, the total area of all the plies used for a laminate could be determined by measuring the dimensions of each ply.

(c) The amount of resin needed for the laminate being prepared depends on how much fabric needs to be impregnated. After some initial experimentation, we settled on using a 50% excess to provide for flow and bleed and to provide sufficient resin to allow uniform wet out of plies during the hand layup operation. Table A.2 lists the ratio of resin to fabric, on both a weight and area basis, that was used during laminate layup.

(d) Quantities of resin mixed for laminate preparation in this program ranged from around 50-60 grams for the smallest panels to 800-900 grams for the largest. In the case of the largest quantities, as many as three separate mixing containers were used (~300 grams each). This was done both to minimize the chance of a premature exotherm/gel and because larger mixing containers were not readily available. Between 5 and 10 grams of extra resin, beyond the quantities determined in step (c), were mixed in each mixing container to allow for the fact that some of the resin would be left behind on the container walls after impregnation.

(e) The actual impregnation process was performed on an 0.16 mm (0.063 inch) thick aluminum sheet coated with Frekote 44 release agent. Two dry plies of reinforcement were laid down atop one another on the aluminum sheet. Care was taken to keep track of the warp and fill direction of each ply of fabric so that the warp fibers were all aligned in the same direction for every ply. In addition, because both the W133 graphite and 7781 glass fabrics were 8-harness satin weaves, the predominant fiber direction on one side of the fabric was in the warp direction while on the other side it was in the fill direction. The plies were stacked such that the plies in the lower half of each laminate had the warp face down while the plies in the upper half had the warp face up. This ensured symmetry about the laminate midplane.



(f) The amount of resin poured onto the top of the first two plies laid down in step (e) was  $2.5 W/P$ , where  $W$  represents the total weight of the resin computed and mixed in step (c) and  $P$  represents the total number of plies in the laminate being prepared. After addition of this resin to the first two plies, it was manually spread over the entire ply surface as uniformly as possible using a plastic spatula.

(g) This step is straightforward and requires no further elaboration.

(h) It will be noted that the amount of resin to be applied in this step ( $2 W/P$ ) is less than the amount applied to the first two plies ( $2.5 W/P$ ) in step (f). The reason for this is that since the intermediate plies pick up resin from the bottom, from previously impregnated plies, not as much resin needs to be added to these intermediate plies as to the first two plies, which do not pick up resin from below.

(i) The thinnest laminates made in this investigation were 8-ply except for those used as skins on honeycomb sandwich. For this case, steps (g) and (h) would be done a total of two times ( $[8-4]/2 = 2$ ). For a 16-ply laminate, steps (g) and (h) would be done a total of six times. For a 4-ply laminate, steps (g) and (h) would not be done at all ( $[4-4]/2 = 0$ ).

(j) This step is straightforward and requires no further elaboration.

(k) Again, it will be noted that the amount of resin applied in this step ( $1.5 W/P$ ) is less than that applied in previous steps (f) and (h). The reason for this is that since these last two plies do not give up any resin to succeeding plies, but do gain resin from previously impregnated plies, not as much resin needs to be added to these top plies.

(l) In this investigation a Zip-Loc reusable vacuum bag system was used for laminate cure. The bleeder material used in the "standard" processing procedure being described here was Mochburg CW1850 ( $\sim 71 \text{ gm/m}^2$ ). Table A.2 lists the number of bleeder plies that were used, relative to the number of plies of reinforcement in the laminate being cured. After completion of the layup and closing of the lid, the unit was placed in a circulating air oven, and a vacuum was drawn to verify that a good seal was present before heating commenced.

(m) The "standard cure cycle" consisted of curing the laminate for 45 minutes at  $93^\circ\text{C}$  ( $200^\circ\text{F}$ ) under vacuum pressure. The laminate was subjected to a nominal vacuum of 635 mm (25 inches) Hg before the oven was turned on. In the oven used, the

temperature of the circulating air reached 93°C (200°F) in approximately 3-4 minutes while the laminate in the vacuum bag reached 93°C (200°F) in about 50 minutes.

Figure A.2 illustrates a typical heat-up curve for a laminate during a vacuum bag cure in the oven. The 45-minute cure period was started when the laminate temperature, as indicated by a thermocouple inside the vacuum bag, reached 90.5°C (195°F). At the conclusion of the 45-minute cure, the oven heaters were turned off, the door was opened, and the circulating air fan was left on. The vacuum was left on the laminate during cooldown. Cooldown time varied from as little as 1 hour to overnight, depending on time of day and oven schedule.

TABLE A.1  
LAMINATE THICKNESSES AND DIMENSIONS

| Type Test                                    | Type Reinforcement |                                                              |               |                                                                  |
|----------------------------------------------|--------------------|--------------------------------------------------------------|---------------|------------------------------------------------------------------|
|                                              | 7781 Glass         |                                                              | W133 Graphite |                                                                  |
|                                              | Thickness(1)       | Size Range<br>(cm) [in]                                      | Thickness(1)  | Size Range<br>(cm) [in]                                          |
| Tension<br>(D3039)                           | 8 ply              | max. (51 x 51)<br>[20 x 20]<br>min. (35.5 x 51)<br>[14 x 20] | 8 ply         | (51 x 51)<br>[20 x 20]                                           |
| Compression<br>(D3410B)                      | 16 ply             | max. (51 x 51)<br>[20 x 20]<br>min. (23 x 43)<br>[9 x 17]    | 12 ply        | max. (51 x 51)<br>[20 x 20]<br>min. (23 x 43)<br>[9 x 17]        |
| 45° Tension/<br>Inplane Shear<br>(D3418)     | 8 ply              | max. (51 x 51)<br>[20 x 20]<br>min. (30.5 x 51)<br>[12 x 20] | 8 ply         | max. (51 x 51)<br>[20 x 20]<br>min. (30.5 x 51)<br>[12 x 20]     |
| Interlaminar<br>Shear (Four-<br>Point Shear) | 16 ply             | max. (51 x 51)<br>[20 x 20]<br>min. (12.7 x 20.3)<br>[5 x 8] | 12 ply        | max. (30.5 x 30.5)<br>[12 x 12]<br>min. (12.7 x 20.3)<br>[5 x 8] |
| Bearing (MIL-<br>HDBK-17)                    | 8 ply              | (30.5 x 35.5)<br>[12 x 14]                                   | 8 ply         | (30.5 x 35.5)<br>[12 x 14]                                       |
| Flatwise<br>Tension (2)<br>(C297)            | ---                | ---                                                          | 2 ply         | (15.2 x 15.2)<br>[6 x 6]                                         |
| Edgewise<br>Compression<br>(2) (C364)        | 4 ply              | (3.3 x 35.5)<br>[13 x 14]                                    | 2 ply         | (33 x 35.5)<br>[13 x 14]                                         |

TABLE A.2  
EA9396 BASELINE LAMINATE FABRICATION PARAMETERS

| Parameter                                                                         | Reinforcement Type                                                                                |                                                       |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------|
|                                                                                   | W133 Gr Fabric                                                                                    | 7781 Gl Fabric                                        |
| Grams of Mixed Resin Per Gram of Reinforcement Used During Impregnation           | 0.755                                                                                             | 0.555                                                 |
| -or-                                                                              |                                                                                                   |                                                       |
| Grams of Mixed Resin Per Unit Area of Reinforcement(1) Used During Impregnation   | 0.178 gm/in <sup>2</sup><br>0.0276 gm/cm <sup>2</sup>                                             | 0.104 gm/in <sup>2</sup><br>0.0161 gm/cm <sup>2</sup> |
| Plies of Mochburg CW1850 Bleeder (71 gm/m <sup>2</sup> ) Per Ply of Reinforcement | 0.40(2)                                                                                           | 0.25(2)                                               |
| Cure Schedule                                                                     | 45 minutes at 93°C (200°F) under vacuum pressure (~125 mm Hg abs. pressure)<br>(~25 inch Hg vac.) |                                                       |

- (1) Total area of all reinforcement plies, not area of laminate. The values listed correspond to the mass/mass ratios listed directly above for the respective graphite and glass fabrics used. These two reinforcing fabrics are described in Table 1 and have the following weight per unit areas:

W133 - 0.236 gm/in<sup>2</sup>  
7781 - 0.190 gm/in<sup>2</sup>

- (2) Round off to the next higher whole number if the calculated number of bleeder plies is a fraction.

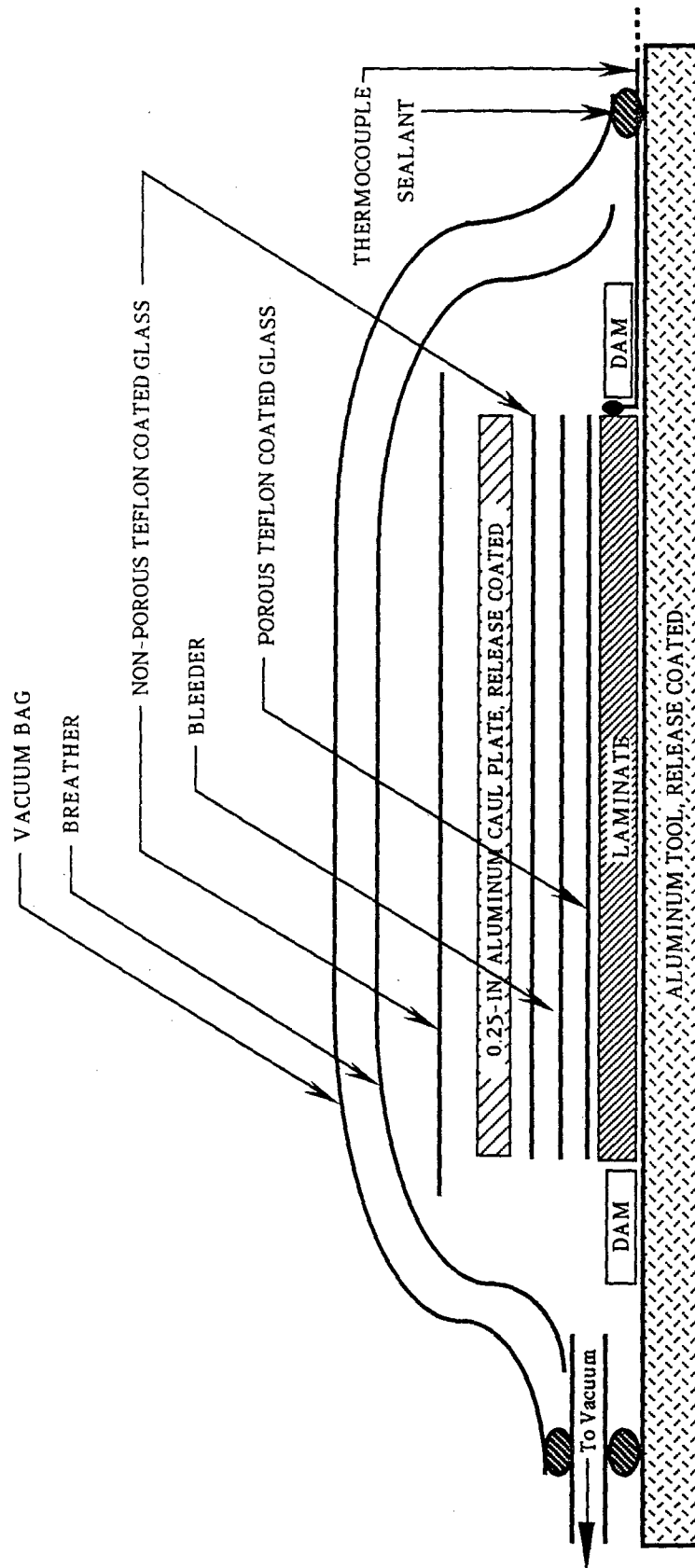


Figure A.1. Typical Vacuum Bag Layup Scheme for Curing EA9396 Composite Laminates.

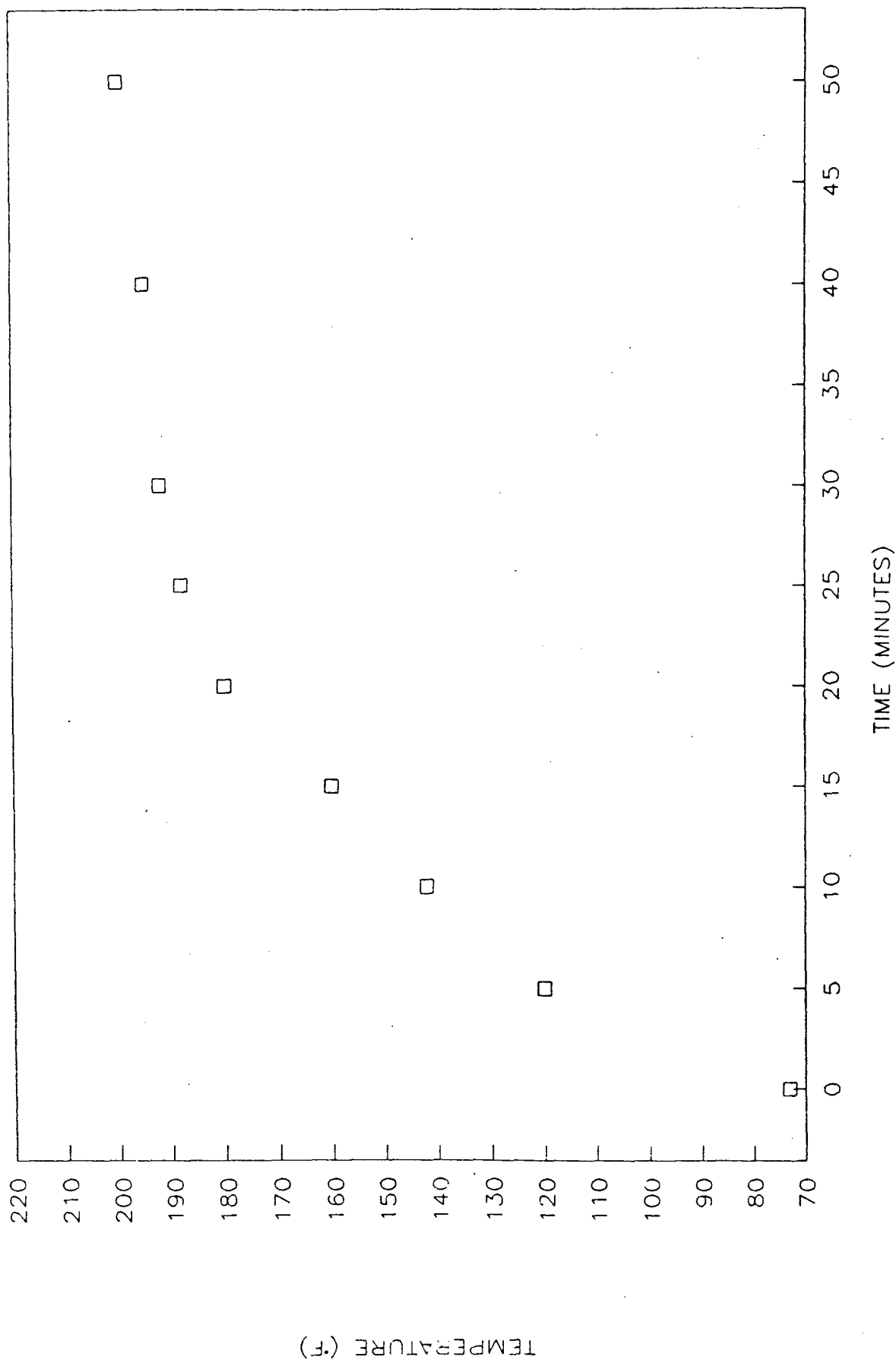


Figure A.2. Heat-Up Curve for Laminate Cure.

## APPENDIX B

### NONSTANDARD LAMINATE PROCESSING PROCEDURES

Quite a few laminates prepared during this investigation were not made in accordance with the "Standard Procedure" described in Appendix A. The processing procedures for these nonstandard laminates were varied in order to determine the effect of processing variations that might occur in field repair situations on resulting mechanical and physical laminate properties.

The processing variations described in this Appendix are subdivided into six categories and each is addressed respectively in Sections B.1-B.6.

#### B.1 NONSTANDARD CURE TIME/TEMPERATURE

In Section 3.5.2, the effect of cure time and temperature on interlaminar shear strength was discussed. Five graphite reinforced laminates were prepared using different cure conditions than those described in step (m) of Appendix A. Except for this difference in cure condition, all five of these laminates were prepared in accordance with the "Standard Procedure" described in Appendix A. Table B.1 identifies the five laminates cured at alternative times/temperatures and lists the time/temperature history used for each.

#### B.2 NONSTANDARD CURE VACUUM PRESSURES

In Section 3.5.3, the effect of vacuum bag vacuum pressure level during cure on interlaminar shear strength was discussed. Four glass reinforced laminates were prepared using different vacuum pressure levels than that noted in step (m) of Appendix A. Except for this difference in vacuum pressure level, all four of these laminates were prepared in accordance with the "Standard Procedure" described in Appendix A. Table B.2 identifies the four laminates cured under alternate vacuum pressure levels and lists the vacuum level used.

#### B.3 NONSTANDARD FIBER CONTENT

In Section 3.8, the effect of fiber content on mechanical properties was discussed. Both glass and graphite fabric reinforced laminates were prepared with fiber contents ranging from the standard 55% by volume down to as low as 34% by volume. All these low fiber content laminates were cured by the "Standard" cure cycle described in step

(m) of Appendix A. The differences in fiber content were achieved by changing either the bleeder ply/reinforcement ply ratio used during cure, or the ratio of resin to reinforcement used during impregnation. Other than these differences, the laminate processing was identical to that described in Appendix A. Table B.3 identifies the laminates for which either the bleeder or resin ratios were varied and lists the particular details for each.

#### B.4 NONSTANDARD PLY IMPREGNATION PROCEDURES

Section 3.9.1 discusses alternative ply impregnation procedures that were investigated. The two alternate impregnation procedures that were investigated were felt to be representative of procedures that might be employed by repair personnel working in the field.

##### Laminate No. BIL-GL-14

The first variation consisted of applying resin to every ply instead of every other ply, as in the "Standard Procedure" described in Appendix A. The difference between this nonstandard procedure and the standard procedure was in steps (e)-(j) of Appendix A. Instead of the procedure described in steps (e)-(j) the procedure outlined below was followed.

- (e) Lay down the first ply of fabric.
- (f) Weigh out an amount of mixed resin equal to W/P. Pour this resin on top of the first ply and manually spread it over the entire surface as uniformly as possible.
- (g) Do steps (e) and (f) a total of P times.

After step (g) was completed, the procedure reverted to steps (l) and (m) of Appendix A.

##### Laminate No. BIL-GL-16

The second variation consisted of using a smaller quantity of resin during impregnation of the reinforcement than the 50% excess used in the "Standard Procedure" described in Appendix A. This smaller quantity of resin represented 0% excess (net resin content). Further, since no excess resin was used, no bleeder plies were used during cure.



Thus the differences between the "Standard Procedure" described in Appendix A, and that used for this laminate, occurred in step (c) (and by reference, Table A.2) and in step (l) (and by reference, Figure A.1). The resin ratio used for glass reinforced laminates in the "Standard Procedure" was 0.555 gm resin/gm reinforcement. In laminate BIL-GL-16, the ratio was 0.377 instead. In addition, the bleeder ratio used for glass reinforced laminates in the "Standard Procedure" was 0.25 plies of bleeder/ply reinforcement (Table A.2). In laminate BIL-GL-16, no bleeder plies were used at all.

## B.5 NONSTANDARD BLEEDER MATERIAL

Section 3.9.2 discusses the use of alternative bleeder materials to the Mochburg CW1850 bleeder used in the "Standard Procedure" of Appendix A. Three glass and two graphite reinforced laminates were prepared using alternative bleeder material. The three glass laminates were made using the E-7781 glass fabric as bleeder while the two graphite laminates were made using the T300-W133 graphite fabric as bleeder. Other than this difference in bleeder material, the laminate processing was identical to the "Standard Procedure" described in Appendix A. Table B.4 identifies the laminates made with the nonstandard bleeder material, the applicable bleeder ratios that were used, and the resin absorption characteristics of the alternative materials.

## B.6 NONSTANDARD BAGGING SCHEMES

Section 3.9.3 discusses the investigation of several laminate bagging schemes that varied from the standard scheme illustrated in Figure A.1. The goal of each of these variant bagging schemes was to improve laminate quality by reducing void content below that normally resulting from a vacuum bag cure (see Table 4). The two variant bagging schemes described in this section were felt to be readily usable in the field. Each is discussed separately below.

### Perforated Barrier Film

The first approach was to perforate the normally non-porous barrier between the bleeder material and the breather material. It will be observed in Figure A.1 that in the standard bagging scheme, this nonporous barrier consists of a caul plate sandwiched between two sheets of nonporous teflon-coated glass. The purpose of the teflon-coated glass is to keep excess resin absorbed in the bleeder plies from being absorbed into the breather, where it might clog the vacuum paths and prevent full vacuum pressure from being uniformly exerted on the laminate surface. The purpose of the caul plate is to

prevent inadvertent wrinkles that may develop in the vacuum bag from imprinting the laminate surface and to prevent the vacuum bag from drawing down more tightly around the laminate edges than in the center, thereby producing nonuniform thickness. In the modified bagging scheme, the two layers of nonporous teflon-coated glass and the caul plate were replaced by a single layer of the teflon-coated glass that had been perforated with a series of knife slits. Figure B.1 illustrates this bagging scheme.

The rationale for investigating this type of bagging scheme was that perforations in the film between the bleeder and breather materials would permit the vacuum to draw air out of the bleeder instead of forcing it into the laminate layup. It was speculated that air might be trapped in the bleeder when the vacuum was applied because the caul plate would be pressed down so tightly that air escape paths would be shut off.

Other than the altered bagging scheme illustrated in Figure B.1, the processing of the laminate made with this procedure, BIL-GL-39, was identical to the "Standard Procedure" described in Appendix A.

#### Double-Bag

The second nonstandard bagging scheme that was investigated was the use of a double vacuum bag rather than the single bag scheme illustrated in Figure A.1. The rationale for this was that while the vacuum applied in the single bag scheme supposedly aids in drawing air and volatiles out of the laminate, the compaction of the layup resulting from the vacuum bag may pinch off escape paths and trap air and volatiles in the layup. The idea of a double bag scheme is that this approach permits the layup to "breathe" even while under vacuum by reducing the compacting force during the early part of the cure cycle. The double bag arrangement is illustrated in Figure B.2. An essential element of this arrangement is the "hardback" shell that holds the outer vacuum bag off the inner vacuum bag, thereby allowing the compacting force on the layup to be reduced during the early part of the cure cycle while simultaneously imposing a vacuum on the layup to draw off air and volatiles.

In using the bagging scheme illustrated in Figure B.2, a different cure cycle than that described in step (m) of Appendix A was followed. The cure cycle for the double-bag cure was as follows:

1. Draw a vacuum (23-24 in Hg) on the shell (#2).
2. Draw a vacuum (~25 in Hg) on the inner bag (#1).
3. Hold these two vacuum levels for 30 minutes at 22°C (72°F).
4. Vent line #2 to the atmosphere while maintaining full vacuum (~25+ in. Hg) on line #1.
5. Heat to 93°C (200°F).
6. When the temperature in the inner bag reaches 91°C (195°F), start a 45-minute hold, maintaining full vacuum on line #1.
7. Cool to 49°C (120°F) or less while maintaining full vacuum on line #1.
8. Remove.

TABLE B.1  
LAMINATES CURED AT NONSTANDARD TIMES/TEMPERATURES

| Laminate Number | Cure Temperature |      | Cure Time                                                                                                                                                   |
|-----------------|------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                 | (°C)             | (°F) |                                                                                                                                                             |
| "STANDARD"      | 93               | 200  | 45 minutes under vacuum                                                                                                                                     |
| BIL-GR-5        | 107              | 225  | 45 minutes under vacuum                                                                                                                                     |
| BIL-GR-1        | 93               | 200  | 30 minutes under vacuum                                                                                                                                     |
| BIL-H7-5        | 82               | 180  | 30 minutes under vacuum                                                                                                                                     |
| BIL-GR-4R       | 79               | 175  | 45 minutes under vacuum                                                                                                                                     |
| BIL-GR-20       | 22               | 72   | 4 hours under vacuum +<br>7 days at ambient conditions +<br>3 months in either dry ambient<br>storage or in 60°C (140°F), 95-<br>100% R.H. humidity cabinet |

TABLE B.2  
LAMINATES CURED UNDER NONSTANDARD VACUUM PRESSURE

| Laminate Number | Vacuum Bag Pressure Level During Cure |                 |
|-----------------|---------------------------------------|-----------------|
|                 | (mm Hg Vacuum)                        | (in. Hg Vacuum) |
| "STANDARD"      | 635                                   | 25              |
| BIL-GL-27       | 254                                   | 10              |
| BIL-GL-28       | 406                                   | 16              |
| BIL-GL-29       | 584                                   | 23              |
| BIL-GL-38       | 686                                   | 27              |

TABLE B.3  
LAMINATES PREPARED WITH NONSTANDARD BLEEDER  
PLY IN RESIN RATIOS

| Laminate Number        | Bleeder Ply/Reinforcement<br>Ply Ratio (1) (plies<br>bleeder/ply reinforcement) | Resin/Reinforcement<br>Ratio (1) (gm resin/<br>gm reinforcement) |
|------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------|
| GRAPHITE<br>"Standard" | 0.40                                                                            | 0.755                                                            |
| BIL-GR-51              | 0.42                                                                            | 0.548                                                            |
| BIL-GR-52              | 0.42                                                                            | 0.787                                                            |
| BIL-GR-53              | 0.33                                                                            | 1.000                                                            |
| BIL-GR-54              | 0.25                                                                            | 1.160                                                            |
| BIL-GR-79              | 0                                                                               | 1.150                                                            |
| BIL-GR-84              | 0.083                                                                           | 1.115                                                            |
| GLASS<br>"Standard"    | 0.25                                                                            | 0.555                                                            |
| BIL-GL-10              | 0.25                                                                            | 0.755                                                            |
| BIL-GL-31              | 0.375                                                                           | 0.555                                                            |
| BIL-GL-33              | 0.25                                                                            | 0.706                                                            |
| BIL-GL-53              | 0                                                                               | 1.000                                                            |
| BIL-GL-54              | 0.125                                                                           | 1.000                                                            |

NOTE:

(1) See Table A.2 (Appendix A) for baseline laminate fabrication parameters.

TABLE B.4  
LAMINATES MADE WITH NONSTANDARD BLEEDER MATERIAL

| Laminate Number     | Bleeder Material | Bleeder Dry Area Density (gm/m <sup>2</sup> ) | Bleeder/Laminate Ply Ratio | Bleeder Absorptivity |                           | Bleeder Ply Equivalents (8) |
|---------------------|------------------|-----------------------------------------------|----------------------------|----------------------|---------------------------|-----------------------------|
|                     |                  |                                               |                            | (gm/gm) (6)          | (gm/cm <sup>2</sup> ) (7) |                             |
| GLASS "Standard"    | CW1850           | 71                                            | 0.25 (1)                   | 3                    | 0.0213                    | 1.0                         |
| BIL-GL-17           | E-7781 fabric    | 295                                           | 0.25 (2)                   | 0.50                 | 0.0147                    | 1.51-1.88                   |
| BIL-GL-37           | E-7781 fabric    | 295                                           | 0.118 (3)                  | 0.39-0.42            | 0.0112-0.0124             | 1.51-1.88                   |
| BIL-GL-47           | E-7781 fabric    | 295                                           | 0.375 (4)                  | 0.41                 | 0.0121                    | 1.51-1.88                   |
| GRAPHITE "Standard" | CW1850           | 71                                            | 0.40 (1)                   | 3                    | 0.0213                    | 1.0                         |
| BIL-GR-58           | T300-W133 fabric | 366                                           | 0.25 (5)                   | 0.58                 | 0.0197                    | 1.13-1.30                   |
| BIL-GR-64R          | T300-W133 fabric | 366                                           | 0.375 (4)                  | 0.47                 | 0.0171                    | 1.13-1.30                   |

NOTES:

- (1) From Table A.2, Appendix A.
- (2) Two plies bleeder, eight plies reinforcement.
- (3) Three plies bleeder, sixteen plies reinforcement.
- (4) Three plies bleeder, eight plies reinforcement.
- (5) Three plies bleeder, twelve plies reinforcement.
- (6) Grams resin absorbed per gram of bleeder. Value for CW1850 represents average for all baseline laminates.
- (7) Grams resin absorbed per unit area of bleeder. Value for CW1850 represents average for all baseline laminates.
- (8) Number of plies needed to absorb some quantity of resin as one ply of Mochburg CW1850.

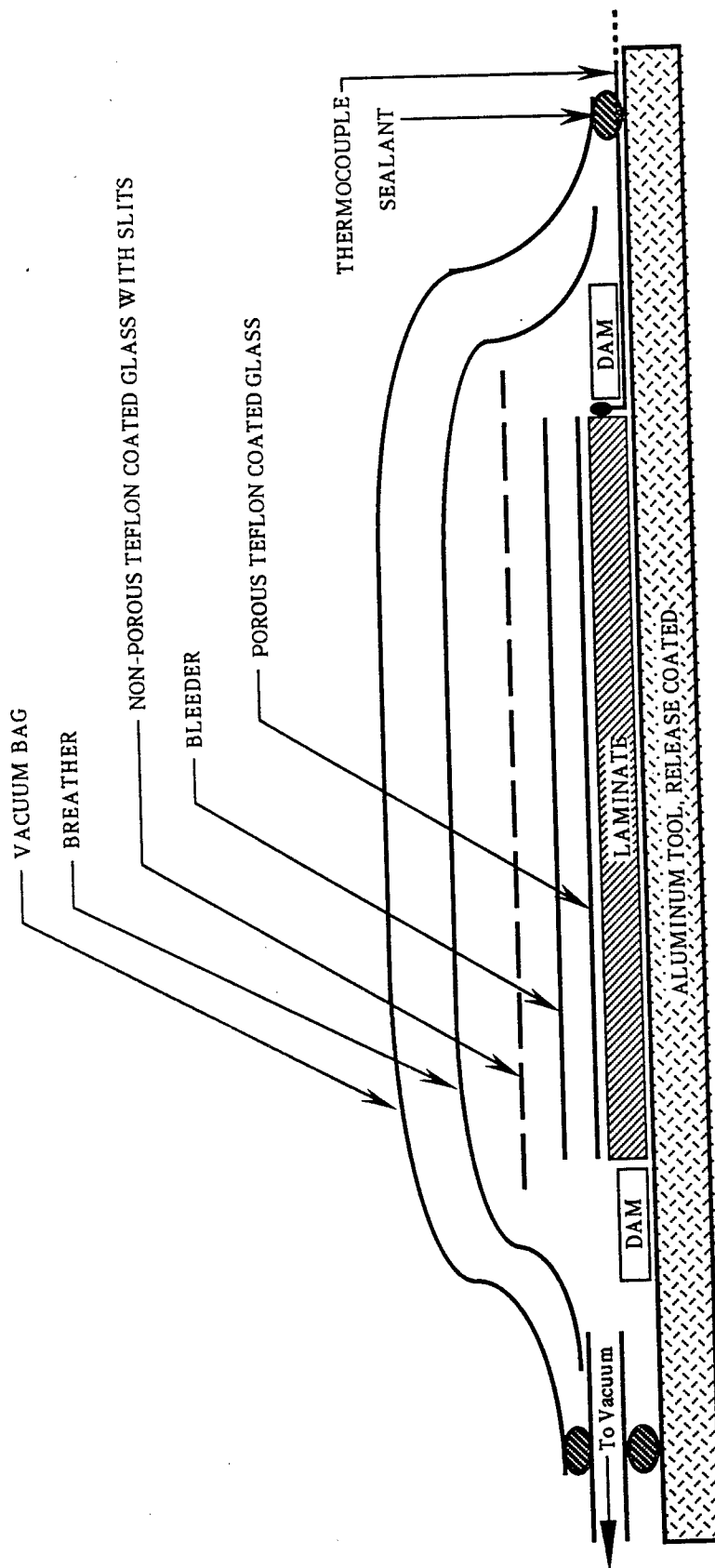


Figure B.1. Nonstandard Vacuum Bag Lay-up Scheme with Perforated Bleeder/Breather Barrier Film.

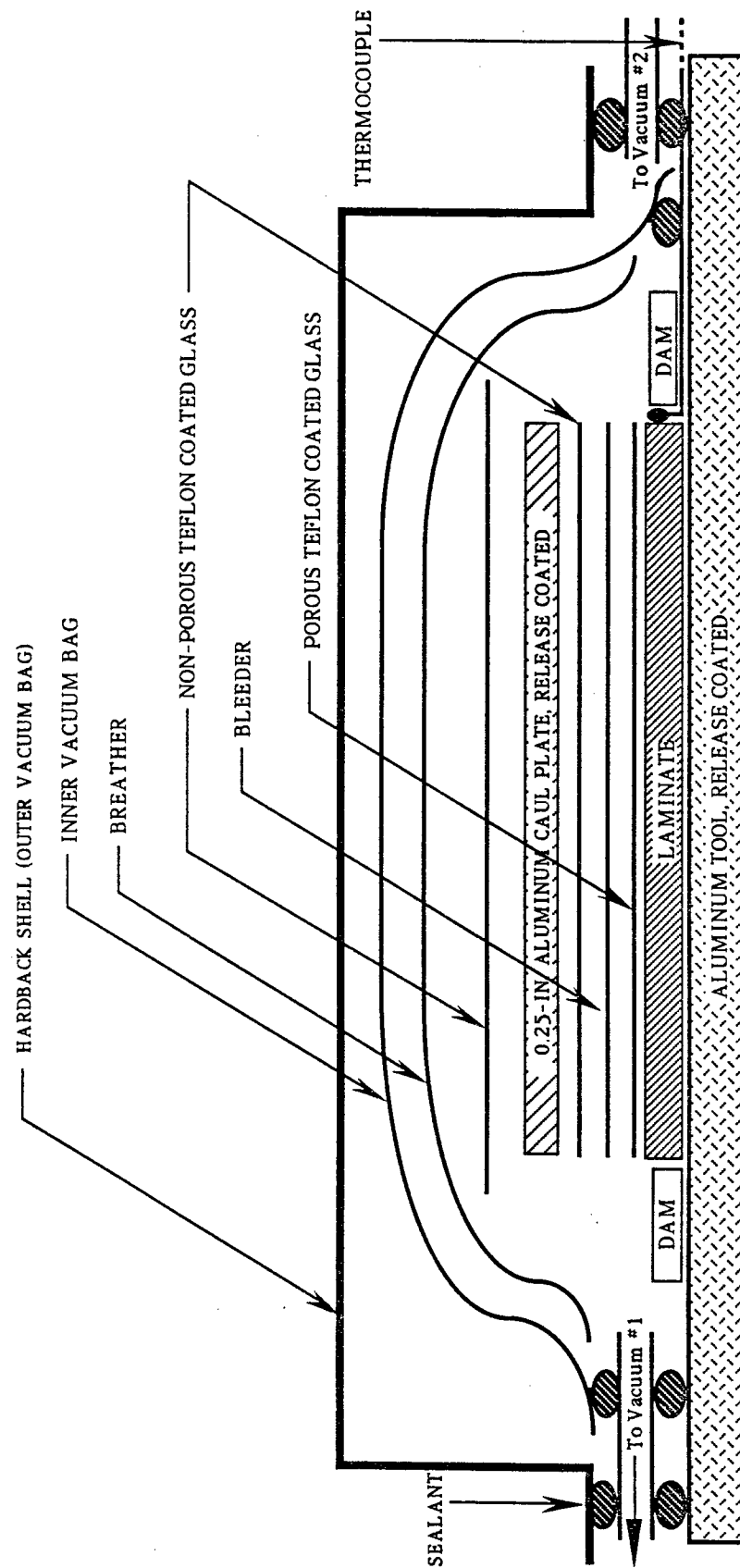


Figure B.2. Nonstandard Vacuum Bag Lay-up Using Double-Bag Scheme.



## APPENDIX C

### LAMINATE PHYSICAL PROPERTIES

The laminate physical properties for all of the glass and graphite reinforced laminates prepared and evaluated during this investigation are listed in this Appendix. Each property value listed represents an average of three replicate determinations from various locations within the same laminate.

The data are organized generally as follows:

- Baseline Laminates
- Laminates Processed at Nonbaseline Temperatures or Pressures
- Laminates Prepared from Stored Resin
- Laminates Prepared with Variable Fiber Content
- Laminates Prepared with Alternate Impregnation and Bagging Schemes
- Laminates Prepared with Silane Sized Glass Reinforcement
- Laminates Prepared for Nonbaseline Environmental Exposure

This sequence corresponds to the sequence in which these various types of laminate, processing and test variables are discussed in Section 3 of the text.

The laminate number listed in the first column of Tables C.1 (graphite reinforced laminates) and C.2 (glass reinforced laminates) corresponds to the individual specimen numbering system that appears in the appendices to follow.

TABLE C.1  
PHYSICAL PROPERTIES OF T300-W133 GRAPHITE  
FABRIC REINFORCED LAMINATES

| Laminate Number                               | No. of Plies | Purpose                        | Process           | Specific Gravity | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
|-----------------------------------------------|--------------|--------------------------------|-------------------|------------------|--------------------|---------------------------------------|---------------------|---------------------|--------------------|
| BIL-GR-7                                      | 8            | Tension                        | Baseline (App. A) | 1.49             | 0.39               | 15.3                                  | 56.3                | 34.2                | 4.0                |
| BIL-GR-8                                      | 8            | Tension                        | Baseline (App. A) | 1.48             | 0.38               | 15.0                                  | 56.4                | 33.6                | 4.5                |
| BIL-GR-9                                      | 8            | Tension                        | Baseline (App. A) | 1.48             | 0.39               | 15.2                                  | 57.3                | 32.7                | 4.5                |
| BIL-GR-10                                     | 8            | Tension                        | Baseline (App. A) | 1.48             | 0.38               | 14.8                                  | 56.6                | 33.3                | 4.8                |
| BIL-GR-11                                     | 8            | Tension                        | Baseline (App. A) | 1.48             | 0.38               | 15.0                                  | 56.4                | 33.8                | 4.1                |
| BIL-GR-12                                     | 8            | Tension                        | Baseline (App. A) | 1.48             | 0.38               | 15.0                                  | 56.4                | 33.8                | 4.2                |
| BIL-GR-13                                     | 12           | Compression                    | Baseline (App. A) | 1.47             | 0.38               | 15.0                                  | 55.5                | 34.7                | 4.3                |
| BIL-GR-14                                     | 12           | Compression                    | Baseline (App. A) | 1.49             | 0.39               | 15.2                                  | 53.7                | 37.1                | 2.8                |
| BIL-GR-15                                     | 12           | Compression                    | Baseline (App. A) | 1.48             | 0.37               | 14.7                                  | 55.5                | 34.7                | 4.3                |
| BIL-GR-16                                     | 12           | Compression                    | Baseline (App. A) | 1.47             | 0.38               | 15.0                                  | 54.9                | 34.9                | 4.8                |
| BIL-GR-37                                     | 8            | Inplane Shear                  | Baseline (App. A) | 1.50             | 0.39               | 15.3                                  | 56.0                | 33.4                | 4.6                |
| BIL-GR-38                                     | 8            | Inplane Shear                  | Baseline (App. A) | 1.48             | 0.39               | 15.2                                  | 53.9                | 35.4                | 4.7                |
| BIL-GR-39                                     | 8            | Inplane Shear                  | Baseline (App. A) | 1.49             | 0.39               | 15.2                                  | 56.1                | 33.0                | 5.6                |
| BIL-GR-40                                     | 8            | Inplane Shear                  | Baseline (App. A) | 1.48             | 0.41               | 16.0                                  | 56.6                | 32.8                | 4.8                |
| BIL-GR-41                                     | 8            | Inplane Shear                  | Baseline (App. A) | 1.49             | 0.38               | 15.0                                  | 57.0                | 31.9                | 5.5                |
| BIL-GR-42                                     | 8            | Inplane Shear                  | Baseline (App. A) | 1.49             | 0.39               | 15.2                                  | 56.9                | 32.1                | 5.5                |
| BIL-GR-17                                     | 12           | Interlaminar Shear             | Baseline (App. A) | 1.48             | 0.37               | 14.6                                  | 54.6                | 35.6                | 4.0                |
| BIL-GR-18                                     | 12           | Interlaminar Shear             | Baseline (App. A) | 1.47             | 0.38               | 14.9                                  | 54.8                | 33.9                | 5.9                |
| BIL-GR-19                                     | 12           | Interlaminar Shear             | Baseline (App. A) | 1.48             | 0.37               | 14.5                                  | 55.9                | 32.6                | 6.2                |
| BIL-GR-43                                     | 8            | Bearing                        | Baseline (App. A) | 1.49             | 0.38               | 15.1                                  | 55.6                | 33.6                | 5.2                |
| BIL-GR-1                                      | 12           | ILS, Effect of Cure Time/Temp. | Appendix B.1      | 1.48             | 0.38               | 15.0                                  | 58.1                | 30.2                | 5.4                |
| BIL-GR-4R                                     | 12           |                                |                   | 1.47             | 0.37               | 14.4                                  | 56.2                | 32.2                | 5.3                |
| BIL-GR-5                                      | 12           |                                |                   | 1.48             | 0.36               | 14.3                                  | 55.2                | 33.0                | 4.5                |
| BIL-GR-20                                     | 12           |                                |                   | 1.48             | 0.37               | 14.6                                  | 58.5                | 31.3                | 5.3                |
| BIL-H7-5                                      | 12           |                                |                   | 1.50             | 0.36               | 14.0                                  | 56.8                | 32.7                | 4.5                |
| Average (Baseline Process Only, 20 Laminates) |              |                                |                   | 1.48             | 0.38               | 15.1                                  | 55.8                | 33.9                | 4.7                |
| Standard Deviation                            |              |                                |                   | 0.01             | 0.01               | 0.3                                   | 1.0                 | 1.3                 | 0.8                |

TABLE C.1  
PHYSICAL PROPERTIES OF T300-W133 GRAPHITE  
FABRIC REINFORCED LAMINATES (Continued)

| Laminate Number | No. of Plies | Purpose                                           | Process           | Specific Gravity | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
|-----------------|--------------|---------------------------------------------------|-------------------|------------------|--------------------|---------------------------------------|---------------------|---------------------|--------------------|
| BIL-GR-2        | 12           | ILS; Effect of Storage;<br>1 month @ 38°C (100°F) | Baseline (App. A) | 1.48             | 0.36               | 14.3                                  | 55.5                | 33.2                | 4.9                |
| BIL-GR-3        | 12           | 1 month @ 49°C (120°F)                            |                   | 1.45             | 0.37               | 14.6                                  | 55.6                | 31.9                | 6.6                |
| BIL-GR-6        | 12           | 1 month @ 22°C (72°F)                             |                   | 1.47             | 0.36               | 14.0                                  | 56.4                | 32.2                | 5.3                |
| BIL-GR-30       | 12           | 3 months @ 22°C (72°F)                            |                   | 1.48             | 0.36               | 14.0                                  | 60.6                | 28.6                | 6.2                |
| BIL-GR-47       | 12           | 6 months @ 49°C (120°F)                           |                   | 1.45             | 0.42               | 16.6                                  | 50.6                | 37.9                | 6.0                |
| BIL-GR-48       | 12           | 6 months @ 38°C (100°F)                           |                   | 1.47             | 0.41               | 16.3                                  | 52.2                | 36.8                | 5.2                |
| BIL-GR-49       | 12           | 6 months @ 22°C (72°F)                            |                   | 1.46             | 0.42               | 16.4                                  | 52.1                | 36.7                | 5.6                |
| BIL-GR-59       | 12           | 12 months @ 38°C (100°F)                          |                   | 1.47             | 0.37               | 14.5                                  | 55.8                | 32.2                | 7.0                |
| BIL-GR-60       | 12           | 12 months @ 22°C (72°F)                           |                   | 1.48             | 0.37               | 14.7                                  | 55.7                | 32.8                | 6.2                |
| BIL-GR-61       | 12           | 12 months @ 49°C (120°F)                          |                   | 1.47             | 0.37               | 14.7                                  | 54.6                | 34.0                | 6.1                |
| BIL-GR-72       | 12           | 18 months @ 49°C (120°F)                          |                   | 1.46             | 0.38               | 14.8                                  | 52.3                | 36.2                | 6.1                |
| BIL-GR-73       | 12           | 18 months @ 38°C (100°F)                          |                   | 1.47             | 0.37               | 14.7                                  | 53.4                | 35.5                | 5.4                |
| BIL-GR-74       | 12           | 18 months @ 22°C (72°F)                           |                   | 1.49             | 0.38               | 14.9                                  | 56.0                | 33.3                | 4.9                |
| BIL-GR-85       | 12           | 24 months @ 22°C (72°F)                           |                   | 1.49             | 0.38               | 14.9                                  | 54.3                | 35.1                | 4.6                |
| BIL-GR-86       | 12           | 24 months @ 38°C (100°F)                          |                   | 1.48             | 0.40               | 15.6                                  | 53.5                | 35.6                | 5.1                |
| BIL-GR-87       | 12           | 24 months @ 49°C (120°F)                          |                   | 1.48             | 0.39               | 15.4                                  | 52.9                | 36.2                | 5.1                |
| BIL-GR-89       | 12           | 43 months @ 22°C (72°F)                           |                   | 1.50             | 0.35               | 13.8                                  | 57.0                | 32.5                | 4.6                |
| BIL-GR-90       | 12           | 43 months @ 38°C (100°F)                          |                   | 1.50             | 0.36               | 14.2                                  | 56.8                | 32.8                | 4.4                |
| BIL-GR-91       | 12           | 50 months @ 22°C (72°F)                           |                   | 1.44             | 0.38               | 14.8                                  | 53.1                | 34.0                | 8.4                |

TABLE C.1  
PHYSICAL PROPERTIES OF T300-W133 GRAPHITE  
FABRIC REINFORCED LAMINATES (Concluded)

| Laminate Number | No. of Plies | Purpose                              | Process           | Specific Gravity | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
|-----------------|--------------|--------------------------------------|-------------------|------------------|--------------------|---------------------------------------|---------------------|---------------------|--------------------|
| BIL-GR-51       | 12           | ILS; Effect of Fiber Content         | Appendix B.3      | 1.47             | 0.37               | 14.5                                  | 55.8                | 32.5                | 6.5                |
| BIL-GR-52       | 12           |                                      |                   | 1.47             | 0.37               | 14.7                                  | 54.7                | 33.6                | 6.4                |
| BIL-GR-53       | 12           |                                      |                   | 1.46             | 0.40               | 15.7                                  | 50.1                | 39.0                | 4.9                |
| BIL-GR-54       | 12           |                                      |                   | 1.47             | 0.40               | 15.8                                  | 49.8                | 39.0                | 4.7                |
| BIL-GR-79       | 12           | Compression; Effect of Fiber Content | Appendix B.3      | 1.41             | 0.52               | 20.6                                  | 40.5                | 48.8                | 5.5                |
| BIL-GR-84       | 12           |                                      |                   | 1.39             | 0.51               | 19.9                                  | 42.3                | 45.6                | 7.5                |
| BIL-GR-58       | 12           | Check Alternate Bleeder Material     | Appendix B.5      | 1.48             | 0.37               | 14.4                                  | 55.4                | 33.1                | 5.8                |
| BIL-GR-64R      | 8            |                                      |                   | 1.49             | 0.39               | 15.4                                  | 53.5                | 36.0                | 4.5                |
| BIL-GR-63R      | 12           | Check Alternate Bagging Scheme       | Appendix B.6      | 1.48             | 0.40               | 15.7                                  | 55.0                | 33.6                | 5.9                |
| BIL-GR-50       | 12           | Compression After Thermal Pulse      | Baseline (App. A) | 1.47             | 0.41               | 16.3                                  | 53.6                | 35.3                | 5.5                |

NOTES: 1. ILS = Interlaminar Shear

TABLE C.2  
PHYSICAL PROPERTIES OF E-7781 GLASS  
FABRIC REINFORCED LAMINATES

| Laminate Number                               | No. of Plies | Purpose                      | Process           | Specific Gravity | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
|-----------------------------------------------|--------------|------------------------------|-------------------|------------------|--------------------|---------------------------------------|---------------------|---------------------|--------------------|
| BIL-GL-1R                                     | 8            | Tension                      | Baseline (App. A) | 1.92             | 0.22               | 8.5                                   | 55.8                | 25.9                | 5.1                |
| BIL-GL-2R                                     | 8            | Tension                      | Baseline (App. A) | 1.94             | 0.22               | 8.5                                   | 56.5                | 25.9                | 3.9                |
| BIL-GL-3                                      | 8            | Tension                      | Baseline (App. A) | 1.93             | 0.2                | 8.6                                   | 55.3                | 27.0                | 3.7                |
| BIL-GL-4                                      | 8            | Tension                      | Baseline (App. A) | 1.91             | 0.22               | 8.5                                   | 54.1                | 27.7                | 4.1                |
| BIL-GL-5                                      | 8            | Tension                      | Baseline (App. A) | 1.92             | 0.22               | 8.6                                   | 55.7                | 26.0                | 5.0                |
| BIL-GL-6                                      | 8            | Tension                      | Baseline (App. A) | 1.89             | 0.22               | 8.6                                   | 54.0                | 27.2                | 5.4                |
| BIL-GL-7                                      | 16           | Compression                  | Baseline (App. A) | 1.90             | 0.21               | 8.3                                   | 53.7                | 27.9                | 4.5                |
| BIL-GL-8                                      | 16           | Compression                  | Baseline (App. A) | 1.90             | 0.22               | 8.6                                   | 53.6                | 28.2                | 4.2                |
| BIL-GL-9                                      | 16           | Compression                  | Baseline (App. A) | 1.89             | 0.22               | 8.6                                   | 53.8                | 27.6                | 5.0                |
| BIL-GL-10R                                    | 16           | Compression                  | Baseline (App. A) | 1.87             | 0.22               | 8.6                                   | 51.2                | 30.4                | 4.0                |
| BIL-GL-18                                     | 8            | Inplane Shear                | Baseline (App. A) | 1.92             | 0.21               | 8.4                                   | 56.5                | 25.1                | 5.5                |
| BIL-GL-19R                                    | 8            | Inplane Shear                | Baseline (App. A) | 1.92             | 0.22               | 8.7                                   | 54.5                | 27.7                | 3.6                |
| BIL-GL-20R                                    | 8            | Inplane Shear                | Baseline (App. A) | 1.92             | 0.21               | 8.3                                   | 56.5                | 25.0                | 5.7                |
| BIL-GL-21                                     | 8            | Inplane Shear                | Baseline (App. A) | 1.94             | 0.22               | 8.5                                   | 56.9                | 25.2                | 4.6                |
| BIL-GL-23R                                    | 8            | Inplane Shear                | Baseline (App. A) | 1.89             | 0.20               | 7.9                                   | 54.2                | 27.0                | 5.5                |
| BIL-GL-24                                     | 8            | Inplane Shear                | Baseline (App. A) | 1.93             | 0.22               | 8.5                                   | 56.8                | 25.0                | 4.9                |
| BIL-GL-11                                     | 16           | Interlaminar Shear           | Baseline (App. A) | 1.88             | 0.21               | 8.3                                   | 55.0                | 25.5                | 7.2                |
| BIL-GL-12                                     | 16           | Interlaminar Shear           | Baseline (App. A) | 1.88             | 0.21               | 8.3                                   | 54.9                | 25.5                | 7.4                |
| BIL-GL-13R                                    | 16           | Interlaminar Shear           | Baseline (App. A) | 1.87             | 0.21               | 8.4                                   | 54.0                | 26.5                | 6.9                |
| BIL-GL-22                                     | 8            | Bearing                      | Baseline (App. A) | 1.96             | 0.20               | 8.0                                   | 57.4                | 25.2                | 3.7                |
| BIL-GL-27                                     | 16           | ILS; Effect of Cure          | Appendix B.2      | 1.87             | 0.22               | 8.5                                   | 52.6                | 28.6                | 5.4                |
| BIL-GL-28                                     | 16           | Vacuum Pressure              |                   | 1.88             | 0.21               | 8.1                                   | 55.0                | 25.6                | 7.1                |
| BIL-GL-29                                     | 16           |                              |                   | 1.91             | 0.21               | 8.1                                   | 56.6                | 24.4                | 6.7                |
| BIL-GL-38                                     | 16           |                              |                   | 1.94             | 0.19               | 7.6                                   | 56.1                | 26.2                | 3.9                |
| BIL-GL-10                                     | 16           | ILS; Effect of Fiber Content | Appendix B.3      | 1.79             | 0.25               | 10.0                                  | 45.6                | 35.2                | 4.7                |
| BIL-GL-30                                     | 16           |                              |                   | 1.89             | 0.22               | 8.5                                   | 54.3                | 26.7                | 6.1                |
| BIL-GL-31                                     | 16           |                              |                   | 1.94             | 0.22               | 8.5                                   | 55.4                | 26.2                | 5.0                |
| BIL-GL-33                                     | 16           |                              |                   | 1.86             | 0.23               | 9.2                                   | 52.3                | 28.4                | 6.4                |
| BIL-GL-53                                     | 16           | Compression; Effect of       | Appendix B.3      | 1.59             | 0.36               | 14.3                                  | 33.9                | 45.6                | 9.3                |
| BIL-GL-54                                     | 16           | Fiber Content                |                   | 1.62             | 0.31               | 12.1                                  | 35.8                | 43.6                | 8.8                |
| Average (Baseline Process Only, 20 Laminates) |              |                              |                   | 1.91             | 0.22               | 8.5                                   | 55.0                | 26.6                | 5.0                |
| Standard Deviation                            |              |                              |                   | 0.03             | 0.005              | 0.2                                   | 1.5                 | 1.4                 | 1.1                |

TABLE C.2  
PHYSICAL PROPERTIES OF E-7781 GLASS  
FABRIC REINFORCED LAMINATES (Concluded)

| Laminate Number | No. of Plies | Purpose                                | Process           | Specific Gravity | Ply Thickness (mm) | Ply Thickness (10 <sup>-3</sup> inch) | Fiber Content (o/v) | Resin Content (o/w) | Void Content (o/v) |
|-----------------|--------------|----------------------------------------|-------------------|------------------|--------------------|---------------------------------------|---------------------|---------------------|--------------------|
| BIL-GL-17       | 8            | Check Alternate                        | Appendix B.5      | 1.85             | 0.21               | 8.2                                   | 49.5                | 31.6                | 4.5                |
| BIL-GL-37       | 16           | Bleeder Material                       |                   | 1.84             | 0.20               | 7.8                                   | 50.0                | 30.7                | 5.6                |
| BIL-GL-47       | 8            |                                        |                   | 1.89             | 0.23               | 8.9                                   | 52.5                | 29.2                | 4.2                |
| BIL-GL-39       | 16           | Check Alternate Bagging Scheme         | Appendix B.6      | 1.86             | 0.20               | 7.7                                   | 52.8                | 27.6                | 6.7                |
| BIL-GL-14       | 8            | Check Alternate                        | Appendix B.4      | 1.87             | 0.21               | 8.1                                   | 52.6                | 28.4                | 5.9                |
| BIL-GL-16       | 8            | Impregnation Scheme                    |                   | 1.85             | 0.20               | 7.9                                   | 50.3                | 30.8                | 4.8                |
| BIL-GL-44       | 8            | Tension                                | Baseline (App. A) | 1.85             | 0.23               | 8.9                                   | 53.7                | 25.9                | 8.5                |
| BIL-GL-45       | 16           | Interlaminar Shear                     | Baseline (App. A) | 1.83             | 0.23               | 8.9                                   | 52.6                | 26.8                | 8.9                |
| BIL-GL-46       | 8            | Inplane Shear; Effect of Silane Sizing | Baseline (App. A) | 1.88             | 0.22               | 8.6                                   | 53.6                | 27.2                | 6.3                |
| BIL-GL-25       | 16           | Compression After Thermal Pulse        | Baseline (App. A) | 1.91             | 0.23               | 9.0                                   | 56.5                | 24.4                | 6.8                |

NOTES: 1. ILS = Interlaminar Shear

## APPENDIX D

### INDIVIDUAL SPECIMEN TENSION PROPERTIES, BASELINE

The 48 tables in this appendix present the detailed mechanical property test data measured during this program for each baseline specimen tested in tension. A summary of these data was presented and discussed in Section 3.2.1.

TABLE D.1

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, WARP DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          | Warp    |        |         |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|---------|--------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 |                     |                         | Tested by :            |                          | PM      |        |         |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Remarks |        |         |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |         |        |         |
| BIL-GL-1R-17    | 72°F (DRY)      | 1.005                              | 0.0677          | 3,725               | 54.76                   | 3.653                  | 18,960                   | 0.128   | 5/3/89 | (2,3,5) |
| BIL-GL-1R-19    | "               | 1.004                              | 0.0685          | 3,589               | 52.18                   | 3.660                  | 17,475                   |         | 5/2/89 | (2,3,4) |
| BIL-GL-1R-21    | "               | 1.002                              | 0.0656          | 3,429               | 52.16                   | 3.667                  | 16,950                   |         | "      | (2,3,4) |
| BIL-GL-1R-18    | "               | 1.001                              | 0.0671          | 3,464               | 51.57                   | 3.535                  | 17,670                   | 0.114   | 5/3/89 | (1,3,5) |
| BIL-GL-1R-20    | "               | 0.996                              | 0.0694          | 3,321               | 48.03                   | 3.486                  | 16,350                   |         | 5/2/89 | (2,3,4) |
| Average         |                 |                                    |                 | 51.74               | 3.600                   | 17,481                 |                          | 0.121   |        |         |
| Std. Dev.       |                 |                                    |                 | 2.41                | 0.084                   | 973                    |                          | 0.010   |        |         |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) 2.00" gage length axial extensometer.
- (5) 2.00" gage length biaxial extensometer.

| SI Conversion          |  |                       |                          |
|------------------------|--|-----------------------|--------------------------|
| Ultimate               |  | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |
| Tensile Strength (MPa) |  | 377.6                 | 18,960                   |
|                        |  | 359.8                 | 17,475                   |
|                        |  | 359.6                 | 16,950                   |
|                        |  | 355.6                 | 17,670                   |
|                        |  | 331.2                 | 16,350                   |
| Average                |  | 24.82                 | 17,481                   |
| Std. Dev.              |  | 0.58                  | 973                      |



TABLE D.2

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, WARP DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :     |                        |         |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 | Batch #2            | Task #2                 | Tested by :            |         |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | Remarks |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |         |
| BIL-GL-5-17     | 72°F (DRY)      | 1.000                              | 0.0683          | 3,954               | 57.89                   | 3.713                  | 19,130  |
| BIL-GL-5-19     | "               | 1.004                              | 0.0682          | 3,821               | 55.83                   | 3.731                  | 21,750  |
| BIL-GL-5-21     | "               | 1.003                              | 0.0671          | 3,554               | 52.79                   | 3.767                  | 17,250  |
| BIL-GL-6-18     | "               | 1.001                              | 0.0694          | 3,439               | 49.49                   | 3.649                  | 16,580  |
| BIL-GL-6-20     | "               | 1.004                              | 0.0693          | 3,564               | 51.22                   | 3.541                  | 17,850  |
| Average         |                 |                                    |                 |                     | 53.44                   | 3.680                  | 18,512  |
| Std. Dev.       |                 |                                    |                 |                     | 3.41                    | 0.088                  | 2,039   |
|                 |                 |                                    |                 |                     | 0.104                   |                        | 5/11/89 |
|                 |                 |                                    |                 |                     | 0.116                   |                        | "       |
|                 |                 |                                    |                 |                     | 0.110                   |                        | "       |
|                 |                 |                                    |                 |                     | 0.009                   |                        | "       |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 399.2                  | 25.60                 | 19,130                   |  |
| 385.0                  | 25.72                 | 21,750                   |  |
| 364.0                  | 25.97                 | 17,250                   |  |
| 341.3                  | 25.16                 | 16,580                   |  |
| 353.2                  | 24.42                 | 17,850                   |  |
| Average                | 25.37                 | 18,512                   |  |
| Std. Dev.              | 0.61                  | 2,039                    |  |

TABLE D.3

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, WARP DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                         | Warp    |         |           |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|-------------------------|---------|---------|-----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 | Batch #3            | Task #2                 | Tested by :            |                         | PM      |         |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                         | Remarks |         |           |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (in/in) |         |         |           |
| BIL-GL-3-17     | 72°F (DRY)      | 1.007                              | 0.0686          | 3,493               | 50.57                   | 3.619                  | 16,980                  | 0.123   | 5/10/89 | (1,2,3,4) |
| BIL-GL-3-19     | "               | 0.999                              | 0.0688          | 3,464               | 50.42                   | 3.613                  | 17,250                  |         | "       | (1,2,3,5) |
| BIL-GL-3-21     | "               | 1.000                              | 0.0699          | 3,429               | 49.07                   | 3.451                  | 17,160                  |         | "       | (1,2,3,5) |
| BIL-GL-4-18     | "               | 0.994                              | 0.0689          | 3,393               | 49.53                   | 3.571                  | 18,150                  |         | "       | (1,2,3,5) |
| BIL-GL-4-20     | "               | 1.003                              | 0.0676          | 3,446               | 50.85                   | 3.662                  | 16,650                  | 0.106   | "       | (1,2,3,4) |
|                 |                 |                                    |                 |                     | Average                 | 50.09                  | 3.583                   | 17,238  | 0.114   |           |
|                 |                 |                                    |                 |                     | Std. Dev.               | 0.75                   | 0.081                   | 559     | 0.011   |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                         |                         |
|------------------------|-----------------------|-------------------------|-------------------------|
| Ultimate               |                       |                         |                         |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (in/in) | Ultimate Strain (in/in) |
| 348.7                  | 24.96                 | 16,980                  | 16,980                  |
| 347.7                  | 24.91                 | 17,250                  | 17,250                  |
| 338.4                  | 23.79                 | 17,160                  | 17,160                  |
| 341.5                  | 24.63                 | 18,150                  | 18,150                  |
| 350.6                  | 25.25                 | 16,650                  | 16,650                  |
| Average                | 24.71                 | 17,238                  | 17,238                  |
| Std. Dev.              | 0.56                  | 559                     | 559                     |

TABLE D.4

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, WARP DIRECTION, 22°C (72°F) WET

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     | Fiber Orientation :     |                        | Warp                     |                 |             |           |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-----------|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     | Tested by :             |                        | PM                       |                 |             |           |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Poisson's Ratio | Date Tested | Remarks   |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |                 |             |           |
| BIL-GL-1(R)-18                            | 72°F (WET)      | 1.004       | 0.0713          | 1,144               | 15.99                   | 3.187                  | 5.068                    | 0.072           | 8/22/89     | (2,3,4,6) |
| BIL-GL-1(R)-20                            | "               | 1.003       | 0.0716          | 1,193               | 16.62                   | 3.176                  | 5.313                    | "               | "           | (2,3,5,6) |
| BIL-GL-1(R)-17                            | "               | 1.005       | 0.0706          | 1,250               | 17.62                   | 3.153                  | 5.850                    | "               | "           | (2,3,5,6) |
| BIL-GL-1(R)-19                            | "               | 1.004       | 0.0713          | 1,106               | 15.46                   | 3.329                  | 4.688                    | 0.085           | 8/21/89     | (2,3,4,6) |
| BIL-GL-1(R)-21                            | "               | 1.004       | 0.0708          | 1,159               | 16.30                   | 3.067                  | 5.498                    | 0.061           | 8/22/89     | (2,3,4,6) |
| Average                                   |                 |             |                 |                     | 16.40                   | 3.182                  | 5.283                    | 0.073           |             |           |
| Std. Dev.                                 |                 |             |                 |                     | 0.81                    | 0.095                  | 438                      | 0.012           |             |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 110.2                  | 21.98                 | 5.068                    |  |
| 114.6                  | 21.90                 | 5.313                    |  |
| 121.5                  | 21.74                 | 5.850                    |  |
| 106.6                  | 22.95                 | 4.688                    |  |
| 112.4                  | 21.15                 | 5.498                    |  |
| 113.1                  | 21.94                 | 5.283                    |  |
| 5.6                    | 0.65                  | 438                      |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |

TABLE D.5

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, WARP DIRECTION, 22°C (72°F) WET

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |       |                 | Fiber Orientation : Warp |         |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-------|-----------------|--------------------------|---------|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     |                         |                        |                          |       |                 | Tested by : PM           |         |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          |       | Poisson's Ratio | Date Tested              | Remarks |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |       |                 |                          |         |
| BIL-GL-5-18                               | 72°F (WET)      | 1.007       | 0.0710          | 1,197               | 16.74                   | 3.343                  | 5,210                    | 0.086 | 8/22/89         | (2,3,4,6)                |         |
| BIL-GL-5-20                               | "               | 1.007       | 0.0718          | 1,206               | 16.67                   | 3.224                  | 5,381                    |       | "               | (2,3,5,6)                |         |
| BIL-GL-6-17                               | "               | 1.004       | 0.0722          | 987                 | 13.63                   | 3.189                  | 4,258                    |       | "               | (2,3,5,6)                |         |
| BIL-GL-6-19                               | "               | 1.005       | 0.0723          | 1,064               | 14.65                   | 3.332                  | 4,448                    | 0.098 | "               | (2,3,4,6)                |         |
| BIL-GL-6-21                               | "               | 1.007       | 0.0704          | 1,094               | 15.44                   | 3.278                  | 4,678                    |       | "               | (2,3,5,6)                |         |
| Average                                   |                 |             |                 |                     | 15.42                   | 3.273                  | 4,795                    | 0.092 |                 |                          |         |
| Std. Dev.                                 |                 |             |                 |                     | 1.33                    | 0.067                  | 484                      | 0.008 |                 |                          |         |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 115.4                  | 23.05                 | 5,210                          |  |
| 115.0                  | 22.23                 | 5,381                          |  |
| 94.0                   | 21.99                 | 4,258                          |  |
| 101.0                  | 22.97                 | 4,448                          |  |
| 106.4                  | 22.60                 | 4,678                          |  |
| 106.4                  | 22.57                 | 4,795                          |  |
| 9.2                    | 0.46                  | 484                            |  |
| Average                |                       |                                |  |
| Std. Dev.              |                       |                                |  |

TABLE D.6

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, WARP DIRECTION, 22°C (72°F) WET

| Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : |  |
|------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|---------------------|--|
| EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                          |                 |             | Tested by :         |  |
| Batch #3                           |                 |             |                 |                     |                         |                        |                          |                 |             | Task #2             |  |
| Ultimate                           |                 |             |                 |                     |                         |                        |                          |                 |             |                     |  |
| Specimen Number                    | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks             |  |
| BIL-GL-3-18                        | 72°F (WET)      | 0.999       | 0.0676          | 1,211               | 17.94                   | 3.519                  | 5,313                    |                 | 9/6/89      | (2,3,5,6)           |  |
| BIL-GL-3-20                        | "               | 1.003       | 0.0677          | 1,243               | 18.30                   | 3.404                  | 5,591                    | 0.094           | 9/5/89      | (2,3,4,6)           |  |
| BIL-GL-4-17                        | "               | 1.002       | 0.0659          | 1,075               | 16.27                   | 3.458                  | 4,746                    |                 | 9/6/89      | (2,3,5,6)           |  |
| BIL-GL-4-19                        | "               | 0.998       | 0.0672          | 1,197               | 17.84                   | 3.448                  | 5,381                    |                 | "           | (2,3,5,6)           |  |
| BIL-GL-4-21                        | "               | 1.002       | 0.0699          | 1,142               | 16.31                   | 3.355                  | 5,034                    | 0.089           | "           | (2,3,4,6)           |  |
|                                    |                 |             |                 |                     | 17.33                   | 3.437                  | 5,213                    | 0.092           |             |                     |  |
| Average                            |                 |             |                 |                     | 0.97                    | 0.061                  | 328                      | 0.003           |             |                     |  |
| Std. Dev.                          |                 |             |                 |                     |                         |                        |                          |                 |             |                     |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 123.7                  | 24.27                 | 5,313                          |  |
| 126.2                  | 23.47                 | 5,591                          |  |
| 112.2                  | 23.84                 | 4,746                          |  |
| 123.0                  | 23.77                 | 5,381                          |  |
| 112.4                  | 23.14                 | 5,034                          |  |
| 119.5                  | 23.70                 | 5,213                          |  |
| 6.7                    | 0.42                  | 328                            |  |

Average  
Std. Dev.

TABLE D.7

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, FILL DIRECTION, -54°C (-65°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :     |                        |                             |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 |                     | Tested by :             |                        |                             |
|                 |                 | Batch #1                           |                 |                     | Task #3                 |                        |                             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | Remarks                     |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |                             |
| BIL-GL-1(R)-1   | -65°F (DRY)     | 1.000                              | 0.0669          | 4,875               | 72.88                   | 4.298                  | 0.153 5/10/89 (1,2,3,4,6,7) |
| BIL-GL-1(R)-7   | "               | 1.002                              | 0.0678          | 5,214               | 76.76                   | 4.206                  | 5/11/89 (1,2,3,5,6)         |
| BIL-GL-1(R)-13  | "               | 1.003                              | 0.0677          | 5,100               | 75.08                   | 4.206                  | " (1,2,3,5,6)               |
| BIL-GL-2(R)-5   | "               | 1.001                              | 0.0667          | 5,093               | 76.26                   | 4.278                  | 5/10/89 (1,2,3,5,6,7)       |
| BIL-GL-2(R)-11  | "               | 1.005                              | 0.0677          | 5,495               | 80.77                   | 4.226                  | " (1,2,3,4,6)               |
| Average         |                 |                                    |                 |                     | 76.35                   | 4.243                  | 0.153                       |
| Std. Dev.       |                 |                                    |                 |                     | 2.89                    | 0.043                  | 0.000                       |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimen soaked for 20 min. at test temperature.
- (7) Strain gage failure due to outer ply separation.

| SI Conversion |  |                |                 |
|---------------|--|----------------|-----------------|
| Ultimate      |  | Tensile        | Ultimate        |
|               |  | Strength (MPa) | Strain (μcm/cm) |
|               |  | 502.5          | 18,429+         |
|               |  | 529.3          | 25,575          |
|               |  | 517.7          | 24,330          |
|               |  | 525.8          | 21,000+         |
|               |  | 556.9          | 26,229          |
| Average       |  | 526.4          | 23,113+         |
| Std. Dev.     |  | 19.9           | 3,304+          |

TABLE D.8

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, FILL DIRECTION, -54°C (-65°F) DRY

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : Fill |  |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|--------------------------|--|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     |                         |                        |                          |                 |             | Tested by : PM           |  |
| Ultimate                                  |                 |             |                 |                     |                         |                        |                          |                 |             |                          |  |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks                  |  |
| BIL-GL-5-1                                | -65°F (DRY)     | 1.000       | 0.0662          | 4,410               | 66.63                   | 4.646                  | 20,507                   | 0.180           | 5/9/89      | (1,2,3,4)                |  |
| BIL-GL-5-7                                | "               | 1.000       | 0.0699          | 4,286               | 61.31                   | 4.036                  | 12,000+                  |                 | 5/10/89     | (1,2,3,5,6)              |  |
| BIL-GL-5-13                               | "               | 1.003       | 0.0699          | 4,150               | 59.20                   | 3.974                  | 19,500+                  |                 | "           | (1,2,3,5,6)              |  |
| BIL-GL-6-5                                | "               | 1.003       | 0.0680          | 5,140               | 75.38                   | 4.180                  | 24,429                   | 0.145           | "           | (1,2,3,4)                |  |
| BIL-GL-6-11                               | "               | 1.002       | 0.0691          | 5,760               | 83.20                   | 4.189                  | 14,357+                  | 0.139           | 5/9/89      | (1,3,4,6)                |  |
|                                           |                 |             |                 |                     | Average                 | 69.15                  | 4.205                    | 18,159+         | 0.155       |                          |  |
|                                           |                 |             |                 |                     | Std. Dev.               | 10.04                  | 0.263                    | 4,975+          | 0.022       |                          |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Strain gage failure due to outer ply separation.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 459.4                  | 32.03                 | 20,507                   |  |
| 422.7                  | 27.83                 | 12,000+                  |  |
| 408.2                  | 27.40                 | 19,500+                  |  |
| 519.8                  | 28.82                 | 24,429                   |  |
| 573.7                  | 28.88                 | 14,357+                  |  |
| 476.8                  | 28.99                 | 18,159+                  |  |
| 69.2                   | 1.81                  | 4,975+                   |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |

TABLE D.9

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, FILL DIRECTION, -54°C (-65°F) DRY

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                         |                        |                        |                          | Fiber Orientation : Fill |             |         |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|-------------------------|------------------------|------------------------|--------------------------|--------------------------|-------------|---------|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     |                         |                         |                        |                        |                          | Tested by : PM           |             |         |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                         |                        | Tensile Modulus (Msi.) | Ultimate Strain (µin/in) | Poisson's Ratio          | Date Tested | Remarks |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |                        |                          |                          |             |         |
| BIL-GL-3-1                                | -65°F (DRY)     | 1.007       | 0.0683          | 4,835               | 70.31                   | 70.31                   | 3.999                  | 23,036                 | 0.164                    | 5/10/89                  | (1,2,3,4)   |         |
| BIL-GL-3-7                                | "               | 1.004       | 0.0703          | 4,857               | 68.83                   | 68.83                   | 4.049                  | 21,300+                |                          | "                        | (1,2,3,5,6) |         |
| BIL-GL-3-13                               | "               | 0.998       | 0.0688          | 4,914               | 71.56                   | 71.56                   | 4.056                  | 24,120                 |                          | "                        | (1,2,3,5)   |         |
| BIL-GL-4-5                                | "               | 0.998       | 0.0674          | 4,693               | 69.74                   | 69.74                   | 4.299                  | 9,000+                 |                          | "                        | (1,2,3,5,6) |         |
| BIL-GL-4-11                               | "               | 1.001       | 0.0690          | 4,915               | 71.17                   | 71.17                   | 4.163                  | 24,643+                | 0.146                    | "                        | (1,2,3,4,6) |         |
| Average                                   |                 |             |                 |                     | 70.32                   | 70.32                   | 4.113                  | 20,419+                | 0.155                    |                          |             |         |
| Std. Dev.                                 |                 |             |                 |                     | 1.10                    | 1.10                    | 0.120                  | 6,511+                 | 0.013                    |                          |             |         |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Strain gage failure due to outer ply separation.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 484.8                  | 27.57                 | 23,036                         |  |
| 474.6                  | 27.92                 | 21,300+                        |  |
| 493.4                  | 27.97                 | 24,120                         |  |
| 480.8                  | 29.64                 | 9,000+                         |  |
| 490.7                  | 28.70                 | 24,643+                        |  |
| Average                | 28.36                 | 20,419+                        |  |
| Std. Dev.              | 0.83                  | 6,511+                         |  |



TABLE D.10

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, FILL DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          |                       |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------------|
| Material :      | EA-9396 A/B     | 7781 Glass                         | Batch #1        | Task #3             | Tested by :             |                        | PM                       |                       |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Remarks               |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |                       |
| BIL-GL-1(R)-2   | 72°F (DRY)      | 1.002                              | 0.0675          | 3,893               | 57.54                   | 3,748                  | 18,420                   | 0.129 4/18/89 (2,3,4) |
| BIL-GL-1(R)-8   | "               | 0.986                              | 0.0669          | 3,864               | 58.58                   | 4,115                  | 18,705                   | " (2,3,5)             |
| BIL-GL-1(R)-14  | "               | 1.002                              | 0.0678          | 3,296               | 48.53                   | 3,812                  | 15,420                   | 4/25/89 (2,3,5)       |
| BIL-GL-2(R)-6   | "               | 0.971                              | 0.0674          | 3,493               | 53.37                   | 4,147                  | 16,920                   | 4/20/89 (2,3,5)       |
| BIL-GL-2(R)-12  | "               | 1.002                              | 0.0687          | 3,350               | 48.66                   | 3,787                  | 15,795                   | " 0.118 (2,3,4)       |
| Average         |                 |                                    |                 |                     | 53.34                   | 3,922                  | 17,052                   | 0.124                 |
| Std. Dev.       |                 |                                    |                 |                     | 4.75                    | 0.193                  | 1,489                    | 0.008                 |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 396.7                  | 25.84                 | 18,420                   |  |
| 403.9                  | 28.37                 | 18,705                   |  |
| 334.6                  | 26.28                 | 15,420                   |  |
| 368.0                  | 28.60                 | 16,920                   |  |
| 335.5                  | 26.11                 | 15,795                   |  |
| 367.7                  | 27.04                 | 17,052                   |  |
| 32.7                   | 1.33                  | 1,489                    |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, FILL DIRECTION: 22°C (72°F) DRY

| Remarks:                                              | SI Conversion                   |                       |                                       |  |
|-------------------------------------------------------|---------------------------------|-----------------------|---------------------------------------|--|
|                                                       | Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| (1) Specimen failed within the 6.5 inch gage section. | 340.1                           | 25.02                 | 16,570                                |  |
| (2) Specimen failed inside tab area.                  | 370.6                           | 24.77                 | 18,450                                |  |
| (3) Test speed = 0.1 in/min.                          | 367.9                           | 24.35                 | 18,150                                |  |
| (4) Specimen had 0° and 90° strain gages attached.    | 381.7                           | 24.68                 | 18,830                                |  |
| (5) Specimen had only 0° strain gage attached.        | 380.3                           | 23.31                 | 20,250                                |  |
|                                                       | 368.2                           | 24.42                 | 18,450                                |  |
|                                                       | 16.8                            | 0.67                  | 1,324                                 |  |
|                                                       | Average                         |                       |                                       |  |
|                                                       | Std. Dev.                       |                       |                                       |  |

D-12

TABLE D.12

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, FILL DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          | Fill            |             |           |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 |                     |                         | Tested by :            |                          | PM              |             |           |
|                 |                 | Batch #3                           |                 |                     |                         | Task #3                |                          |                 |             |           |
|                 |                 | Ultimate                           |                 |                     |                         |                        |                          |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (µin/in) | Poisson's Ratio | Date Tested | Remarks   |
| BIL-GL-3-2      | 72°F (DRY)      | 0.997                              | 0.0692          | 3,729               | 54.02                   | 3.493                  | 25,950+                  | 0.131           | 5/11/89     | (1,3,4,9) |
| BIL-GL-3-8      | "               | 1.001                              | 0.0702          | 3,957               | 56.33                   | 3.482                  | 19,950                   |                 | "           | (1,3,5)   |
| BIL-GL-3-14     | "               | 1.004                              | 0.0677          | 3,686               | 54.21                   | 3.520                  | 18,585                   |                 | "           | (1,3,5)   |
| BIL-GL-4-6      | "               | 0.999                              | 0.0658          | 3,882               | 59.03                   | 3.726                  | 19,650                   |                 | "           | (1,2,3,5) |
| BIL-GL-4-12     | "               | 1.001                              | 0.0687          | 3,904               | 56.78                   | 3.506                  | 19,695                   | 0.129           | "           | (1,2,3,4) |
|                 |                 | Average                            |                 |                     |                         | 3.545                  |                          | 0.130           |             |           |
|                 |                 | Std. Dev.                          |                 |                     |                         | 0.102                  |                          | 0.002           |             |           |
|                 |                 |                                    |                 | 56.08               |                         | 20,766+                |                          |                 |             |           |
|                 |                 |                                    |                 | 2.06                |                         | 2,945+                 |                          |                 |             |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Strain gage failure due to outer ply separation.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 372.5                  | 24.08                 | 25,950+                        |  |
| 388.4                  | 24.01                 | 19,950                         |  |
| 373.8                  | 24.27                 | 18,585                         |  |
| 407.0                  | 25.69                 | 19,650                         |  |
| 391.5                  | 24.18                 | 19,695                         |  |
| Average                |                       |                                |  |
| 386.6                  | 24.45                 | 20,766+                        |  |
| 14.2                   | 0.70                  | 2,945+                         |  |
| Std. Dev.              |                       |                                |  |

TABLE D.13

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, FILL DIRECTION, 93°C (200°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         |                        | Fiber Orientation :      |                 |             |           |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 |                     |                         |                        | Tested by :              |                 |             |           |
|                 |                 | Batch #1                           |                 |                     |                         |                        | Task #3                  |                 |             |           |
|                 |                 | Ultimate                           |                 |                     |                         |                        |                          |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks   |
| BIL-GL-1(R)-3   | 200°F (DRY)     | 1.001                              | 0.0680          | 3,150               | 46.29                   | 3.527                  | 14,979                   | 0.111           | 5/11/89     | (2,3,4)   |
| BIL-GL-1(R)-9   | "               | 0.998                              | 0.0671          | 3,018               | 45.08                   | 3.575                  | 14,445                   |                 | 5/12/89     | (1,2,3,5) |
| BIL-GL-1(R)-15  | "               | 0.999                              | 0.0695          | 3,289               | 47.36                   | 3.548                  | 15,450                   |                 | 5/11/89     | (2,3,5)   |
| BIL-GL-2(R)-7   | "               | 1.003                              | 0.0692          | 3,507               | 50.54                   | 3.680                  | 16,500                   |                 | "           | (1,3,5)   |
| BIL-GL-2(R)-13  | "               | 0.999                              | 0.0691          | 3,000               | 43.45                   | 3.404                  | 14,614                   | 0.121           | "           | (1,3,4)   |
|                 |                 | Average                            |                 | 46.55               |                         | 3.547                  | 15,198                   | 0.116           |             |           |
|                 |                 | Std. Dev.                          |                 | 2.66                |                         | 0.099                  | 824                      | 0.008           |             |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 319.2                  | 24.32                 | 14,979                   |  |
| 310.9                  | 24.65                 | 14,445                   |  |
| 326.6                  | 24.46                 | 15,450                   |  |
| 348.5                  | 25.37                 | 16,500                   |  |
| 299.6                  | 23.47                 | 14,614                   |  |
| Average                | 24.45                 | 15,198                   |  |
| Std. Dev.              | 0.68                  | 824                      |  |

TABLE D.14

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, FILL DIRECTION, 93°C (200°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          |                 |             | Fill      |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 | Batch #2            | Task #3                 | Tested by :            |                          |                 |             | PM        |
| Ultimate        |                 |                                    |                 |                     |                         |                        |                          |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks   |
| BIL-GL-5-3      | 200°F (DRY)     | 1.002                              | 0.0709          | 3,025               | 42.60                   | 3.380                  | 14,700                   | 0.096           | 5/12/89     | (2,3,4)   |
| BIL-GL-5-9      | "               | 0.998                              | 0.0673          | 2,996               | 44.63                   | 3.537                  | 14,565                   |                 | 5/11/89     | (1,3,5)   |
| BIL-GL-5-15     | "               | 1.001                              | 0.0663          | 3,029               | 45.64                   | 3.579                  | 14,325                   |                 | 5/12/89     | (1,2,3,5) |
| BIL-GL-6-7      | "               | 1.001                              | 0.0669          | 3,186               | 47.56                   | 3.626                  | 15,180                   |                 | 5/11/89     | (1,2,3,5) |
| BIL-GL-6-13     | "               | 0.999                              | 0.0692          | 3,178               | 45.95                   | 3.453                  | 15,707                   | 0.093           | 5/12/89     | (1,3,4)   |
|                 |                 |                                    |                 |                     | 45.28                   | 3.515                  | 14,895                   | 0.095           |             |           |
| Average         |                 |                                    |                 |                     | 1.83                    | 0.099                  | 551                      | 0.003           |             |           |
| Std. Dev.       |                 |                                    |                 |                     |                         |                        |                          |                 |             |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |  |                       |                                |
|------------------------|--|-----------------------|--------------------------------|
| Ultimate               |  | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |
| Tensile Strength (MPa) |  | 23.30                 | 14,700                         |
|                        |  | 24.39                 | 14,565                         |
|                        |  | 24.68                 | 14,325                         |
|                        |  | 25.00                 | 15,180                         |
|                        |  | 23.81                 | 15,707                         |
| Average                |  | 24.24                 | 14,895                         |
| Std. Dev.              |  | 0.68                  | 551                            |

TABLE D.15

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, FILL DIRECTION, 93°C (200°F) DRY

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : Fill |         |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|--------------------------|---------|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     |                         |                        |                          |                 |             | Tested by : PM           |         |
|                                           |                 |             |                 |                     |                         |                        |                          |                 |             | Batch #3                 | Task #3 |
| Ultimate                                  |                 |             |                 |                     |                         |                        |                          |                 |             |                          |         |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks                  |         |
| BIL-GL-3-3                                | 200°F (DRY)     | 1.004       | 0.0699          | 2,600               | 37.04                   | 3.579                  | 13,500                   | 0.100           | 5/12/89     | (2,3,4)                  |         |
| BIL-GL-3-9                                | "               | 1.001       | 0.0686          | 3,161               | 46.05                   | 3.434                  | 9,750                    |                 | 5/8/89      | (1,3,5)                  |         |
| BIL-GL-3-15                               | "               | 1.004       | 0.0689          | 2,968               | 42.89                   | 3.587                  | 13,980                   |                 | 5/11/89     | (1,2,3,5)                |         |
| BIL-GL-4-7                                | "               | 1.000       | 0.0674          | 3,246               | 48.16                   | 3.629                  | 15,795                   |                 | "           | (1,2,3,5)                |         |
| BIL-GL-4-13                               | "               | 1.004       | 0.0694          | 3,120               | 44.80                   | 3.356                  | 12,000+                  | 0.087           | 5/12/89     | (1,2,3,4,6)              |         |
|                                           |                 |             |                 | Average             | 43.79                   | 3.517                  | 13,005+                  | 0.094           |             |                          |         |
|                                           |                 |             |                 | Std. Dev.           | 4.23                    | 0.116                  | 2,268+                   | 0.009           |             |                          |         |

Remarks:

(1) Specimen failed within the 6.5 inch gage section.

(2) Specimen failed inside tab area.

(3) Test speed = 0.1 in/min.

(4) Specimen had 0° and 90° strain gages attached.

(5) Specimen had only 0° strain gage attached.

(6) Strain gage failure due to outer ply separation.

| SI Conversion |                        |                       |                          |  |
|---------------|------------------------|-----------------------|--------------------------|--|
| Ultimate      |                        |                       |                          |  |
|               | Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|               | 255.4                  | 24.68                 | 13,500                   |  |
|               | 317.5                  | 23.68                 | 9,750                    |  |
|               | 295.7                  | 24.73                 | 13,980                   |  |
|               | 332.0                  | 25.02                 | 15,795                   |  |
|               | 308.9                  | 23.14                 | 12,000+                  |  |
| Average       | 301.9                  | 24.25                 | 13,005+                  |  |
| Std. Dev.     | 29.2                   | 0.80                  | 2,268+                   |  |

TABLE D.16

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, FILL DIRECTION, -54°C (-65°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :     |                        |                   |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|-------------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 | Batch #1            | Task #3                 | Tested by :            |                   |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | Remarks           |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |                   |
| BIL-GL-1(R)-4   | -65°F (WET)     | 1.002                              | 0.0682          | 1,238               | 18.11                   | 3.890                  | 9/13/89 (2,3,5,6) |
| BIL-GL-1(R)-10  | "               | 0.996                              | 0.0684          | 1,421               | 20.86                   | 3.986                  | 9/12/89 (2,3,4,6) |
| BIL-GL-2(R)-1   | "               | 1.002                              | 0.0656          | 1,490               | 22.67                   | 3.875                  | 9/13/89 (2,3,5,6) |
| BIL-GL-2(R)-8   | "               | 1.005                              | 0.0699          | 1,439               | 20.50                   | 3.767                  | " (2,3,5,6)       |
| BIL-GL-2(R)-14  | "               | 0.999                              | 0.0677          | 1,048               | 15.49                   | 3.880                  | 9/12/89 (2,3,4,6) |
| Average         |                 |                                    |                 |                     | 19.53                   | 3.880                  | 0.143             |
| Std. Dev.       |                 |                                    |                 |                     | 2.78                    | 0.078                  | 0.015             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                        |                       |
|------------------------|-----------------------|------------------------|-----------------------|
| Ultimate               |                       | Ultimate               |                       |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Tensile Strength (MPa) | Tensile Modulus (GPa) |
| 124.9                  | 26.82                 | 143.8                  | 27.48                 |
| 143.8                  | 26.72                 | 156.3                  | 25.97                 |
| 141.4                  | 26.75                 | 106.8                  | 26.75                 |
| 134.6                  | 26.75                 | 19.2                   | 0.53                  |
| Average                |                       | Average                |                       |
| Std. Dev.              |                       | Std. Dev.              |                       |

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS, GLASS REINFORCEMENT, BATCH 2, FILL DIRECTION, -54°C (-65°F) WET

| Remarks:                                              | SI Conversion                   |                       |                                       |  |
|-------------------------------------------------------|---------------------------------|-----------------------|---------------------------------------|--|
|                                                       | Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| (1) Specimen failed within the 6.5 inch gage section. | 155.9                           | 25.51                 | 6,943                                 |  |
| (2) Specimen failed inside tab area.                  | 150.2                           | 25.87                 | 6,567                                 |  |
| (3) Test speed = 0.1 in/min.                          | 174.0                           | 27.77                 | 7,168                                 |  |
| (4) Specimen had 0° and 90° strain gages attached.    | 168.2                           | 26.68                 | 7,295                                 |  |
| (5) Specimen had only 0° strain gage attached.        | 135.0                           | 23.94                 | 6,172                                 |  |
| (6) Specimens aged @ 140°F/95–100% R.H.               |                                 |                       |                                       |  |
|                                                       | 156.7                           | 25.95                 | 6,829                                 |  |
|                                                       | 15.4                            | 1.42                  | 460                                   |  |
|                                                       | Average                         |                       |                                       |  |
|                                                       | Std. Dev.                       |                       |                                       |  |



TABLE D.18

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, FILL DIRECTION, -54°C (-65°F) WET

|                 |                 |                                    |                 |                     |                         |                        |                                |                 |             |           |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-----------------|-------------|-----------|
| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         |                        | Fiber Orientation :            |                 |             | Fill      |
| Material :      |                 | EA-9396 A/B; 7781 Glass            |                 |                     |                         |                        | Batch #3                       |                 |             | Task #3   |
|                 |                 |                                    |                 |                     |                         |                        | Tested by :                    |                 |             | DRB       |
| Ultimate        |                 |                                    |                 |                     |                         |                        |                                |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain ( $\mu$ in/in) | Poisson's Ratio | Date Tested | Remarks   |
| BIL-GL-3-4      | -65°F (WET)     | 1.003                              | 0.0709          | 1,331               | 18.72                   | 3.740                  | 5,435                          |                 | 9/13/89     | (2,3,5,6) |
| BIL-GL-3-10     | "               | 1.005                              | 0.0672          | 1,430               | 21.17                   | 3.873                  | 6,138                          | 0.144           | 9/12/89     | (2,3,4,6) |
| BIL-GL-4-1      | "               | 1.000                              | 0.0662          | 1,582               | 23.89                   | 3.785                  | 7,109                          |                 | 9/13/89     | (2,3,5,6) |
| BIL-GL-4-8      | "               | 0.999                              | 0.0671          | 1,549               | 23.11                   | 3.843                  | 6,846                          |                 | "           | (2,3,5,6) |
| BIL-GL-4-14     | "               | 1.006                              | 0.0701          | 1,416               | 20.07                   | 3.632                  | 6,216                          | 0.145           | 9/12/89     | (2,3,4,6) |
| Average         |                 |                                    |                 | 21.39               |                         | 3.775                  |                                | 6,349           |             | 0.145     |
| Std. Dev.       |                 |                                    |                 | 2.13                |                         | 0.095                  |                                | 656             |             | 0.001     |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 129.1                  | 25.79                 | 5,435                          |  |
| 145.9                  | 26.71                 | 6,138                          |  |
| 164.7                  | 26.09                 | 7,109                          |  |
| 159.3                  | 26.50                 | 6,846                          |  |
| 138.4                  | 25.04                 | 6,216                          |  |
| 147.5                  | 26.03                 | 6,349                          |  |
| 14.7                   | 0.65                  | 656                            |  |
| Average                |                       |                                |  |
| Std. Dev.              |                       |                                |  |

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, FILL DIRECTION, 22°C (72°F) WET

|                                                       | SI Conversion                   |                       |                                       |  |
|-------------------------------------------------------|---------------------------------|-----------------------|---------------------------------------|--|
|                                                       | Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| (1) Specimen failed within the 6.5 inch gage section. | 124.3                           | 23.18                 | 5,591                                 |  |
| (2) Specimen failed inside tab area.                  | 130.0                           | 22.31                 | 6,206                                 |  |
| (3) Test speed = 0.1 in/min.                          | 140.4                           | 22.86                 | 6,460                                 |  |
| (4) Specimen had 0° and 90° strain gages attached.    | 130.5                           | 22.55                 | 6,099                                 |  |
| (5) Specimen had only 0° strain gage attached.        | 121.2                           | 21.55                 | 5,957                                 |  |
| (6) Specimens aged @ 140°F/95–100% R.H.               |                                 |                       |                                       |  |
|                                                       | 129.3                           | 22.49                 | 6,063                                 |  |
|                                                       | 7.3                             | 0.62                  | 322                                   |  |
|                                                       | Average                         |                       |                                       |  |
|                                                       | Std. Dev.                       |                       |                                       |  |

TABLE D.20

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, FILL DIRECTION, 22°C (72°F) WET

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : Fill |  |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|--------------------------|--|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     |                         |                        |                          |                 |             | Tested by :              |  |
| Batch #2                                  |                 |             |                 |                     |                         |                        |                          |                 |             | Task #3                  |  |
| Ultimate                                  |                 |             |                 |                     |                         |                        |                          |                 |             | TOB                      |  |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks                  |  |
| BIL-GL-5-5                                | 72°F (WET)      | 1.004       | 0.0683          | 1,077               | 15.70                   | 3.090                  | 5,273                    |                 | 9/7/89      | (2,3,5,6)                |  |
| BIL-GL-5-11                               | "               | 1.001       | 0.0676          | 1,142               | 16.87                   | 5.200                  | 3,135                    | 0.016           | "           | (2,3,4,6,7)              |  |
| BIL-GL-6-2                                | "               | 1.001       | 0.0664          | 1,090               | 16.40                   | 3.316                  | 5,076                    |                 | "           | (2,3,5,6)                |  |
| BIL-GL-6-9                                | "               | 1.000       | 0.0691          | 1,181               | 17.09                   | 3.198                  | 5,527                    |                 | "           | (2,3,5,6)                |  |
| BIL-GL-6-15                               | "               | 1.001       | 0.0682          | 1,072               | 15.70                   | 5.023                  | 3,040                    | 0.016           | "           | (2,3,4,6,7)              |  |
|                                           |                 |             |                 | Average             | 16.35                   | 3.201                  | 5,292                    | 0.016           |             |                          |  |
|                                           |                 |             |                 | Std. Dev.           | 0.64                    | 0.113                  | 226                      | 0.000           |             |                          |  |

Remarks:

(1) Specimen failed within the 6.5 inch  
gage section.

(2) Specimen failed inside tab area.

(3) Test speed = 0.1 in/min.

(4) Specimen had 0° and 90° strain gages  
attached.

(5) Specimen had only 0° strain gage  
attached.

(6) Specimens aged @ 140°F/95–100% R.H.

(7) Probable improper strain range set. Not  
included in modulus, strain or Poisson's  
ratio averages.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 108.2                  | 21.30                 | 5,273                    |  |
| 116.3                  | 35.85                 | 3,135                    |  |
| 113.1                  | 22.86                 | 5,076                    |  |
| 117.8                  | 22.05                 | 5,527                    |  |
| 108.3                  | 34.63                 | 3,040                    |  |
| 112.7                  | 22.07                 | 5,292                    |  |
| 4.4                    | 0.78                  | 226                      |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS, GLASS REINFORCEMENT, BATCH 3, FILL DIRECTION, 22°C (72°F) WET

Remarks:

- ## SI Conversion

| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |
|---------------------------------|-----------------------|---------------------------------------|
| 113.5                           | 21.84                 | 5,430                                 |
| 137.4                           | 22.19                 | 6,514                                 |
| 124.3                           | 22.12                 | 5,957                                 |
| 119.8                           | 22.20                 | 5,664                                 |
| 109.4                           | 21.70                 | 5,303                                 |
| Average 120.9                   | 22.01                 | 5,773                                 |
| Std. Dev. 10.9                  | 0.22                  | 483                                   |

TABLE D.22

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, FILL DIRECTION, 93°C (200°F) WET

| Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : Fill |  |
|------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|--------------------------|--|
| EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                          |                 |             | DRB                      |  |
| Specimen Number                    | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Poisson's Ratio | Date Tested | Remarks                  |  |
|                                    |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |                 |             |                          |  |
| BIL-GL-1(R)-6                      | 200°F (WET)     | 0.994       | 0.0672          | 948                 | 14.19                   | 2.944                  | 4,751                    |                 | 9/14/89     | (2,3,4,6)                |  |
| BIL-GL-1(R)-12                     | "               | 0.997       | 0.0677          | 934                 | 13.85                   | 2.910                  | 4,697                    | 0.081           | "           | (2,3,5,6)                |  |
| BIL-GL-2(R)-3                      | "               | 1.000       | 0.0672          | 910                 | 13.53                   | 2.865                  | 4,644                    |                 | "           | (2,3,5,6)                |  |
| BIL-GL-2(R)-10                     | "               | 0.995       | 0.0672          | 848                 | 12.67                   | 2.825                  | 4,370                    |                 | "           | (2,3,5,6)                |  |
| BIL-GL-2(R)-16                     | "               | 1.004       | 0.0672          | 933                 | 13.83                   | 2.816                  | 4,663                    | 0.016           | "           | (1,3,4,6)                |  |
| Average                            |                 |             |                 |                     | 13.61                   | 2.872                  | 4,625                    | 0.048           |             |                          |  |
| Std. Dev.                          |                 |             |                 |                     | 0.58                    | 0.055                  | 148                      | 0.046           |             |                          |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion                   |                       |                          |  |
|---------------------------------|-----------------------|--------------------------|--|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 97.9                            | 20.30                 | 4,751                    |  |
| 95.5                            | 20.07                 | 4,697                    |  |
| 93.3                            | 19.76                 | 4,644                    |  |
| 87.4                            | 19.48                 | 4,370                    |  |
| 95.3                            | 19.41                 | 4,663                    |  |
| 93.9                            | 19.80                 | 4,625                    |  |
| 4.0                             | 0.38                  | 148                      |  |
| Average                         |                       |                          |  |
| Std. Dev.                       |                       |                          |  |

TABLE D.23

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, FILL DIRECTION, 93°C (200°F) WET

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                 |                          |                 | Fiber Orientation : Fill |           |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------|--------------------------|-----------------|--------------------------|-----------|
| Material : EA-9396 A/B; 7781 Glass        |                 |             |                 |                     |                         |                        |                 |                          |                 | Tested by : DRB          |           |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                 |                          | Poisson's Ratio | Date Tested              | Remarks   |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Strain (μin/in) | Ultimate Strain (μin/in) |                 |                          |           |
| BIL-GL-5-6                                | 200°F (WET)     | 1.003       | 0.0681          | 903                 | 13.21                   | 3.497                  | 4,873           | 0.126                    | 9/14/89         |                          | (2,3,4,6) |
| BIL-GL-5-12                               | "               | 1.005       | 0.0699          | 895                 | 12.75                   | 2.592                  | 4,658           | 0.076                    | "               |                          | (2,3,4,6) |
| BIL-GL-6-3                                | "               | 1.001       | 0.0699          | 908                 | 12.98                   | 3.671                  | 3,364           |                          | 9/15/89         |                          | (2,3,5,6) |
| BIL-GL-6-10                               | "               | 1.003       | 0.0687          | 881                 | 12.78                   | 3.253                  | 3,711           |                          | "               |                          | (2,3,5,6) |
| BIL-GL-6-16                               | "               | 0.994       | 0.0660          | 1,041               | 15.86                   | 3.172                  | 4,883           |                          | 9/14/89         |                          | (1,3,5,6) |
| Average                                   |                 |             |                 |                     | 13.52                   | 3.237                  | 4,298           | 0.101                    |                 |                          |           |
| Std. Dev.                                 |                 |             |                 |                     | 1.32                    | 0.411                  | 710             | 0.035                    |                 |                          |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion |  |                |                       |
|---------------|--|----------------|-----------------------|
| Ultimate      |  | Tensile        | Ultimate              |
|               |  | Strength (MPa) | Strain ( $\mu$ cm/cm) |
|               |  | 91.1           | 4,873                 |
|               |  | 87.9           | 4,658                 |
|               |  | 89.5           | 3,364                 |
|               |  | 88.1           | 3,711                 |
|               |  | 109.3          | 4,883                 |
| Average       |  | 93.2           | 4,298                 |
| Std. Dev.     |  | 9.1            | 710                   |
|               |  |                | 2.84                  |
|               |  | 22.32          |                       |

TABLE D.24

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, FILL DIRECTION, 93°C (200°F) WET

| Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : Fill |  |
|------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|--------------------------|--|
| Batch #3 Task #3                   |                 |             |                 |                     |                         |                        |                          |                 |             | Tested by : DRB          |  |
| Material : EA-9396 A/B; 7781 Glass |                 |             |                 |                     |                         |                        |                          |                 |             |                          |  |
| Specimen Number                    | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Poisson's Ratio | Date Tested | Remarks                  |  |
|                                    |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |                 |             |                          |  |
| BIL-GL-3-6                         | 200°F (WET)     | 1.005       | 0.0699          | 955                 | 13.59                   | 2.863                  | 4,468                    |                 | 9/15/89     | (2,3,5,6)                |  |
| BIL-GL-3-12                        | "               | 1.006       | 0.0688          | 930                 | 13.45                   | 2.642                  | 4,902                    | 0.086           | 9/14/89     | (2,3,4,6)                |  |
| BIL-GL-4-3                         | "               | 1.000       | 0.0685          | 1,013               | 14.79                   | 2.919                  | 4,712                    |                 | 9/15/89     | (2,3,5,6)                |  |
| BIL-GL-4-10                        | "               | 1.002       | 0.0680          | 940                 | 13.79                   | 3.551                  | 3,774                    |                 | "           | (2,3,5,6)                |  |
| BIL-GL-4-16                        | "               | 1.004       | 0.0689          | 822                 | 11.89                   | 2.583                  | 4,575                    | 0.088           | 9/14/89     | (2,3,4,6)                |  |
| Average                            |                 |             |                 |                     | 13.50                   | 2.912                  | 4,486                    | 0.087           |             |                          |  |
| Std. Dev.                          |                 |             |                 |                     | 1.04                    | 0.385                  | 430                      | 0.002           |             |                          |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion                   |                       |                          |           |
|---------------------------------|-----------------------|--------------------------|-----------|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |           |
| 93.7                            | 19.74                 | 4,468                    |           |
| 92.7                            | 18.22                 | 4,902                    |           |
| 102.0                           | 20.13                 | 4,712                    |           |
| 95.1                            | 24.48                 | 3,774                    |           |
| 82.0                            | 17.81                 | 4,575                    |           |
| 93.1                            | 20.08                 | 4,486                    | Average   |
| 7.2                             | 2.65                  | 430                      | Std. Dev. |

TABLE D.25

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, WARP DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :     |                        |               |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|---------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     | Tested by :             |                        |               |
|                 |                 | Batch #1                           |                 |                     | Task #2                 |                        |               |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | Remarks       |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |               |
| BIL-GR-7-17     | 72°F (DRY)      | 1.002                              | 0.1247          | 10,740              | 85.95                   | 8.283                  | 9,320 (2,3,4) |
| BIL-GR-7-19     | "               | 1.004                              | 0.1246          | 10,600              | 84.73                   | 7.914                  | 9,480 (2,3,4) |
| BIL-GR-7-21     | "               | 1.004                              | 0.1222          | 10,420              | 84.93                   | 8.191                  | 8,280 (2,3,4) |
| BIL-GR-8-18     | "               | 1.003                              | 0.1224          | 9,143               | 74.44                   | 8.643                  | 8,325 (2,3,5) |
| BIL-GR-8-20     | "               | 1.002                              | 0.1214          | 9,907               | 81.44                   | 8.866                  | 9,150 (2,3,5) |
| Average         |                 |                                    |                 |                     | 82.30                   | 8.380                  | 8,911         |
| Std. Dev.       |                 |                                    |                 |                     | 4.71                    | 0.377                  | 568           |
|                 |                 |                                    |                 |                     |                         |                        | 0.053         |
|                 |                 |                                    |                 |                     |                         |                        | 0.008         |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) 2.00" gage length axial extensometer attached.
- (5) Specimen had 0° and 90° strain gages attached.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 592.7                  | 57.11                 | 9,320                    |  |
| 584.2                  | 54.57                 | 9,480                    |  |
| 585.6                  | 56.48                 | 8,280                    |  |
| 513.3                  | 59.59                 | 8,325                    |  |
| 561.6                  | 61.13                 | 9,150                    |  |
| 567.5                  | 57.78                 | 8,911                    |  |
| 32.5                   | 2.60                  | 568                      |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |



TABLE D.26

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, WARP DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :      |                        |             |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|--------------------------|------------------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     | Tested by :              |                        |             |
|                 |                 | Batch #2                           |                 |                     | Task #2                  |                        |             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                 |                        | Remarks     |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.)  | Tensile Modulus (Msi.) |             |
| BIL-GR-11-17    | 72°F (DRY)      | 1.003                              | 0.1290          | 9,775               | 75.53                    | 7,689                  | 0.065       |
| BIL-GR-11-19    | "               | 0.999                              | 0.1234          | 9,750               | 79.07                    | 8,272                  | "           |
| BIL-GR-11-21    | "               | 1.002                              | 0.1200          | 10,340              | 85.97                    | 8,647                  | "           |
| BIL-GR-12-18    | "               | 1.000                              | 0.1252          | 10,650              | 85.06                    | 8,227                  | "           |
| BIL-GR-12-20    | "               | 1.003                              | 0.1264          | 10,300              | 81.24                    | 8,084                  | "           |
| Average         |                 |                                    |                 |                     | 81.37                    | 8,184                  | 0.053       |
| Std. Dev.       |                 |                                    |                 |                     | 4.31                     | 0.346                  | 0.013       |
|                 |                 |                                    |                 |                     | Ultimate Strain (μin/in) |                        | Date Tested |
|                 |                 |                                    |                 |                     | 7,950                    |                        | 4/3/89      |
|                 |                 |                                    |                 |                     | 8,700                    |                        | "           |
|                 |                 |                                    |                 |                     | 7,200                    |                        | "           |
|                 |                 |                                    |                 |                     | 7,150                    |                        | "           |
|                 |                 |                                    |                 |                     | 6,535                    |                        | "           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) 2.00" gage length axial extensometer attached.
- (5) 2.00" gage length biaxial extensometer attached.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 520.8                  | 53.01                 | 7,950                    |  |
| 545.2                  | 57.03                 | 8,700                    |  |
| 592.8                  | 59.62                 | 7,200                    |  |
| 586.5                  | 56.72                 | 7,150                    |  |
| 560.1                  | 55.74                 | 6,535                    |  |
| Average                | 56.43                 | 7,507                    |  |
| Std. Dev.              | 2.39                  | 835                      |  |

TABLE D.27

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, WARP DIRECTION, 22°C (72°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          |                 |             |         |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         | Tested by :            |                          |                 |             |         |
|                 |                 | Batch #3                           |                 | Task #2             |                         | PM                     |                          |                 |             |         |
|                 |                 | Ultimate                           |                 |                     |                         |                        |                          |                 |             |         |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks |
| BIL-GR-9-17     | 72°F (DRY)      | 0.995                              | 0.1251          | 9,150               | 73.54                   | 8.519                  | 7,400                    | 0.075           | 4/4/89      | (2,3,5) |
| BIL-GR-9-19     | "               | 1.002                              | 0.1245          | 10,630              | 85.18                   | 9.215                  | 5,500                    |                 | "           | (2,3,4) |
| BIL-GR-9-21     | "               | 0.997                              | 0.1263          | 9,200               | 73.08                   | 8.619                  | 6,900                    | 0.071           | "           | (2,3,5) |
| BIL-GR-10-18    | "               | 1.006                              | 0.1272          | 9,475               | 74.07                   | 8.131                  | 7,200                    |                 | "           | (2,3,4) |
| BIL-GR-10-20    | "               | 0.995                              | 0.1238          | 10,500              | 85.28                   | 8.325                  | 8,300                    |                 | "           | (2,3,4) |
| Average         |                 |                                    |                 | 78.23               |                         | 8.562                  | 7,060                    | 0.073           |             |         |
| Std. Dev.       |                 |                                    |                 | 6.40                |                         | 0.410                  | 1,016                    | 0.003           |             |         |

TABLE D.28

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, WARP DIRECTION, 22°C (72°F) WET

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     |                         | Fiber Orientation : Warp |                 |             |             |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|--------------------------|-----------------|-------------|-------------|
| Material : EA-9396 A/B; W133 Graphite     |                 | Batch #1    | Task #2         | Tested by : PM      |                         |                          |                 |             |             |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                          | Poisson's Ratio | Date Tested | Remarks     |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.)   |                 |             |             |
| BIL-GR-7-18                               | 72°F (WET)      | 1.004       | 0.1243          | 9,971               | 79.94                   | 9.088                    | 8.804           | 9/13/89     | (2,3,5,6,7) |
| BIL-GR-7-20                               | "               | 1.004       | 0.1227          | 11,172              | 90.69                   | 9.128                    | 10,144          | "           | (1,3,4,6,7) |
| BIL-GR-8-17                               | "               | 1.005       | 0.1219          | 11,099              | 90.63                   | 8.885                    | 10,049          | "           | (1,3,5,6)   |
| BIL-GR-8-19                               | "               | 1.001       | 0.1246          | 10,059              | 80.67                   | 8.807                    | 9,148           | "           | (1,2,3,5,6) |
| BIL-GR-8-21                               | "               | 0.998       | 0.1171          | 10,689              | 91.43                   | 9.342                    | 9,946           | "           | (1,3,4,6)   |
| Average                                   |                 |             |                 | 86.67               | 9.050                   | 9,618                    | 0.029           |             |             |
| Std. Dev.                                 |                 |             |                 | 5.83                | 0.212                   | 603                      | 0.015           |             |             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.
- (7) Tabs debonded; specimen did not fail.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 551.2                  | 62.66                 | 8,804                    |  |
| 625.3                  | 62.93                 | 10,144                   |  |
| 624.9                  | 61.26                 | 10,049                   |  |
| 556.2                  | 60.72                 | 9,148                    |  |
| 630.4                  | 64.41                 | 9,946                    |  |
| 597.6                  | 62.40                 | 9,618                    |  |
| 40.2                   | 1.46                  | 603                      |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |

TABLE D.29

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, WARP DIRECTION, 22°C (72°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                   |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|-------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 | Batch #2            | Task #2                 | Tested by :            |                   |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | Remarks           |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |                   |
| BIL-GR-11-18    | 72°F (WET)      | 1.002                              | 0.1286          | 9,575               | 74.28                   | 8.280                  | 9/12/89 (1,3,5,6) |
| BIL-GR-11-20    | "               | 0.999                              | 0.1233          | 10,264              | 83.34                   | 8.765                  | " (1,3,4,6)       |
| BIL-GR-12-17    | "               | 1.004                              | 0.1279          | 11,045              | 85.98                   | 8.773                  | " (1,2,3,5,6)     |
| BIL-GR-12-19    | "               | 1.000                              | 0.1254          | 10,718              | 85.43                   | 8.536                  | " (1,3,5,6)       |
| BIL-GR-12-21    | "               | 1.002                              | 0.1230          | 9,712               | 78.79                   | 8.856                  | " (1,3,4,6)       |
| Average         |                 |                                    |                 |                     | 81.56                   | 8.642                  | 9,277             |
| Std. Dev.       |                 |                                    |                 |                     | 4.96                    | 0.235                  | 472               |
|                 |                 |                                    |                 |                     |                         |                        | 0.041             |
|                 |                 |                                    |                 |                     |                         |                        | 0.011             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 512.2                  | 57.09                 | 8,796                    |  |
| 574.6                  | 60.43                 | 9,294                    |  |
| 592.8                  | 60.49                 | 9,595                    |  |
| 589.1                  | 58.85                 | 9,873                    |  |
| 543.2                  | 61.06                 | 8,826                    |  |
| Average                | 59.59                 | 9,277                    |  |
| Std. Dev.              | 1.62                  | 472                      |  |

TABLE D.30

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, WARP DIRECTION, 22°C (72°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          |                 |             |             |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         | Tested by :            |                          |                 |             |             |
|                 |                 | Batch #3                           |                 | Task #2             |                         | PM                     |                          |                 |             |             |
|                 |                 | Ultimate                           |                 |                     |                         |                        |                          |                 |             |             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks     |
| BIL-GR-9-18     | 72°F (WET)      | 1.002                              | 0.1244          | 11,257              | 90.36                   | 8.854                  | 10,410                   |                 | 9/12/89     | (1,3,5,6)   |
| BIL-GR-9-20     | "               | 0.997                              | 0.1249          | 10,200              | 81.95                   | 8.649                  | 9,653                    | 0.034           | "           | (1,2,3,4,6) |
| BIL-GR-10-17    | "               | 1.002                              | 0.1262          | 10,643              | 84.16                   | 8.438                  | 9,780                    |                 | 9/13/89     | (2,3,5,6)   |
| BIL-GR-10-19    | "               | 1.000                              | 0.1241          | 10,879              | 87.66                   | 8.743                  | 9,880                    |                 | "           | (1,2,3,5,6) |
| BIL-GR-10-21    | "               | 1.001                              | 0.1187          | 10,490              | 88.27                   | 9.200                  | 9,429                    | 0.048           | 9/12/89     | (2,3,4,6)   |
|                 |                 | Average                            |                 | 86.48               |                         | 8.777                  |                          | 9,831           |             | 0.041       |
|                 |                 | Std. Dev.                          |                 | 3.37                |                         | 0.282                  |                          | 365             |             | 0.010       |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                                       |  |
|------------------------|-----------------------|---------------------------------------|--|
| Ultimate               |                       |                                       |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 623.0                  | 61.05                 | 10,410                                |  |
| 565.1                  | 59.64                 | 9,653                                 |  |
| 580.3                  | 58.18                 | 9,780                                 |  |
| 604.4                  | 60.29                 | 9,880                                 |  |
| 608.6                  | 63.43                 | 9,429                                 |  |
| 596.3                  | 60.52                 | 9,831                                 |  |
| 23.2                   | 1.94                  | 365                                   |  |
| Average                |                       |                                       |  |
| Std. Dev.              |                       |                                       |  |

TABLE D.31

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, FILL DIRECTION, -54°C (-65°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :              |                                       |                 |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|----------------------------------|---------------------------------------|-----------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     | Tested by :                      |                                       |                 |
|                 |                 | Batch #1 Task #3                   |                 |                     | Fill                             |                                       |                 |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate Tensile Strength (Ksi.) |                                       | Remarks         |
|                 |                 |                                    |                 |                     | Tensile Modulus (Msi.)           | Ultimate Strain ( $\mu\text{in/in}$ ) |                 |
| BIL-GR-7-1      | -65°F (DRY)     | 1.0005                             | 0.1113          | 11,196              | 9.153                            | 10,576                                | 6/13/89 (2,3,4) |
| BIL-GR-7-7      | "               | 0.9971                             | 0.1228          | 11,411              | 9.129                            | 10,129                                | " (1,2,3,5)     |
| BIL-GR-7-13     | "               | 0.9972                             | 0.1208          | 11,118              | 9.085                            | 10,283                                | " (2,3,5)       |
| BIL-GR-8-5      | "               | 1.0000                             | 0.1194          | 10,581              | 9.044                            | 10,581                                | " (2,3,4)       |
| BIL-GR-8-11     | "               | 1.0010                             | 0.1189          | 10,864              | 9.125                            | 9,624                                 | " (1,2,3,4)     |
| Average         |                 |                                    |                 |                     | 9.107                            | 10,239                                | 0.060           |
| Std. Dev.       |                 |                                    |                 |                     | 0.043                            | 395                                   | 0.008           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                                       |  |
|------------------------|-----------------------|---------------------------------------|--|
| Ultimate               |                       |                                       |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 693.3                  | 63.11                 | 10,576                                |  |
| 642.6                  | 62.95                 | 10,129                                |  |
| 636.4                  | 62.64                 | 10,283                                |  |
| 611.0                  | 62.36                 | 10,581                                |  |
| 629.4                  | 62.92                 | 9,624                                 |  |
| Average                | 62.80                 | 10,239                                |  |
| Std. Dev.              | 0.30                  | 395                                   |  |

TABLE D.32

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, FILL DIRECTION, -54°C (-65°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     | Fiber Orientation :              |                          |                   |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|----------------------------------|--------------------------|-------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     | Tested by :                      |                          |                   |
|                 |                 | Batch #2                           |                 | Task #3             |                                  |                          |                   |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate Tensile Strength (Ksi.) |                          | Remarks           |
|                 |                 |                                    |                 |                     | Tensile Modulus (Msi.)           | Ultimate Strain (μin/in) |                   |
| BIL-GR-11-1     | -65°F (DRY)     | 0.997                              | 0.1098          | 11,699              | 106.88                           | 10,195                   | 6/13/89 (1,2,3,5) |
| BIL-GR-11-7     | "               | 0.996                              | 0.1229          | 10,147              | 82.89                            | 9,031                    | " (2,3,5)         |
| BIL-GR-11-13    | "               | 1.001                              | 0.1180          | 10,205              | 86.38                            | 8,958                    | " (1,3,4)         |
| BIL-GR-12-5     | "               | 1.003                              | 0.1159          | 9,912               | 85.28                            | 8,936                    | " (2,3,5)         |
| BIL-GR-12-11    | "               | 1.001                              | 0.1180          | 10,361              | 87.73                            | 9,294                    | " (2,3,4)         |
|                 |                 |                                    |                 | Average             | 89.83                            | 9,229                    | 0.048             |
|                 |                 |                                    |                 | Std. Dev.           | 9.69                             | 0.670                    | 0.003             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion                   |  |                       |                          |
|---------------------------------|--|-----------------------|--------------------------|
| Ultimate Tensile Strength (MPa) |  | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |
| 736.9                           |  | 70.34                 | 10,195                   |
| 571.5                           |  | 57.45                 | 9,031                    |
| 595.6                           |  | 63.15                 | 8,958                    |
| 588.0                           |  | 62.63                 | 8,936                    |
| 604.9                           |  | 64.60                 | 9,294                    |
| Average                         |  | 63.63                 | 9,283                    |
| Std. Dev.                       |  | 4.62                  | 530                      |

TABLE D.33

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, FILL DIRECTION, -54°C (-65°F) DRY

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     | Fiber Orientation : Fill |                        |                                       |                 |             |           |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|--------------------------|------------------------|---------------------------------------|-----------------|-------------|-----------|
| Material : EA-9396 A/B; W133 Graphite     |                 |             |                 |                     | Tested by : PM           |                        |                                       |                 |             |           |
|                                           |                 |             |                 |                     | Batch #3                 | Task #3                |                                       |                 |             |           |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                 |                        |                                       |                 |             |           |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.)  | Tensile Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) |                 |             |           |
| BIL-GR-9-1                                | -65°F (DRY)     | 0.998       | 0.1096          | 10,034              | 91.71                    | 10.005                 | 8,914                                 | Poisson's Ratio | Date Tested | Remarks   |
| BIL-GR-9-7                                | "               | 0.995       | 0.1192          | 10,137              | 85.46                    | 9.251                  | 9,900                                 |                 | 6/14/89     | (1,3,5)   |
| BIL-GR-9-13                               | "               | 0.988       | 0.1199          | 10,566              | 89.20                    | 9.540                  | 8,848                                 | 0.049           | "           | (2,3,5)   |
| BIL-GR-10-5                               | "               | 0.999       | 0.1189          | 10,205              | 85.88                    | 9.472                  | 9,053                                 |                 | 6/13/89     | (2,3,4)   |
| BIL-GR-10-11                              | "               | 0.996       | 0.1172          | 10,640              | 91.16                    | 9.434                  | 9,324                                 | 0.056           | 6/14/89     | (2,3,5)   |
| Average                                   |                 |             |                 |                     | 88.68                    | 9.540                  | 9,208                                 | 0.053           | 6/13/89     | (1,2,3,4) |
| Std. Dev.                                 |                 |             |                 |                     | 2.91                     | 0.281                  | 428                                   | 0.005           |             |           |



TABLE D.34

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, FILL DIRECTION, 22°C (72°F) DRY

| Straight sided tension; ASTM-D3039    |                 |             |                 |                     |                         |                        |                                |                 |             | Fiber Orientation : Fill |  |
|---------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-----------------|-------------|--------------------------|--|
| Material : EA-9396 A/B; W133 Graphite |                 |             |                 |                     |                         |                        |                                |                 |             | Tested by : PM           |  |
| Specimen Number                       | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                                | Poisson's Ratio | Date Tested | Remarks                  |  |
|                                       |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain ( $\mu$ in/in) |                 |             |                          |  |
| BIL-GR-7-2                            | 72°F (DRY)      | 1.004       | 0.1166          | 11,600              | 99.12                   | 8.630                  | 11,600                         | 0.048           | 5/3/89      | (1,2,3,4)                |  |
| BIL-GR-7-8                            | "               | 1.002       | 0.1275          | 12,243              | 95.88                   | 7.943                  | 11,100                         | 0.048           | "           | (1,2,3,5)                |  |
| BIL-GR-7-14                           | "               | 0.999       | 0.1250          | 11,520              | 92.25                   | 8.408                  | 10,542                         |                 | "           | (2,3,4)                  |  |
| BIL-GR-8-6                            | "               | 1.003       | 0.1242          | 12,586              | 101.02                  | 8.170                  | 11,700                         |                 | "           | (1,3,5)                  |  |
| BIL-GR-8-12                           | "               | 1.004       | 0.1233          | 11,530              | 93.15                   | 8.240                  | 10,843                         | 0.046           | "           | (2,3,4)                  |  |
| Average                               |                 |             |                 |                     | 96.28                   | 8.278                  | 11,157                         | 0.048           |             |                          |  |
| Std. Dev.                             |                 |             |                 |                     | 3.77                    | 0.258                  | 493                            | 0.001           |             |                          |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion                   |                       |                                |  |
|---------------------------------|-----------------------|--------------------------------|--|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 683.4                           | 59.50                 | 11,600                         |  |
| 661.1                           | 54.77                 | 11,100                         |  |
| 636.1                           | 57.98                 | 10,542                         |  |
| 696.5                           | 56.33                 | 11,700                         |  |
| 642.3                           | 56.82                 | 10,843                         |  |
| 663.9                           | 57.08                 | 11,157                         |  |
| 26.0                            | 1.78                  | 493                            |  |
| Average                         |                       |                                |  |
| Std. Dev.                       |                       |                                |  |

TABLE D.35

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, FILL DIRECTION, 22°C (72°F) DRY

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 |                     | Fiber Orientation : Fill |                        |                                |                 |             |           |
|-------------------------------------------|-----------------|-------------|-----------------|---------------------|--------------------------|------------------------|--------------------------------|-----------------|-------------|-----------|
| Material : EA-9396 A/B; W133 Graphite     |                 |             |                 |                     | Tested by : PM           |                        |                                |                 |             |           |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                 |                        |                                | Poisson's Ratio | Date Tested | Remarks   |
|                                           |                 |             |                 |                     | Tensile Strength (Ksi.)  | Tensile Modulus (Msi.) | Ultimate Strain ( $\mu$ in/in) |                 |             |           |
| BIL-GR-11-2                               | 72°F(DRY)       | 0.9997      | 0.1192          | 12,065              | 101.25                   | 8.870                  | 11,616                         | 0.053           | 6/13/89     | (1,2,3,4) |
| BIL-GR-11-8                               | "               | 0.4982      | 0.1260          | 5,175               | 82.44                    | 7.308                  | 9,493                          | 0.039           | 4/26/89     | (1,3,4,6) |
| BIL-GR-11-14                              | "               | 1.0029      | 0.1231          | 12,056              | 97.65                    | 8.563                  | 10,920                         | 0.068           | 6/13/89     | (1,2,3,4) |
| BIL-GR-12-6                               | "               | 0.4981      | 0.1228          | 4,880               | 79.78                    | 7.868                  | 9,632                          | 0.044           | 4/26/89     | (1,3,4,6) |
| BIL-GR-12-12                              | "               | 1.0039      | 0.1227          | 12,329              | 100.09                   | 8.936                  | 11,148                         | 0.068           | 6/13/89     | (1,3,4)   |
| Average                                   |                 |             |                 |                     | 99.66                    | 8.790                  | 11,228                         | 0.063           |             |           |
| Std. Dev.                                 |                 |             |                 |                     | 1.84                     | 0.199                  | 355                            | 0.009           |             |           |

## Remarks:

- (1) Specimen failed within the gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) 2.00" biaxial gage length extensometer.
- (5) Specimen had 0° and 90° strain gages attached.
- (6) Specimen tested in dogbone shape, not included in averages.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 698.1                  | 61.16                 | 11,616                         |  |
| 568.4                  | 50.39                 | 9,493                          |  |
| 673.3                  | 59.04                 | 10,920                         |  |
| 550.1                  | 54.25                 | 9,632                          |  |
| 690.1                  | 61.61                 | 11,148                         |  |
| Average                | 60.60                 | 11,228                         |  |
| Std. Dev.              | 1.37                  | 355                            |  |

TABLE D.36

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, FILL DIRECTION, 22°C (72°F) DRY

|                 |                 |                                    |                 |                     |                         |                        |                          |                 |             |         |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|---------|
| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          | Fill            |             |         |
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         | Batch #3               | Task #3                  | Tested by :     | PM          |         |
| Ultimate        |                 |                                    |                 |                     |                         |                        |                          |                 |             |         |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks |
| BIL-GR-9-2      | 72°F (DRY)      | 0.994                              | 0.1149          | 10,200              | 89.32                   | 9.445                  | 9,180                    |                 | 4/20/89     | (2,3,5) |
| BIL-GR-9-8      | "               | 1.004                              | 0.1237          | 12,500              | 100.70                  | 8.890                  | 11,085                   |                 | 4/24/89     | (1,3,5) |
| BIL-GR-9-14     | "               | 1.001                              | 0.1216          | 11,457              | 94.13                   | 8.978                  | 8,940                    | 0.044           | "           | (2,3,4) |
| BIL-GR-10-6     | "               | 1.000                              | 0.1216          | 9,129               | 75.07                   | 8.635                  | 8,520                    |                 | 4/20/89     | (2,3,5) |
| Average         |                 |                                    |                 | 89.80               |                         | 8.987                  | 9,431                    |                 |             |         |
| Std. Dev.       |                 |                                    |                 | 10.87               |                         | 0.338                  | 1,136                    |                 |             |         |
| Poisson's Ratio |                 |                                    |                 |                     |                         |                        |                          |                 |             | 0.044   |
| Date Tested     |                 |                                    |                 |                     |                         |                        |                          |                 |             | 4/20/89 |
| Remarks         |                 |                                    |                 |                     |                         |                        |                          |                 |             | (2,3,5) |
|                 |                 |                                    |                 |                     |                         |                        |                          |                 |             | (1,3,5) |
|                 |                 |                                    |                 |                     |                         |                        |                          |                 |             | (2,3,4) |
|                 |                 |                                    |                 |                     |                         |                        |                          |                 |             | (2,3,5) |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) 2.00" gage length biaxial extensometer attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 615.8                  | 65.12                 | 9,180                    |  |
| 694.3                  | 61.30                 | 11,085                   |  |
| 649.0                  | 61.91                 | 8,940                    |  |
| 517.6                  | 59.54                 | 8,520                    |  |
| Average                | 61.97                 | 9,431                    |  |
| Std. Dev.              | 2.33                  | 1,136                    |  |

TABLE D.37

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, FILL DIRECTION, 93°C (200°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                 | Fill        |                   |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------|-------------|-------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         | Tested by :            |                 |             | DH                |
|                 |                 | Batch #1                           |                 |                     |                         | Task #3                |                 |             |                   |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | Poisson's Ratio | Date Tested | Remarks           |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |                 |             |                   |
| BIL-GR-7-3      | 200°F (DRY)     | 0.999                              | 0.1183          | 6,768               | 57.30                   | 8.830                  | 6,460           | 6/15/89     | (2,3,5,6)         |
| BIL-GR-7-9      | "               | 1.002                              | 0.1187          | 8,499               | 71.45                   | 8.235                  | 8,467           | 1/9/90      | (2,3,5,6)         |
| BIL-GR-7-15     | "               | 0.999                              | 0.1189          | 8,132               | 68.46                   | 8.387                  | 7,998           | 0.051       | 1/10/90 (2,3,4,6) |
| BIL-GR-8-7      | "               | 0.998                              | 0.1194          | 8,108               | 68.05                   | 8.305                  | 8,066           | 1/9/90      | (2,3,5,6)         |
| BIL-GR-8-13     | "               | 1.000                              | 0.1256          | 8,147               | 64.87                   | 7.746                  | 8,145           | 0.022       | 1/10/90 (2,3,4,6) |
| Average         |                 |                                    |                 |                     | 66.03                   | 8.301                  | 7,827           | 0.037       |                   |
| Std. Dev.       |                 |                                    |                 |                     | 5.41                    | 0.387                  | 785             | 0.020       |                   |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Tabs debonded; specimen tested without tabs.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 395.1                  | 60.88                 | 6,460                          |  |
| 492.7                  | 56.78                 | 8,467                          |  |
| 472.1                  | 57.83                 | 7,998                          |  |
| 469.2                  | 57.27                 | 8,066                          |  |
| 447.3                  | 53.41                 | 8,145                          |  |
| 455.3                  | 57.23                 | 7,827                          |  |
| 37.3                   | 2.67                  | 785                            |  |
| Average                |                       |                                |  |
| Std. Dev.              |                       |                                |  |

TABLE D.38

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, FILL DIRECTION, 93°C (200°F) DRY

| Straight sided tension; ASTM-D3039 |                 |                            |                 |                     |                         |                        |        |                                |                 | Fiber Orientation : Fill |           |
|------------------------------------|-----------------|----------------------------|-----------------|---------------------|-------------------------|------------------------|--------|--------------------------------|-----------------|--------------------------|-----------|
| Test :                             |                 | EA-9396 A/B; W133 Graphite |                 |                     |                         |                        |        |                                |                 | Tested by : DH           |           |
| Material :                         |                 | Batch #2                   |                 | Task #3             |                         |                        |        |                                |                 |                          |           |
| Specimen Number                    | Test Conditions | Width (in.)                | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |        | Ultimate Strain ( $\mu$ in/in) | Poisson's Ratio | Date Tested              | Remarks   |
|                                    |                 |                            |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |        |                                |                 |                          |           |
| BIL-GR-11-3                        | 200°F (DRY)     | 1.001                      | 0.1172          | 10,757              | 91.70                   | 9.226                  | 9,712  |                                |                 | 6/15/89                  | (1,2,3,5) |
| BIL-GR-11-9                        | "               | 0.998                      | 0.1198          | 8,416               | 70.37                   | 8.491                  | 8,110  |                                |                 | 1/9/90                   | (2,3,5,6) |
| BIL-GR-11-15                       | "               | 1.000                      | 0.1139          | 9,229               | 81.06                   | 8.776                  | 9,087  |                                | 0.046           | "                        | (2,3,4)   |
| BIL-GR-12-7                        | "               | 0.996                      | 0.1172          | 7,686               | 65.83                   | 8.366                  | 7,749  |                                |                 | "                        | (2,3,5,6) |
| BIL-GR-12-13                       | "               | 1.000                      | 0.1170          | 9,583               | 81.89                   | 8.119                  | 10,039 |                                | 0.060           | "                        | (1,3,4)   |
| Average                            |                 |                            |                 | 78.17               | 8.596                   | 8,940                  |        | 0.053                          |                 |                          |           |
| Std. Dev.                          |                 |                            |                 | 10.23               | 0.424                   | 992                    |        | 0.010                          |                 |                          |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Tabs debonded; specimen tested without tabs.

## SI Conversion

| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |
|---------------------------------|-----------------------|--------------------------------|
| 632.3                           | 63.61                 | 9,712                          |
| 485.2                           | 58.55                 | 8,110                          |
| 558.9                           | 60.51                 | 9,087                          |
| 453.9                           | 57.68                 | 7,749                          |
| 564.6                           | 55.98                 | 10,039                         |
| 539.0                           | 59.27                 | 8,940                          |
| 70.5                            | 2.93                  | 992                            |

Average  
Std. Dev.

TABLE D.39

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, FILL DIRECTION, 93°C (200°F) DRY

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          |                 |             |           |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         | Tested by : PM         |                          |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Poisson's Ratio | Date Tested | Remarks   |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (µin/in) |                 |             |           |
| BIL-GR-9-3      | 200°F (DRY)     | 0.9982                             | 0.1192          | 10,271              | 86.33                   | 9.155                  | 9,195                    |                 | 5/8/89      | (1,2,3,5) |
| BIL-GR-9-9      | "               | 1.0013                             | 0.1233          | 9,929               | 80.42                   | 8.910                  | 8,895                    |                 | "           | (1,3,5)   |
| BIL-GR-9-16     | "               | 1.0024                             | 0.1195          | 9,810               | 81.90                   | 9.183                  | 8,850                    | 0.063           | 5/9/89      | (1,3,4)   |
| BIL-GR-10-7     | "               | 0.9971                             | 0.1198          | 8,900               | 74.51                   | 8.910                  | 8,340                    |                 | 5/8/89      | (2,3,5)   |
| BIL-GR-10-13    | "               | 1.0001                             | 0.1151          | 10,140              | 88.09                   | 9.035                  | 9,686                    | 0.102           | 5/9/89      | (1,2,3,4) |
| Average         |                 |                                    |                 |                     | 82.25                   | 9.038                  | 8,993                    | 0.082           |             |           |
| Std. Dev.       |                 |                                    |                 |                     | 5.34                    | 0.130                  | 494                      | 0.028           |             |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 595.2                  | 63.12                 | 9,195                          |  |
| 554.5                  | 61.43                 | 8,895                          |  |
| 564.7                  | 63.32                 | 8,850                          |  |
| 513.7                  | 61.43                 | 8,340                          |  |
| 607.4                  | 62.29                 | 9,686                          |  |
| Average                | 62.32                 | 8,993                          |  |
| Std. Dev.              | 0.90                  | 494                            |  |

TABLE D.40

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, FILL DIRECTION, -54°C (-65°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         |                        | Fiber Orientation :      |                 |             | Fill        |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         |                        | Tested by :              |                 |             | PM          |
|                 |                 | Batch #1                           |                 |                     |                         |                        | Task #3                  |                 |             |             |
|                 |                 | Ultimate                           |                 |                     |                         |                        |                          |                 |             |             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks     |
| BIL-GR-7-4      | -65°F (WET)     | 0.997                              | 0.1239          | 12,505              | 101.24                  | 9.214                  | 11,104                   | 0.052           | 9/7/89      | (1,2,3,4,6) |
| BIL-GR-7-10     | "               | 0.999                              | 0.1248          | 11,499              | 92.23                   | 8.906                  | 10,225                   |                 | "           | (2,3,5,6)   |
| BIL-GR-8-1      | "               | 0.998                              | 0.1099          | 10,586              | 96.53                   | 9.912                  | 9,514                    |                 | "           | (2,3,5,6)   |
| BIL-GR-8-8      | "               | 1.001                              | 0.1213          | 11,470              | 94.46                   | 9.454                  | 7,214                    |                 | "           | (1,2,3,5,6) |
| BIL-GR-8-14     | "               | 1.003                              | 0.1152          | 11,831              | 102.39                  | 9.434                  | 10,745                   | 0.041           | "           | (1,2,3,4,6) |
|                 |                 | Average                            |                 | 97.37               |                         | 9.384                  | 9,760                    | 0.046           |             |             |
|                 |                 | Std. Dev.                          |                 | 4.35                |                         | 0.369-                 | 1,544                    | 0.008           |             |             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 698.1                  | 63.53                 | 11,104                   |  |
| 635.9                  | 61.41                 | 10,225                   |  |
| 665.5                  | 68.34                 | 9,514                    |  |
| 651.3                  | 65.18                 | 7,214                    |  |
| 706.0                  | 65.05                 | 10,745                   |  |
| Average                | 64.70                 | 9,760                    |  |
| Std. Dev.              | 2.54                  | 1,544                    |  |

TABLE D.41

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, FILL DIRECTION, -54°C (-65°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |             |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 | Batch #2            | Task #3                 | Tested by :            |             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                | Poisson's Ratio        | Date Tested |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |             |
| BIL-GR-11-4     | -65°F (WET)     | 0.999                              | 0.1197          | 10,996              | 91.93                   | 9.485                  | 9/8/89      |
| BIL-GR-11-10    | "               | 0.999                              | 0.1206          | 12,148              | 100.82                  | 9.382                  | 9/7/89      |
| BIL-GR-12-1     | "               | 0.999                              | 0.1119          | 9,009               | 80.60                   | 9.655                  | 9/8/89      |
| BIL-GR-12-8     | "               | 0.998                              | 0.1181          | 11,895              | 100.93                  | 9.347                  | "           |
| BIL-GR-12-14    | "               | 0.999                              | 0.1177          | 11,480              | 97.61                   | 9.680                  | 9/7/89      |
| Average         |                 |                                    |                 |                     | 94.38                   | 9.510                  |             |
| Std. Dev.       |                 |                                    |                 |                     | 8.53                    | 0.153                  |             |
|                 |                 |                                    |                 |                     |                         | 9.662                  |             |
|                 |                 |                                    |                 |                     |                         | 1.017                  |             |
|                 |                 |                                    |                 |                     |                         | 0.046                  |             |
|                 |                 |                                    |                 |                     |                         | 0.008                  |             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 633.8                  | 65.40                 | 9,368                    |  |
| 695.2                  | 64.69                 | 10,378                   |  |
| 555.7                  | 66.57                 | 8,005                    |  |
| 695.9                  | 64.44                 | 10,408                   |  |
| 673.0                  | 66.74                 | 10,151                   |  |
| Average                | 65.57                 | 9,662                    |  |
| Std. Dev.              | 1.05                  | 1,017                    |  |



INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS, GRAPHITE REINFORCEMENT, BATCH 3, FILL DIRECTION, -54°C (-65°F) WET

| Remarks:                                              | SI Conversion                   |                       |                                       |  |
|-------------------------------------------------------|---------------------------------|-----------------------|---------------------------------------|--|
|                                                       | Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| (1) Specimen failed within the 6.5 inch gage section. | 686.7                           | 66.33                 | 10,217                                |  |
| (2) Specimen failed inside tab area.                  | 600.7                           | 63.18                 | 9,353                                 |  |
| (3) Test speed = 0.1 in/min.                          | 723.2                           | 71.43                 | 9,976                                 |  |
| (4) Specimen had 0° and 90° strain gages attached.    | 657.8                           | 64.13                 | 10,129                                |  |
| (5) Specimen had only 0° strain gage attached.        | 717.7                           | 67.93                 | 10,613                                |  |
| (6) Specimens aged @ 140°F/95–100% R.H.               |                                 |                       |                                       |  |
|                                                       | 677.2                           | 66.60                 | 10,058                                |  |
|                                                       | 50.2                            | 3.28                  | 459                                   |  |
|                                                       | Average                         |                       |                                       |  |
|                                                       | Std. Dev.                       |                       |                                       |  |

TABLE D.43

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, FILL DIRECTION, 22°C (72°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                        | Fiber Orientation : Fill              |                 |             |           |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|------------------------|---------------------------------------|-----------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                        | Tested by : PM                        |                 |             |           |
|                 |                 | Batch #1                           |                 |                     |                        | Task #3                               |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) |                        | Ultimate Strain ( $\mu\text{in/in}$ ) | Poisson's Ratio | Date Tested | Remarks   |
|                 |                 |                                    |                 | Strength (Ksi.)     | Tensile Modulus (Msi.) |                                       |                 |             |           |
| BIL-GR-7-5      | 72°F (WET)      | 1.002                              | 0.1267          | 9,146               | 72.02                  | 8.386                                 |                 | 9/6/89      | (2,3,5,6) |
| BIL-GR-7-11     | "               | 0.999                              | 0.1260          | 10,327              | 82.08                  | 9.338                                 | 0.035           | "           | (2,3,4,6) |
| BIL-GR-8-2      | "               | 1.003                              | 0.1152          | 11,533              | 99.84                  | 10,994                                |                 | "           | (1,3,5,6) |
| BIL-GR-8-4      | "               | 1.005                              | 0.1244          | 10,508              | 84.05                  | 9,829                                 |                 | "           | (1,3,5,6) |
| BIL-GR-8-9      | "               | 1.003                              | 0.1266          | 9,771               | 76.96                  | 9,082                                 | 0.038           | "           | (2,3,4,6) |
| Average         |                 |                                    |                 | 82.99               | 8.627                  | 9,526                                 | 0.037           |             |           |
| Std. Dev.       |                 |                                    |                 | 10.52               | 0.262                  | 972                                   | 0.002           |             |           |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |                       |                                       |  |
|------------------------|-----------------------|---------------------------------------|--|
| Ultimate               |                       |                                       |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 496.6                  | 58.97                 | 8,386                                 |  |
| 566.0                  | 60.98                 | 9,338                                 |  |
| 688.4                  | 61.76                 | 10,994                                |  |
| 579.5                  | 57.97                 | 9,829                                 |  |
| 530.6                  | 57.73                 | 9,082                                 |  |
| 572.2                  | 59.48                 | 9,526                                 |  |
| 72.5                   | 1.81                  | 972                                   |  |

Average  
Std. Dev.

TABLE D.44

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, FILL DIRECTION, 22°C (72°F) WET

| Straight sided tension; ASTM-D3039    |                 |             |                 |                     |                         |                        |                          |                 |             | Fiber Orientation : Fill |  |
|---------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|--------------------------|--|
| Material : EA-9396 A/B; W133 Graphite |                 |             |                 |                     |                         |                        |                          |                 |             | Tested by : PM           |  |
| Batch #2 Task #3                      |                 |             |                 |                     |                         |                        |                          |                 |             |                          |  |
| Ultimate                              |                 |             |                 |                     |                         |                        |                          |                 |             |                          |  |
| Specimen Number                       | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks                  |  |
| BIL-GR-11-5                           | 72°F (WET)      | 1.003       | 0.1171          | 10,586              | 90.17                   | 9.150                  | 9,543                    |                 | 9/11/89     | (1,2,3,5,6)              |  |
| BIL-GR-11-11                          | "               | 1.000       | 0.1118          | 11,318              | 101.27                  | 9.633                  | 10,430                   | 0.043           | "           | (1,2,3,4,6)              |  |
| BIL-GR-12-2                           | "               | 1.001       | 0.1177          | 10,332              | 87.66                   | 8.581                  | 9,998                    |                 | "           | (1,2,3,5,6)              |  |
| BIL-GR-12-9                           | "               | 1.004       | 0.1237          | 10,176              | 81.94                   | 8.383                  | 9,653                    |                 | "           | (1,3,5,6)                |  |
| BIL-GR-12-15                          | "               | 1.005       | 0.1239          | 10,986              | 88.25                   | 8.222                  | 11,697                   | 0.049           | "           | (1,3,4,6)                |  |
|                                       |                 |             |                 | Average             | 89.86                   | 8.794                  | 10,264                   | 0.046           |             |                          |  |
|                                       |                 |             |                 | Std. Dev.           | 7.08                    | 0.586                  | 872                      | 0.004           |             |                          |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

## SI Conversion

| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (μcm/cm) |
|---------------------------------|-----------------------|--------------------------|
| 621.7                           | 63.09                 | 9,543                    |
| 698.2                           | 66.42                 | 10,430                   |
| 604.4                           | 59.16                 | 9,998                    |
| 565.0                           | 57.80                 | 9,653                    |
| 608.5                           | 56.69                 | 11,697                   |
| Average                         | 60.63                 | 10,264                   |
| Std. Dev.                       | 4.04                  | 872                      |

TABLE D.45

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, FILL DIRECTION, 22°C (72°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                                |                 |             |             |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-----------------|-------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 | Batch #3            | Task #3                 | Tested by :            |                                |                 | PM          |             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                                | Poisson's Ratio | Date Tested | Remarks     |
|                 |                 |                                    |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain ( $\mu$ in/in) |                 |             |             |
| BIL-GR-9-5      | 72°F (WET)      | 1.003                              | 0.1240          | 10,703              | 86.08                   | 8.624                  | 9.741                          |                 | 9/11/89     | (1,2,3,5,6) |
| BIL-GR-9-11     | "               | 1.002                              | 0.1247          | 10,762              | 86.10                   | 8.881                  | 9.683                          | 0.058           | "           | (1,2,3,4,6) |
| BIL-GR-10-2     | "               | 1.002                              | 0.1163          | 11,040              | 94.73                   | 8.933                  | 10,547                         |                 | "           | (1,2,3,5,6) |
| BIL-GR-10-9     | "               | 1.002                              | 0.1253          | 10,674              | 85.04                   | 8.516                  | 10,181                         |                 | "           | (1,3,5,6)   |
| BIL-GR-10-15    | "               | 1.002                              | 0.1173          | 11,401              | 96.99                   | 8.947                  | 11,279                         | 0.053           | "           | (1,3,4,6)   |
| Average         |                 |                                    |                 |                     | 89.79                   | 8.780                  | 10,286                         | 0.056           |             |             |
| Std. Dev.       |                 |                                    |                 |                     | 5.62                    | 0.197                  | 657                            | 0.003           |             |             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.

| SI Conversion          |  |                       |                                |
|------------------------|--|-----------------------|--------------------------------|
| Ultimate               |  | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |
| Tensile Strength (MPa) |  | 59.47                 | 9.741                          |
| 593.5                  |  | 61.24                 | 9.683                          |
| 593.7                  |  | 61.59                 | 10.547                         |
| 653.1                  |  | 58.72                 | 10.181                         |
| 586.4                  |  | 61.69                 | 11.279                         |
| 668.8                  |  |                       |                                |
| Average                |  | 60.54                 | 10,286                         |
| Std. Dev.              |  | 1.36                  | 657                            |

TABLE D.46

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, FILL DIRECTION, 93°C (200°F) WET

| Test : Straight sided tension; ASTM-D3039 |                 |             |                 | Fiber Orientation : Fill |                         |                        |                          |             |         |                 |
|-------------------------------------------|-----------------|-------------|-----------------|--------------------------|-------------------------|------------------------|--------------------------|-------------|---------|-----------------|
| Material : EA-9396 A/B; W133 Graphite     |                 |             |                 | Batch #1                 | Task #3                 | Tested by : PM & DH    |                          |             |         |                 |
| Specimen Number                           | Test Conditions | Width (in.) | Thickness (in.) | Ultimate                 |                         |                        |                          | Date Tested | Remarks |                 |
|                                           |                 |             |                 | Maximum Load (lbs.)      | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (µin/in) |             |         | Poisson's Ratio |
| BIL-GR-7-6                                | 200°F (WET)     | 0.997       | 0.1244          | 7,993                    | 64.47                   | 7.612                  | 7,727                    | 0.034       | 1/23/90 | (2,3,4,6,8)     |
| BIL-GR-7-12                               | "               | 1.001       | 0.1229          | 7,666                    | 62.31                   | 7.801                  | 7,427                    | 0.015       | 9/13/89 | (1,3,4,6)       |
| BIL-GR-8-3                                | "               | 1.007       | 0.1141          | 8,096                    | 70.46                   | 9.197                  | 3,071                    |             | 9/15/89 | (1,3,5,6,7)     |
| BIL-GR-8-10                               | "               | 0.998       | 0.1205          | 6,824                    | 56.72                   | 7.492                  | 7,749                    |             | 1/23/90 | (2,3,5,6,8)     |
| BIL-GR-8-16                               | "               | 1.006       | 0.1138          | 8,140                    | 71.10                   | 7.679                  | 9,316                    | 0.052       | "       | (1,3,4,6,8)     |
| Average                                   |                 |             |                 | 65.01                    | 7.956                   | 7,058                  |                          |             |         |                 |
| Std. Dev.                                 |                 |             |                 | 5.98                     | 0.703                   | 2,348                  |                          |             |         |                 |

Remarks:

(1) Specimen failed within the 6.5 inch gage section.

(2) Specimen failed at grip edge.

(3) Test speed = 0.1 in/min.

(4) Specimen had 0° and 90° Strain gages attached.

(5) Specimen had only 0° strain gage attached.

(6) Specimens aged @ 140°F/95-100% R.H.

(7) Strain gage failed prematurely due to ply failure.

(8) Tested without tabs.

| SI Conversion          |                       |                          |  |
|------------------------|-----------------------|--------------------------|--|
| Ultimate               |                       |                          |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain (µcm/cm) |  |
| 444.5                  | 52.49                 | 7,727                    |  |
| 429.7                  | 53.79                 | 7,427                    |  |
| 485.8                  | 63.41                 | 3,071                    |  |
| 391.1                  | 51.65                 | 7,749                    |  |
| 490.2                  | 52.94                 | 9,316                    |  |
| 448.3                  | 54.86                 | 7,058                    |  |
| 41.2                   | 4.84                  | 2,348                    |  |
| Average                |                       |                          |  |
| Std. Dev.              |                       |                          |  |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed at grip edge.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° Strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.
- (7) Strain gage failed prematurely due to ply failure.
- (8) Tested without tabs.

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS, GRAPHITE REINFORCEMENT, BATCH 2, FILL DIRECTION, 93°C (200°F) WET

Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95–100% R.H.
- (7) Testd without tabs.
- (8) Failed at grip edge.

TABLE D.48

INDIVIDUAL SPECIMEN TENSILE TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, FILL DIRECTION, 93°C (200°F) WET

| Test :          |                 | Straight sided tension; ASTM-D3039 |                 |                     |                         | Fiber Orientation :    |                          | Fill            |             |             |
|-----------------|-----------------|------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite         |                 |                     |                         | Tested by :            |                          |                 | PM & DH     |             |
|                 |                 | Batch #3                           |                 |                     |                         | Task #3                |                          |                 |             |             |
|                 |                 | Ultimate                           |                 |                     |                         |                        |                          |                 |             |             |
| Specimen Number | Test Conditions | Width (in.)                        | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) | Poisson's Ratio | Date Tested | Remarks     |
| BIL-GR-9-6      | 200°F (WET)     | 0.999                              | 0.1203          | 7,598               | 63.22                   | 8.047                  | 7.939                    |                 | 1/23/90     | (1,3,5,6,7) |
| BIL-GR-9-12     | "               | 0.999                              | 0.1197          | 7,715               | 64.50                   | 8.091                  | 7.603                    | 0.085           | 9/13/89     | (1,3,4,6)   |
| BIL-GR-10-3     | "               | 1.001                              | 0.1132          | 8,169               | 72.13                   | 7.596                  | 6,929                    |                 | 1/23/90     | (3,5,6,7,8) |
| BIL-GR-10-10    | "               | 0.998                              | 0.1197          | 7,705               | 64.47                   | 8.027                  | 5,339                    |                 | 9/14/89     | (1,3,5,6)   |
| BIL-GR-10-12    | "               | 1.002                              | 0.1181          | 7,019               | 59.31                   | 7.014                  | 8,540                    | 0.066           | 1/23/90     | (1,3,4,6)   |
| BIL-GR-10-16    | "               | 0.998                              | 0.1122          | 7,202               | 64.31                   | 8.766                  | 5,522                    | 0.048           | 9/13/89     | (1,3,4,6)   |
|                 |                 |                                    |                 |                     | Average                 | 7.923                  | 6,979                    | 0.067           |             |             |
|                 |                 |                                    |                 |                     | Std. Dev.               | 0.583                  | 1,308                    | 0.018           |             |             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H.
- (7) Tested without tabs.
- (8) Failed at grip edge.

| SI Conversion          |                       |                                |  |
|------------------------|-----------------------|--------------------------------|--|
| Ultimate               |                       |                                |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |  |
| 435.9                  | 55.48                 | 7,939                          |  |
| 444.7                  | 55.79                 | 7,603                          |  |
| 497.3                  | 52.37                 | 6,929                          |  |
| 444.5                  | 55.34                 | 5,339                          |  |
| 409.0                  | 48.36                 | 8,540                          |  |
| 443.4                  | 60.44                 | 5,522                          |  |
| 445.8                  | 54.63                 | 6,979                          |  |
| 28.7                   | 4.02                  | 1,308                          |  |
| Average                |                       |                                |  |
| Std. Dev.              |                       |                                |  |

## APPENDIX E

### INDIVIDUAL SPECIMEN COMPRESSION PROPERTIES, BASELINE

The 48 tables in this appendix present the detailed mechanical property test data measured during this program for each baseline specimen tested in compression. A summary of these data was presented and discussed in Section 3.2.2. Two types of compressive failure modes are referred to in this Appendix. Figure E.1 illustrates the type of failure behavior associated with each verbal description.

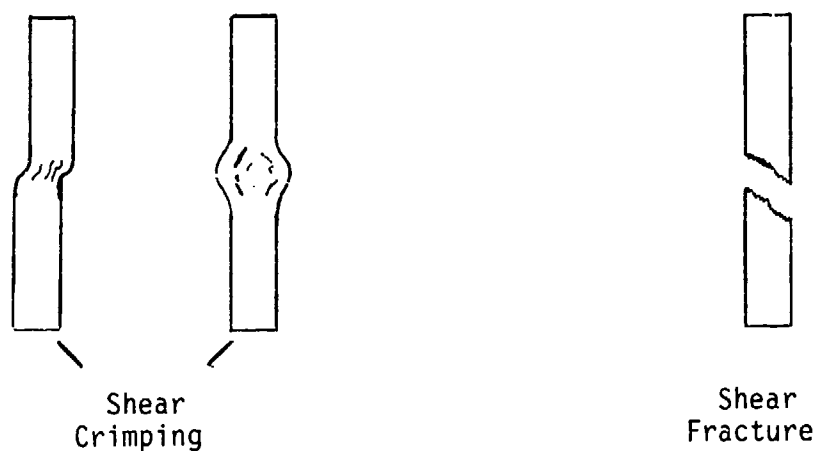


Figure E.1. Types of Compressive Failure Modes Observed.



TABLE E.1

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, WARP DIRECTION, BATCH 1, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: |                                | Warp                     |             |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------|--------------------------------|--------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 |                     |                             | Tested By:         |                                | PM                       |             |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                    | Initial Tangent Modulus (Msi.) | Ultimate Strain (μin/in) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) |                    |                                |                          |             |         |
| BIL-GL-8-17     | 72°F (DRY)      | 1.001                         | 0.1317          | 6,140               | 46.58                       |                    | 3.635                          | 13,506                   | 6/20/89     | (1,4,5) |
| BIL-GL-8-19     | "               | 0.998                         | 0.1311          | 5,960               | 53.18                       |                    | 3.665                          | 13,608                   | 6/21/89     | (1,4)   |
| BIL-GL-8-22     | "               | 1.003                         | 0.1369          | 6,025               | 43.89                       |                    | 3.168                          | 19,585                   | "           | (1,2,4) |
| BIL-GL-8-24     | "               | 1.004                         | 0.1372          | 7,104               | 51.60                       |                    | 4.110                          | 14,876                   | "           | (1,4)   |
| BIL-GL-8-25     | "               | 1.003                         | 0.1375          | 6,721               | 48.74                       |                    | 3.597                          | 13,857                   | "           | (1,4)   |
| Average         |                 |                               |                 |                     | 48.80                       |                    | 3.635                          | 15,086                   |             |         |
| Std. Dev.       |                 |                               |                 |                     | 3.74                        |                    | 0.334                          | 2,573                    |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (3) Failed outside gage section.
- (4) Test speed = 0.05 in/min.
- (5) Specimen did not fail; tab debonded.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 321.2                               | 25.06                         | 13,506                   |  |
| 366.7                               | 25.27                         | 13,608                   |  |
| 302.6                               | 21.84                         | 19,585                   |  |
| 355.8                               | 28.34                         | 14,876                   |  |
| 336.0                               | 24.80                         | 13,857                   |  |
| Average                             | 25.06                         | 15,086                   |  |
| Std. Dev.                           | 2.30                          | 2,573                    |  |

TABLE E.2

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, WARP DIRECTION, BATCH 2, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 | Fiber Orientation:                   |                                | Warp                    |
|-----------------|-----------------|-------------------------------|-----------------|--------------------------------------|--------------------------------|-------------------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Tested By:                           |                                | PM                      |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.)                  |                                | Remarks                 |
|                 |                 |                               |                 | Batch #2                             | Task #4                        |                         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Ultimate Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) | Ultimate Strain (in/in) |
|                 |                 |                               |                 |                                      |                                |                         |
| BIL-GL-9-17     | 72°F (DRY)      | 1.003                         | 0.1408          | 6,545                                | 3,415                          | 11,704                  |
| BIL-GL-9-19     | "               | 1.003                         | 0.1401          | 6,770                                | 3,693                          | 12,869                  |
| BIL-GL-9-22     | "               | 1.000                         | 0.1348          | 7,473                                | 3,719                          | 14,648                  |
| BIL-GL-9-24     | "               | 1.000                         | 0.1359          | 6,807                                | 3,895                          | 14,392                  |
| BIL-GL-9-25     | "               | 0.998                         | 0.1361          | 6,650                                | 3,897                          | 13,184                  |
| Average         |                 |                               |                 | 49.80                                | 3.724                          | 13,359                  |
| Std. Dev.       |                 |                               |                 | 3.44                                 | 0.197                          | 1,198                   |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                         |         |
|-------------------------------------|-------------------------------|-------------------------|---------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (in/in) | Remarks |
|                                     |                               |                         |         |
| 319.7                               | 23.55                         | 11,704                  |         |
| 332.1                               | 25.46                         | 12,869                  |         |
| 382.4                               | 25.64                         | 14,648                  |         |
| 345.2                               | 26.85                         | 14,392                  |         |
| 337.6                               | 26.87                         | 13,184                  |         |
| Average                             | 343.4                         | 25.68                   | 13,359  |
| Std. Dev.                           | 23.7                          | 1.36                    | 1,198   |

TABLE E.3

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, WARP DIRECTION, BATCH 3, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                |            |             |         |  |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|----------------|------------|-------------|---------|--|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #3            |                             | Task #4                |                | Tested By: |             | Warp    |  |
|                 |                 |                               |                 |                     |                             |                        |                |            |             | BH      |  |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | -Initial       |            | Date Tested | Remarks |  |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (in/in) |            |             |         |  |
| BIL-GL-10(R)-17 | 72°F (DRY)      | 1.003                         | 0.1360          | 6,760               | 49.56                       | 3.512                  | 15,380         | 10/26/89   | (1,3)       |         |  |
| BIL-GL-10(R)-19 | "               | 1.004                         | 0.1320          | 6,430               | 48.52                       | 3.735                  | 16,500         | "          | (1,3)       |         |  |
| BIL-GL-10(R)-22 | "               | 1.002                         | 0.1410          | 7,205               | 51.00                       | 3.663                  | 15,040         | "          | (1,3)       |         |  |
| BIL-GL-10(R)-24 | "               | 1.007                         | 0.1370          | 7,215               | 52.30                       | 3.842                  | 16,600         | "          | (1,3)       |         |  |
| BIL-GL-10(R)-25 | "               | 1.003                         | 0.1420          | 7,145               | 50.17                       | 3.704                  | 14,480         | "          | (1,3)       |         |  |
|                 |                 |                               |                 | Average             |                             | 50.31                  |                | 3.691      |             | 15,600  |  |
|                 |                 |                               |                 | Std. Dev.           |                             | 1.43                   |                | 0.120      |             | 926     |  |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 341.7                               | 24.21                         | 15,380                                |  |
| 334.5                               | 25.75                         | 16,500                                |  |
| 351.6                               | 25.26                         | 15,040                                |  |
| 360.6                               | 26.49                         | 16,600                                |  |
| 345.3                               | 25.54                         | 14,480                                |  |
| Average                             | 25.45                         | 15,600                                |  |
| Std. Dev.                           | 0.83                          | 926                                   |  |

TABLE E.4

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, WARP DIRECTION, BATCH 1, 22°C (72°F) WET

| Test : IITRI Compression; ASTM-D3410 |                 |             |                 | Fiber Orientation:     |                             |                          |
|--------------------------------------|-----------------|-------------|-----------------|------------------------|-----------------------------|--------------------------|
| Material : EA-9396 A/B; 7781 Glass   |                 |             |                 | Tested By: TB          |                             |                          |
| Specimen Number                      | Test Conditions | Width (in.) | Thickness (in.) | Ultimate               |                             | Remarks                  |
|                                      |                 |             |                 | Maximum Load (lbs.)    | Compressive Strength (Ksi.) |                          |
| BIL-GL-8-18                          | 72°F (WET)      | 1.003       | 0.1354          | 3,259                  | 24.01                       | 7,490 1/10/90 (1,3,4,5)  |
| BIL-GL-8-21                          | "               | 1.005       | 0.1458          | 2,515                  | 17.16                       | 7,520 " (1,3,4,5)        |
| BIL-GL-8-23                          | "               | 1.002       | 0.1431          | 3,430                  | 23.92                       | 8,936 " (1,3,4,5)        |
| BIL-GL-8-26                          | "               | 1.007       | 0.1416          | 3,809                  | 26.72                       | 8,076 " (1,3,4,5)        |
| BIL-GL-8-28                          | "               | 1.002       | 0.1424          | 3,856                  | 27.03                       | 10,600 " (1,3,4,5)       |
| Average                              |                 |             |                 | 23.77                  |                             | 8,524                    |
| Std. Dev.                            |                 |             |                 | 3.97                   |                             | 1,300                    |
|                                      |                 |             |                 | Tangent Modulus (Msi.) |                             | Ultimate Strain (μin/in) |
|                                      |                 |             |                 | 3.210                  |                             | 7,490                    |
|                                      |                 |             |                 | 2.563                  |                             | 7,520                    |
|                                      |                 |             |                 | 3.280                  |                             | 8,936                    |
|                                      |                 |             |                 | 3.253                  |                             | 8,076                    |
|                                      |                 |             |                 | 3.044                  |                             | 10,600                   |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 180 days.
- (5) Average weight gain = 1.9643%

| SI Conversion                       |                       |                          |         |
|-------------------------------------|-----------------------|--------------------------|---------|
| Ultimate Compressive Strength (MPa) | Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) | Remarks |
|                                     |                       |                          |         |
| 165.5                               | 22.13                 | 7,490                    |         |
| 118.3                               | 17.67                 | 7,520                    |         |
| 164.9                               | 22.61                 | 8,936                    |         |
| 184.3                               | 22.43                 | 8,076                    |         |
| 186.3                               | 20.99                 | 10,600                   |         |
| Average                             | 163.9                 | 21.17                    | 8,524   |
| Std. Dev.                           | 27.4                  | 2.05                     | 1,300   |

TABLE E.5

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, WARP DIRECTION, BATCH 2, 22°C (72°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 | Fiber Orientation:     |                             | Warp                     |             |
|-----------------|-----------------|-------------------------------|-----------------|------------------------|-----------------------------|--------------------------|-------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #2               |                             | Task #4                  |             |
|                 |                 |                               |                 | Tested By:             |                             | TB                       |             |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Ultimate               |                             | Ultimate Strain (μin/in) | Date Tested |
|                 |                 |                               |                 | Maximum Load (lbs.)    | Compressive Strength (Ksi.) |                          |             |
| BIL-GL-9-18     | 200°F (WET)     | 0.999                         | 0.1454          | 2,295                  | 15.80                       | 5,166                    | 12/5/89     |
| BIL-GL-9-21     | "               | 1.001                         | 0.1400          | 1,636                  | 11.68                       | 5,469                    | "           |
| BIL-GL-9-23     | "               | 1.001                         | 0.1395          | 2,100                  | 15.04                       | 4,775                    | "           |
| BIL-GL-9-26     | "               | 1.001                         | 0.1396          | 1,953                  | 13.98                       | 6,572                    | "           |
| BIL-GL-9-28     | "               | 1.000                         | 0.1400          | 1,794                  | 12.82                       | 4,160                    | "           |
| Average         |                 |                               |                 | 13.86                  |                             | 5,229                    |             |
| Std. Dev.       |                 |                               |                 | 1.66                   |                             | 896                      |             |
|                 |                 |                               |                 | Initial                |                             |                          | Remarks     |
|                 |                 |                               |                 | Tangent Modulus (Msi.) | Strain                      |                          |             |
|                 |                 |                               |                 | 3.132                  |                             |                          | (3,4,5)     |
|                 |                 |                               |                 | 2.969                  |                             |                          | (3,4,5)     |
|                 |                 |                               |                 | 3.074                  |                             |                          | (3,4,5)     |
|                 |                 |                               |                 | 2.763                  |                             |                          | (3,4,5)     |
|                 |                 |                               |                 | 3.307                  |                             |                          | (3,4,5)     |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 143 days.
- (5) Average weight gain = 2.3264%

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 108.9                               | 21.60                         | 5,166                    |  |
| 80.5                                | 20.47                         | 5,469                    |  |
| 103.7                               | 21.19                         | 4,775                    |  |
| 96.4                                | 19.05                         | 6,572                    |  |
| 88.4                                | 22.80                         | 4,160                    |  |
| Average                             | 21.02                         | 5,229                    |  |
| Std. Dev.                           | 1.39                          | 896                      |  |

TABLE E.6

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, WARP DIRECTION, BATCH 3, 22°C (72°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |             | Warp             |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|-------------|------------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 |                     |                             | Tested By:             |             | RG               |
|                 |                 | Batch #3                      |                 | Task #4             |                             |                        |             |                  |
|                 |                 |                               |                 |                     |                             | Warp                   |             |                  |
|                 |                 |                               |                 |                     |                             | RG                     |             |                  |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Date Tested | Remarks          |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |             |                  |
| BIL-GL-10(R)-18 | 72°F (WET)      | 1.004                         | 0.1350          | 3,418               | 25.22                       | 3.395                  | 8,262       | 1/5/90 (1,3,4,5) |
| BIL-GL-10(R)-21 | "               | 1.001                         | 0.1370          | 3,687               | 26.88                       | 3.308                  | 7,920       | " (1,3,4,5)      |
| BIL-GL-10(R)-23 | "               | 1.002                         | 0.1410          | 3,711               | 26.27                       | 2.921                  | 10,495      | " (1,3,4,5)      |
| BIL-GL-10(R)-26 | "               | 1.002                         | 0.1430          | 3,809               | 26.58                       | 3.854                  | 6,182       | " (1,3,4,5)      |
| BIL-GL-10(R)-28 | "               | 1.003                         | 0.1420          | 3,174               | 22.28                       | 3.618                  | 5,850       | " (1,3,4,5)      |
|                 |                 |                               |                 | Average             | 25.45                       | 3.419                  | 7,742       |                  |
|                 |                 |                               |                 | Std. Dev.           | 1.88                        | 0.350                  | 1,864       |                  |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/55-100% R.H. for 68 days.
- (5) Average weight gain = 1.6754%

| SI Conversion              |                       |                            |                       |
|----------------------------|-----------------------|----------------------------|-----------------------|
| Ultimate                   |                       | Initial                    |                       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Compressive Strength (MPa) | Tangent Modulus (GPa) |
| 173.9                      | 23.41                 | 8,262                      | 22.81                 |
| 185.4                      | 22.81                 | 7,920                      | 20.14                 |
| 181.1                      | 20.14                 | 10,495                     | 26.58                 |
| 183.3                      | 26.58                 | 6,182                      | 24.94                 |
| 153.6                      | 24.94                 | 5,850                      |                       |
| Average                    | 175.5                 | 23.58                      | 7,742                 |
| Std. Dev.                  | 12.9                  | 2.41                       | 1,864                 |

TABLE E.7

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 1, -54°C (-65°F) DRY

| Test : IITRI Compression; ASTM-D3410 |                 |             |                 | Fiber Orientation: Fill |                             |                                |             |               |
|--------------------------------------|-----------------|-------------|-----------------|-------------------------|-----------------------------|--------------------------------|-------------|---------------|
| Material : EA-9396 A/B; 7781 Glass   |                 | Batch #1    | Task #5         | Tested By: PM           |                             |                                |             |               |
| Specimen Number                      | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.)     | Ultimate                    |                                | Date Tested | Remarks       |
|                                      |                 |             |                 |                         | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |             |               |
| BIL-GL-7-4                           | -65°F (DRY)     | 1.000       | 0.1325          | 8,671                   | 65.43                       | 4.042                          | 19,170      | 5/1/89 (1,3)  |
| BIL-GL-7-25                          | "               | 1.002       | 0.1361          | 9,293                   | 68.15                       | 3.903                          | 16,545      | " (1,3)       |
| BIL-GL-7-47                          | "               | 1.002       | 0.1309          | 8,979                   | 68.46                       | 4.139                          | 16,935      | " (1,3)       |
| BIL-GL-8-11                          | "               | 1.003       | 0.1359          | 7,898                   | 57.92                       | 4.057                          | 17,512      | 6/22/89 (1,3) |
| BIL-GL-8-40                          | "               | 1.004       | 0.1385          | 8,450                   | 60.75                       | 3.924                          | 17,395      | " (1,3)       |
|                                      |                 |             |                 | Average                 | 64.14                       | 4.013                          | 17,511      |               |
|                                      |                 |             |                 | Std. Dev.               | 4.65                        | 0.099                          | 1,004       |               |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                         |        |
|-------------------------------------|-------------------------------|-------------------------|--------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μm/cm) |        |
| 451.2                               | 27.87                         | 19,170                  |        |
| 469.9                               | 26.91                         | 16,545                  |        |
| 472.0                               | 28.54                         | 16,935                  |        |
| 399.4                               | 27.98                         | 17,512                  |        |
| 418.9                               | 27.06                         | 17,395                  |        |
| Average                             | 442.3                         | 27.67                   | 17,511 |
| Std. Dev.                           | 32.1                          | 0.68                    | 1,004  |

TABLE E.8

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 2, -54°C (-65°F) DRY

| Test :          |                 | IITRI Compression, ASTM-D3410 |                 | Fiber Orientation:     |                             | Fill          |
|-----------------|-----------------|-------------------------------|-----------------|------------------------|-----------------------------|---------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #2 Task #5       |                             | PM            |
|                 |                 |                               |                 | Tested By:             |                             |               |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Ultimate               |                             | Remarks       |
|                 |                 |                               |                 | Maximum Load (lbs.)    | Compressive Strength (Ksi.) |               |
| BIL-GL-9-4      | -65°F (DRY)     | 1.002                         | 0.1380          | 7,969                  | 57.61                       | 6/22/83 (1,3) |
| BIL-GL-9-11     | "               | 1.002                         | 0.1329          | 7,429                  | 55.80                       | " (1,3)       |
| BIL-GL-9-30     | "               | 1.002                         | 0.1339          | 7,683                  | 57.25                       | " (1,3)       |
| BIL-GL-9-37     | "               | 1.005                         | 0.1361          | 8,171                  | 59.77                       | " (1,3)       |
| BIL-GL-9-41     | "               | 1.005                         | 0.1360          | 7,854                  | 57.47                       | " (1,3)       |
|                 |                 |                               |                 | Average                | 57.58                       | 14,622        |
|                 |                 |                               |                 | Std. Dev.              | 1.42                        | 953           |
|                 |                 |                               |                 | Initial                |                             |               |
|                 |                 |                               |                 | Tangent Modulus (Msi.) | Ultimate Strain (μin/in)    |               |
|                 |                 |                               |                 | 4,138                  | 15,960                      | 6/22/83 (1,3) |
|                 |                 |                               |                 | 4,348                  | 13,433                      | " (1,3)       |
|                 |                 |                               |                 | 4,545                  | 14,070                      | " (1,3)       |
|                 |                 |                               |                 | 3,626                  | 14,971                      | " (1,3)       |
|                 |                 |                               |                 | 4,276                  | 14,678                      | " (1,3)       |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                       |                          |  |
|-------------------------------------|-----------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                       |                          |  |
| 397.2                               | 28.53                 | 15,960                   |  |
| 384.7                               | 29.98                 | 13,433                   |  |
| 394.7                               | 31.34                 | 14,070                   |  |
| 412.1                               | 25.00                 | 14,971                   |  |
| 396.2                               | 29.48                 | 14,678                   |  |
| Average                             | 28.87                 | 14,622                   |  |
| Std. Dev.                           | 2.39                  | 953                      |  |



INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS, GLASS REINFORCEMENT, FILL DIRECTION, BATCH 3, -54°C (-65°F) DRY

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

|           | SI Conversion                                |                                        |                                             |
|-----------|----------------------------------------------|----------------------------------------|---------------------------------------------|
|           | Ultimate<br>Compressive<br>Strength<br>(MPa) | Initial<br>Tangent<br>Modulus<br>(GPa) | Ultimate<br>Strain<br>( $\mu\text{cm/cm}$ ) |
|           | 487.7                                        | 30.82                                  | 16,924                                      |
|           | 447.1                                        | 29.04                                  | 18,994                                      |
|           | 502.7                                        | 29.95                                  | 17,305                                      |
|           | 506.6                                        | 30.08                                  | 20,800                                      |
|           | 460.5                                        | 30.09                                  | 16,582                                      |
| Average   | 480.9                                        | 30.00                                  | 18,121                                      |
| Std. Dev. | 26.2                                         | 0.64                                   | 1,761                                       |

TABLE E.10

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 1, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: |                                | Fill                                  |             |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------|--------------------------------|---------------------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 |                     |                             | Tested By:         |                                |                                       | PM          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                    | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) |                    |                                |                                       |             |         |
| BIL-GL-7-2      | 72°F (DRY)      | 1.001                         | 0.1357          | 5,986               | 44.07                       |                    | 3,549                          | 9,345                                 | 5/1/89      | (1,4)   |
| BIL-GL-7-23     | "               | 1.002                         | 0.1347          | 6,214               | 46.03                       |                    | 3,783                          | 13,710                                | "           | (1,2,4) |
| BIL-GL-7-45     | "               | 1.002                         | 0.1283          | 5,143               | 40.02                       |                    | 3,863                          | 14,115                                | "           | (1,2,4) |
| BIL-GL-8-9      | "               | 1.004                         | 0.1335          | 5,000               | 37.32                       |                    | 3,862                          | 10,400                                | 6/20/89     | (1,4)   |
| BIL-GL-8-38     | "               | 1.001                         | 0.1351          | 5,547               | 41.00                       |                    | 3,880                          | 10,781                                | "           | (1,2,4) |
| Average         |                 |                               |                 | 41.69               |                             |                    | 3,788                          | 11,670                                |             |         |
| Std. Dev.       |                 |                               |                 | 3.42                |                             |                    | 0.138                          | 2,118                                 |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (3) Specimen failed outside gage section.
- (4) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
|                                     |                               |                                       |  |
| 303.8                               | 24.47                         | 9,345                                 |  |
| 317.4                               | 26.09                         | 13,710                                |  |
| 275.9                               | 26.64                         | 14,115                                |  |
| 257.3                               | 26.63                         | 10,400                                |  |
| 282.7                               | 26.75                         | 10,781                                |  |
| Average                             | 26.12                         | 11,670                                |  |
| Std. Dev.                           | 0.95                          | 2,118                                 |  |

TABLE E.11

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 2, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; AL "M-D3410 |                 |                     | Fiber Orientation:          |                        |             |
|-----------------|-----------------|--------------------------------|-----------------|---------------------|-----------------------------|------------------------|-------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass        |                 |                     | Tested By:                  |                        |             |
|                 |                 | Batch #2                       |                 |                     | Task #5                     |                        |             |
| Specimen Number | Test Conditions | Width (in.)                    | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Date Tested |
|                 |                 |                                |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |             |
| BIL-GL-9-2      | 72°F (DRY)      | 1.004                          | 0.1351          | 5,396               | 39.80                       | 3.388                  | 6/26/89     |
| BIL-GL-9-9      | "               | 1.002                          | 0.1351          | 5,134               | 37.95                       | 3.676                  | "           |
| BIL-GL-9-16     | "               | 1.004                          | 0.1305          | 5,083               | 38.80                       | 3.873                  | "           |
| BIL-GL-9-35     | "               | 1.003                          | 0.1332          | 5,823               | 43.58                       | 3.433                  | "           |
| BIL-GL-9-44     | "               | 1.003                          | 0.1338          | 4,736               | 35.29                       | 3.581                  | "           |
| Average         |                 |                                |                 |                     | 39.08                       | 3.590                  | 11,725      |
| Std. Dev.       |                 |                                |                 |                     | 3.02                        | 0.195                  | 2,050       |
|                 |                 |                                |                 |                     |                             |                        | 9,360       |
|                 |                 |                                |                 |                     |                             |                        | 11,543      |
|                 |                 |                                |                 |                     |                             |                        | 10,730      |
|                 |                 |                                |                 |                     |                             |                        | 14,898      |
|                 |                 |                                |                 |                     |                             |                        | 12,092      |
|                 |                 |                                |                 |                     |                             |                        | (1,3)       |
|                 |                 |                                |                 |                     |                             |                        | (1,3)       |
|                 |                 |                                |                 |                     |                             |                        | (1,3)       |
|                 |                 |                                |                 |                     |                             |                        | (1,3)       |
|                 |                 |                                |                 |                     |                             |                        | (1,3)       |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                       |                                       |             |
|-------------------------------------|-----------------------|---------------------------------------|-------------|
| Ultimate Compressive Strength (MPa) | Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) | Date Tested |
|                                     |                       |                                       |             |
| 274.4                               | 23.36                 | 9,360                                 |             |
| 261.6                               | 25.35                 | 11,543                                |             |
| 267.5                               | 26.70                 | 10,730                                |             |
| 300.5                               | 23.67                 | 14,898                                |             |
| 243.3                               | 24.69                 | 12,092                                |             |
| Average                             | 269.5                 | 24.75                                 | 11,725      |
| Std. Dev.                           | 20.8                  | 1.35                                  | 2,050       |

TABLE E.12

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 3, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                          | Fill        |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|--------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #3            | Task #5                     | Tested By:             |                          | BH          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Ultimate Strain (µin/in) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |                          |             |         |
| BIL-GL-10(R)-2  | 72°F (DRY)      | 1.002                         | 0.1340          | 5,110               | 38.06                       | 3.929                  | 9,020                    | 10/26/89    | (1,3)   |
| BIL-GL-10(R)-9  | "               | 0.997                         | 0.1370          | 5,510               | 40.34                       | 3.130                  | 17,800                   | "           | (1,3)   |
| BIL-GL-10(R)-16 | "               | 1.001                         | 0.1400          | 5,975               | 42.64                       | 3.336                  | 12,240                   | "           | (1,3)   |
| BIL-GL-10(R)-35 | "               | 1.007                         | 0.1390          | 6,310               | 45.08                       | 3.715                  | 11,420                   | "           | (1,3)   |
| BIL-GL-10(R)-44 | "               | 1.006                         | 0.1360          | 5,840               | 42.69                       | 3.874                  | 10,752                   | "           | (1,3)   |
| Average         |                 |                               |                 |                     | 41.76                       | 3.597                  | 12,246                   |             |         |
| Std. Dev.       |                 |                               |                 |                     | 2.66                        | 0.349                  | 3,323                    |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)  
 (2) Specimen failed outside gage section.  
 (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (µcm/cm) |  |
| 262.4                               | 27.09                         | 9,020                    |  |
| 278.1                               | 21.58                         | 17,800                   |  |
| 294.0                               | 23.00                         | 12,240                   |  |
| 310.8                               | 25.61                         | 11,420                   |  |
| 294.3                               | 26.71                         | 10,752                   |  |
| Average                             | 24.80                         | 12,246                   |  |
| Std. Dev.                           | 2.41                          | 3,323                    |  |

TABLE E.13

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 1, 93°C (200°F) DRY

| Test :          |                 |             |                 | IITRI Compression; ASTM-D3410 |                             |                        | Fiber Orientation:    |             |         | Fill |
|-----------------|-----------------|-------------|-----------------|-------------------------------|-----------------------------|------------------------|-----------------------|-------------|---------|------|
| Material :      |                 |             |                 | EA-9396 A/B; 7781 Glass       |                             |                        | Tested By:            |             |         | PM   |
|                 |                 |             |                 | Batch #1                      |                             | Task #5                |                       |             |         |      |
| Specimen Number | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.)           | Ultimate                    |                        | Initial               |             | Remarks |      |
|                 |                 |             |                 |                               | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain ( $\mu$ in/in) | Date Tested |         |      |
| GL8-10          | 200°F (DRY)     | 1.004       | 0.1345          | 3,805                         | 28.17                       | 3.530                  | 9,360                 | 6/26/89     | (1,3)   |      |
| GL8-39          | "               | 1.004       | 0.1382          | 3,848                         | 27.72                       | 3.412                  | 9,119                 | "           | (1,3)   |      |
| Average         |                 |             |                 | 27.95                         |                             | 3.471                  | 9,240                 |             |         |      |
| Std. Dev.       |                 |             |                 | 0.32                          |                             | 0.083                  | 171                   |             |         |      |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear Fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion              |                                       |                       |                                       |
|----------------------------|---------------------------------------|-----------------------|---------------------------------------|
| Ultimate                   |                                       | Initial               |                                       |
| Compressive Strength (MPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) | Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |
| 194.3                      | 9,360                                 | 24.34                 | 9,360                                 |
| 191.2                      | 9,119                                 | 23.53                 | 9,119                                 |
| Average 192.7              | 9,240                                 | 23.93                 | 9,240                                 |
| Std. Dev. 2.2              | 171                                   | 0.58                  | 171                                   |

TABLE E.14

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 2, 93°C (200°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                                      | Fiber Orientation:             |                                       |             |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|--------------------------------------|--------------------------------|---------------------------------------|-------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #2            | Task #5                              | Tested By:                     |                                       | PM          |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested |
| BIL-GL-9-3      | 200°F (DRY)     | 1.003                         | 0.1375          | 3,225               | 23.39                                | 3.753                          | 7,280                                 | 6/23/89     |
| BIL-GL-9-10     | "               | 1.002                         | 0.1320          | 3,318               | 25.09                                | 3.373                          | 7,537                                 | "           |
| BIL-GL-9-29     | "               | 1.003                         | 0.1265          | 2,975               | 23.45                                | 3.399                          | 6,658                                 | "           |
| BIL-GL-9-36     | "               | 1.003                         | 0.1359          | 3,661               | 26.85                                | 3.257                          | 9,229                                 | "           |
| BIL-GL-9-40     | "               | 1.006                         | 0.1377          | 3,656               | 26.39                                | 2.985                          | 6,548                                 | "           |
| Average         |                 |                               |                 |                     | 25.04                                | 3.353                          | 7,450                                 |             |
| Std. Dev.       |                 |                               |                 |                     | 1.61                                 | 0.277                          | 1,077                                 |             |

E-15

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 161.3                               | 25.88                         | 7,280                                 |  |
| 173.0                               | 23.25                         | 7,537                                 |  |
| 161.7                               | 23.44                         | 6,658                                 |  |
| 185.2                               | 22.46                         | 9,229                                 |  |
| 182.0                               | 20.58                         | 6,548                                 |  |
| Average                             | 23.12                         | 7,450                                 |  |
| Std. Dev.                           | 1.91                          | 1,077                                 |  |

TABLE E.15

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 3, 93°C (200°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     | Fiber Orientation:                   |                                       |                    |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|--------------------------------------|---------------------------------------|--------------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 |                     | Tested By:                           |                                       |                    |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) |                                       | Remarks            |
|                 |                 |                               |                 |                     | Initial Tangent Modulus (Msi.)       | Ultimate Strain ( $\mu\text{in/in}$ ) |                    |
| BIL-GL-10(R)-3  | 200°F (DRY)     | 1.009                         | 0.1350          | 4,248               | 31.19                                | 3.827                                 | 7,500 1/2/90 (1,3) |
| BIL-GL-10(R)-10 | "               | 0.997                         | 0.1380          | 4,712               | 34.25                                | 3.244                                 | 12,412 " (1,3)     |
| BIL-GL-10(R)-29 | "               | 0.998                         | 0.1350          | 4,346               | 32.25                                | 3.752                                 | 8,369 " (1,3)      |
| BIL-GL-10(R)-36 | "               | 1.011                         | 0.1390          | 4,529               | 32.23                                | 3.621                                 | 9,775 " (1,3)      |
| BIL-GL-10(R)-40 | "               | 1.010                         | 0.1350          | 5,075               | 37.22                                | 3.667                                 | 10,070 " (1,3)     |
| Average         |                 |                               |                 |                     | 33.43                                | 3.622                                 | 9,625              |
| Std. Dev.       |                 |                               |                 |                     | 2.39                                 | 0.226                                 | 1,876              |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
|                                     |                               |                                       |  |
| 215.0                               | 26.39                         | 7,500                                 |  |
| 236.1                               | 22.37                         | 12,412                                |  |
| 222.4                               | 25.87                         | 8,369                                 |  |
| 222.2                               | 24.97                         | 9,775                                 |  |
| 256.6                               | 25.28                         | 10,070                                |  |
| Average                             | 24.98                         | 9,625                                 |  |
| Std. Dev                            | 1.56                          | 1,876                                 |  |

TABLE E.16

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 1, -54°C (-65°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: Fill |                         |             |           |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|-------------------------|-------------------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 |                     |                             | Tested By: TB           |                         |             |           |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Ultimate            |                             | Initial                 |                         | Date Tested | Remarks   |
|                 |                 |                               |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.) | Tangent Modulus (Msi.)  | Ultimate Strain (in/in) |             |           |
| BIL-GL-7-1      | -65°F (WET)     | 1.001                         | 0.1306          | 5,906               | 45.17                       | 4.111                   | 10,450                  | 1/10/90     | (1,3,4,5) |
| BIL-GL-7-22     | "               | 1.000                         | 0.1351          | 7,019               | 51.94                       | 4.295                   | 13,848                  | "           | (1,3,4,5) |
| BIL-GL-7-44     | "               | 1.002                         | 0.1306          | 6,482               | 49.55                       | 4.171                   | 10,313                  | "           | (1,3,4,5) |
| BIL-GL-8-8      | "               | 1.004                         | 0.1385          | 5,786               | 41.61                       | 4.130                   | 12,969                  | "           | (1,3,4,6) |
| BIL-GL-8-37     | "               | 1.003                         | 0.1425          | 6,200               | 43.40                       | 3.872                   | 13,400                  | "           | (1,3,4,6) |
|                 |                 |                               |                 | Average             | 46.34                       | 4.116                   | 12,196                  |             |           |
|                 |                 |                               |                 | Std. Dev.           | 4.30                        | 0.154                   | 1,686                   |             |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 180 days.
- (5) Weight gain = 1.6916%
- (6) Weight gain = 1.9759%

| SI Conversion                       |                               |                          |        |
|-------------------------------------|-------------------------------|--------------------------|--------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |        |
| 311.5                               | 28.35                         | 10,450                   |        |
| 358.1                               | 29.61                         | 13,848                   |        |
| 341.7                               | 28.76                         | 10,313                   |        |
| 286.9                               | 28.48                         | 12,969                   |        |
| 299.2                               | 26.70                         | 13,400                   |        |
| Average                             | 319.5                         | 28.38                    | 12,196 |
| Std. Dev.                           | 29.7                          | 1.06                     | 1,686  |



TABLE E.17

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 2, -54°C (-65°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: Fill |                          |             |           |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|-------------------------|--------------------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #2            | Task #5                     | Tested By: TB           |                          |             |           |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                         | Ultimate Strain (µin/in) | Date Tested | Remarks   |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.)  |                          |             |           |
| BIL-GL-9-1      | -65°F (WET)     | 1.002                         | 0.1341          | 5,322               | 39.61                       | 3,783                   | 9,893                    | 1/10/90     | (1,3,4,5) |
| BIL-GL-9-8      | "               | 1.002                         | 0.1376          | 6,113               | 44.33                       | 3,876                   | 10,685                   | "           | (1,3,4,5) |
| BIL-GL-9-15     | "               | 1.002                         | 0.1419          | 5,481               | 38.55                       | 3,410                   | 12,324                   | "           | (1,3,4,5) |
| BIL-GL-9-34     | "               | 1.003                         | 0.1393          | 6,433               | 46.04                       | 4,359                   | 11,289                   | "           | (1,3,4,5) |
| BIL-GL-9-43     | "               | 1.002                         | 0.1394          | 6,628               | 47.44                       | 3,975                   | 12,461                   | "           | (1,3,4,5) |
| Average         |                 |                               |                 |                     | 43.19                       | 3,881                   | 11,330                   |             |           |
| Std. Dev.       |                 |                               |                 |                     | 3.93                        | 0.342                   | 1,090                    |             |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 180 days.
- (5) Weight gain = 2.0685%

| SI Conversion              |       |                       |                          |
|----------------------------|-------|-----------------------|--------------------------|
| Ultimate                   |       | Initial               |                          |
| Compressive Strength (MPa) |       | Tangent Modulus (GPa) | Ultimate Strain (µcm/cm) |
| 273.1                      | 26.08 | 26.72                 | 9,893                    |
| 305.7                      | 26.72 | 23.51                 | 10,685                   |
| 265.8                      | 23.51 | 30.06                 | 12,324                   |
| 317.4                      | 30.06 | 27.41                 | 11,289                   |
| 327.1                      | 27.41 | 26.76                 | 12,461                   |
| Average                    | 297.8 | 26.76                 | 11,330                   |
| Std. Dev.                  | 27.1  | 2.36                  | 1,090                    |

TABLE E.18

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 3, -54°C (-65°F) WET

| Test : IITRI Compression; ASTM-D3410 |                 |             |                 | Fiber Orientation:             |                                      |
|--------------------------------------|-----------------|-------------|-----------------|--------------------------------|--------------------------------------|
| Material : EA-9396 A/B; 7781 Glass   |                 |             |                 | Tested By:                     | RG                                   |
| Specimen Number                      | Test Conditions | Width (in.) | Thickness (in.) | Batch #3 Task #5               |                                      |
|                                      |                 |             |                 | Maximum Load (lbs.)            | Ultimate Compressive Strength (Ksi.) |
|                                      |                 |             |                 | Initial Tangent Modulus (Msi.) | Ultimate Strain (in/in)              |
|                                      |                 |             |                 |                                | Date Tested                          |
| BIL-GL-10(R)-4                       | -65°F (WET)     | 1.004       | 0.1360          | 4.221                          | 13,916                               |
| BIL-GL-10(R)-11                      | "               | 0.995       | 0.1370          | 3.984                          | 15,693                               |
| BIL-GL-10(R)-30                      | "               | 1.001       | 0.1340          | 4.459                          | 13,721                               |
| BIL-GL-10(R)-37                      | "               | 1.005       | 0.1370          | 4.046                          | 11,777                               |
| BIL-GL-10(R)-41                      | "               | 1.004       | 0.1370          | 4.427                          | 13,057                               |
| Average                              |                 |             |                 | 4.227                          | 13,633                               |
| Std. Dev.                            |                 |             |                 | 0.215                          | 1,424                                |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 68 days.
- (5) Weight gain = 1.7721%

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 345.2                               | 29.11                         | 13,916                   |  |
| 386.5                               | 27.47                         | 15,693                   |  |
| 323.8                               | 30.74                         | 13,721                   |  |
| 329.5                               | 27.90                         | 11,777                   |  |
| 338.4                               | 30.52                         | 13,057                   |  |
| Average                             | 29.15                         | 13,633                   |  |
| Std. Dev.                           | 1.48                          | 1,424                    |  |

TABLE E.19

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 1, 22°C (72°F) WET

| IITRI Compression; ASTM-D3410 |                 |                         |                 |                     |                             |                        |                 |        |             | Fiber Orientation: |  |
|-------------------------------|-----------------|-------------------------|-----------------|---------------------|-----------------------------|------------------------|-----------------|--------|-------------|--------------------|--|
| Test :                        |                 | EA-9396 A/B; 7781 Glass |                 |                     |                             |                        |                 |        |             | Fill               |  |
| Material :                    |                 | Batch #1                |                 | Task #5             |                             | Tested By:             |                 |        |             | TB                 |  |
| Specimen Number               | Test Conditions | Width (in.)             | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Initial         |        | Date Tested | Remarks            |  |
|                               |                 |                         |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (μin/in) |        |             |                    |  |
| BIL-GL-7-5                    | 72°F (WET)      | 1.001                   | 0.1308          | 3,174               | 24.24                       | 3.385                  | 6,172           | 1/4/90 | (1,3,4,5)   |                    |  |
| BIL-GL-7-26                   | "               | 1.000                   | 0.1345          | 3,186               | 23.70                       | 3.276                  | 8,945           | "      | (1,3,4,5)   |                    |  |
| BIL-GL-7-48                   | "               | 1.003                   | 0.1301          | 2,466               | 18.90                       | 3.320                  | 8,750           | "      | (1,3,4,5)   |                    |  |
| BIL-GL-8-12                   | "               | 1.004                   | 0.1422          | 2,991               | 20.94                       | 3.335                  | 4,570           | "      | (1,3,4,6)   |                    |  |
| BIL-GL-8-41                   | "               | 1.004                   | 0.1415          | 2,763               | 19.44                       | 3.232                  | 8,480           | "      | (1,3,4,6)   |                    |  |
| Average                       |                 |                         |                 | 21.44               |                             | 3.310                  |                 | 7,384  |             |                    |  |
| Std. Dev.                     |                 |                         |                 | 2.43                |                             | 0.058                  |                 | 1,929  |             |                    |  |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 143 days.
- (5) Weight gain = 1.4829%
- (6) Weight gain = 2.1793%

| SI Conversion              |                       |                            |                       |
|----------------------------|-----------------------|----------------------------|-----------------------|
| Ultimate                   |                       | Initial                    |                       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Compressive Strength (MPa) | Tangent Modulus (GPa) |
| 167.1                      | 23.34                 | 167.1                      | 23.34                 |
| 163.4                      | 22.59                 | 163.4                      | 22.59                 |
| 130.3                      | 22.89                 | 130.3                      | 22.89                 |
| 144.4                      | 23.00                 | 144.4                      | 23.00                 |
| 134.0                      | 22.29                 | 134.0                      | 22.29                 |
| Average                    | 147.9                 | Average                    | 22.82                 |
| Std. Dev.                  | 16.8                  | Std. Dev.                  | 0.40                  |
|                            |                       |                            | 7,384                 |
|                            |                       |                            | 1,929                 |

TABLE E.20

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 3, 22°C (72°F) WET

| Test : IITRI Compression; ASTM-D3410 |                 |             |                 |                     | Fiber Orientation: Fill     |                        |                                       |             |           |
|--------------------------------------|-----------------|-------------|-----------------|---------------------|-----------------------------|------------------------|---------------------------------------|-------------|-----------|
| Material : EA-9396 A/B; 7781 Glass   |                 |             |                 |                     | Tested By: RG               |                        |                                       |             |           |
| Specimen Number                      | Test Conditions | Width (in.) | Thickness (in.) | Ultimate            |                             | Initial                |                                       | Date Tested | Remarks   |
|                                      |                 |             |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) |             |           |
| BIL-GL-10(R)-5                       | 72°F (WET)      | 1.003       | 0.1360          | 3,137               | 23.00                       | 3,490                  | 9,307                                 | 1/9/90      | (1,3,4,5) |
| BIL-GL-10(R)-12                      | "               | 0.992       | 0.1390          | 3,821               | 27.71                       | 4,568                  | 7,314                                 | "           | (1,3,4,5) |
| BIL-GL-10(R)-31                      | "               | 1.001       | 0.1370          | 3,394               | 24.75                       | 3,261                  | 7,949                                 | "           | (1,3,4,5) |
| BIL-GL-10(R)-38                      | "               | 1.006       | 0.1380          | 3,638               | 26.20                       | 3,355                  | 8,789                                 | "           | (1,3,4,5) |
| BIL-GL-10(R)-42                      | "               | 1.005       | 0.1370          | 3,681               | 26.74                       | 3,405                  | 7,710                                 | "           | (1,3,4,5) |
| Average                              |                 |             |                 | 25.68               |                             | 3,616                  |                                       | 8,214       |           |
| Std. Dev.                            |                 |             |                 | 1.84                |                             | 0.539                  |                                       | 815         |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 68 days.
- (5) Weight gain = 1.7721%

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 158.6                               | 24.06                         | 9,307                                 |  |
| 191.1                               | 31.50                         | 7,314                                 |  |
| 170.6                               | 22.49                         | 7,949                                 |  |
| 180.7                               | 23.13                         | 8,789                                 |  |
| 184.3                               | 23.47                         | 7,710                                 |  |
| Average                             | 24.93                         | 8,214                                 |  |
| Std. Dev.                           | 3.71                          | 815                                   |  |

TABLE E.21

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 1, 93°C (200°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: |                                |                                       |             |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------|--------------------------------|---------------------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #1            | Task #5                     | Tested By:         |                                |                                       | TB          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                    | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) |                    |                                |                                       |             |         |
| BIL-GL-7-6      | 200°F (WET)     | 1.001                         | 0.1335          | 1,917               | 14.34                       |                    | 3.160                          | 4,609                                 | 12/4/89     | (3,4,5) |
| BIL-GL-7-27     | "               | 0.999                         | 0.1333          | 1,978               | 14.85                       |                    | 3.373                          | 4,326                                 | "           | (3,4,5) |
| BIL-GL-8-13     | "               | 1.002                         | 0.1376          | 1,697               | 12.30                       |                    | 3.585                          | 3,896                                 | "           | (3,4,6) |
| BIL-GL-8-42     | "               | 1.002                         | 0.1401          | 1,953               | 13.91                       |                    | 2.827                          | 5,140                                 | "           | (3,4,6) |
|                 |                 |                               |                 | Average             | 13.85                       |                    | 3.236                          | 4,493                                 |             |         |
|                 |                 |                               |                 | Std. Dev.           | 1.10                        |                    | 0.323                          | 521                                   |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 143 days.
- (5) Weight gain = 1.6563%
- (6) Weight gain = 2.0359%

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 98.9                                | 21.79                         | 4,609                                 |  |
| 102.4                               | 23.25                         | 4,326                                 |  |
| 84.8                                | 24.72                         | 3,896                                 |  |
| 95.9                                | 19.49                         | 5,140                                 |  |
| Average                             | 22.31                         | 4,493                                 |  |
| Std. Dev.                           | 2.23                          | 521                                   |  |

TABLE E.22

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 2, 93°C (200°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                                      | Fiber Orientation:             |                                       |             |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|--------------------------------------|--------------------------------|---------------------------------------|-------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 | Batch #2            | Task #5                              | Tested By:                     |                                       | TB          |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested |
| BIL-GL-9-6      | 200°F (WET)     | 1.003                         | 0.1384          | 1,721               | 12.39                                | 2,544                          | 5,352                                 | 12/4/89     |
| BIL-GL-9-13     | "               | 1.004                         | 0.1392          | 1,721               | 12.31                                | 2,806                          | 4,268                                 | "           |
| BIL-GL-9-32     | "               | 1.003                         | 0.1421          | 1,953               | 13.70                                | 3,330                          | 3,838                                 | "           |
| BIL-GL-9-39     | "               | 1.005                         | 0.1405          | 1,672               | 11.84                                | 3,017                          | 3,691                                 | "           |
| BIL-GL-9-33     | "               | 1.002                         | 0.1420          | 2,283               | 16.04                                | 2,316                          | 6,895                                 | 1/18/90     |
|                 |                 |                               |                 | Average             | 13.26                                | 2,803                          | 4,809                                 |             |
|                 |                 |                               |                 | Std. Dev.           | 1.70                                 | 0.396                          | 1,335                                 |             |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 143 days..
- (5) Weight gain = 1.9580%

| SI Conversion                       |  |                               |  |
|-------------------------------------|--|-------------------------------|--|
| Ultimate Compressive Strength (MPa) |  | Initial Tangent Modulus (GPa) |  |
| 85.5                                |  | 17.54                         |  |
| 84.9                                |  | 19.35                         |  |
| 94.4                                |  | 22.96                         |  |
| 81.7                                |  | 20.81                         |  |
| 110.6                               |  | 15.97                         |  |
| Average                             |  | 19.32                         |  |
| Std. Dev.                           |  | 2.73                          |  |

TABLE E.23

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 2, 93°C (200°F) WET

| Test :          |                 | IIITRI Compression: ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                         | Fill              |
|-----------------|-----------------|--------------------------------|-----------------|---------------------|-----------------------------|------------------------|-------------------------|-------------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass        |                 | Batch #2            | Task #5                     | Tested By:             |                         | TB                |
| Specimen Number | Test Conditions | Width (in.)                    | Thickness (in.) | Ultimate            |                             | Initial                |                         | Remarks           |
|                 |                 |                                |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Ultimate Strain (in/in) |                   |
| BIL-GL-9-5      | 200°F (WET)     | 1.001                          | 0.1362          | 1,850               | 13.56                       | 2,979                  | 3,620                   | 12/5/89 (3,4,5,6) |
| BIL-GL-9-12     | "               | 1.002                          | 0.1358          | 1,721               | 12.65                       | 2,862                  | 4,189                   | " (3,4,5,6)       |
| BIL-GL-9-31     | "               | 1.003                          | 0.1404          | 1,660               | 11.80                       | 3,606                  | 3,320                   | " (3,4,5,6)       |
| BIL-GL-9-38     | "               | 1.005                          | 0.1395          | 1,782               | 12.72                       | 2,958                  | 5,500                   | " (3,4,5,6)       |
| BIL-GL-9-42     | "               | 1.002                          | 0.1400          | 1,863               | 13.28                       | 2,897                  | 4,150                   | " (3,4,5,6)       |
|                 |                 |                                |                 | Average             | 12.80                       | 3,060                  | 4,156                   |                   |
|                 |                 |                                |                 | Std. Dev.           | 0.68                        | 0,308                  | 836                     |                   |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 143 days.
- (5) Weight gain = 2.3254%
- (6) These specimens were supposed to have been tested at 72°F(Wet) condition. They were inadvertently tested at 200°F(Wet).

| SI Conversion                       |                               |                          |       |
|-------------------------------------|-------------------------------|--------------------------|-------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |       |
|                                     |                               |                          |       |
| 93.5                                | 20.54                         | 3,620                    |       |
| 87.2                                | 19.73                         | 4,189                    |       |
| 81.3                                | 24.86                         | 3,320                    |       |
| 87.7                                | 20.39                         | 5,500                    |       |
| 91.6                                | 19.98                         | 4,150                    |       |
| Average                             | 88.3                          | 21.10                    | 4,156 |
| Std. Dev.                           | 4.7                           | 2.13                     | 836   |

TABLE E.24

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, FILL DIRECTION, BATCH 3, 93°C (200°F) WET

| Test :          |                 | ILTRI Compression: ASTM-D3410 |                 |                     | Fiber Orientation:          |                                |                        |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|------------------------|
| Material :      |                 | EA-9396 A/B: 7781 Glass       |                 |                     | Tested By:                  |                                |                        |
|                 |                 | Batch #3                      |                 |                     | Task #5                     |                                |                        |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Remarks                |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |                        |
| BIL-GL-10(R)-6  | 200°F (WET)     | 1.003                         | 0.1370          | 2,515               | 18.30                       | 3,673                          | 4,238 1/9/90 (1,3,4,5) |
| BIL-GL-10(R)-32 | "               | 1.001                         | 0.1390          | 2,515               | 18.07                       | 3,915                          | 2,881 " (1,3,4,5)      |
| BIL-GL-10(R)-33 | "               | 1.005                         | 0.1380          | 2,234               | 16.11                       | 2,767                          | 5,801 " (1,3,4,5)      |
| BIL-GL-10(R)-39 | "               | 1.006                         | 0.1400          | 2,393               | 16.99                       | 2,736                          | 5,986 " (1,3,4,5)      |
| Average         |                 |                               |                 |                     | 17.37                       | 3,273                          | 4,727                  |
| Std. Dev.       |                 |                               |                 |                     | 1.02                        | 0.610                          | 1,459                  |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 68 days.
- (5) Weight gain = 1.7721%

| SI Conversion              |       |                       |                          |
|----------------------------|-------|-----------------------|--------------------------|
| Ultimate                   |       | Initial               |                          |
| Compressive Strength (MPa) |       | Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |
| 126.2                      | 25.33 | 4,238                 |                          |
| 124.6                      | 26.99 | 2,881                 |                          |
| 111.1                      | 19.08 | 5,801                 |                          |
| 117.1                      | 18.86 | 5,986                 |                          |
| Average                    | 119.7 | 22.57                 | 4,727                    |
| Std. Dev.                  | 7.0   | 4.21                  | 1,459                    |



TABLE E.25

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, WARP DIRECTION, BATCH 1, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: |                                | Warp                                  |             |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------|--------------------------------|---------------------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Tested By:         |                                |                                       | TB          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                    | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) |                    |                                |                                       |             |         |
| BIL-GR-14-22    | 72°F (DRY)      | 1.003                         | 0.1905          | 14,392              | 75.34                       |                    | 8.388                          | 8,720                                 | 11/14/89    | (1,3)   |
| BIL-GR-14-24    | "               | 1.004                         | 0.1817          | 10,300              | 56.44                       |                    | 8.289                          | 7,330                                 | "           | (1,3)   |
| BIL-GR-14-25    | "               | 1.003                         | 0.1908          | 12,830              | 67.02                       |                    | 6.333                          | 12,830                                | "           | (1,3)   |
| Average         |                 |                               |                 |                     | 66.27                       |                    | 7.670                          | 9,627                                 |             |         |
| Std. Dev.       |                 |                               |                 |                     | 9.47                        |                    | 1.159                          | 2,860                                 |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
|                                     |                               |                                       |  |
| 519.5                               | 57.84                         | 8,720                                 |  |
| 389.2                               | 57.15                         | 7,330                                 |  |
| 462.1                               | 43.67                         | 12,830                                |  |
| Average                             | 52.88                         | 9,627                                 |  |
| Std. Dev.                           | 7.99                          | 2,860                                 |  |

TABLE E.26

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, WARP DIRECTION, BATCH 2, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression: ASTM-D3410 |                 |                     | Fiber Orientation:          |                                |                       |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|-----------------------|
| Material :      |                 | EA-9396 A/B: W133 Graphite    |                 |                     | Tested By:                  |                                |                       |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Remarks               |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |                       |
| BIL-GR-15-17    | 72°F (DRY)      | 1.001                         | 0.1790          | 13,288              | 74.16                       | 8.441                          | 10,580 11/15/89 (1,3) |
| BIL-GR-15-19    | "               | 1.002                         | 0.1800          | 14,163              | 78.52                       | 9.363                          | 8,330 " (1,3)         |
| BIL-GR-15-22    | "               | 1.003                         | 0.1840          | 12,263              | 66.44                       | 8.399                          | 7,150 " (1,3)         |
| BIL-GR-15-24    | "               | 1.002                         | 0.1830          | 13,363              | 72.87                       | 7.226                          | 7,580 " (1,3)         |
| BIL-GR-15-25    | "               | 1.003                         | 0.1770          | 12,122              | 68.28                       | 10.245                         | 6,670 " (1,3)         |
| Average         |                 |                               |                 |                     | 72.06                       | 8.735                          | 8,062                 |
| Std. Dev.       |                 |                               |                 |                     | 4.81                        | 1.135                          | 1,534                 |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 511.3                               | 58.20                         | 10,580                   |  |
| 541.4                               | 64.56                         | 8,330                    |  |
| 458.1                               | 57.91                         | 7,150                    |  |
| 502.5                               | 49.82                         | 7,580                    |  |
| 470.8                               | 70.64                         | 6,670                    |  |
| Average                             | 60.23                         | 8,062                    |  |
| Std. Dev.                           | 7.82                          | 1,534                    |  |

TABLE E.27

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, WARP DIRECTION, BATCH 3, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression: ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                 | Warp        |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|-----------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Batch #3               |                 | Task #4     |         |
|                 |                 |                               |                 |                     |                             | Tested By:             |                 | TB          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Initial         |             | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (µin/in) | Date Tested |         |
| BIL-GR-16-17    | 72°F (DRY)      | 1.001                         | 0.1810          | 12,183              | 67.24                       | 7.927                  | 9,380           | 11/15/89    | (1,3)   |
| BIL-GR-16-19    | "               | 1.001                         | 0.1830          | 13,425              | 73.29                       | 10.236                 | 7,680           | "           | (1,3)   |
| BIL-GR-16-22    | "               | 1.001                         | 0.1850          | 12,475              | 67.37                       | 8.843                  | 6,800           | "           | (1,3)   |
| BIL-GR-16-24    | "               | 1.002                         | 0.1820          | 13,063              | 71.63                       | 6.154                  | 14,268+         | "           | (1,3)   |
| Average         |                 |                               |                 |                     | 69.88                       | 8.290                  | 9,532+          |             |         |
| Std. Dev.       |                 |                               |                 |                     | 3.05                        | 1.711                  | 3,334+          |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 463.6                               | 54.66                         | 9,380                                 |  |
| 505.3                               | 70.57                         | 7,680                                 |  |
| 454.5                               | 60.97                         | 6,800                                 |  |
| 493.9                               | 42.43                         | 14,268+                               |  |
| Average                             | 57.16                         | 9,532+                                |  |
| Std. Dev.                           | 11.80                         | 3,334+                                |  |

TABLE E.28

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, WARP DIRECTION, BATCH 1, 22°C (72°F) WET

| Test :          |                 | IITRI Compression: ASTM-D3410 |                 |                     |                             | Fiber Orientation: |                                | Warp                     |             |           |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------|--------------------------------|--------------------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Tested By:         |                                | TB                       |             |           |
|                 |                 | Batch #1                      | Task #4         |                     |                             |                    |                                |                          |             |           |
|                 |                 |                               |                 |                     |                             |                    |                                |                          |             |           |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                    | Initial Tangent Modulus (Msi.) | Ultimate Strain (µin/in) | Date Tested | Remarks   |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Compressive        |                                |                          |             |           |
| BIL-GR-14-18    | 72°F (WET)      | 0.994                         | 0.1867          | 11,163              | 60.17                       |                    | 8.008                          | 6,570                    | 1/12/90     | (1,3,4,5) |
| BIL-GR-14-21    | "               | 1.001                         | 0.1900          | 12,450              | 65.43                       |                    | 6.660                          | 12,285                   | "           | (1,3,4,5) |
| BIL-GR-14-23    | "               | 0.998                         | 0.1914          | 8,081               | 42.30                       |                    | 7.438                          | 5,762                    | "           | (1,3,4,5) |
| BIL-GR-14-26    | "               | 1.006                         | 0.1854          | 10,852              | 58.20                       |                    | 8.117                          | 7,246                    | "           | (1,3,4,5) |
| BIL-GR-14-28    | "               | 1.003                         | 0.1881          | 11,600              | 61.47                       |                    | 7.286                          | 9,700                    | "           | (1,3,4,5) |
|                 |                 |                               |                 | Average             | 57.51                       |                    | 7.502                          | 8,313                    |             |           |
|                 |                 |                               |                 | Std. Dev.           | 8.91                        |                    | 0.590                          | 2,664                    |             |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 99 days.
- (5) Weight gain = 2.4270%

| SI Conversion              |                       |                            |                       |
|----------------------------|-----------------------|----------------------------|-----------------------|
| Ultimate                   |                       | Initial                    |                       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Compressive Strength (MPa) | Tangent Modulus (GPa) |
| 414.9                      | 55.21                 | 414.9                      | 55.21                 |
| 451.2                      | 45.92                 | 451.2                      | 45.92                 |
| 291.6                      | 51.28                 | 291.6                      | 51.28                 |
| 401.3                      | 55.97                 | 401.3                      | 55.97                 |
| 423.8                      | 50.24                 | 423.8                      | 50.24                 |
| Average                    | 396.5                 | Average                    | 51.72                 |
| Std. Dev.                  | 61.4                  | Std. Dev.                  | 4.07                  |
|                            |                       |                            | 8,313                 |
|                            |                       |                            | 2,664                 |

TABLE E.29

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, WARP DIRECTION, BATCH 2, 22°C (72°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:             |                          |             |           |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|--------------------------|-------------|-----------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | RG                             |                          |             |           |
|                 |                 | Batch #2                      | Task #4         | Tested By:          |                             |                                |                          |             |           |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Ultimate            |                             | Initial Tangent Modulus (Msi.) | Ultimate Strain (µin/in) | Date Tested | Remarks   |
|                 |                 |                               |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.) |                                |                          |             |           |
| BIL-GR-15-18    | 72°F (WET)      | 1.001                         | 0.1790          | 9,985               | 55.73                       | 9.178                          | 5,889                    | 1/12/90     | (1,3,4,5) |
| BIL-GR-15-21    | "               | 1.002                         | 0.1820          | 9,387               | 51.48                       | 9.142                          | 6,270                    | "           | (1,3,4,5) |
| BIL-GR-15-23    | "               | 1.003                         | 0.1840          | 9,705               | 52.58                       | 6.442                          | 10,420                   | "           | (1,3,4,5) |
| BIL-GR-15-26    | "               | 1.002                         | 0.1760          | 10,193              | 57.80                       | 7.811                          | 6,963                    | "           | (1,3,4,5) |
| BIL-GR-15-28    | "               | 1.003                         | 0.1770          | 8,997               | 50.68                       | 7.216                          | 7,441                    | "           | (1,3,4,5) |
| Average         |                 |                               |                 | 53.65               |                             | 7.958                          |                          | 7,397       |           |
| Std. Dev.       |                 |                               |                 | 3.01                |                             | 1.200                          |                          | 1,794       |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 99 days.
- (5) Weight gain = 2.2206%

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 384.2                               | 63.29                         | 5,889                    |  |
| 354.9                               | 63.03                         | 6,270                    |  |
| 362.6                               | 44.42                         | 10,420                   |  |
| 398.5                               | 53.86                         | 6,963                    |  |
| 349.4                               | 49.75                         | 7,441                    |  |
| Average                             | 54.87                         | 7,397                    |  |
| Std. Dev.                           | 8.27                          | 1,794                    |  |

TABLE E.30

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, WARP DIRECTION, BATCH 3, 22°C (72°F) WET

| Test : IITRI Compression; ASTM-D3410  |                 |             |                 |                     | Fiber Orientation: Warp     |                        |                 |             |           |
|---------------------------------------|-----------------|-------------|-----------------|---------------------|-----------------------------|------------------------|-----------------|-------------|-----------|
| Material : EA-9396 A/B; W133 Graphite |                 |             |                 |                     | Tested By: TB               |                        |                 |             |           |
| Specimen Number                       | Test Conditions | Width (in.) | Thickness (in.) | Ultimate            |                             | Initial                |                 | Date Tested | Remarks   |
|                                       |                 |             |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (μin/in) |             |           |
| BIL-GR-16-18                          | 72°F (WET)      | 1.002       | 0.1830          | 9,180               | 50.06                       | 6.051                  | 9,111           | 1/4/90      | (1,3,4,5) |
| BIL-GR-16-21                          | "               | 1.002       | 0.1860          | 9,802               | 52.60                       | 6.661                  | 10,300          | "           | (1,3,4,5) |
| BIL-GR-16-23                          | "               | 1.002       | 0.1840          | 9,595               | 52.04                       | 8.848                  | 6,084           | "           | (1,3,4,5) |
| BIL-GR-16-26                          | "               | 1.001       | 0.1830          | 8,630               | 47.11                       | 9.209                  | 5,410           | "           | (1,3,4,5) |
| BIL-GR-16-28                          | "               | 1.002       | 0.1790          | 9,009               | 50.23                       | 7.507                  | 8,130           | "           | (1,3,4,5) |
| Average                               |                 |             |                 | 50.41               |                             | 7.655                  |                 | 7,807       |           |
| Std. Dev.                             |                 |             |                 | 2.15                |                             | 1.362                  |                 | 2,045       |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 99 days.
- (5) Weight gain = 2.1824%

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 345.2                               | 41.72                         | 9,111                    |  |
| 362.6                               | 45.93                         | 10,300                   |  |
| 358.8                               | 61.01                         | 6,084                    |  |
| 324.8                               | 63.50                         | 5,410                    |  |
| 346.3                               | 51.76                         | 8,130                    |  |
| Average                             | 52.78                         | 7,807                    |  |
| Std. Dev.                           | 9.39                          | 2,045                    |  |

TABLE E.31

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 1, -54°C (-65°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:       |                          | Fill        |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------|--------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Tested By:               |                          | BH          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                          | Ultimate Strain (µin/in) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus - (Msi.) |                          |             |         |
| BIL-GR-13-1     | -65°F (DRY)     | 0.998                         | 0.1680          | 13,123              | 78.27                       | 8.946                    | 8,400                    | 11/6/89     | (1,3)   |
| BIL-GR-13-22    | "               | 1.001                         | 0.1830          | 15,963              | 87.14                       | 11.191                   | 8,860                    | "           | (1,3)   |
| BIL-GR-13-44    | "               | 1.000                         | 0.1810          | 16,513              | 91.23                       | 8.910                    | 12,040                   | 11/13/89    | (1,3)   |
| BIL-GR-14-8     | "               | 1.003                         | 0.1804          | 15,763              | 87.14                       | 8.949                    | 10,670                   | 11/6/89     | (1,3)   |
| BIL-GR-14-37    | "               | 1.000                         | 0.1822          | 15,650              | 85.87                       |                          |                          | "           | (1,3,4) |
| Average         |                 |                               |                 |                     | 85.93                       | 9.499                    | 9,993                    |             |         |
| Std. Dev.       |                 |                               |                 |                     | 4.74                        | 1.128                    | 1,680                    |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Load only recorded.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (µcm/cm) |  |
| 539.7                               | 61.69                         | 8,400                    |  |
| 600.8                               | 77.16                         | 8,860                    |  |
| 629.0                               | 61.44                         | 12,040                   |  |
| 600.8                               | 61.70                         | 10,670                   |  |
| 592.1                               |                               |                          |  |
| Average                             | 65.50                         | 9,993                    |  |
| Std. Dev.                           | 7.78                          | 1,680                    |  |

TABLE E.32

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 2, -54°C (-65°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     | Fiber Orientation: |                          |             |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|--------------------|--------------------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     | Tested By:         |                          |             |
|                 |                 | Batch #2 Task #5              |                 |                     | Fill               |                          |             |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) |                    | Ultimate Strain (μin/in) | Date Tested |
|                 |                 |                               |                 | Initial             | Final              |                          |             |
| BIL-GR-15-1     | -65°F (DRY)     | 1.000                         | 0.1724          | 71.53               | 8.806              | 8,230                    | 10/31/89    |
| BIL-GR-15-15    | "               | 1.004                         | 0.1766          | 70.60               | 7.899              | 12,490                   | 11/2/89     |
| BIL-GR-15-34    | "               | 1.000                         | 0.1790          | 85.21               | 7.728              | 12,850                   | "           |
| BIL-GR-15-43    | "               | 1.007                         | 0.1738          | 78.44               | 8.109              | 12,891                   | 10/31/89    |
| BIL-GR-15-8     | "               | 1.004                         | 0.1724          | 79.28               |                    |                          | "           |
| Average         |                 |                               |                 | 77.01               | 8.135              | 11,615                   |             |
| Std. Dev.       |                 |                               |                 | 6.03                | 0.473              | 2,264                    |             |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Load only recorded.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 493.2                               | 60.72                         | 8,230                    |  |
| 486.8                               | 54.46                         | 12,490                   |  |
| 587.5                               | 53.29                         | 12,850                   |  |
| 540.9                               | 55.91                         | 12,891                   |  |
| 546.6                               |                               |                          |  |
| Average                             | 56.09                         | 11,615                   |  |
| Std. Dev.                           | 3.26                          | 2,264                    |  |



TABLE E.33

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 3, -54°C (-65°F) DRY

|                 |                 |                               |                 |                     |                             |                        |                 |         |             |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|-----------------|---------|-------------|---------|
| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                 |         |             | Fill    |
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Tested By:             |                 |         |             | BH      |
|                 |                 | Batch #3                      |                 | Task #5             |                             |                        |                 |         |             |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Initial         |         | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (μin/in) |         |             |         |
| BIL-GR-16-1     | -65°F (DRY)     | 1.001                         | 0.1732          | 14,771              | 85.18                       | 8.255                  | 11,934          | 11/6/89 | (1,3)       |         |
| BIL-GR-16-8     | "               | 1.001                         | 0.1821          | 16,463              | 90.36                       | 7.547                  | 13,400          | "       | (1,3)       |         |
| BIL-GR-16-15    | "               | 1.004                         | 0.1796          | 16,438              | 91.14                       | 7.381                  | 13,590          | "       | (1,3)       |         |
| BIL-GR-16-34    | "               | 1.006                         | 0.1783          | 16,126              | 89.95                       | 8.367                  | 12,300          | "       | (1,3)       |         |
| BIL-GR-16-43    | "               | 1.003                         | 0.1754          | 13,367              | 75.97                       | 7.886                  | 14,014          | "       | (1,3)       |         |
| Average         |                 |                               |                 |                     | 86.52                       | 7.887                  | 13.047          |         |             |         |
| Std. Dev.       |                 |                               |                 |                     | 6.34                        | 0.429                  | 888             |         |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 587.3                               | 56.92                         | 11,934                   |  |
| 623.0                               | 52.04                         | 13,400                   |  |
| 628.4                               | 50.89                         | 13,590                   |  |
| 620.2                               | 57.69                         | 12,300                   |  |
| 523.8                               | 54.37                         | 14,014                   |  |
| Average                             | 54.38                         | 13,047                   |  |
| Std. Dev.                           | 2.96                          | 888                      |  |

TABLE E.34

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 1, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 | Batch #1            |                                      | Task #5                        |                                       | Fiber Orientation: |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|--------------------------------------|--------------------------------|---------------------------------------|--------------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                                      |                                |                                       | Tested By:         |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested        | Remarks |
| BIL-GR-13-2     | 72°F (DRY)      | 0.998                         | 0.1720          | 10,088              | 58.77                                | 8.229                          | 8,100                                 | 10/26/89           | (1,3,4) |
| BIL-GR-13-23    | "               | 1.001                         | 0.1840          | 9,838               | 53.41                                | 5.938                          | 8,380                                 | "                  | (1,3)   |
| BIL-GR-13-45    | "               | 1.001                         | 0.1824          | 11,694              | 64.02                                | 8.361                          | 6,377                                 | 12/15/89           | (1,3)   |
| BIL-GR-14-9     | "               | 1.002                         | 0.1802          | 10,675              | 59.13                                | 7.097                          | 8,450                                 | "                  | (1,3)   |
| BIL-GR-14-38    | "               | 1.001                         | 0.1824          | 11,888              | 65.08                                | 7.733                          | 8,290                                 | 11/2/89            | (1,3)   |
|                 |                 |                               |                 | Average             | 60.08                                | 7.471                          | 7,919                                 |                    |         |
|                 |                 |                               |                 | Std. Dev.           | 4.68                                 | 0.990                          | 872                                   |                    |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Tabs debonded.

| SI Conversion              |       |                       |                                       |
|----------------------------|-------|-----------------------|---------------------------------------|
| Ultimate                   |       | Initial               |                                       |
| Compressive Strength (MPa) |       | Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |
| 405.2                      |       | 56.74                 | 8,100                                 |
| 368.3                      |       | 40.94                 | 8,380                                 |
| 441.4                      |       | 57.65                 | 6,377                                 |
| 407.7                      |       | 48.93                 | 8,450                                 |
| 448.7                      |       | 53.32                 | 8,290                                 |
| Average                    | 414.3 | 51.52                 | 7,919                                 |
| Std. Dev.                  | 32.3  | 6.83                  | 872                                   |

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS, GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 2, 22°C (72°F) DRY

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                                |                                        |                                             |           |
|----------------------------------------------|----------------------------------------|---------------------------------------------|-----------|
| Ultimate<br>Compressive<br>Strength<br>(MPa) | Initial<br>Tangent<br>Modulus<br>(GPa) | Ultimate<br>Strain<br>( $\mu\text{cm/cm}$ ) |           |
| 446.7                                        | 63.50                                  | 7,640                                       |           |
| 404.7                                        | 58.61                                  | 6,580                                       |           |
| 428.5                                        | 51.32                                  | 10,590                                      |           |
| 360.5                                        | 56.08                                  | 7,780                                       |           |
| 410.1                                        | 57.4                                   | 8,148                                       | Average   |
| 37.3                                         | 5.1                                    | 1,714                                       | Std. Dev. |

TABLE E.36

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 3, 22°C (72°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     | Fiber Orientation:          |                                |             |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     | Tested By:                  |                                |             |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Date Tested |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |             |
| BIL-GR-16-2     | 72°F (DRY)      | 1.002                         | 0.1767          | 11,425              | 64.56                       | 7.707                          | 11/13/89    |
| BIL-GR-16-9     | "               | 1.004                         | 0.1821          | 11,275              | 61.66                       | 6.905                          | "           |
| BIL-GR-16-16    | "               | 1.004                         | 0.1798          | 11,838              | 65.59                       | 8.588                          | "           |
| BIL-GR-16-35    | "               | 1.006                         | 0.1810          | 10,632              | 58.37                       | 7.720                          | "           |
| BIL-GR-16-44    | "               | 1.003                         | 0.1735          | 11,304              | 64.98                       | 8.489                          | 12/15/89    |
| Average         |                 |                               |                 |                     | 63.03                       | 7.882                          | 8,698       |
| Std. Dev.       |                 |                               |                 |                     | 3.01                        | 0.685                          | 3,423       |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |  |                          |
|-------------------------------------|-------------------------------|--|--------------------------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) |  | Ultimate Strain (µcm/cm) |
|                                     |                               |  |                          |
| 445.1                               | 53.14                         |  | 13,926                   |
| 425.2                               | 47.61                         |  | 10,300                   |
| 452.2                               | 59.21                         |  | 7,270                    |
| 402.5                               | 53.23                         |  | 5,580                    |
| 448.0                               | 58.53                         |  | 6,416                    |
| Average                             | 54.34                         |  | 8,698                    |
| Std. Dev.                           | 4.73                          |  | 3,423                    |

TABLE E.37

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 1, 93°C (200°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                          | Fill        |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|--------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Tested By:             |                          | RG          |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Ultimate Strain (μin/in) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |                          |             |         |
| BIL-GR-13-3     | 200°F (DRY)     | 0.997                         | 0.1760          | 7,363               | 41.96                       | 8.691                  | 4,830                    | 11/15/89    | (1,3,4) |
| BIL-GR-13-24    | "               | 0.998                         | 0.1840          | 8,413               | 45.81                       | 8.237                  | 5,254                    | "           | (1,3)   |
| BIL-GR-13-46    | "               | 1.001                         | 0.1790          | 7,800               | 43.53                       | 8.957                  | 4,350                    | "           | (1,3)   |
| BIL-GR-14-10    | "               | 1.002                         | 0.1804          | 7,642               | 42.28                       | 7.180                  | 7,120                    | "           | (1,3)   |
| BIL-GR-14-39    | "               | 1.001                         | 0.1799          | 7,947               | 44.13                       | 7.496                  | 5,156                    | 11/16/89    | (1,3)   |
| Average         |                 |                               |                 |                     | 43.54                       | 8.112                  | 5,342                    |             |         |
| Std. Dev.       |                 |                               |                 |                     | 1.55                        | 0.760                  | 1,055                    |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Tabs debonded.

| SI Conversion              |                       |                            |                       |
|----------------------------|-----------------------|----------------------------|-----------------------|
| Ultimate                   |                       | Initial                    |                       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Compressive Strength (MPa) | Tangent Modulus (GPa) |
| 289.3                      | 59.92                 | 4,830                      | 59.92                 |
| 315.9                      | 56.79                 | 5,254                      | 56.79                 |
| 300.2                      | 61.76                 | 4,350                      | 61.76                 |
| 291.5                      | 49.51                 | 7,120                      | 49.51                 |
| 304.3                      | 51.69                 | 5,156                      | 51.69                 |
| Average                    | 300.2                 | 55.93                      | 5,342                 |
| Std. Dev.                  | 10.7                  | 5.24                       | 1,055                 |

TABLE E.38

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 2, 93°C (200°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Batch #2               |                              | Task #5  |             | Fiber Orientation: |  | Fill |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|------------------------------|----------|-------------|--------------------|--|------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             |                        |                              |          |             | Tested By:         |  | TB   |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Initial                      |          | Date Tested | Remarks            |  |      |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain ( $\mu\text{in/in}$ ) |          |             |                    |  |      |
| BIL-GR-15-3     | 200°F (DRY)     | 0.998                         | 0.1772          | 7,141               | 40.40                       | 9.584                  | 3,779                        | 11/16/89 | (1,3)       |                    |  |      |
| BIL-GR-15-10    | "               | 1.002                         | 0.1783          | 7,031               | 39.34                       | 6.461                  | 5,957                        | "        | (1,3)       |                    |  |      |
| BIL-GR-15-29    | "               | 1.002                         | 0.1697          | 5,975               | 35.15                       | 7.905                  | 4,200                        | "        | (1,3)       |                    |  |      |
| BIL-GR-15-36    | "               | 1.000                         | 0.1769          | 6,363               | 35.96                       | 9.446                  | 3,590                        | "        | (1,3)       |                    |  |      |
| BIL-GR-15-40    | "               | 1.006                         | 0.1736          | 6,213               | 35.59                       | 7.447                  | 5,030                        | "        | (1,3)       |                    |  |      |
|                 |                 |                               |                 | Average             |                             | 8.164                  |                              |          | 4,511       |                    |  |      |
|                 |                 |                               |                 | Std. Dev.           |                             | 1.331                  |                              |          | 980         |                    |  |      |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 278.5                               | 65.94                         | 3,779                                 |  |
| 271.3                               | 44.55                         | 5,957                                 |  |
| 242.4                               | 54.50                         | 4,200                                 |  |
| 248.0                               | 65.13                         | 3,590                                 |  |
| 245.4                               | 51.35                         | 5,030                                 |  |
| Average                             | 56.29                         | 4,511                                 |  |
| Std. Dev.                           | 9.18                          | 980                                   |  |

TABLE E.39

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 3, 93°C (200°F) DRY

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                                       | Fill        |         |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|---------------------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Tested By:             |                                       | RG          |         |
|                 |                 | Batch #3                      | Task #5         |                     |                             |                        |                                       |             |         |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Ultimate Strain ( $\mu\text{in/in}$ ) | Date Tested | Remarks |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |                                       |             |         |
| BIL-GR-16-3     | 200°F (DRY)     | 1.001                         | 0.1797          | 7,471               | 41.55                       | 7.636                  | 7,610                                 | 11/16/89    | (1,3)   |
| BIL-GR-16-10    | "               | 1.004                         | 0.1804          | 7,738               | 42.70                       | 7.102                  | 5,566                                 | "           | (1,3)   |
| BIL-GR-16-29    | "               | 1.006                         | 0.1706          | 6,625               | 38.62                       | 7.778                  | 6,220                                 | "           | (1,3)   |
| BIL-GR-16-36    | "               | 1.007                         | 0.1778          | 7,166               | 40.03                       | 7.612                  | 6,210                                 | "           | (1,3)   |
| Bil-GR-16-40    | "               | 1.006                         | 0.1774          | 7,043               | 39.47                       | 7.741                  | 5,479                                 | "           | (1,3)   |
| Average         |                 |                               |                 |                     | 40.48                       | 7.574                  | 6,217                                 |             |         |
| Std. Dev.       |                 |                               |                 |                     | 1.64                        | 0.273                  | 853                                   |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 286.5                               | 52.65                         | 7.610                                 |  |
| 294.4                               | 48.97                         | 5.566                                 |  |
| 266.3                               | 53.63                         | 6,220                                 |  |
| 276.0                               | 52.49                         | 6,210                                 |  |
| 272.2                               | 53.38                         | 5,479                                 |  |
| Average                             | 52.22                         | 6,217                                 |  |
| Std. Dev.                           | 1.88                          | 853                                   |  |

TABLE E.40

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 1, -54°C (-65°F) WET

| Test : IITRI Compression; ASTM-D3410  |                 |             |                 |                     | Fiber Orientation:          |                        |             |         |             |
|---------------------------------------|-----------------|-------------|-----------------|---------------------|-----------------------------|------------------------|-------------|---------|-------------|
| Material : EA-9396 A/B; W133 Graphite |                 |             |                 |                     | Tested By: RG               |                        |             |         |             |
| Specimen Number                       | Test Conditions | Width (in.) | Thickness (in.) | Ultimate            |                             |                        | Date Tested | Remarks |             |
|                                       |                 |             |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |             |         |             |
| BIL-GR-13-4                           | -65°F (WET)     | 0.996       | 0.1750          | 12,268              | 70.38                       | 8.831                  | 8,311       | 1/16/90 | (1,3,4,5,6) |
| BIL-GR-13-25                          | "               | 0.994       | 0.1840          | 15,735              | 86.03                       | 9.315                  | 9,600       | "       | (1,3,5,6)   |
| BIL-GR-13-47                          | "               | 1.000       | 0.1760          | 13,538              | 76.92                       | 10.211                 | 7,500       | "       | (1,3,5,6)   |
| BIL-GR-14-11                          | "               | 1.002       | 0.1809          | 13,538              | 74.66                       | 8.401                  | 9,189       | "       | (1,3,5,7)   |
| BIL-GR-14-40                          | "               | 1.001       | 0.1767          | 13,806              | 78.09                       | 9.139                  | 14,072      | "       | (1,3,5,7)   |
| Average                               |                 |             |                 | 78.92               | 9.179                       | 10,090                 |             |         |             |
| Std. Dev.                             |                 |             |                 | 4.95                | 0.673                       | 2,806                  |             |         |             |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Tabs debonded. Not included in average strength or ultimate strain.
- (5) Specimens aged @ 140°F/95-100% R.H. for 99 days.
- (6) Weight gain = 2.3016%
- (7) Weight gain = 2.4270%

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 485.3                               | 60.89                         | 8,311                                 |  |
| 593.2                               | 64.23                         | 9,600                                 |  |
| 530.4                               | 70.40                         | 7,500                                 |  |
| 514.7                               | 57.93                         | 9,189                                 |  |
| 538.4                               | 63.01                         | 14,072                                |  |
| Average                             | 63.29                         | 10,090                                |  |
| Std. Dev.                           | 4.64                          | 2,806                                 |  |



TABLE E.41

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 2, -54°C (-65°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     | Fiber Orientation:          |                                |                           |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|---------------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     | Tested By:                  |                                |                           |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Remarks                   |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |                           |
| BIL-GR-15-4     | -65°F (WET)     | 1.004                         | 0.1781          | 13,074              | 73.10                       | 8.390                          | 10,039 11/16/89 (1,3,4,5) |
| BIL-GR-15-11    | "               | 1.004                         | 0.1791          | 14,612              | 81.27                       | 8.426                          | 10,273 " (1,3,4,5)        |
| BIL-GR-15-30    | "               | 1.004                         | 0.1732          | 12,940              | 74.45                       | 8.671                          | 11,729 " (1,3,4,5)        |
| BIL-GR-15-37    | "               | 1.007                         | 0.1756          | 13,330              | 75.38                       | 8.635                          | 8,486 " (1,3,4,5)         |
| BIL-GR-15-41    | "               | 1.006                         | 0.1717          | 11,853              | 68.59                       | 8.897                          | 11,853 " (1,3,4,5)        |
| Average         |                 |                               |                 |                     | 74.56                       | 8.604                          | 10,476                    |
| Std. Dev.       |                 |                               |                 |                     | 4.57                        | 0.206                          | 1,383                     |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 99 days.
- (5) Weight gain = 2.2206%

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 504.0                               | 57.85                         | 10,039                   |  |
| 560.3                               | 58.09                         | 10,273                   |  |
| 513.3                               | 59.79                         | 11,729                   |  |
| 519.7                               | 59.54                         | 8,486                    |  |
| 473.0                               | 61.35                         | 11,853                   |  |
| Average                             | 59.32                         | 10,476                   |  |
| Std. Dev.                           | 1.42                          | 1,383                    |  |

TABLE E.42

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 3, -54°C (-65°F) WET

| Test :          |                 |             |                 | IITRI Compression; ASTM-D3410 |                             |                        |                 | Fiber Orientation: |             |         |  | Fill |
|-----------------|-----------------|-------------|-----------------|-------------------------------|-----------------------------|------------------------|-----------------|--------------------|-------------|---------|--|------|
| Material :      |                 |             |                 | EA-9396 A/B; W133 Graphite    |                             |                        |                 | Tested By:         |             |         |  | BH   |
|                 |                 |             |                 | Batch #3                      | Task #5                     |                        |                 |                    |             |         |  |      |
| Specimen Number | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.)           | Ultimate                    |                        | Initial         |                    | Date Tested | Remarks |  |      |
|                 |                 |             |                 |                               | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (μin/in) |                    |             |         |  |      |
| BIL-GR-16-4     | -65°F (WET)     | 1.001       | 0.1819          | 15,283                        | 83.97                       | 9.062                  | 9,336           | 1/11/90            | (1,3,4,5)   |         |  |      |
| BIL-GR-16-11    | "               | 1.006       | 0.1806          | 14,356                        | 79.02                       | 8.186                  | 9,854           | "                  | (1,3,4,5)   |         |  |      |
| BIL-GR-16-30    | "               | 1.006       | 0.1755          | 11,938                        | 67.61                       | 8.247                  | 7,720           | "                  | (1,3,4,5)   |         |  |      |
| BIL-GR-16-37    | "               | 1.004       | 0.1757          | 14,941                        | 84.73                       | 8.394                  | 12,315          | "                  | (1,3,4,5)   |         |  |      |
| BIL-GR-16-41    | "               | 1.005       | 0.1759          | 12,756                        | 72.16                       | 9.129                  | 7,461           | "                  | (1,3,4,5)   |         |  |      |
|                 |                 |             |                 | Average                       | 77.50                       | 8.604                  | 9,337           |                    |             |         |  |      |
|                 |                 |             |                 | Std. Dev.                     | 7.46                        | 0.456                  | 2,256           |                    |             |         |  |      |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 99 days.
- (5) Weight gain = 2.1824%

| SI Conversion              |                       |                            |                       |
|----------------------------|-----------------------|----------------------------|-----------------------|
| Ultimate                   |                       | Initial                    |                       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Compressive Strength (MPa) | Tangent Modulus (GPa) |
| 579.0                      | 62.48                 | 579.0                      | 62.48                 |
| 544.9                      | 56.44                 | 544.9                      | 56.44                 |
| 466.2                      | 56.87                 | 466.2                      | 56.87                 |
| 584.2                      | 57.88                 | 584.2                      | 57.88                 |
| 497.5                      | 62.94                 | 497.5                      | 62.94                 |
| Average                    | 59.32                 | Average                    | 59.32                 |
| Std. Dev.                  | 3.14                  | Std. Dev.                  | 3.14                  |

TABLE E.43

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 1, 22°C (72°F) WET

| Test :          |                 |                            |                 | IITRI Compression; ASTM-D3410 |                             |                        |                          | Fiber Orientation: |           |
|-----------------|-----------------|----------------------------|-----------------|-------------------------------|-----------------------------|------------------------|--------------------------|--------------------|-----------|
| Material :      |                 | EA-9396 A/B; W133 Graphite |                 | Batch #1                      | Task #5                     | Tested By:             |                          | TB                 |           |
| Specimen Number | Test Conditions | Width (in.)                | Thickness (in.) | Maximum Load (lbs.)           | Ultimate                    |                        | Ultimate Strain (μin/in) | Date Tested        | Remarks   |
|                 |                 |                            |                 |                               | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) |                          |                    |           |
| BIL-GR-13-5     | 72°F (WET)      | 0.999                      | 0.1770          | 9,650                         | 54.57                       | 9.225                  | 5,350                    | 12/6/89            | (1,3,4,5) |
| BIL-GR-13-26    | "               | 0.996                      | 0.1860          | 11,100                        | 59.92                       | 8.805                  | 7,340                    | "                  | (1,3,4,5) |
| BIL-GR-13-48    | "               | 0.998                      | 0.1760          | 8,275                         | 47.11                       | 9.109                  | 5,230                    | "                  | (1,3,4,5) |
| BIL-GR-14-12    | "               | 1.002                      | 0.1774          | 9,188                         | 51.70                       | 8.934                  | 5,870                    | "                  | (1,3,4,6) |
| BIL-GR-14-41    | "               | 1.001                      | 0.1761          | 9,167                         | 52.00                       | 8.515                  | 5,674                    | "                  | (1,3,4,6) |
|                 |                 |                            |                 | Average                       | 53.06                       | 8.918                  | 5,893                    |                    |           |
|                 |                 |                            |                 | Std. Dev.                     | 4.68                        | 0.277                  | 848                      |                    |           |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 62 days.
- (5) Weight gain = 2.2390%
- (6) Weight gain = 2.0377%

| SI Conversion              |                       |                            |                       |
|----------------------------|-----------------------|----------------------------|-----------------------|
| Ultimate                   |                       | Initial                    |                       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Compressive Strength (MPa) | Tangent Modulus (GPa) |
| 376.3                      | 63.61                 | 376.3                      | 63.61                 |
| 413.1                      | 60.71                 | 413.1                      | 60.71                 |
| 324.8                      | 62.81                 | 324.8                      | 62.81                 |
| 356.5                      | 61.60                 | 356.5                      | 61.60                 |
| 358.5                      | 58.71                 | 358.5                      | 58.71                 |
| Average                    | 61.49                 | Average                    | 61.49                 |
| Std. Dev.                  | 1.91                  | Std. Dev.                  | 1.91                  |

TABLE E.44

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 2, 22°C (72°F) WET

| Test :          |                 | ITRI Compression; ASTM-D3410 |                 | Fiber Orientation:  |                             | Fill                           |                    |
|-----------------|-----------------|------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|--------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite   |                 | Batch #2            |                             | Task #5                        |                    |
|                 |                 |                              |                 |                     |                             | Tested By:                     |                    |
| Specimen Number | Test Conditions | Width (in.)                  | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Remarks            |
|                 |                 |                              |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |                    |
| BIL-GR-15-5     | 72°F (WET)      | 1.005                        | 0.1797          | 8,716               | 48.25                       | 6.563                          | 12/6/89 (1,3,4,5)  |
| BIL-GR-15-12    | "               | 1.004                        | 0.1755          | 8,850               | 50.25                       | 7.389                          | " (1,3,4,5)        |
| BIL-GR-15-31    | "               | 1.003                        | 0.1757          | 8,911               | 50.55                       | 7.025                          | " (1,3,4,5)        |
| BIL-GR-15-38    | "               | 1.007                        | 0.1749          | 8,801               | 49.95                       | 8.432                          | " (1,3,4,5)        |
| BIL-GR-15-42    | "               | 1.007                        | 0.1715          | 8,008               | 46.36                       | 9.337                          | 12/11/89 (1,3,4,5) |
|                 |                 |                              |                 | Average             | 49.07                       | 7.749                          | 7,366              |
|                 |                 |                              |                 | Std. Dev.           | 1.76                        | 1.123                          | 3,156              |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 62 days.
- (5) Weight gain = 1.9091%

| SI Conversion                       |                               |                          |       |
|-------------------------------------|-------------------------------|--------------------------|-------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |       |
|                                     |                               |                          |       |
| 332.7                               | 45.26                         | 6,738                    |       |
| 346.5                               | 50.95                         | 6,390                    |       |
| 348.5                               | 48.44                         | 12,900                   |       |
| 344.4                               | 58.14                         | 5,664                    |       |
| 319.6                               | 64.38                         | 5,137                    |       |
| Average                             | 338.4                         | 53.43                    | 7,366 |
| Std. Dev.                           | 12.1                          | 7.74                     | 3,156 |

TABLE E.45

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 3, 22°C (72°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                    | Fiber Orientation:          |                                |             |
|-----------------|-----------------|-------------------------------|-----------------|--------------------|-----------------------------|--------------------------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                    | Tested By:                  |                                |             |
|                 |                 | Batch #3                      |                 |                    | Task #5                     |                                |             |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs) | Ultimate                    |                                | Date Tested |
|                 |                 |                               |                 |                    | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |             |
| BIL-GR-16-5     | 72°F (WET)      | 1.001                         | 0.1788          | 9,338              | 52.19                       | 7.488                          | 12/11/89    |
| BIL-GR-16-12    | "               | 1.005                         | 0.1812          | 9,570              | 52.55                       | 7.587                          | "           |
| BIL-GR-16-31    | "               | 1.007                         | 0.1779          | 8,179              | 45.66                       | 8.043                          | "           |
| BIL-GR-16-38    | "               | 1.005                         | 0.1794          | 9,937              | 55.13                       | 8.590                          | "           |
| BIL-GR-16-42    | "               | 1.005                         | 0.1762          | 7,861              | 44.39                       | 8.538                          | "           |
| Average         |                 |                               |                 |                    | 49.98                       | 8.049                          | 6,754       |
| Std. Dev.       |                 |                               |                 |                    | 4.69                        | 0.515                          | 1,256       |
|                 |                 |                               |                 |                    |                             |                                | (1b,3,4,5)  |
|                 |                 |                               |                 |                    |                             |                                | (1b,3,4,5)  |
|                 |                 |                               |                 |                    |                             |                                | (1b,3,4,5)  |
|                 |                 |                               |                 |                    |                             |                                | (1b,3,4,5)  |
|                 |                 |                               |                 |                    |                             |                                | (1a,3,4,5)  |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
- (1a) Shear fracture
- (1b) Shear crimping
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 62 days.
- (5) Weight gain = 2.0033%

| SI Conversion                       |                               |                          |       |
|-------------------------------------|-------------------------------|--------------------------|-------|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |       |
|                                     |                               |                          |       |
| 359.8                               | 51.63                         | 6,826                    |       |
| 362.3                               | 52.31                         | 6,299                    |       |
| 314.8                               | 55.46                         | 8,350                    |       |
| 380.1                               | 59.23                         | 7,334                    |       |
| 306.1                               | 58.87                         | 4,961                    |       |
| Average                             | 344.6                         | 55.50                    | 6,754 |
| Std. Dev.                           | 32.3                          | 3.55                     | 1,256 |

TABLE E.46

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 1, 93°C (200°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 | Fiber Orientation:  |                                       | Fill                        |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|---------------------------------------|-----------------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 | Tested By:          |                                       | RG                          |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Ultimate            |                                       | Date Tested                 |
|                 |                 |                               |                 | Maximum Load (lbs.) | Compressive Strength (Ksi.)           |                             |
|                 |                 |                               |                 |                     | Initial Tangent Modulus (Msi.)        | Remarks                     |
|                 |                 |                               |                 |                     | Ultimate Strain ( $\mu\text{in/in}$ ) |                             |
| BIL-GR-13-6     | 200°F (WET)     | 1.000                         | 0.1780          | 3,516               | 19.75                                 | 1,934 11/29/89 (3,4,5,7,8)  |
| BIL-GR-13-43    | "               | 0.998                         | 0.1840          | 4,944               | 26.92                                 | 2,959 11/30/89 (1b,3,4,5,8) |
| BIL-GR-14-13    | "               | 1.003                         | 0.1774          | 4,480               | 25.18                                 | 2,520 12/1/89 (1a,3,4,6,8)  |
| BIL-GR-14-42    | "               | 1.002                         | 0.1768          | 4,541               | 25.14                                 | 2,529 11/30/89 (1a,3,4,6,8) |
| Average         |                 |                               |                 | 24.37               | 9.701                                 | 2,485                       |
| Std. Dev.       |                 |                               |                 | 3.17                | 0.810                                 | 421                         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
- (1a) Shear fracture
- (1b) Shear crimping
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 62 days.
- (5) Weight gain = 2.2390%
- (6) Weight gain = 2.0377%
- (7) Tabs debonded.
- (8) Tested without tabs.

| SI Conversion                       |                               |                                       |  |
|-------------------------------------|-------------------------------|---------------------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
|                                     |                               |                                       |  |
| 136.2                               | 73.70                         | 1,934                                 |  |
| 185.6                               | 67.68                         | 2,959                                 |  |
| 173.6                               | 60.11                         | 2,520                                 |  |
| 176.8                               | 66.05                         | 2,529                                 |  |
| Average                             | 67.16                         | 2,485                                 |  |
| Std. Dev.                           | 6.81                          | 421                                   |  |

TABLE E.47

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 2, 93°C (200°F) WET

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     | Fiber Orientation:          |                                |             |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|-------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     | Tested By:                  |                                |             |
|                 |                 | Batch #2                      |                 |                     | Task #5                     |                                |             |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Date Tested |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |             |
| BIL-GR-15-6     | 200°F (WET)     | 1.005                         | 0.1791          | 4,919               | 27.32                       | 7.701                          | 11/30/89    |
| BIL-GR-15-13    | "               | 1.000                         | 0.1739          | 5,825               | 33.50                       | 7.365                          | 12/4/89     |
| BIL-GR-15-32    | "               | 1.003                         | 0.1765          | 3,833               | 21.66                       | 9.152                          | 11/30/89    |
| BIL-GR-15-33    | "               | 1.000                         | 0.1787          | 5,611               | 31.40                       | 8.128                          | 12/4/89     |
| BIL-GR-15-39    | "               | 1.007                         | 0.1742          | 4,236               | 24.15                       | 8.386                          | 11/30/89    |
| Average         |                 |                               |                 |                     | 27.61                       | 8.146                          | 3,783       |
| Std. Dev.       |                 |                               |                 |                     | 4.91                        | 0.685                          | 1,064       |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
- (1a) Shear fracture
- (1b) Shear crimping
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 62 days.
- (5) Weight gain = 1.9091%
- (6) Tested without tabs.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
|                                     |                               |                          |  |
| 188.4                               | 53.10                         | 3,262                    |  |
| 231.0                               | 50.78                         | 5,127                    |  |
| 149.3                               | 63.10                         | 2,295                    |  |
| 216.5                               | 56.04                         | 4,023                    |  |
| 166.5                               | 57.82                         | 4,210                    |  |
| Average                             | 56.17                         | 3,783                    |  |
| Std. Dev.                           | 4.73                          | 1,064                    |  |

TABLE E.48

INDIVIDUAL SPECIMEN COMPRESSION TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, FILL DIRECTION, BATCH 3, 93°C (200°F) WET

| Test :          |                 | IITRI Compression: ASTM-D3410 |                 |                     | Fiber Orientation:          |                                |                      |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------------------|----------------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     | Tested By:                  |                                |                      |
|                 |                 | Batch #3                      |                 |                     | Task #5                     |                                |                      |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                                | Remarks              |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Initial Tangent Modulus (Msi.) |                      |
| BIL-GR-16-6     | 200°F (WET)     | 1.002                         | 0.1791          | 5,432               | 30.28                       | 7.548                          | 11/30/89 (1,3,4,5,7) |
| BIL-GR-16-13    | "               | 1.005                         | 0.1807          | 6,738               | 37.12                       | 8.469                          | 12/4/89 (1,3,4,5,7)  |
| BIL-GR-16-32    | "               | 1.005                         | 0.1789          | 5,750               | 31.97                       | 8.235                          | 11/30/89 (1,3,4,5,7) |
| BIL-GR-16-39    | "               | 1.005                         | 0.1780          | 5,298               | 29.61                       | 9.731                          | " (1,3,4,5,6,7)      |
| Average         |                 |                               |                 |                     | 32.24                       | 8.495                          | 3,950                |
| Std. Dev.       |                 |                               |                 |                     | 3.40                        | 0.912                          | 704                  |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Specimens aged @ 140°F/95-100% R.H. for 62 days.
- (5) Weight gain = 2.0033%
- (6) Tested without tabs.

| SI Conversion                       |                               |                          |  |
|-------------------------------------|-------------------------------|--------------------------|--|
| Ultimate Compressive Strength (MPa) | Initial Tangent Modulus (GPa) | Ultimate Strain (μcm/cm) |  |
| 208.8                               | 52.04                         | 4,482                    |  |
| 255.9                               | 58.39                         | 4,375                    |  |
| 220.4                               | 56.78                         | 4,004                    |  |
| 204.1                               | 67.10                         | 2,939                    |  |
| Average                             | 58.58                         | 3,950                    |  |
| Std. Dev.                           | 6.29                          | 704                      |  |



**APPENDIX F**  
**INDIVIDUAL SPECIMEN  $\pm 45^\circ$  TENSION/INPLANE SHEAR**  
**PROPERTIES, BASELINE**

The 36 tables in this appendix present the detailed mechanical property test data measured during this program for each baseline specimen tested in inplane shear. A summary of these data was presented and discussed in Section 3.2.3.

TABLE F.1

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, -54°C (-65°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                 |                |                 |                |                       | Fiber Orientation: ±45° |             |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-----------------|----------------|-----------------|----------------|-----------------------|-------------------------|-------------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                 |                |                 |                |                       | Tested By: PM           |             |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate        |                | Tensile         |                | In-Plane              |                         | Date Tested |
|                                               |                 |             |                 |                     | Strength (Ksi.) | Modulus (Msi.) | Strength (Ksi.) | Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.)    |             |
| BIL-GL-18-T1                                  | -65°F (DRY)     | 1.000       | 0.0699          | 2,842               | 40.68           | 2.956          | 20.34           | 1.058          | 0.397                 | 0.397                   | 8/17/89     |
| BIL-GL-18-T7                                  | "               | 1.001       | 0.0673          | 2,375               | 35.25           | 3.185          | 17.63           | 1.085          | 0.468                 | 0.468                   | 8/16/89     |
| BIL-GL-18-T13                                 | "               | 0.998       | 0.0665          | 1,964               | 29.59           | 3.267          | 14.80           | 1.140          | 0.433                 | 0.433                   | "           |
| BIL-GL-19-T4                                  | "               | 0.999       | 0.0640          | 1,862               | 29.12           | 2.871          | 14.56           | 1.041          | 0.378                 | 0.378                   | 8/17/89     |
| BIL-GL-19-T10                                 | "               | 1.001       | 0.0710          | 1,857               | 26.13           | 2.779          | 13.06           | 0.981          | 0.417                 | 0.417                   | "           |
| BIL-GL-19(R)-T4                               | "               | 1.003       | 0.0640          | 2,075               | 32.32           | 3.573          | 16.16           | 1.289          | 0.386                 | 0.386                   | "           |
| BIL-GL-19(R)-T10                              | "               | 1.007       | 0.0720          | 2,920               | 40.29           | 2.633          | 20.15           | 0.912          | 0.444                 | 0.444                   | 8/16/89     |
| Average                                       |                 |             |                 |                     | 33.34           | 3.038          | 16.67           | 1.072          | 0.418                 | 0.418                   |             |
| Std. Dev.                                     |                 |             |                 |                     | 5.64            | 0.323          | 2.82            | 0.120          | 0.033                 | 0.033                   |             |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G = E/2(1 + \nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |               |                |               |                      |                     |
|------------------------|---------------|----------------|---------------|----------------------|---------------------|
| Ultimate               |               | In-Plane       |               | In-Plane             |                     |
| Tensile Strength (MPa) | Modulus (GPa) | Strength (MPa) | Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 280.5                  | 20.38         | 140.2          | 7.294         | 140.2                | 7.294               |
| 243.1                  | 21.96         | 121.5          | 7.480         | 121.5                | 7.480               |
| 204.1                  | 22.52         | 102.0          | 7.858         | 102.0                | 7.858               |
| 200.8                  | 19.79         | 100.4          | 7.179         | 100.4                | 7.179               |
| 180.2                  | 19.16         | 90.1           | 6.761         | 90.1                 | 6.761               |
| 222.9                  | 24.63         | 111.4          | 8.888         | 111.4                | 8.888               |
| 277.8                  | 18.15         | 138.9          | 6.286         | 138.9                | 6.286               |
| Average                | 20.94         | 114.9          | 7.392         | 114.9                | 7.392               |
| Std. Dev.              | 2.23          | 19.4           | 0.831         | 19.4                 | 0.831               |

TABLE F.2

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, -54°C (-65°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     | Fiber Orientation: ±45° |                        |                       |                      |                 |             |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------|-----------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     | Tested By: PM & DH      |                        |                       |                      |                 |             |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |             |           |
| BIL-GL-23(R)-X1                               | -65°F (DRY)     | 0.627       | 0.0616          | 1,395               | 36.12                   | 2,818                  | 18.06                 | 1.031                | 0.366           | 3/15/90     | (1,2,3,5) |
| BIL-GL-23(R)-X3                               | "               | 0.990       | 0.0636          | 1,759               | 27.93                   | 2,547                  | 13.97                 | 0.904                | 0.408           | "           | (1,2,3,5) |
| BIL-GL-23(R)-X7                               | "               | 0.875       | 0.0635          | 1,831               | 32.97                   | 2,561                  | 16.48                 | 0.901                | 0.421           | "           | (1,2,3,5) |
| BIL-GL-23(R)-16                               | "               | 0.999       | 0.0628          | 2,430               | 38.74                   | 2,610                  | 19.37                 | 0.929                | 0.405           | "           | (1,2,3,5) |
| BIL-GL-20(R)-T4                               | "               | 0.996       | 0.0657          | 2,587               | 39.54                   | 3,338                  | 19.77                 | 1.136                | 0.469           | 7/31/89     | (1,2,3,5) |
| BIL-GL-20(R)-T10                              | "               | 0.997       | 0.0656          | 2,004               | 30.66                   | 3,273                  | 15.33                 | 1.129                | 0.449           | "           | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 34.33                   | 2,858                  | 17.16                 | 1.005                | 0.420           |             |           |
| Std. Dev.                                     |                 |             |                 |                     | 4.61                    | 0.361                  | 2.30                  | 0.109                | 0.036           |             |           |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion                   |                       |                               |                              |
|---------------------------------|-----------------------|-------------------------------|------------------------------|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) |
| 249.1                           | 19.43                 | 124.5                         | 7.112                        |
| 192.6                           | 17.56                 | 96.3                          | 6.236                        |
| 227.3                           | 17.66                 | 113.7                         | 6.214                        |
| 267.1                           | 18.00                 | 133.6                         | 6.405                        |
| 272.6                           | 23.01                 | 136.3                         | 7.834                        |
| 211.4                           | 22.57                 | 105.7                         | 7.784                        |
| Average                         | 19.70                 | 118.3                         | 6.931                        |
| Std. Dev.                       | 2.49                  | 15.9                          | 0.755                        |

TABLE F.3

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, -54°C (-65°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |             |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-------------|-----------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM           |             |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | In-Plane        |                         | Date Tested | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) | Poisson's Ratio | Ratio                   |             |           |
| BIL-GL-24-T1                                  | -65°F (DRY)     | 1.000       | 0.0662          | 2,246               | 33.93                   | 2.970                  | 16.96                 | 1.064                | 0.396           | 0.396                   | 8/17/89     | (1,2,3,5) |
| BIL-GL-24-T7                                  | "               | 1.000       | 0.0693          | 2,211               | 31.90                   | 2.647                  | 15.95                 | 0.962                | 0.376           | 0.376                   | "           | (1,2,3,5) |
| BIL-GL-24-T13                                 | "               | 0.999       | 0.0705          | 1,945               | 27.61                   | 2.762                  | 13.81                 | 0.975                | 0.416           | 0.416                   | "           | (1,2,3,5) |
| BIL-GL-21-T4                                  | "               | 0.996       | 0.0676          | 2,725               | 40.46                   | 3.388                  | 20.23                 | 1.163                | 0.457           | 0.457                   | "           | (1,2,3,5) |
| BIL-GL-21-T10                                 | "               | 0.998       | 0.0703          | 2,374               | 33.84                   | 2.458                  | 16.92                 | 0.917                | 0.341           | 0.341                   | 8/18/89     | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 33.55                   | 2.845                  | 16.77                 | 1.016                | 0.397           |                         |             |           |
| Std. Dev.                                     |                 |             |                 |                     | 4.64                    | 0.356                  | 2.32                  | 0.098                | 0.043           |                         |             |           |

F-4

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G=E/2(1+\nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 233.9                  | 20.48                 | 117.0                | 7.337               | 117.0                | 7.337               |
| 220.0                  | 18.25                 | 110.0                | 6.632               | 110.0                | 6.632               |
| 190.4                  | 19.04                 | 95.2                 | 6.724               | 95.2                 | 6.724               |
| 279.0                  | 23.36                 | 139.5                | 8.018               | 139.5                | 8.018               |
| 233.3                  | 16.95                 | 116.7                | 6.320               | 116.7                | 6.320               |
| Average                | 19.62                 | 115.7                | 7.006               | 115.7                | 7.006               |
| Std. Dev.              | 2.45                  | 16.0                 | 0.675               | 16.0                 | 0.675               |

TABLE F.4

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, 22°C (72°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |             |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-------------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: TOB          |             |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | In-Plane        |                         | Remarks     |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) | Poisson's Ratio | Date Tested             |             |
| BIL-GL-18-T2                                  | 72°F (DRY)      | 1.002       | 0.0675          | 1,828               | 27.03                   | 2.565                  | 13.52                 | 0.880                | 0.457           | 8/11/89                 | (1,2,3,5)   |
| BIL-GL-18-T8                                  | "               | 1.000       | 0.0670          | 1,729               | 25.80                   | 2.683                  | 12.90                 | 0.928                | 0.445           | "                       | (1,2,3,5)   |
| BIL-GL-18-T14                                 | "               | 0.998       | 0.0663          | 1,525               | 23.06                   | 2.390                  | 11.53                 | 0.836                | 0.429           | "                       | (1,2,3,5)   |
| BIL-GL-19-T5                                  | "               | 0.995       | 0.0640          | 1,204               | 18.91                   | 2.645                  | 9.45                  | 0.876                | 0.510           | 8/16/89                 | (1,2,3,5)   |
| BIL-GL-19-T11                                 | "               | 1.001       | 0.0650          | 1,371               | 21.07                   | 2.212                  | 10.54                 | 0.765                | 0.446           | "                       | (1,2,3,5)   |
| BIL-GL-19(R)-T5                               | "               | 1.003       | 0.0640          | 1,366               | 21.28                   | 2.515                  | 10.64                 | 0.878                | 0.432           | "                       | (1,2,3,5)   |
| BIL-GL-19(R)-T11                              | "               | 1.008       | 0.0720          | 1,565               | 21.56                   |                        | 10.78                 |                      | 0.425           | "                       | (1,2,3,5,6) |
|                                               |                 |             |                 | Average             | 22.67                   | 2.502                  | 11.34                 | 0.861                | 0.449           |                         |             |
|                                               |                 |             |                 | Std. Dev.           | 2.85                    | 0.176                  | 1.43                  | 0.055                | 0.029           |                         |             |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Incorrect load range; modulus calculations not included in averages.

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 186.4                  | 17.68                 | 93.2                 | 6.068               |                      |                     |
| 177.9                  | 18.50                 | 88.9                 | 6.401               |                      |                     |
| 159.0                  | 16.48                 | 79.5                 | 5.765               |                      |                     |
| 130.4                  | 18.24                 | 65.2                 | 6.039               |                      |                     |
| 145.3                  | 15.25                 | 72.6                 | 5.273               |                      |                     |
| 146.7                  | 17.34                 | 73.3                 | 6.054               |                      |                     |
| 148.7                  |                       | 74.3                 |                     |                      |                     |
| Average                | 17.25                 | 78.2                 | 5.933               |                      |                     |
| Std. Dev.              | 1.21                  | 9.8                  | 0.381               |                      |                     |

TABLE F.5

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 22°C (72°F) DRY

| Test : ±45° Tension/inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM & DH      |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GL-23(R)-1                                | 72°F (DRY)      | 0.994       | 0.0625          | 1,365               | 21.97                   | 2,068                  | 10.98                 | 0.742                | 0.394           | 2/22/90                 | (1,2,3,5) |
| BIL-GL-23(R)-7                                | "               | 1.001       | 0.0651          | 1,537               | 23.59                   | 2,208                  | 11.79                 | 0.746                | 0.480           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-13                               | "               | 1.001       | 0.0617          | 1,344               | 21.75                   | 2,101                  | 10.88                 | 0.784                | 0.340           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-2                                | "               | 0.998       | 0.0648          | 1,415               | 21.88                   | 1,829                  | 10.94                 | 0.664                | 0.377           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-8                                | "               | 1.001       | 0.0643          | 1,601               | 24.89                   | 1,817                  | 12.44                 | 0.625                | 0.454           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-14                               | "               | 1.002       | 0.0623          | 1,396               | 22.38                   | 2,268                  | 11.19                 | 0.817                | 0.388           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-3                                | "               | 0.999       | 0.0657          | 1,488               | 22.67                   | 1,800                  | 11.34                 | 0.674                | 0.336           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-9                                | "               | 0.999       | 0.0642          | 1,542               | 24.06                   | 1,953                  | 12.03                 | 0.652                | 0.498           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-15                               | "               | 1.000       | 0.0614          | 1,552               | 25.27                   | 2,230                  | 12.64                 | 0.800                | 0.394           | "                       | (1,2,3,5) |
| BIL-GL-20(R)-T5                               | "               | 0.995       | 0.0657          | 1,743               | 26.67                   | 2,095                  | 13.34                 | 0.686                | 0.526           | 7/26/89                 | (1,2,3,5) |
| BIL-GL-20(R)-T1                               | "               | 0.996       | 0.0655          | 1,475               | 22.59                   | 2,412                  | 11.30                 | 0.765                | 0.577           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 23.43                   | 2,071                  | 11.71                 | 0.723                | 0.433           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 1.62                    | 0.203                  | 0.81                  | 0.066                | 0.079           |                         |           |

Remarks:

(1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .

(2) Specimen had 0° and 90° strain gages attached.

(3) Test speed = 0.1 in/min.

(4) Specimen failed inside the "tab area".

(5) Specimen failed within the 6.5 inch gage section.

| SI Conversion                   |                       |                               |                              |       |
|---------------------------------|-----------------------|-------------------------------|------------------------------|-------|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) |       |
| 151.5                           | 14.26                 | 75.7                          | 5.113                        |       |
| 162.6                           | 15.22                 | 81.3                          | 5.143                        |       |
| 150.0                           | 14.49                 | 75.0                          | 5.406                        |       |
| 150.9                           | 12.61                 | 75.4                          | 4.577                        |       |
| 171.6                           | 12.53                 | 85.8                          | 4.307                        |       |
| 154.3                           | 15.64                 | 77.1                          | 5.635                        |       |
| 156.3                           | 12.41                 | 78.2                          | 4.645                        |       |
| 165.9                           | 13.46                 | 82.9                          | 4.494                        |       |
| 174.3                           | 15.38                 | 87.1                          | 5.517                        |       |
| 183.9                           | 14.44                 | 91.9                          | 4.732                        |       |
| 155.8                           | 16.63                 | 77.9                          | 5.272                        |       |
| Average                         | 161.5                 | 14.28                         | 80.8                         | 4.986 |
| Std. Dev.                       | 11.2                  | 1.40                          | 5.6                          | 0.453 |

Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.



TABLE F.7

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, 93°C (200°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                       |                        |                      |                      | Fiber Orientation: ±45° |             |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|-----------------------|------------------------|----------------------|----------------------|-------------------------|-------------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                       |                        |                      |                      | Tested By: PM           |             |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                       | Tensile Modulus (Msi.) | In-Plane             |                      | Poisson's Ratio         | Date Tested |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Shear Strength (Ksi.) |                        | Shear Modulus (Msi.) | Shear Modulus (Msi.) |                         |             |
| BIL-GL-18-T3                                  | 200°F (DRY)     | 1.000       | 0.0671          | 1,218               | 18.15                   | 9.08                  | 1.406                  | 0.392                | 0.392                | 0.794                   | 8/18/89     |
| BIL-GL-18-T9                                  | "               | 1.000       | 0.0684          | 985                 | 14.40                   | 7.20                  | 1.514                  | 0.477                | 0.477                | 0.589                   | "           |
| BIL-GL-18-T15                                 | "               | 0.997       | 0.0677          | 1,012               | 14.99                   | 7.50                  | 1.698                  | 0.505                | 0.505                | 0.681                   | "           |
| BIL-GL-19-T6                                  | "               | 1.000       | 0.0650          | 597                 | 9.18                    | 4.59                  | 1.035                  | 0.289                | 0.289                | 0.793                   | "           |
| BIL-GL-19-T12                                 | "               | 1.001       | 0.0650          | 898                 | 13.80                   | 6.90                  | 1.591                  | 0.499                | 0.499                | 0.594                   | "           |
| BIL-GL-19(R)-T6                               | "               | 1.006       | 0.0690          | 935                 | 13.47                   | 6.73                  | 1.578                  | 0.485                | 0.485                | 0.628                   | "           |
| BIL-GL-19(R)-T12                              | "               | 1.006       | 0.0710          | 1,061               | 14.85                   | 7.43                  | 1.567                  | 0.474                | 0.474                | 0.652                   | "           |
| Average                                       |                 |             |                 |                     | 14.12                   | 7.06                  | 1.484                  | 0.446                | 0.446                | 0.676                   |             |
| Std. Dev.                                     |                 |             |                 |                     | 2.66                    | 1.33                  | 0.217                  | 0.079                | 0.079                | 0.087                   |             |

T  
1  
8

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G=E/2(1+\nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Incorrect load range; modulus calculations not included in averages.

| SI Conversion                   |                       |                               |                              |         |           |
|---------------------------------|-----------------------|-------------------------------|------------------------------|---------|-----------|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) | Average | Std. Dev. |
|                                 |                       |                               |                              |         |           |
| 125.2                           | 9.69                  | 62.6                          | 2.701                        |         |           |
| 99.3                            | 10.44                 | 49.6                          | 3.287                        |         |           |
| 103.4                           | 11.71                 | 51.7                          | 3.481                        |         |           |
| 63.3                            | 7.14                  | 31.7                          | 1.989                        |         |           |
| 95.2                            | 10.97                 | 47.6                          | 3.443                        |         |           |
| 92.9                            | 10.88                 | 46.4                          | 3.341                        |         |           |
| 102.4                           | 10.81                 | 51.2                          | 3.270                        |         |           |
| 97.4                            | 10.23                 | 48.7                          | 3.073                        |         |           |
| 18.4                            | 1.49                  | 9.2                           | 0.544                        |         |           |



TABLE F.8

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 93°C (200°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                                |                               |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-------------------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                                |                               |                 | Tested By: PM & DH      |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane                       |                               | Poisson's Ratio | Date Tested             | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | In-Plane Shear Strength (Ksi.) | In-Plane Shear Modulus (Msi.) |                 |                         |           |
| BIL-GL-23(R)-X2                               | 200°F (DRY)     | 1.002       | 0.0635          | 865                 | 13.60                   | 1.463                  | 6.80                           | 0.512                         | 0.429           | 3/15/90                 | (1,2,3,5) |
| BIL-GL-23(R)-X4                               | "               | 0.997       | 0.0641          | 779                 | 12.18                   | 1.246                  | 6.09                           | 0.413                         | 0.508           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-X5                               | "               | 1.001       | 0.0616          | 747                 | 12.12                   | 1.301                  | 6.06                           | 0.418                         | 0.555           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-X6                               | "               | 0.876       | 0.0637          | 820                 | 14.71                   | 1.459                  | 7.35                           | 0.451                         | 0.617           | "                       | (1,2,3,5) |
| BIL-GL-23(R)-7                                | "               | 1.022       | 0.0610          | 814                 | 13.07                   | 1.432                  | 6.53                           | 0.450                         | 0.591           | "                       | (1,2,3,5) |
| BIL-GL-20(R)-T6                               | "               | 0.994       | 0.0655          | 989                 | 15.19                   | 1.377                  | 7.59                           | 0.423                         | 0.630           | 7/28/89                 | (1,2,3,5) |
| BIL-GL-20(R)-T12                              | "               | 0.999       | 0.0644          | 1,050               | 16.33                   | 1.596                  | 8.16                           | 0.467                         | 0.709           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 13.88                   | 1.411                  | 6.94                           | 0.448                         | 0.577           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 1.59                    | 0.116                  | 0.79                           | 0.035                         | 0.091           |                         |           |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion                   |                       |                               |                              |  |
|---------------------------------|-----------------------|-------------------------------|------------------------------|--|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) |  |
| 93.8                            | 10.09                 | 46.9                          | 3.532                        |  |
| 84.0                            | 8.59                  | 42.0                          | 2.848                        |  |
| 83.5                            | 8.97                  | 41.8                          | 2.884                        |  |
| 101.4                           | 10.06                 | 50.7                          | 3.111                        |  |
| 90.1                            | 9.88                  | 45.0                          | 3.103                        |  |
| 104.7                           | 9.50                  | 52.4                          | 2.913                        |  |
| 112.6                           | 11.00                 | 56.3                          | 3.219                        |  |
| Average                         | 9.73                  | 47.9                          | 3.087                        |  |
| Std. Dev.                       | 0.80                  | 5.5                           | 0.239                        |  |

TABLE F.9

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, 93°C (200°F) DRY

| ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|----------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; 7781 Glass     |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM           |           |
| Specimen Number                        | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                        |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GL-24-T3                           | 200°F (DRY)     | 1.000       | 0.0689          | 1,106               | 16.06                   | 1.777                  | 8.03                  | 0.549                | 0.619           | 8/21/89                 | (1,2,3,5) |
| BIL-GL-24-T9                           | "               | 1.001       | 0.0679          | 891                 | 13.11                   | 1.503                  | 6.56                  | 0.466                | 0.614           | "                       | (1,2,3,5) |
| BIL-GL-24-T15                          | "               | 1.000       | 0.0655          | 895                 | 13.67                   | 1.479                  | 6.83                  | 0.433                | 0.710           | "                       | (1,2,3,5) |
| BIL-GL-21-T6                           | "               | 0.998       | 0.0689          | 845                 | 12.29                   | 1.443                  | 6.14                  | 0.456                | 0.583           | "                       | (1,2,3,5) |
| BIL-GL-21-T12                          | "               | 0.998       | 0.0699          | 1,334               | 19.11                   | 1.785                  | 9.56                  | 0.547                | 0.631           | "                       | (1,2,3,5) |
|                                        |                 |             |                 | Average             | 14.85                   | 1.597                  | 7.42                  | 0.490                | 0.631           |                         |           |
|                                        |                 |             |                 | Std. Dev.           | 2.77                    | 0.169                  | 1.38                  | 0.054                | 0.047           |                         |           |

T. 10

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |          |  |
|------------------------|-----------------------|----------------------|---------------------|----------|--|
| Ultimate               |                       | In-Plane             |                     | In-Plane |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |          |  |
| 110.7                  | 12.25                 | 55.4                 | 3.785               |          |  |
| 90.4                   | 10.36                 | 45.2                 | 3.210               |          |  |
| 94.2                   | 10.20                 | 47.1                 | 2.982               |          |  |
| 84.7                   | 9.95                  | 42.4                 | 3.142               |          |  |
| 131.8                  | 12.31                 | 65.9                 | 3.772               |          |  |
| Average                | 11.01                 | 51.2                 | 3.378               |          |  |
| Std. Dev.              | 1.17                  | 9.5                  | 0.375               |          |  |

TABLE F.10

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, -54°C (-65°F) WET

| ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |               |
|----------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|---------------|
| Material : EA-9396 A/B; 7781 Glass     |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |               |
| Specimen Number                        | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks       |
|                                        |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |               |
| BIL-GL-18-T4                           | -65°F (WET)     | 0.997       | 0.0670          | 1,071               | 16.03                   | 2.806                  | 8.02                  | 0.924                | 0.519           | 1/18/90                 | (1,2,3,4,6,7) |
| BIL-GL-18-T10                          | "               | 0.999       | 0.0660          | 1,296               | 19.56                   | 2.789                  | 9.83                  | 0.959                | 0.454           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19-T1                           | "               | 0.993       | 0.0650          | 1,375               | 21.31                   | 2.793                  | 10.66                 | 0.933                | 0.496           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19-T7                           | "               | 1.000       | 0.0640          | 1,011               | 15.80                   | 2.636                  | 7.90                  | 0.947                | 0.392           | "                       | (1,2,3,5,6,7) |
| BIL-GL-19-T13                          | "               | 1.003       | 0.0660          | 1,404               | 21.21                   | 2.752                  | 10.61                 | 0.969                | 0.421           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19(R)-T1                        | "               | 1.003       | 0.0670          | 1,021               | 15.20                   | 2.670                  | 7.60                  | 0.885                | 0.509           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19(R)-T7                        | "               | 1.006       | 0.0730          | 1,084               | 14.75                   | 2.568                  | 7.38                  | 0.870                | 0.476           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19(R)-T13                       | "               | 1.006       | 0.0710          | 1,133               | 15.87                   | 2.934                  | 7.93                  | 0.951                | 0.543           | "                       | (1,2,3,4,6,7) |
| Average                                |                 |             |                 |                     | 17.48                   | 2.743                  | 8.74                  | 0.930                | 0.476           |                         |               |
| Std. Dev.                              |                 |             |                 |                     | 2.77                    | 0.115                  | 1.38                  | 0.035                | 0.051           |                         |               |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 112 days.
- (7) Weight gain = 1.9484%

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 110.5                  | 19.35                 | 55.3                 | 6.370               | 67.8                 | 6.610               |
| 135.6                  | 19.23                 | 73.5                 | 6.435               | 73.1                 | 6.678               |
| 146.9                  | 18.17                 | 54.5                 | 6.528               | 52.4                 | 6.102               |
| 108.9                  | 18.98                 | 50.9                 | 5.999               | 54.7                 | 6.558               |
| 146.3                  | 18.41                 |                      |                     |                      |                     |
| 104.8                  | 17.71                 |                      |                     |                      |                     |
| 101.7                  | 20.23                 |                      |                     |                      |                     |
| 109.4                  |                       |                      |                     |                      |                     |
| Average                | 120.5                 | 60.3                 | 6.407               |                      |                     |
| Std. Dev.              | 19.1                  | 9.5                  | 0.377               |                      |                     |

TABLE F.11

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, -54°C (-65°F) WET

| Test :           |                 | ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                     |                         | Fiber Orientation:     |                       | ±45°                 |             |
|------------------|-----------------|----------------------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-------------|
| Material :       |                 | EA-9396 A/B; 7781 Glass                |                 |                     |                         | Tested By:             |                       | PM & DH              |             |
| Specimen Number: | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Date Tested |
|                  |                 |                                        |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |             |
| BIL-GL-23(R)-4   | -65°F (WET)     | 1.000                                  | 0.0644          | 1,179               | 18.31                   | 2.403                  | 9.15                  | 0.867                | 0.385       |
| BIL-GL-23(R)-10  | "               | 1.002                                  | 0.0629          | 1,178               | 18.70                   | 2.494                  | 9.35                  | 0.855                | 0.458       |
| BIL-GL-20(R)-T1  | "               | 0.997                                  | 0.0640          | 1,105               | 17.32                   | 2.297                  | 8.66                  | 0.749                | 0.534       |
| BIL-GL-20(R)-T7  | "               | 0.995                                  | 0.0660          | 1,045               | 15.92                   | 2.279                  | 7.96                  | 0.749                | 0.521       |
| BIL-GL-20(R)-T13 | "               | 0.996                                  | 0.0690          | 927                 | 13.49                   | 2.051                  | 6.74                  | 0.624                | 0.644       |
| Average          |                 |                                        |                 |                     | 16.75                   | 2.305                  | 8.37                  | 0.769                | 0.508       |
| Std. Dev.        |                 |                                        |                 |                     | 2.12                    | 0.166                  | 1.06                  | 0.099                | 0.096       |

F-12

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 111 days.
- (7) Weight gain = 1.5524%
- (8) Weight gain = 2.1134%

| SI Conversion |                        |                       |                      |                     |             |
|---------------|------------------------|-----------------------|----------------------|---------------------|-------------|
| Ultimate      | In-Plane               |                       | In-Plane             |                     | Date Tested |
|               | Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |             |
| 126.2         | 16.57                  | 63.1                  | 5.981                |                     |             |
| 128.9         | 17.19                  | 64.5                  | 5.897                |                     |             |
| 119.5         | 15.84                  | 59.7                  | 5.163                |                     |             |
| 109.8         | 15.71                  | 54.9                  | 5.167                |                     |             |
| 93.0          | 14.14                  | 46.5                  | 4.301                |                     |             |
| Average       | 15.89                  | 57.7                  | 5.302                |                     |             |
| Std. Dev.     | 1.14                   | 7.3                   | 0.681                |                     |             |

TABLE F.12

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, -54°C (-65°F) WET

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |               |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|---------------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |               |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | in-Plane              |                      | In-Plane        |                         | Remarks       |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) | Poisson's Ratio | Date Tested             |               |
| BIL-GL-21-T1                                  | -65°F (WET)     | 0.996       | 0.0660          | 1,203               | 18.29                   | 2.954                  | 9.15                  | 0.976                | 0.514           | 1/18/90                 | (1,2,3,4,6,7) |
| BIL-GL-21-T7                                  | "               | 0.997       | 0.0670          | 916                 | 13.71                   | 2.394                  | 6.85                  | 0.800                | 0.496           | "                       | (1,2,3,4,6,7) |
| BIL-GL-21-T13                                 | "               | 0.998       | 0.0680          | 1,187               | 17.48                   | 2.822                  | 8.74                  | 0.965                | 0.463           | "                       | (1,2,3,4,6,7) |
| BIL-GL-24-T4                                  | "               | 0.998       | 0.0680          | 1,151               | 16.96                   | 2.540                  | 8.48                  | 0.847                | 0.499           | "                       | (1,2,3,4,6,8) |
| BIL-GL-24-T10                                 | "               | 1.001       | 0.0670          | 1,115               | 16.62                   | 2.350                  | 8.31                  | 0.774                | 0.519           | "                       | (1,2,3,4,6,8) |
| Average                                       |                 |             |                 |                     | 16.61                   | 2.612                  | 8.31                  | 0.872                | 0.498           |                         |               |
| Std. Dev.                                     |                 |             |                 |                     | 1.74                    | 0.266                  | 0.87                  | 0.093                | 0.022           |                         |               |

| SI Conversion          |                       |                      |                     |  |  |
|------------------------|-----------------------|----------------------|---------------------|--|--|
| Ultimate               | In-Plane              |                      | In-Plane            |  |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |  |  |
| 126.1                  | 20.37                 | 63.1                 | 6.727               |  |  |
| 94.5                   | 16.51                 | 47.3                 | 5.517               |  |  |
| 120.6                  | 19.46                 | 60.3                 | 6.653               |  |  |
| 116.9                  | 17.52                 | 58.5                 | 5.842               |  |  |
| 114.6                  | 16.21                 | 57.3                 | 5.335               |  |  |
| Average                | 18.01                 | 57.3                 | 6.015               |  |  |
| Std. Dev.              | 1.83                  | 6.0                  | 0.643               |  |  |

F-13

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 112 days.
- (7) Weight gain = 1.7099%
- (8) Weight gain = 1.8162%

TABLE F.13

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, 22°C (72°F) WET

| ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                         |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |               |
|----------------------------------------|-----------------|-------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|---------------|
| Material :                             |                 | EA-9396 A/B; 7781 Glass |                 |                     | Batch #1                |                        | Task #6               |                      | Tested By: DH   |                         |               |
| Specimen Number                        | Test Conditions | Width (in.)             | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks       |
|                                        |                 |                         |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |               |
| BIL-GL-18-T5                           | 72°F (WET)      | 0.997                   | 0.0670          | 792                 | 11.86                   | 1.643                  | 5.93                  | 0.478                | 0.720           | 1/16/90                 | (1,2,3,5,6,7) |
| BIL-GL-18-T11                          | "               | 1.000                   | 0.0650          | 789                 | 12.13                   | 1.533                  | 6.07                  | 0.492                | 0.559           | "                       | (1,2,3,5,6,7) |
| BIL-GL-19-T2                           | "               | 0.998                   | 0.0660          | 753                 | 11.43                   | 1.318                  | 5.72                  | 0.438                | 0.504           | "                       | (1,2,3,5,6,7) |
| BIL-GL-19-T8                           | "               | 1.000                   | 0.0640          | 533                 | 8.32                    | 1.589                  | 4.16                  | 0.559                | 0.422           | "                       | (1,2,3,5,6,7) |
| BIL-GL-19-T14                          | "               | 1.002                   | 0.0680          | 759                 | 11.14                   | 1.558                  | 5.57                  | 0.436                | 0.788           | "                       | (1,2,3,5,6,7) |
| BIL-GL-19(R)-T2                        | "               | 1.004                   | 0.0690          | 834                 | 12.04                   | 1.385                  | 6.02                  | 0.419                | 0.650           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19(R)-T8                        | "               | 1.004                   | 0.0720          | 634                 | 8.77                    | 1.450                  | 4.38                  | 0.467                | 0.552           | "                       | (1,2,3,4,6,7) |
| BIL-GL-19(R)-T14                       | "               | 1.007                   | 0.0710          | 733                 | 10.25                   | 1.821                  | 5.13                  | 0.540                | 0.685           | "                       | (1,2,3,4,6,7) |
| Average                                |                 |                         |                 |                     | 10.74                   | 1.537                  | 5.37                  | 0.479                | 0.610           |                         |               |
| Std. Dev.                              |                 |                         |                 |                     | 1.49                    | 0.158                  | 0.74                  | 0.050                | 0.121           |                         |               |

F.14

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G=E/2(1+\nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 111 days.
- (7) Weight gain = 2.0141%

| SI Conversion                   |                       |                               |                              |
|---------------------------------|-----------------------|-------------------------------|------------------------------|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) |
| 81.8                            | 11.33                 | 40.9                          | 3.293                        |
| 83.6                            | 10.57                 | 41.8                          | 3.390                        |
| 78.8                            | 9.08                  | 39.4                          | 3.020                        |
| 57.4                            | 10.96                 | 28.7                          | 3.851                        |
| 76.8                            | 10.74                 | 38.4                          | 3.005                        |
| 83.0                            | 9.55                  | 41.5                          | 2.892                        |
| 60.5                            | 10.00                 | 30.2                          | 3.221                        |
| 70.7                            | 12.55                 | 35.3                          | 3.726                        |
| Average                         | 10.60                 | 37.0                          | 3.291                        |
| Std. Dev.                       | 1.09                  | 5.1                           | 0.484                        |

TABLE F.14

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 22°C (72°F) WET

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |               |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|---------------|
| Material : EA-9396 A/B; 7781 Glass            |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By:              |               |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks       |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |               |
|                                               |                 |             |                 |                     |                         |                        |                       |                      |                 |                         |               |
| BIL-GL-23(R)-5                                | 72°F (WET)      | 0.998       | 0.0644          | 713                 | 11.10                   | 1.543                  | 5.55                  | 0.510                | 0.511           | 4/5/90                  | (1,2,3,5,6,8) |
| BIL-GL-23(R)-11                               | "               | 1.002       | 0.0626          | 714                 | 11.39                   | 1.575                  | 5.70                  | 0.564                | 0.397           | "                       | (1,2,3,5,6,8) |
| BIL-GL-20(R)-T2                               | "               | 0.998       | 0.0720          | 730                 | 10.17                   | 1.279                  | 5.08                  | 0.363                | 0.761           | 1/16/90                 | (1,2,3,4,6,7) |
| BIL-GL-20(R)-T8                               | "               | 0.996       | 0.0650          | 660                 | 10.20                   | 1.121                  | 5.10                  | 0.336                | 0.668           | "                       | (1,2,3,5,6,7) |
| BIL-GL-20(R)-T14                              | "               | 0.999       | 0.0680          | 818                 | 12.05                   | 1.461                  | 6.02                  | 0.429                | 0.703           | "                       | (1,2,3,4,5,7) |
| Average                                       |                 |             |                 |                     | 10.98                   | 1.396                  | 5.49                  | 0.441                | 0.608           |                         |               |
| Std. Dev.                                     |                 |             |                 |                     | 0.81                    | 0.192                  | 0.40                  | 0.096                | 0.150           |                         |               |

TABLE F.15

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, 22°C (72°F) WET

| Test :          |                 | ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                     |                         | Fiber Orientation: ±45° |                       |                      |             |
|-----------------|-----------------|----------------------------------------|-----------------|---------------------|-------------------------|-------------------------|-----------------------|----------------------|-------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass                |                 |                     |                         | Tested By: DH           |                       |                      |             |
| Specimen Number | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                         | In-Plane              |                      | Date Tested |
|                 |                 |                                        |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.)  | Shear Strength (Ksi.) | Shear Modulus (Msi.) |             |
| BIL-GL-21-T2    | 72°F (WET)      | 0.993                                  | 0.0670          | 817                 | 12.28                   | 1.997                   | 6.14                  | 0.585                | 1/17/90     |
| BIL-GL-21-T8    | "               | 0.996                                  | 0.0650          | 588                 | 9.09                    | 1.653                   | 4.54                  | 0.541                | "           |
| BIL-GL-21-T14   | "               | 0.996                                  | 0.0690          | 885                 | 12.88                   | 2.203                   | 6.44                  | 0.666                | "           |
| BIL-GL-24-T5    | "               | 0.997                                  | 0.0670          | 810                 | 12.12                   | 1.629                   | 6.06                  | 0.535                | "           |
| BIL-GL-24-T11   | "               | 0.998                                  | 0.0670          | 694                 | 10.38                   | 1.778                   | 5.19                  | 0.457                | "           |
| Average         |                 |                                        |                 |                     | 11.35                   | 1.852                   | 5.67                  | 0.557                | 0.672       |
| Std. Dev.       |                 |                                        |                 |                     | 1.57                    | 0.244                   | 0.79                  | 0.076                | 0.172       |

Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G = E/2(1 + \nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 111 days.
- (7) Weight gain = 1.6932%
- (8) Weight gain = 1.8157%

| SI Conversion |                        |                       |                      |                     |  |
|---------------|------------------------|-----------------------|----------------------|---------------------|--|
| Ultimate      | In-Plane               |                       | In-Plane             |                     |  |
|               | Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |  |
|               | 84.7                   | 13.77                 | 42.3                 | 4.035               |  |
|               | 62.7                   | 11.40                 | 31.3                 | 3.729               |  |
|               | 88.8                   | 15.19                 | 44.4                 | 4.589               |  |
|               | 83.6                   | 11.23                 | 41.8                 | 3.686               |  |
|               | 71.5                   | 12.26                 | 35.8                 | 3.151               |  |
| Average       | 78.3                   | 12.77                 | 39.1                 | 3.838               |  |
| Std. Dev.     | 10.8                   | 1.68                  | 5.4                  | 0.527               |  |



TABLE F.16

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH I, 93°C (200°F) WET

| Test : $\pm 45^\circ$ Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: $\pm 45^\circ$ |               |
|---------------------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-----------------------------------|---------------|
| Material : EA-9396 A/B; 7781 Glass                      |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH                     |               |
| Specimen Number                                         | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested                       | Remarks       |
|                                                         |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                                   |               |
| BIL-GL-18-T6                                            | 200°F (WET)     | 0.999       | 0.0680          | 465                 | 6.85                    | 0.824                  | 3.42                  | 0.262                | 0.571           | 1/19/90                           | (1,2,3,5,6,7) |
| BIL-GL-18-T12                                           | "               | 0.998       | 0.0650          | 360                 | 5.55                    | 0.724                  | 2.78                  | 0.206                | 0.758           | "                                 | (1,2,3,5,6,7) |
| BIL-GL-19-T3                                            | "               | 0.999       | 0.0640          | 305                 | 4.77                    | 0.888                  | 2.38                  | 0.249                | 0.784           | "                                 | (1,2,3,5,6,7) |
| BIL-GL-19-T9                                            | "               | 1.001       | 0.0650          | 286                 | 4.39                    | 0.967                  | 2.20                  | 0.319                | 0.514           | "                                 | (1,2,3,5,6,7) |
| BIL-GL-19-T15                                           | "               | 1.003       | 0.0670          | 408                 | 6.08                    | 0.673                  | 3.04                  | 0.157                | 1.139           | "                                 | (1,2,3,5,6,7) |
| BIL-GL-19(R)-T3                                         | "               | 1.004       | 0.0690          | 413                 | 5.96                    | 0.667                  | 2.98                  | 0.164                | 1.039           | "                                 | (1,2,3,5,6,7) |
| BIL-GL-19(R)-T9                                         | "               | 1.003       | 0.0700          | 304                 | 4.34                    | 0.921                  | 2.17                  | 0.284                | 0.620           | "                                 | (1,2,3,4,6,7) |
| Average                                                 |                 |             |                 |                     | 5.42                    | 0.809                  | 2.71                  | 0.234                | 0.775           |                                   |               |
| Std. Dev.                                               |                 |             |                 |                     | 0.95                    | 0.122                  | 0.48                  | 0.061                | 0.237           |                                   |               |

F-17

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had  $0^\circ$  and  $90^\circ$  strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @  $140^\circ\text{F}/95\text{--}100\%$  R.H. for 117 days.
- (7) Weight gain = 2.0860%

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 47.2                   | 5.68                  | 23.6                 | 1.809               | 19.1                 | 1.419               |
| 38.3                   | 4.99                  | 16.4                 | 1.716               | 15.1                 | 2.202               |
| 32.9                   | 6.12                  | 21.0                 | 1.084               | 20.5                 | 1.128               |
| 30.3                   | 6.67                  | 14.9                 | 1.960               |                      |                     |
| 41.9                   | 4.64                  |                      |                     |                      |                     |
| 41.1                   | 4.60                  |                      |                     |                      |                     |
| 29.9                   | 6.35                  |                      |                     |                      |                     |
| Average                | 5.58                  | 18.7                 | 1.571               |                      |                     |
| Std. Dev.              | 0.84                  | 3.3                  | 0.341               |                      |                     |

TABLE F.17

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 93°C (200°F) WET

| ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                                |                               |                 | Fiber Orientation: ±45° |               |
|----------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-------------------------------|-----------------|-------------------------|---------------|
| Material: EA-9396 A/B; 7781 Glass      |                 |             |                 |                     |                         |                        |                                |                               |                 | Tested By: PM & DH      |               |
| Specimen Number                        | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane                       |                               | Poisson's Ratio | Date Tested             | Remarks       |
|                                        |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | In-Plane Shear Strength (Ksi.) | In-Plane Shear Modulus (Msi.) |                 |                         |               |
| BIL-GL-23(R)-6                         | 200°F (WET)     | 1.002       | 0.0643          | 377                 | 5.86                    | 0.739                  | 2.93                           | 0.208                         | 0.778           | 4/5/90                  | (1,2,3,5,6,8) |
| BIL-GL-23(R)-12                        | "               | 1.000       | 0.0633          | 349                 | 5.51                    | 0.770                  | 2.76                           | 0.252                         | 0.529           | "                       | (1,2,3,5,6,8) |
| BIL-GL-20(R)-T3                        | "               | 0.996       | 0.0660          | 386                 | 5.87                    | 0.856                  | 2.94                           | 0.202                         | 1.124           | 1/22/90                 | (1,2,3,5,6,7) |
| BIL-GL-20(R)-T9                        | "               | 0.993       | 0.0660          | 345                 | 5.26                    | 0.537                  | 2.63                           | 0.146                         | 0.842           | "                       | (1,2,3,5,6,7) |
| BIL-GL-20(R)-T15                       | "               | 1.000       | 0.0670          | 366                 | 5.47                    | 0.529                  | 2.73                           | 0.163                         | 0.927           | "                       | (1,2,3,5,6,7) |
| Average                                |                 |             |                 |                     | 5.59                    | 0.706                  | 2.80                           | 0.194                         | 0.840           |                         |               |
| Std. Dev.                              |                 |             |                 |                     | 0.26                    | 0.125                  | 0.13                           | 0.041                         | 0.217           |                         |               |

Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 114 days.
- (7) Weight gain = 1.5621%
- (8) Weight gain = 1.9967%

| SI Conversion |                        |                       |          |       |         |
|---------------|------------------------|-----------------------|----------|-------|---------|
| Ultimate      | In-Plane               |                       | In-Plane | Shear | Modulus |
|               | Tensile Strength (MPa) | Tensile Modulus (GPa) |          |       |         |
| 40.4          | 5.09                   | 20.2                  | 1.432    |       |         |
| 38.0          | 5.31                   | 19.0                  | 1.735    |       |         |
| 40.5          | 5.91                   | 20.2                  | 1.390    |       |         |
| 36.3          | 3.70                   | 18.1                  | 1.005    |       |         |
| 37.7          | 4.34                   | 18.9                  | 1.125    |       |         |
| Average       | 38.6                   | 4.87                  | 19.3     |       | 1.338   |
| Std. Dev.     | 1.8                    | 0.86                  | 0.9      |       | 0.285   |

TABLE F.18

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, 93°C (200°F) WET

| Test :          |                 | ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                     |                         | Fiber Orientation: ±45° |                       |                      |                 |
|-----------------|-----------------|----------------------------------------|-----------------|---------------------|-------------------------|-------------------------|-----------------------|----------------------|-----------------|
| Material :      |                 | EA-9396 A/B; 7781 Glass                |                 |                     |                         | Tested By: DH           |                       |                      |                 |
| Specimen Number | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                         | In-Plane              |                      | Remarks         |
|                 |                 |                                        |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.)  | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |
| BIL-GL-21-T3    | 200°F (WET)     | 0.998                                  | 0.0680          | 371                 | 5.46                    | 1.175                   | 2.73                  | 0.309                | 0.898 1/22/90   |
| BIL-GL-21-T9    | "               | 0.998                                  | 0.0700          | 320                 | 4.58                    | 1.479                   | 2.29                  | 0.436                | " (1,2,3,4,6,7) |
| BIL-GL-21-T15   | "               | 0.996                                  | 0.0660          | 432                 | 6.57                    | 1.268                   | 3.29                  | 0.363                | " (1,2,3,5,6,7) |
| BIL-GL-24-T6    | "               | 0.999                                  | 0.0670          | 360                 | 5.37                    | 0.673                   | 2.69                  | 0.183                | " (1,2,3,4,6,7) |
| BIL-GL-24-T12   | "               | 0.998                                  | 0.0690          | 348                 | 5.05                    | 0.860                   | 2.53                  | 0.215                | " (1,2,3,5,6,8) |
| Average         |                 |                                        |                 |                     | 5.41                    | 1.091                   | 2.70                  | 0.301                | 0.835           |
| Std. Dev.       |                 |                                        |                 |                     | 0.74                    | 0.323                   | 0.37                  | 0.104                | 0.120           |

| SI Conversion          |                       |                      |                     |  |
|------------------------|-----------------------|----------------------|---------------------|--|
| Ultimate               | In-Plane              |                      | In-Plane            |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |  |
| 37.7                   | 8.10                  | 18.8                 | 2.134               |  |
| 31.6                   | 10.19                 | 15.8                 | 3.006               |  |
| 45.3                   | 8.74                  | 22.7                 | 2.504               |  |
| 37.0                   | 4.64                  | 18.5                 | 1.260               |  |
| 34.8                   | 5.93                  | 17.4                 | 1.485               |  |
| Average                | 7.52                  | 18.6                 | 2.078               |  |
| Std. Dev.              | 2.22                  | 2.5                  | 0.719               |  |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G=E/2(1+\nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 114 days.
- (7) Weight gain = 1.7197%
- (8) Weight gain = 1.8613%

TABLE F.19

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, -54°C (-65°F) DRY

| Test :          |                 | ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                     |                         | Fiber Orientation: ±45°        |                 |
|-----------------|-----------------|----------------------------------------|-----------------|---------------------|-------------------------|--------------------------------|-----------------|
| Material :      |                 | EA-9396 A/B; W133 Graphite             |                 |                     |                         | Tested By: PM                  |                 |
| Specimen Number | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                                | Date Tested     |
|                 |                 |                                        |                 |                     | Tensile Strength (Ksi.) | In-Plane Shear Strength (Ksi.) |                 |
| BIL-GR-37-1     | -65°F (DRY)     | 1.003                                  | 0.1163          | 5,090               | 43.62                   | 21.81                          | 12/29/89        |
| BIL-GR-37-7     | "               | 1.002                                  | 0.1236          | 4,778               | 38.56                   | 19.28                          | "               |
| BIL-GR-37-13    | "               | 1.001                                  | 0.1223          | 4,248               | 34.69                   | 17.35                          | "               |
| BIL-GR-42-T4    | "               | 0.996                                  | 0.1212          | 4,011               | 33.22                   | 16.61                          | 1/2/90          |
| BIL-GR-42-T10   | "               | 0.999                                  | 0.1229          | 3,848               | 31.34                   | 15.67                          | "               |
| Average         |                 |                                        |                 |                     | 35.29                   | 18.14                          | 0.797           |
| Std. Dev.       |                 |                                        |                 |                     | 4.88                    | 2.44                           | 0.097           |
|                 |                 |                                        |                 |                     |                         |                                | 0.723           |
|                 |                 |                                        |                 |                     |                         |                                | 0.052           |
| Specimen Number | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Tensile Modulus (Msi.)  |                                | Poisson's Ratio |
|                 |                 |                                        |                 |                     | Tensile Modulus (Msi.)  | In-Plane Shear Modulus (Msi.)  |                 |
| BIL-GR-37-1     | -65°F (DRY)     | 1.003                                  | 0.1163          | 5,090               | 3.222                   | 0.967                          | 0.666           |
| BIL-GR-37-7     | "               | 1.002                                  | 0.1236          | 4,778               | 2.718                   | 0.776                          | 0.751           |
| BIL-GR-37-13    | "               | 1.001                                  | 0.1223          | 4,248               | 2.744                   | 0.766                          | 0.792           |
| BIL-GR-42-T4    | "               | 0.996                                  | 0.1212          | 4,011               | 2.544                   | 0.758                          | 0.679           |
| BIL-GR-42-T10   | "               | 0.999                                  | 0.1229          | 3,848               | 2.482                   | 0.719                          | 0.726           |
| Average         |                 |                                        |                 |                     | 2.742                   | 0.797                          | 0.723           |
| Std. Dev.       |                 |                                        |                 |                     | 0.290                   | 0.097                          | 0.052           |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion |                        |                      |                     |
|---------------|------------------------|----------------------|---------------------|
| Ultimate      | In-Plane               |                      | In-Plane            |
|               | Tensile Strength (MPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 300.8         | 22.21                  | 150.4                | 6.667               |
| 265.9         | 18.74                  | 132.9                | 5.350               |
| 239.2         | 18.92                  | 119.6                | 5.279               |
| 229.0         | 17.54                  | 114.5                | 5.224               |
| 216.1         | 17.11                  | 108.1                | 4.959               |
| Average       | 18.90                  | 125.1                | 5.496               |
| Std. Dev.     | 2.00                   | 16.8                 | 0.671               |

TABLE F.20

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, -54°C (-65°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM           |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GR-38-1                                   | -65°F (DRY)     | 1.003       | 0.1220          | 4,167               | 34.05                   | 2.673                  | 17.03                 | 0.819                | 0.632           | 1/2/90                  | (1,2,3,5) |
| BIL-GR-38-7                                   | "               | 1.002       | 0.1243          | 4,797               | 38.50                   | 3.204                  | 19.25                 | 0.940                | 0.704           | "                       | (1,2,3,5) |
| BIL-GR-38-13                                  | "               | 1.002       | 0.1245          | 4,063               | 32.58                   | 2.972                  | 16.29                 | 0.898                | 0.656           | "                       | (1,2,3,5) |
| BIL-GR-39-4                                   | "               | 0.996       | 0.1220          | 4,456               | 36.67                   | 2.559                  | 18.33                 | 0.772                | 0.659           | "                       | (1,2,3,5) |
| BIL-GR-39-10                                  | "               | 0.997       | 0.1220          | 4,014               | 33.00                   | 2.647                  | 16.50                 | 0.769                | 0.722           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 34.96                   | 2.811                  | 17.48                 | 0.839                | 0.674           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 2.54                    | 0.269                  | 1.27                  | 0.077                | 0.037           |                         |           |

F-21

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion                   |                       |                               |                              |  |
|---------------------------------|-----------------------|-------------------------------|------------------------------|--|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) |  |
| 234.8                           | 18.43                 | 117.4                         | 5.649                        |  |
| 265.5                           | 22.09                 | 132.7                         | 6.482                        |  |
| 224.7                           | 20.49                 | 112.3                         | 6.188                        |  |
| 252.8                           | 17.65                 | 126.4                         | 5.320                        |  |
| 227.6                           | 18.25                 | 113.8                         | 5.301                        |  |
| Average                         | 19.38                 | 120.5                         | 5.788                        |  |
| Std. Dev.                       | 1.85                  | 8.8                           | 0.529                        |  |

TABLE F.21

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, -54°C (-65°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                                |                               |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-------------------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                                |                               |                 | Tested By: PM           |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Batch #3                |                        | Task #6                        |                               | In-Plane        |                         |           |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | In-Plane Shear Strength (Ksi.) | In-Plane Shear Modulus (Msi.) | Poisson's Ratio | Date Tested             | Remarks   |
| BIL-GR-40-1                                   | -65°F (DRY)     | 0.998       | 0.1187          | 4,697               | 39.64                   | 3.122                  | 19.82                          | 0.874                         | 0.787           | 1/2/90                  | (1,2,3,5) |
| BIL-GR-40-7                                   | "               | 1.001       | 0.1305          | 4,951               | 37.89                   | 2.588                  | 18.95                          | 0.769                         | 0.682           | "                       | (1,2,3,5) |
| BIL-GR-40-13                                  | "               | 1.002       | 0.1283          | 5,098               | 39.65                   | 2.889                  | 19.83                          | 0.834                         | 0.733           | 1/3/90                  | (1,2,3,5) |
| BIL-GR-41-T4                                  | "               | 1.000       | 0.1202          | 4,878               | 40.50                   | 3.180                  | 20.30                          | 0.890                         | 0.787           | "                       | (1,2,3,5) |
| BIL-GR-41-T10                                 | "               | 0.998       | 0.1195          | 4,504               | 37.75                   | 2.943                  | 18.88                          | 0.882                         | 0.668           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 39.11                   | 2.945                  | 19.55                          | 0.850                         | 0.731           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 1.24                    | 0.233                  | 0.62                           | 0.050                         | 0.056           |                         |           |

F-22

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 273.3                  | 21.53                 | 136.6                | 6.024               | 136.6                | 5.305               |
| 261.3                  | 17.85                 | 130.6                | 5.305               | 136.7                | 5.749               |
| 273.4                  | 19.92                 | 136.7                | 6.134               | 140.0                | 6.083               |
| 280.0                  | 21.93                 | 140.0                | 6.134               | 130.2                | 5.859               |
| 260.3                  | 20.29                 | 130.2                | 5.859               | 4.3                  | 0.344               |
| Average                | 20.30                 | 134.8                | 5.859               |                      |                     |
| Std. Dev.              | 1.61                  | 4.3                  | 0.344               |                      |                     |

TABLE F.22

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, 22°C (72°F) DRY

| Test : $\pm 45^\circ$ Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: $\pm 45^\circ$ |           |
|---------------------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-----------------------------------|-----------|
| Material : EA-9396 A/B; W133 Graphite                   |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM                     |           |
| Specimen Number                                         | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested                       | Remarks   |
|                                                         |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                                   |           |
| BIL-GR-37-2                                             | 72°F (DRY)      | 1.002       | 0.1201          | 3,599               | 29.91                   | 2.582                  | 14.95                 | 0.721                | 0.790           | 12/11/89                          | (1,2,3,5) |
| BIL-GR-37-8                                             | "               | 1.004       | 0.1236          | 3,413               | 27.50                   | 1.937                  | 13.75                 | 0.535                | 0.810           | "                                 | (1,2,3,5) |
| BIL-GR-37-14                                            | "               | 1.003       | 0.1227          | 3,125               | 25.39                   | 2.107                  | 12.69                 | 0.560                | 0.881           | "                                 | (1,2,3,5) |
| BIL-GR-42-T5                                            | "               | 0.992       | 0.1238          | 2,883               | 23.49                   | 1.979                  | 11.74                 | 0.568                | 0.742           | "                                 | (1,2,3,5) |
| T <sup>1</sup> BIL-GR-42-T11                            | "               | 0.998       | 0.1238          | 2,864               | 23.17                   | 1.766                  | 11.59                 | 0.510                | 0.733           | "                                 | (1,2,3,5) |
| Average                                                 |                 |             |                 |                     | 25.89                   | 2.074                  | 12.95                 | 0.579                | 0.791           |                                   |           |
| Std. Dev.                                               |                 |             |                 |                     | 2.83                    | 0.309                  | 1.42                  | 0.083                | 0.060           |                                   |           |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |          |  |
|------------------------|-----------------------|----------------------|---------------------|----------|--|
| Ultimate               |                       | In-Plane             |                     | In-Plane |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |          |  |
| 206.2                  | 17.81                 | 103.1                | 4.974               |          |  |
| 189.6                  | 13.35                 | 94.8                 | 3.689               |          |  |
| 175.1                  | 14.53                 | 87.5                 | 3.861               |          |  |
| 162.0                  | 13.64                 | 81.0                 | 3.916               |          |  |
| 159.8                  | 12.18                 | 79.9                 | 3.513               |          |  |
| Average                | 14.30                 | 89.3                 | 3.991               |          |  |
| Std. Dev.              | 2.13                  | 9.8                  | 0.572               |          |  |

TABLE F.23

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 22°C (72°F) DRY

| Test : ±45° Tension/Inplane Shear: ASTM-D3518      |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|----------------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : E <sub>f</sub> -9396 A/B; W133 Graphite |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |           |
| Specimen Number                                    | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                                    |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GR-38-2                                        | 72°F (DRY)      | 1.002       | 0.1213          | 3,064               | 25.20                   | 2.208                  | 12.60                 | 0.657                | 0.679           | 11/27/89                | (1,2,3,5) |
| BIL-GR-38-8                                        | "               | 1.004       | 0.1241          | 2,939               | 23.58                   | 2.186                  | 11.79                 | 0.676                | 0.618           | "                       | (1,2,3,5) |
| BIL-GR-38-14                                       | "               | 0.999       | 0.1229          | 2,803               | 22.84                   | 2.275                  | 11.42                 | 0.668                | 0.702           | "                       | (1,2,3,5) |
| BIL-GR-39-5                                        | "               | 0.990       | 0.1231          | 2,958               | 24.27                   | 1.929                  | 12.13                 | 0.550                | 0.753           | "                       | (1,2,3,5) |
| BIL-GR-39-11                                       | "               | 0.990       | 0.1236          | 2,804               | 22.91                   | 2.041                  | 11.46                 | 0.551                | 0.851           | "                       | (1,2,3,5) |
| Average                                            |                 |             |                 |                     | 23.76                   | 2.128                  | 11.88                 | 0.621                | 0.721           |                         |           |
| Std. Dev.                                          |                 |             |                 |                     | 0.99                    | 0.140                  | 0.50                  | 0.064                | 0.087           |                         |           |

F-24

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion |                        |                       |                      |                     |  |
|---------------|------------------------|-----------------------|----------------------|---------------------|--|
| Ultimate      | In-Plane               |                       | In-Plane             |                     |  |
|               | Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |  |
|               | 173.7                  | 15.23                 | 86.9                 | 4.533               |  |
|               | 162.6                  | 15.07                 | 81.3                 | 4.658               |  |
|               | 157.5                  | 15.69                 | 78.7                 | 4.608               |  |
|               | 167.3                  | 13.30                 | 83.7                 | 3.794               |  |
|               | 158.0                  | 14.07                 | 79.0                 | 3.802               |  |
| Average       | 163.8                  | 14.67                 | 81.9                 | 4.279               |  |
| Std. Dev.     | 6.8                    | 0.97                  | 3.4                  | 0.441               |  |



TABLE F.24

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 22°C (72°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GR-40-2                                   | 72°F (DRY)      | 0.999       | 0.1203          | 3,696               | 30.75                   | 2.402                  | 15.37                 | 0.673                | 0.783           | 11/27/89                | (1,2,3,5) |
| BIL-GR-40-8                                   | "               | 1.001       | 0.1312          | 3,229               | 24.60                   | 1.984                  | 12.30                 | 0.568                | 0.747           | "                       | (1,2,3,5) |
| BIL-GR-40-14                                  | "               | 1.001       | 0.1242          | 3,390               | 27.26                   | 2.232                  | 13.63                 | 0.626                | 0.783           | "                       | (1,2,3,5) |
| BIL-GR-41-5                                   | "               | 1.000       | 0.1213          | 3,435               | 28.32                   | 2.423                  | 14.16                 | 0.659                | 0.840           | "                       | (1,2,3,5) |
| BIL-GR-41-11                                  | "               | 0.997       | 0.1208          | 3,051               | 25.32                   | 2.012                  | 12.66                 | 0.685                | 0.468           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 27.25                   | 2.211                  | 13.62                 | 0.642                | 0.724           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 2.46                    | 0.208                  | 1.23                  | 0.047                | 0.147           |                         |           |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 212.0                  | 16.56                 | 106.0                | 4.642               | 106.0                | 4.642               |
| 169.6                  | 13.68                 | 84.8                 | 3.916               | 84.8                 | 3.916               |
| 187.9                  | 15.39                 | 94.0                 | 4.318               | 94.0                 | 4.318               |
| 195.2                  | 16.71                 | 97.6                 | 4.540               | 97.6                 | 4.540               |
| 174.6                  | 13.88                 | 87.3                 | 4.725               | 87.3                 | 4.725               |
| Average                | 15.24                 | 93.9                 | 4.428               | 93.9                 | 4.428               |
| Std. Dev.              | 1.43                  | 8.5                  | 0.325               | 8.5                  | 0.325               |

TABLE F.25

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, 93°C (200°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GR-37-3                                   | 200°F (DRY)     | 1.004       | 0.1242          | 2,319               | 18.60                   | 1.654                  | 9.30                  | 0.433                | 0.908           | 1/3/90                  | (1,2,3,5) |
| BIL-GR-37-9                                   | "               | 1.005       | 0.1241          | 2,122               | 17.01                   | 1.380                  | 8.50                  | 0.357                | 0.933           | "                       | (1,2,3,5) |
| BIL-GR-37-15                                  | "               | 1.005       | 0.1231          | 1,718               | 13.88                   | 1.423                  | 6.94                  | 0.365                | 0.951           | "                       | (1,2,3,5) |
| BIL-GR-42-T6                                  | "               | 0.998       | 0.1233          | 1,710               | 13.90                   | 1.381                  | 6.95                  | 0.378                | 0.827           | "                       | (1,2,3,5) |
| BIL-GR-42-T12                                 | "               | 0.997       | 0.1231          | 1,747               | 14.23                   | 1.356                  | 7.12                  | 0.366                | 0.851           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 15.52                   | 1.439                  | 7.76                  | 0.380                | 0.894           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 2.16                    | 0.122                  | 1.08                  | 0.031                | 0.053           |                         |           |

T-26

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion |                        |                       |                |                     |                              |
|---------------|------------------------|-----------------------|----------------|---------------------|------------------------------|
| Ultimate      | Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane       |                     | In-Plane Shear Modulus (GPa) |
|               |                        |                       | Strength (MPa) | Shear Modulus (GPa) |                              |
| 128.2         | 11.40                  | 11.40                 | 64.1           | 2.988               |                              |
| 117.3         | 9.51                   | 9.51                  | 58.6           | 2.461               |                              |
| 95.7          | 9.81                   | 9.81                  | 47.9           | 2.514               |                              |
| 95.8          | 9.52                   | 9.52                  | 47.9           | 2.606               |                              |
| 98.1          | 9.35                   | 9.35                  | 49.1           | 2.526               |                              |
| Average       | 107.0                  | 9.92                  | 53.5           | 2.619               |                              |
| Std. Dev.     | 14.9                   | 0.84                  | 7.4            | 0.213               |                              |

TABLE F.26

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 93°C (200°F) DRY

|                 |                 |                                        |                 |                     |                         |                        |                       |                      |                 |             |           |
|-----------------|-----------------|----------------------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------|-----------|
| Test :          |                 | ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                     |                         |                        | Fiber Orientation:    |                      | ±45°            |             |           |
| Material :      |                 | EA-9396 A/B; W133 Graphite             |                 |                     |                         |                        | Tested By:            |                      | DH              |             |           |
|                 |                 | Batch #2                               |                 | Task #6             |                         |                        |                       |                      |                 |             |           |
| Specimen Number | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested | Remarks   |
|                 |                 |                                        |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |             |           |
| BIL-GR-38-3     | 200°F (DRY)     | 0.999                                  | 0.1205          | 2,065               | 17.16                   | 1.945                  | 8.58                  | 0.546                | 0.780           | 1/5/90      | (1,2,3,5) |
| BIL-GR-38-9     | "               | 1.004                                  | 0.1228          | 1,812               | 14.70                   | 1.667                  | 7.35                  | 0.477                | 0.747           | "           | (1,2,3,5) |
| BIL-GR-38-15    | "               | 0.998                                  | 0.1207          | 1,747               | 14.50                   | 1.887                  | 7.25                  | 0.561                | 0.683           | "           | (1,2,3,5) |
| BIL-GR-39-6     | "               | 0.998                                  | 0.1222          | 1,816               | 14.89                   | 1.406                  | 7.45                  | 0.372                | 0.891           | "           | (1,2,3,5) |
| BIL-GR-39-12    | "               | 0.990                                  | 0.1226          | 1,831               | 15.09                   | 1.318                  | 7.54                  | 0.347                | 0.896           | "           | (1,2,3,5) |
|                 |                 |                                        |                 | Average             | 15.27                   | 1.645                  | 7.63                  | 0.461                | 0.799           |             |           |
|                 |                 |                                        |                 | Std. Dev.           | 1.08                    | 0.280                  | 0.54                  | 0.098                | 0.093           |             |           |

T. 27

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |          |  |
|------------------------|-----------------------|----------------------|---------------------|----------|--|
| Ultimate               |                       | In-Plane             |                     | In-Plane |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |          |  |
| 118.3                  | 13.41                 | 59.2                 | 3.768               |          |  |
| 101.3                  | 11.49                 | 50.7                 | 3.290               |          |  |
| 100.0                  | 13.01                 | 50.0                 | 3.866               |          |  |
| 102.7                  | 9.70                  | 51.3                 | 2.563               |          |  |
| 104.0                  | 9.08                  | 52.0                 | 2.396               |          |  |
| Average                | 11.34                 | 52.6                 | 3.176               |          |  |
| Std. Dev.              | 1.93                  | 3.7                  | 0.675               |          |  |

TABLE F.27

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 93°C (200°F) DRY

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |           |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |           |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks   |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |           |
| BIL-GR-40-3                                   | 200°F (DRY)     | 1.002       | 0.1208          | 2,041               | 16.86                   | 1.640                  | 8.43                  | 0.449                | 0.824           | 1/5/90                  | (1,2,3,5) |
| BIL-GR-40-9                                   | "               | 1.004       | 0.1296          | 1,897               | 14.58                   | 1.386                  | 7.29                  | 0.377                | 0.835           | "                       | (1,2,3,5) |
| BIL-GR-40-15                                  | "               | 1.005       | 0.1225          | 2,014               | 16.37                   | 1.475                  | 8.18                  | 0.399                | 0.851           | "                       | (1,2,3,5) |
| BIL-GR-41-6                                   | "               | 0.998       | 0.1218          | 2,133               | 17.54                   | 1.603                  | 8.77                  | 0.409                | 0.960           | "                       | (1,2,3,5) |
| BIL-GR-41-12                                  | "               | 0.999       | 0.1212          | 1,846               | 15.24                   | 1.236                  | 7.62                  | 0.357                | 0.732           | "                       | (1,2,3,5) |
| Average                                       |                 |             |                 |                     | 16.12                   | 1.468                  | 8.06                  | 0.398                | 0.840           |                         |           |
| Std. Dev.                                     |                 |             |                 |                     | 1.20                    | 0.164                  | 0.60                  | 0.035                | 0.081           |                         |           |

T<sub>28</sub>

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G=E/2(1+\nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 116.3                  | 11.30                 | 58.1                 | 3.098               |                      |                     |
| 100.6                  | 9.55                  | 50.3                 | 2.603               |                      |                     |
| 112.9                  | 10.17                 | 56.4                 | 2.748               |                      |                     |
| 120.9                  | 11.05                 | 60.5                 | 2.819               |                      |                     |
| 105.1                  | 8.52                  | 52.5                 | 2.461               |                      |                     |
| Average                | 10.12                 | 55.6                 | 2.746               |                      |                     |
| Std. Dev.              | 1.13                  | 4.1                  | 0.241               |                      |                     |

TABLE F.28

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, -54°C (-65°F) WET

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |               |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|---------------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM           |               |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks       |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |               |
| BIL-GR-37-4                                   | -65°F (WET)     | 1.004       | 0.1236          | 5,164               | 41.60                   | 3.246                  | 20.80                 | 0.894                | 0.816           | 2/16/90                 | (1,2,3,5,6,7) |
| BIL-GR-37-10                                  | "               | 1.003       | 0.1233          | 3,779               | 30.55                   | 2.985                  | 15.27                 | 0.881                | 0.694           | "                       | (1,2,3,5,6,7) |
| BIL-GR-42-T1                                  | "               | 0.985       | 0.1121          | 3,278               | 29.69                   | 2.825                  | 14.84                 | 0.879                | 0.606           | "                       | (1,2,3,5,6,8) |
| BIL-GR-42-T7                                  | "               | 0.997       | 0.1221          | 3,746               | 30.76                   | 2.633                  | 15.38                 | 0.834                | 0.578           | "                       | (1,2,3,5,6,8) |
| BIL-GR-42-T13                                 | "               | 0.997       | 0.1216          | 3,690               | 30.44                   | 2.795                  | 15.22                 | 0.837                | 0.671           | "                       | (1,2,3,5,6,8) |
| Average                                       |                 |             |                 |                     | 32.61                   | 2.897                  | 16.30                 | 0.865                | 0.673           |                         |               |
| Std. Dev.                                     |                 |             |                 |                     | 5.04                    | 0.232                  | 2.52                  | 0.028                | 0.093           |                         |               |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. to saturation.
- (7) Weight gain = 2.1103%
- (8) Weight gain = 2.1150%

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 286.8                  | 22.38                 | 143.4                | 6.163               | 105.3                | 6.074               |
| 210.6                  | 20.58                 | 105.3                | 6.063               | 102.3                | 5.754               |
| 204.7                  | 19.48                 | 102.3                | 5.768               | 106.1                | 5.768               |
| 212.1                  | 18.16                 | 106.1                |                     | 105.0                |                     |
| 209.9                  | 19.27                 | 105.0                |                     |                      |                     |
| Average                | 19.97                 | 112.4                | 5.964               |                      |                     |
| Std. Dev.              | 1.60                  | 17.4                 | 0.190               |                      |                     |

TABLE F.29

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, -54°C (-65°F) WET

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |             | Fiber Orientation: ±45° |               |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-------------|-------------------------|---------------|
| Material : EA-9396 A/B; W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |             | Tested By: PM           |               |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Date Tested | Poisson's Ratio         | Remarks       |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |             |                         |               |
| BIL-GR-38-4                                   | -65°F (WET)     | 1.001       | 0.1227          | 4,800               | 39.09                   | 3.685                  | 19.54                 | 1.080                | 2/20/90     | 0.706                   | (1,2,3,5,6,7) |
| BIL-GR-38-10                                  | "               | 0.982       | 0.1226          | 3,977               | 33.04                   | 3.295                  | 16.52                 | 1.015                | "           | 0.623                   | (1,2,3,5,6,7) |
| BIL-GR-39-1                                   | "               | 0.996       | 0.1119          | 3,567               | 32.01                   | 2.998                  | 16.01                 | 0.867                | "           | 0.729                   | (1,2,3,5,6,8) |
| BIL-GR-39-7                                   | "               | 0.996       | 0.1247          | 4,032               | 32.46                   | 2.663                  | 16.23                 | 0.794                | "           | 0.677                   | (1,2,3,5,6,8) |
| BIL-GR-39-13                                  | "               | 0.996       | 0.1227          | 3,878               | 31.74                   | 2.774                  | 15.87                 | 0.862                | "           | 0.609                   | (1,2,3,5,6,8) |
| Average                                       |                 |             |                 |                     | 33.67                   | 3.083                  | 16.83                 | 0.924                |             |                         |               |
| Std. Dev.                                     |                 |             |                 |                     | 3.07                    | 0.414                  | 1.54                  | 0.119                |             |                         |               |

F-30

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/(2(1+\nu))]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. to saturation.
- (7) Weight gain = 2.0754%
- (8) Weight gain = 2.3377%

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       | In-Plane             |                     | In-Plane             |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 269.5                  | 25.41                 | 134.8                | 7.449               | 113.9                | 6.997               |
| 227.8                  | 22.72                 | 110.4                | 5.980               | 111.9                | 5.474               |
| 220.7                  | 20.67                 | 109.4                | 5.945               | 116.1                | 6.369               |
| 223.8                  | 18.36                 | 10.6                 | 0.820               |                      |                     |
| 218.8                  | 19.12                 |                      |                     |                      |                     |
| 232.1                  | 21.26                 |                      |                     |                      |                     |
| 21.2                   | 2.86                  |                      |                     |                      |                     |
| Average                |                       |                      |                     |                      |                     |
| Std. Dev.              |                       |                      |                     |                      |                     |

TABLE F.30

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, -54°C (-65°F) WET

| Test            |                 | ±45° Tension/Inplane Shear: ASTM-D3518 |                 |                     |                         | Fiber Orientation: ±45° |                          |                         |                 |
|-----------------|-----------------|----------------------------------------|-----------------|---------------------|-------------------------|-------------------------|--------------------------|-------------------------|-----------------|
| Material        |                 | EA-9396 A/B: W133 Graphite             |                 |                     |                         | Tested By:              |                          |                         |                 |
|                 |                 | Batch #3                               |                 | Task #6             |                         | In-Plane                |                          | In-Plane                |                 |
|                 |                 | Ultimate                               |                 | Tensile             |                         | Shear                   |                          | Shear                   |                 |
| Specimen Number | Test Conditions | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.)  | In-Plane Strength (Ksi.) | In-Plane Modulus (Msi.) | Poisson's Ratio |
|                 |                 |                                        |                 |                     |                         |                         |                          |                         | Date Tested     |
| BIL-GR-40-4     | -65°F (WET)     | 1.002                                  | 0.1233          | 4,675               | 37.84                   | 2.790                   | 18.92                    | 0.761                   | 0.834           |
| BIL-GR-40-10    | "               | 1.000                                  | 0.1327          | 3,647               | 27.50                   | 2.116                   | 13.75                    | 0.623                   | 0.698           |
| BIL-GR-41-1     | "               | 0.989                                  | 0.1152          | 4,202               | 36.86                   | 2.594                   | 18.43                    | 0.714                   | 0.816           |
| BIL-GR-41-7     | "               | 0.999                                  | 0.1220          | 4,521               | 37.11                   | 2.696                   | 18.55                    | 0.775                   | 0.740           |
| BIL-GR-41-13    | "               | 0.998                                  | 0.1182          | 3,955               | 33.53                   | 2.509                   | 16.77                    | 0.672                   | 0.868           |
| Average         |                 |                                        |                 |                     |                         | 2.541                   | 17.28                    | 0.709                   | 0.791           |
| Std. Dev.       |                 |                                        |                 |                     |                         | 0.260                   | 2.14                     | 0.063                   | 0.070           |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. to saturation.
- (7) Weight gain = 2.0838%
- (8) Weight gain = 2.1628%

| SI Conversion  |               |                |               |
|----------------|---------------|----------------|---------------|
| Ultimate       | In-Plane      | In-Plane       | In-Plane      |
| Tensile        | Tensile       | Shear          | Shear         |
| Strength (MPa) | Modulus (GPa) | Strength (MPa) | Modulus (GPa) |
| 260.9          | 19.23         | 130.5          | 5.244         |
| 189.6          | 14.59         | 94.8           | 4.296         |
| 254.2          | 17.88         | 127.1          | 4.924         |
| 255.8          | 18.59         | 127.9          | 5.343         |
| 231.2          | 17.30         | 115.6          | 4.631         |
| Average        | 17.52         | 119.2          | 4.888         |
| Std. Dev.      | 1.79          | 14.8           | 0.433         |

TABLE F.31

INDIVIDUAL SPECIMEN IN-PLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, 22°C (72°F) WET

| +45° Tension/Inplane Shear: ASTM-C3518                                             |                 |                            |                 |                     |                         |                        |                       |                      |             |
|------------------------------------------------------------------------------------|-----------------|----------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-------------|
| Test                                                                               |                 | Fiber Orientation:         |                 | ±45°                |                         |                        |                       |                      |             |
| Material                                                                           |                 | EA-9396 A/B; W133 Graphite |                 | Batch #1            |                         | Task #6                |                       | Tested By:           |             |
| Specimen Number                                                                    | Test Conditions | Width (in.)                | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Date Tested |
|                                                                                    |                 |                            |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |             |
| BIL-GR-37-5                                                                        | 72°F (WET)      | 1.004                      | 0.1232          | 3.014               | 24.37                   | 1.789                  | 12.19                 | 0.477                | 2/16/90     |
| BIL-GR-37-11                                                                       | "               | 1.003                      | 0.1232          | 2.504               | 20.25                   | 1.920                  | 10.13                 | 0.563                | "           |
| BIL-GR-42-T2                                                                       | "               | 0.996                      | 0.1168          | 2.264               | 19.46                   | 1.697                  | 9.73                  | 0.508                | "           |
| BIL-GR-42-T8                                                                       | "               | 1.000                      | 0.1245          | 2.188               | 17.57                   | 1.530                  | 8.79                  | 0.452                | "           |
| BIL-GR-42-T14                                                                      | "               | 0.998                      | 0.1219          | 2.196               | 18.05                   | 1.573                  | 9.02                  | 0.462                | "           |
| Average                                                                            |                 |                            |                 |                     | 19.94                   | 1.702                  | 9.97                  | 0.492                | 0.729       |
| Std. Dev.                                                                          |                 |                            |                 |                     | 2.70                    | 0.159                  | 1.35                  | 0.045                | 0.083       |
| Remarks:                                                                           |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (1) The in-plane shear modulus is calculated using the equation $G = E/2(1+\nu)$ . |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (2) Specimen had 0° and 90° strain gages attached                                  |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (3) Test speed = 0.1 in/min                                                        |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (4) Specimen failed inside the "tab area".                                         |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (5) Specimen failed within the 6.5 inch gage section.                              |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (6) Specimens aged @ 140°F/95-100% R.H. for 91 days.                               |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (7) Weight gain = 2.1103%                                                          |                 |                            |                 |                     |                         |                        |                       |                      |             |
| (8) Weight gain = 2.1150%                                                          |                 |                            |                 |                     |                         |                        |                       |                      |             |
| Average                                                                            |                 |                            |                 |                     | 137.5                   | 11.73                  | 68.7                  | 3.395                |             |
| Std. Dev.                                                                          |                 |                            |                 |                     | 18.6                    | 1.10                   | 9.3                   | 0.307                |             |

## SI Conversion

| Ultimate               |                       | In-Plane             |                     | In-Plane |  |
|------------------------|-----------------------|----------------------|---------------------|----------|--|
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |          |  |
| 168.1                  | 12.34                 | 84.0                 | 3.288               |          |  |
| 139.7                  | 13.24                 | 69.8                 | 3.879               |          |  |
| 134.2                  | 11.70                 | 67.1                 | 3.502               |          |  |
| 121.1                  | 10.55                 | 60.6                 | 3.118               |          |  |
| 124.4                  | 10.84                 | 62.2                 | 3.186               |          |  |
| Average                | 11.73                 | 68.7                 | 3.395               |          |  |
| Std. Dev.              | 1.10                  | 9.3                  | 0.307               |          |  |



TABLE F.32

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 22°C (72°F) WET

| ±45° Tension/Inplane Shear; ASTM-D3518                                           |                 |             |                 |                     |                         |                        |         |                       |                      | Fiber Orientation: ±45° |             |
|----------------------------------------------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|---------|-----------------------|----------------------|-------------------------|-------------|
| Material: EA-9396 A/B; W133 Graphite                                             |                 |             |                 |                     |                         |                        |         |                       |                      | Tested By: PM           |             |
| Specimen Number                                                                  | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Batch #2                |                        | Task #6 | In-Plane              |                      | Poisson's Ratio         | Date Tested |
|                                                                                  |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |         | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                         |             |
| BIL-GR-38-5                                                                      | 72°F (WET)      | 0.993       | 0.1218          | 3,062               | 25.30                   | 2.818                  |         | 12.65                 | 0.757                | 0.861                   | 2/15/90     |
| BIL-GR-38-11                                                                     | "               | 0.990       | 0.1208          | 2,283               | 19.09                   | 2.428                  |         | 9.54                  | 0.744                | 0.631                   | "           |
| BIL-GR-39-2                                                                      | "               | 0.993       | 0.1159          | 2,175               | 18.90                   | 1.998                  |         | 9.45                  | 0.512                | 0.951                   | "           |
| BIL-GR-39-8                                                                      | "               | 0.996       | 0.1243          | 2,476               | 20.00                   | 1.853                  |         | 10.00                 | 0.526                | 0.762                   | "           |
| BIL-GR-39-14                                                                     | "               | 0.995       | 0.1228          | 2,324               | 19.03                   | 1.719                  |         | 9.51                  | 0.508                | 0.691                   | "           |
| Average                                                                          |                 |             |                 |                     | 20.46                   | 2.163                  |         | 10.23                 | 0.610                | 0.779                   |             |
| Std. Dev.                                                                        |                 |             |                 |                     | 2.74                    | 0.453                  |         | 1.37                  | 0.129                | 0.126                   |             |
| Remarks                                                                          |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (1) The in-plane shear modulus is calculated using the equation $G=E/2(1+\nu)$ . |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (2) Specimen had 0° and 90° strain gages attached.                               |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (3) Test speed = 0.1 in/min.                                                     |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (4) Specimen failed inside the "tab area".                                       |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (5) Specimen failed within the 6.5 inch gage section.                            |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (6) Specimens aged @ 140°F/95-100% R.H. for 91 days.                             |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (7) Weight gain = 2.0754%                                                        |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |
| (8) Weight gain = 2.3377%                                                        |                 |             |                 |                     |                         |                        |         |                       |                      |                         |             |

## SI Conversion

| Ultimate  | In-Plane               |                      |
|-----------|------------------------|----------------------|
|           | Tensile Strength (MPa) | Shear Strength (MPa) |
| 174.5     | 19.43                  | 87.2                 |
| 131.6     | 16.74                  | 65.8                 |
| 130.3     | 13.78                  | 65.2                 |
| 137.9     | 12.78                  | 69.0                 |
| 131.2     | 11.85                  | 65.6                 |
| Average   | 14.92                  | 70.6                 |
| Std. Dev. | 3.12                   | 9.4                  |

| Ultimate  | In-Plane              |                     |
|-----------|-----------------------|---------------------|
|           | Tensile Modulus (GPa) | Shear Modulus (GPa) |
| 174.5     | 19.43                 | 5.221               |
| 131.6     | 16.74                 | 5.132               |
| 130.3     | 13.78                 | 3.531               |
| 137.9     | 12.78                 | 3.626               |
| 131.2     | 11.85                 | 3.504               |
| Average   | 14.92                 | 4.203               |
| Std. Dev. | 3.12                  | 0.891               |

TABLE F.33

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 22°C (72°F)  $\pm 45^\circ$

| ±45° Tension/inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |               |
|----------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|---------------|
| Material : EA-9396 A/B; W133 Graphite  |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM           |               |
| Specimen Number                        | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks       |
|                                        |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |               |
| BIL-GR-40-5                            | 72°F (WET)      | 1.002       | 0.1264          | 2,921               | 23.07                   | 1.785                  | 11.53                 | 0.471                | 0.894           | 2/16/90                 | (1,2,3,5,6,7) |
| BIL-GR-40-11                           | "               | 1.003       | 0.1311          | 2,617               | 19.90                   | 1.788                  | 9.95                  | 0.514                | 0.738           | "                       | (1,2,3,5,6,7) |
| BIL-GR-41-T2                           | "               | 0.996       | 0.1188          | 2,943               | 24.88                   | 2.103                  | 12.44                 | 0.550                | 0.912           | "                       | (1,2,3,5,6,8) |
| BIL-GR-41-T8                           | "               | 0.998       | 0.1210          | 2,772               | 22.97                   | 2.193                  | 11.48                 | 0.613                | 0.788           | "                       | (1,2,3,5,6,8) |
| BIL-GR-41-T14                          | "               | 0.997       | 0.1181          | 2,474               | 21.01                   | 1.888                  | 10.51                 | 0.469                | 1.014           | "                       | (1,2,3,5,6,8) |
| Average                                |                 |             |                 |                     | 22.37                   | 1.952                  | 11.18                 | 0.524                | 0.869           |                         |               |
| Std. Dev.                              |                 |             |                 |                     | 1.94                    | 0.187                  | 0.97                  | 0.060                | 0.108           |                         |               |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G = E/2(1 + \nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95–100% R.H. for 91 days.
- (7) Weight gain = 2.0838%
- (8) Weight gain = 2.1628%

| SI Conversion                   |                       |                        |               |                      |               |
|---------------------------------|-----------------------|------------------------|---------------|----------------------|---------------|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane               |               | In-Plane             |               |
|                                 |                       | Tensile Strength (MPa) | Modulus (GPa) | Shear Strength (MPa) | Modulus (GPa) |
| 159.1                           | 12.31                 | 79.5                   | 3.249         |                      |               |
| 137.2                           | 12.33                 | 68.6                   | 3.547         |                      |               |
| 171.6                           | 14.50                 | 85.8                   | 3.792         |                      |               |
| 158.4                           | 15.12                 | 79.2                   | 4.230         |                      |               |
| 144.9                           | 13.02                 | 72.4                   | 3.233         |                      |               |
| Average                         | 13.46                 | 77.1                   | 3.610         |                      |               |
| Std. Dev.                       | 1.29                  | 6.7                    | 0.416         |                      |               |

TABLE F.34

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, 93°C (200°F) WET

| ±45° Tension/Inplane Shear: ASTM-D3518 |                 |             |                 |                     |                                  |                        |         |                                |                               | Fiber Orientation: ±45° |             |
|----------------------------------------|-----------------|-------------|-----------------|---------------------|----------------------------------|------------------------|---------|--------------------------------|-------------------------------|-------------------------|-------------|
| Material: EA-9396 A/B; W133 Graphite   |                 |             |                 |                     |                                  |                        |         |                                |                               | Tested By: DH           |             |
| Specimen Number                        | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Batch #1                         |                        | Task #6 | Fiber Orientation: ±45°        |                               | Tested By: DH           |             |
|                                        |                 |             |                 |                     | Ultimate Tensile Strength (Ksi.) | Tensile Modulus (Msi.) |         | In-Plane Shear Strength (Ksi.) | In-Plane Shear Modulus (Msi.) | Poisson's Ratio         | Date Tested |
| BIL-GR-37-6                            | 200°F (WET)     | 1.001       | 0.1230          | 1,343               | 10.91                            | 0.784                  |         | 5.46                           | 0.201                         | 0.954                   | 2/20/90     |
| BIL-GR-37-12                           | "               | 1.002       | 0.1238          | 1,179               | 9.51                             | 1.168                  |         | 4.75                           | 0.330                         | 0.772                   | "           |
| BIL-GR-42-T3                           | "               | 0.998       | 0.1194          | 1,069               | 8.97                             | 0.985                  |         | 4.49                           | 0.290                         | 0.696                   | "           |
| BIL-GR-42-T9                           | "               | 0.990       | 0.1240          | 1,008               | 8.21                             | 0.694                  |         | 4.11                           | 0.200                         | 0.732                   | "           |
| BIL-GR-42-T15                          | "               | 1.000       | 0.1107          | 846                 | 7.64                             | 0.699                  |         | 3.82                           | 0.216                         | 0.621                   | "           |
| Average                                |                 |             |                 |                     | 9.05                             | 0.866                  |         | 4.52                           | 0.247                         | 0.755                   |             |
| Std. Dev.                              |                 |             |                 |                     | 1.26                             | 0.206                  |         | 0.63                           | 0.059                         | 0.124                   |             |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $G=E/2(1+\nu)$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. to saturation.
- (7) Weight gain = 2.1103%
- (8) Weight gain = 2.1150%
- (9) These specimens were supposed to have been tested at the 200°F(Wet) condition. They were inadvertently tested at 72°(Wet).

| SI Conversion                   |                               |                       |                              |         |           |
|---------------------------------|-------------------------------|-----------------------|------------------------------|---------|-----------|
| Ultimate Tensile Strength (MPa) | In-Plane Shear Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Modulus (GPa) | Average | Std. Dev. |
| 75.2                            | 37.6                          | 5.41                  | 1.383                        | 62.4    | 8.7       |
| 65.6                            | 32.8                          | 8.05                  | 2.272                        | 31.2    | 4.4       |
| 61.9                            | 30.9                          | 6.79                  | 2.002                        | 5.97    | 1.42      |
| 56.6                            | 28.3                          | 4.78                  | 1.380                        |         |           |
| 52.7                            | 26.3                          | 4.82                  | 1.487                        |         |           |
| Average                         |                               |                       |                              | 1.705   | 0.408     |
| Std. Dev.                       |                               |                       |                              |         |           |

TABLE F.35

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 93°C (200°F) WET

| ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                            |                 |                     |                         |                        |                                |                               |                 | Fiber Orientation: ±45° |                 |
|----------------------------------------|-----------------|----------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|-------------------------------|-----------------|-------------------------|-----------------|
| Material :                             |                 | EA-9396 A/B: W133 Graphite |                 |                     | Batch #2                |                        | Task #6                        |                               | Tested By: PM   |                         |                 |
| Specimen Number                        | Test Conditions | Width (in.)                | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane                       |                               | Poisson's Ratio | Date Tested             | Remarks         |
|                                        |                 |                            |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | In-Plane Shear Strength (Ksi.) | In-Plane Shear Modulus (Msi.) |                 |                         |                 |
| BIL-GR-38-6                            | 200°F (WET)     | 1.001                      | 0.1226          | 1,315               | 10.71                   | 1.276                  | 5.36                           | 0.303                         | 1.106           | 2/20/90                 | (1,2,3,5,6,7,9) |
| BIL-GR-38-12                           | "               | 0.999                      | 0.1245          | 1,053               | 8.47                    | 1.560                  | 4.23                           | 0.468                         | 0.666           | "                       | (1,2,3,5,6,7,9) |
| BIL-GR-39-3                            | "               | 0.996                      | 0.1194          | 1,011               | 8.50                    | 0.775                  | 4.25                           | 0.198                         | 0.961           | "                       | (1,2,3,5,6,8,9) |
| BIL-GR-39-9                            | "               | 0.999                      | 0.1244          | 1,034               | 8.31                    | 0.740                  | 4.16                           | 0.218                         | 0.699           | "                       | (1,2,3,5,6,8,9) |
| BIL-GR-39-15                           | "               | 0.996                      | 0.1184          | 1,025               | 8.70                    | 0.592                  | 4.35                           | 0.153                         | 0.934           | "                       | (1,2,3,5,6,8,9) |
| Average                                |                 |                            |                 |                     | 8.94                    | 0.989                  | 4.47                           | 0.268                         | 0.873           |                         |                 |
| Std. Dev.                              |                 |                            |                 |                     | 1.00                    | 0.410                  | 0.50                           | 0.124                         | 0.186           |                         |                 |

## Remarks:

(1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .

(2) Specimens were tested at 0° and 90° strain gages

(3) Specimen was tested at 0.1 in/min.

(4) Specimen was tested inside the "tab area".

(5) Specimen was tested within the 6.5 inch gage section.

(6) Specimen was tested @ 140°F/95-100% R.H. to saturate.

(7) Weight gain = 2.0754%

(8) Weight gain = 2.3377%

(9) These specimens were supposed to have been tested at the 200°F(Wet) condition. They were inadvertently tested at 72°(Wet).

| SI Conversion                   |                       |                               |                              |  |  |
|---------------------------------|-----------------------|-------------------------------|------------------------------|--|--|
| Ultimate Tensile Strength (MPa) | Tensile Modulus (GPa) | In-Plane Shear Strength (MPa) | In-Plane Shear Modulus (GPa) |  |  |
| 73.9                            | 8.80                  | 36.9                          | 2.088                        |  |  |
| 58.4                            | 10.75                 | 29.2                          | 3.227                        |  |  |
| 58.6                            | 5.34                  | 29.3                          | 1.363                        |  |  |
| 57.3                            | 5.10                  | 28.7                          | 1.502                        |  |  |
| 60.0                            | 4.08                  | 30.0                          | 1.055                        |  |  |
| Average                         | 61.6                  | 30.8                          | 1.847                        |  |  |
| Std. Dev.                       | 6.9                   | 3.5                           | 0.858                        |  |  |

TABLE F.36

INDIVIDUAL SPECIMEN INPLANE SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 93°C (200°F) WET

| Test : ±45° Tension/Inplane Shear; ASTM-D3518 |                 |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: ±45° |                 |
|-----------------------------------------------|-----------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-------------------------|-----------------|
| Material : EA-9396 A/B: W133 Graphite         |                 |             |                 |                     |                         |                        |                       |                      |                 | Tested By: DH           |                 |
| Specimen Number                               | Test Conditions | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested             | Remarks         |
|                                               |                 |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                         |                 |
| BIL-GR-40-6                                   | 200°F (WET)     | 1.003       | 0.1284          | 1,213               | 9.42                    | 0.848                  | 4.71                  | 0.209                | 1.029           | 2/20/90                 | (1,2,3,5,6,7)   |
| BIL-GR-40-12                                  | "               | 1.003       | 0.1297          | 1,139               | 8.75                    | 1.048                  | 4.38                  | 0.266                | 0.969           | "                       | (1,2,3,5,6,7)   |
| BIL-GR-41-T3                                  | "               | 0.996       | 0.1202          | 1,234               | 10.31                   | 1.030                  | 5.15                  |                      |                 | "                       | (1,2,3,5,6,8,9) |
| BIL-GR-41-T9                                  | "               | 0.979       | 0.1196          | 999                 | 8.53                    | 1.054                  | 4.26                  | 0.262                | 1.015           | "                       | (1,2,3,5,6,8)   |
| BIL-GR-41-T15                                 | "               | 1.000       | 0.1213          | 941                 | 7.76                    | 0.803                  | 3.88                  | 0.176                | 1.284           | "                       | (1,2,3,5,6,8)   |
| Average                                       |                 |             |                 |                     | 8.95                    | 0.956                  | 4.48                  | 0.228                | 1.074           |                         |                 |
| Std. Dev.                                     |                 |             |                 |                     | 0.96                    | 0.121                  | 0.48                  | 0.043                | 0.142           |                         |                 |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. for 91 days.
- (7) Weight gain = 2.0838%
- (8) Weight gain = 2.1628%
- (9) 90° strain gage failed.

| SI Conversion          |                       |                      |                     |                      |                     |
|------------------------|-----------------------|----------------------|---------------------|----------------------|---------------------|
| Ultimate               |                       |                      | In-Plane            |                      |                     |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |
| 65.0                   | 5.84                  | 32.5                 | 1.440               |                      |                     |
| 60.4                   | 7.22                  | 30.2                 | 1.835               |                      |                     |
| 71.1                   | 7.10                  | 35.5                 | 3.551               |                      |                     |
| 58.8                   | 7.27                  | 29.4                 | 1.804               |                      |                     |
| 53.5                   | 5.53                  | 26.8                 | 1.211               |                      |                     |
| Average                | 61.7                  | 6.59                 | 30.9                | 1.968                |                     |
| Std. Dev.              | 6.6                   | 0.84                 | 3.3                 | 0.922                |                     |

**APPENDIX G**  
**INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR PROPERTIES, BASELINE**

The 18 tables in this appendix present the detailed mechanical property test data measured during this program for each baseline specimen tested in interlaminar shear. A summary of these data was presented and discussed in Section 3.2.4.

TABLE G.1

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, 22°C (72°F) DRY

|                                                |                 |                         |                 |                                     |              |                            |             |         |
|------------------------------------------------|-----------------|-------------------------|-----------------|-------------------------------------|--------------|----------------------------|-------------|---------|
| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |                         |                 | (4pt loading at 1/4 pts. L/D = 8/1) |              | Specimen Orientation: Warp |             |         |
| Material :                                     |                 | EA-9396 A/B; 7781 Glass |                 | Batch #1                            | Task #7      | Tested By: TOB             |             |         |
|                                                |                 |                         |                 | Ultimate                            |              |                            |             |         |
| Specimen Number                                | Test Conditions | Width (in.)             | Thickness (in.) | Span (in.)                          | Maximum Load | Shear Strength             | Date Tested | Remarks |
|                                                |                 |                         |                 |                                     | (lbs.)       | (Ksi.)                     |             |         |
| BIL-GL-13(R)-3                                 | 72°F (DRY)      | 1.001                   | 0.1357          | 1.063                               | 1,040        | 5.742                      | 4/14/89     |         |
| BIL-GL-13(R)-11                                | "               | 0.999                   | 0.1371          | 1.063                               | 1,066        | 5.839                      | "           |         |
| BIL-GL-13(R)-24                                | "               | 1.001                   | 0.1359          | 1.063                               | 1,120        | 6.174                      | "           |         |
| BIL-GL-13(R)-33                                | "               | 1.002                   | 0.1341          | 1.063                               | 1,036        | 5.786                      | "           |         |
| BIL-GL-13(R)-53                                | "               | 1.001                   | 0.1336          | 1.063                               | 980          | 5.493                      | "           |         |
| Average                                        |                 |                         |                 |                                     |              | 5.806                      |             |         |
| Std. Dev.                                      |                 |                         |                 |                                     |              | 0.244                      |             |         |

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
| 39.59                         |       |
| 40.26                         |       |
| 42.57                         |       |
| 39.89                         |       |
| 37.87                         |       |
| Average                       | 40.04 |
| Std. Dev.                     | 1.69  |

TABLE G.2

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 22°C (72°F) DRY

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|-------------|-----------------|-------------------------------------|---------------------|----------------------------|-------------|---------|
| Material : EA-9396 A/B; 7781 Glass             |                 |             |                 | Batch #2                            | Task #7             | Tested By:                 | TOB         |         |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                          | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |             |                 |                                     | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| BIL-GL-11-1                                    | 72°F (DRY)      | 0.998       | 0.1309          | 1.063                               | 926                 | 5.316                      | 4/14/89     |         |
| BIL-GL-11-4                                    | "               | 1.001       | 0.1312          | 1.063                               | 969                 | 5.530                      | "           |         |
| BIL-GL-11-7                                    | "               | 0.992       | 0.1316          | 1.063                               | 1,012               | 5.816                      | "           |         |
| BIL-GL-11-10                                   | "               | 1.002       | 0.1315          | 1.063                               | 974                 | 5.543                      | "           |         |
| BIL-GL-11-13                                   | "               | 1.000       | 0.1345          | 1.063                               | 996                 | 5.549                      | "           |         |
| Average                                        |                 |             |                 |                                     |                     | 5.551                      |             |         |
| Std. Dev.                                      |                 |             |                 |                                     |                     | 0.177                      |             |         |

| SI Conversion        |       |
|----------------------|-------|
| Ultimate             |       |
| Shear Strength (MPa) |       |
|                      | 36.66 |
|                      | 38.13 |
|                      | 40.10 |
|                      | 38.22 |
|                      | 38.26 |
| Average              | 38.27 |
| Std. Dev.            | 1.22  |



TABLE G.3

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, 22°C (72°F) DRY

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp     |                     |
|------------------------------------------------|-----------------|-------------|-----------------|-------------------------------------|---------------------|--------------------------------|---------------------|
| Material : EA-9396 A/B; 7781 Glass             |                 |             |                 | Batch #3                            | Task #7             | Tested By: TOB                 |                     |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Ultimate Shear Strength (Ksi.) | Date Tested Remarks |
| BIL-GL-12-1                                    | 72°F (DRY)      | 0.996       | 0.1281          | 1.063                               | 922                 | 5.419                          | 4/14/89             |
| BIL-GL-12-4                                    | "               | 1.000       | 0.1332          | 1.063                               | 1,017               | 5.729                          | "                   |
| BIL-GL-12-7                                    | "               | 1.001       | 0.1304          | 1.063                               | 958                 | 5.508                          | "                   |
| BIL-GL-12-10                                   | "               | 1.003       | 0.1313          | 1.063                               | 905                 | 5.156                          | "                   |
| BIL-GL-12-13                                   | "               | 1.001       | 0.1342          | 1.063                               | 1,025               | 5.721                          | "                   |
| Average                                        |                 |             |                 |                                     |                     | 5.507                          |                     |
| Std. Dev.                                      |                 |             |                 |                                     |                     | 0.238                          |                     |

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
| 37.37                         |       |
| 39.50                         |       |
| 37.98                         |       |
| 35.55                         |       |
| 39.45                         |       |
| Average                       | 37.97 |
| Std. Dev.                     | 1.64  |

TABLE G.4

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, 22°C (72°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp     |                     |
|------------------------------------------------|-----------------|-------------|-----------------|-------------------------------------|---------------------|--------------------------------|---------------------|
| Material : EA-9396 A/B; 7781 Glass             |                 |             |                 | Batch #1                            | Task #7             | Tested By:                     | DH                  |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Ultimate Shear Strength (Ksi.) | Date Tested Remarks |
| BIL-GL-13(R)-4                                 | 72°F (WET)      | 1.001       | 0.1353          | 1.0804                              | 482                 | 2.669                          | 10/30/89 (1,2)      |
| BIL-GL-13(R)-12                                | "               | 0.999       | 0.1344          | 1.0804                              | 477                 | 2.663                          | " (1,2)             |
| BIL-GL-13(R)-25                                | "               | 1.001       | 0.1369          | 1.0804                              | 510                 | 2.793                          | " (1,2)             |
| BIL-GL-13(R)-34                                | "               | 1.000       | 0.1352          | 1.0804                              | 489                 | 2.714                          | " (1,2)             |
| BIL-GL-13(R)-54                                | "               | 1.000       | 0.1320          | 1.0804                              | 473                 | 2.690                          | " (1,2)             |
| Average                                        |                 |             |                 |                                     |                     | 2.706                          |                     |
| Std. Dev.                                      |                 |             |                 |                                     |                     | 0.053                          |                     |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.32%

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
|                               | 18.40 |
|                               | 18.36 |
|                               | 19.26 |
|                               | 18.71 |
|                               | 18.55 |
| Average                       | 18.66 |
| Std. Dev.                     | 0.36  |

TABLE G.5

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 22°C (72°F) WET

| Test : Apparent Interlaminar Shear: ASTM-D2344 |                 |                         |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp     |                     |
|------------------------------------------------|-----------------|-------------------------|-----------------|-------------------------------------|---------------------|--------------------------------|---------------------|
| Material :                                     |                 | EA-9396 A/B; 7781 Glass |                 | Batch #2                            | Task #7             | Tested By:                     | DH                  |
| Specimen Number                                | Test Conditions | Width (in.)             | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Ultimate Shear Strength (Ksi.) | Date Tested Remarks |
| BIL-GL-11-2                                    | 72°F (WET)      | 0.998                   | 0.1318          | 1.063                               | 511                 | 2.912                          | 10/27/89 (1,2)      |
| BIL-GL-11-5                                    | "               | 0.998                   | 0.1325          | 1.063                               | 533                 | 3.019                          | " (1,2)             |
| BIL-GL-11-8                                    | "               | 0.991                   | 0.1315          | 1.063                               | 499                 | 2.874                          | " (1,2)             |
| BIL-GL-11-11                                   | "               | 1.006                   | 0.1337          | 1.063                               | 547                 | 3.049                          | " (1,2)             |
| BIL-GL-11-14                                   | "               | 1.001                   | 0.1346          | 1.063                               | 573                 | 3.188                          | " (1,2)             |
| Average                                        |                 |                         |                 |                                     |                     | 3.008                          |                     |
| Std. Dev.                                      |                 |                         |                 |                                     |                     | 0.124                          |                     |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.10%

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
|                               | 20.08 |
|                               | 20.82 |
|                               | 19.81 |
|                               | 21.02 |
|                               | 21.98 |
| Average                       | 20.74 |
| Std. Dev.                     | 0.85  |

TABLE G.6

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, 22°C (72°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |                         |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|-------------------------|-----------------|-------------------------------------|---------------------|----------------------------|-------------|---------|
| Material :                                     |                 | EA-9396 A/B; 7781 Glass |                 | Batch #3                            | Task #7             | Tested By: DH              |             |         |
| Specimen Number                                | Test Conditions | Width (in.)             | Thickness (in.) | Span (in.)                          | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |                         |                 |                                     | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| BIL-GL-12-2                                    | 72°F (WET)      | 1.000                   | 0.1324          | 1.066                               | 572                 | 3.244                      | 10/27/89    | (1,2)   |
| BIL-GL-12-5                                    | "               | 1.000                   | 0.1340          | 1.066                               | 562                 | 3.148                      | "           | (1,2)   |
| BIL-GL-12-8                                    | "               | 1.000                   | 0.1318          | 1.066                               | 559                 | 3.180                      | "           | (1,2)   |
| BIL-GL-12-11                                   | "               | 0.999                   | 0.1319          | 1.066                               | 569                 | 3.240                      | "           | (1,2)   |
| BIL-GL-12-14                                   | "               | 1.006                   | 0.1355          | 1.066                               | 594                 | 3.271                      | "           | (1,2)   |
| Average                                        |                 |                         |                 |                                     |                     | 3.216                      |             |         |
| Std. Dev.                                      |                 |                         |                 |                                     |                     | 0.051                      |             |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.09%

| SI Conversion |       |
|---------------|-------|
| Ultimate      |       |
| Shear         |       |
| Strength      |       |
| (MPa)         |       |
| 22.36         |       |
| 21.70         |       |
| 21.92         |       |
| 22.34         |       |
| 22.55         |       |
| Average       | 22.18 |
| Std. Dev.     | 0.35  |

TABLE G.7

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 1, 93°C (200°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             | (4pt loading at 1/4 pts. L/D = 8/1) |            |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|-------------|-------------------------------------|------------|---------------------|----------------------------|-------------|---------|
| Material : EA-9396 A/B; 7781 Glass             |                 |             | Batch #1                            | Task #7    | Tested By: DH       |                            |             |         |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.)                     | Span (in.) | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |             |                                     |            | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| BIL-GL-13(R)-5                                 | 200°F (WET)     | 1.001       | 0.1369                              | 1.080      | 230                 | 1.258                      | 10/30/89    | (1,2)   |
| BIL-GL-13(R)-13                                | "               | 1.002       | 0.1349                              | 1.080      | 229                 | 1.272                      | "           | (1,2)   |
| BIL-GL-13(R)-26                                | "               | 1.002       | 0.1350                              | 1.080      | 247                 | 1.369                      | "           | (1,2)   |
| BIL-GL-13(R)-35                                | "               | 1.001       | 0.1346                              | 1.080      | 249                 | 1.388                      | "           | (1,2)   |
| BIL-GL-13(R)-55                                | "               | 1.002       | 0.1353                              | 1.080      | 257                 | 1.421                      | "           | (1,2)   |
| Average                                        |                 |             |                                     |            |                     | 1.342                      |             |         |
| Std. Dev.                                      |                 |             |                                     |            |                     | 0.073                      |             |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.24%

| SI Conversion                 |      |
|-------------------------------|------|
| Ultimate Shear Strength (MPa) | 8.67 |
|                               | 8.77 |
|                               | 9.44 |
|                               | 9.57 |
|                               | 9.80 |
| Average                       | 9.25 |
| Std. Dev.                     | 0.50 |

TABLE G.8

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 2, 93°C (200°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |                         |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|-------------------------|-----------------|-------------------------------------|---------------------|----------------------------|-------------|---------|
| Material :                                     |                 | EA-9396 A/B; 7781 Glass |                 | Batch #2                            | Task #7             | Tested By: DH              |             |         |
| Specimen Number                                | Test Conditions | Width (in.)             | Thickness (in.) | Span (in.)                          | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |                         |                 |                                     | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| BIL-GL-11-3                                    | 200°F (WET)     | 1.002                   | 0.1312          | 1.063                               | 349                 | 1.989                      | 10/27/89    | (1,2)   |
| BIL-GL-11-6                                    | "               | 0.999                   | 0.1324          | 1.063                               | 329                 | 1.865                      | "           | (1,2)   |
| BIL-GL-11-9                                    | "               | 1.001                   | 0.1291          | 1.063                               | 313                 | 1.817                      | "           | (1,2)   |
| BIL-GL-11-12                                   | "               | 1.002                   | 0.1359          | 1.063                               | 351                 | 1.931                      | "           | (1,2)   |
| BIL-GL-11-15                                   | "               | 0.995                   | 0.1357          | 1.063                               | 362                 | 2.011                      | "           | (1,2)   |
| Average                                        |                 |                         |                 |                                     |                     | 1.922                      |             |         |
| Std. Dev.                                      |                 |                         |                 |                                     |                     | 0.082                      |             |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.09%

| SI Conversion        |       |
|----------------------|-------|
| Ultimate             |       |
| Shear Strength (MPa) |       |
|                      | 13.71 |
|                      | 12.86 |
|                      | 12.53 |
|                      | 13.32 |
|                      | 13.86 |
| Average              | 13.26 |
| Std. Dev.            | 0.56  |

TABLE G.9

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GLASS REINFORCEMENT, BATCH 3, 93°C (200°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|-------------|-----------------|-------------------------------------|---------------------|----------------------------|-------------|---------|
| Material : EA-9396 A/B; 7781 Glass             |                 |             |                 | Batch #3                            | Task #7             | Tested By: DH              |             |         |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                          | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |             |                 |                                     | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| BIL-GL-12-3                                    | 200°F (WET)     | 1.002       | 0.1331          | 1.066                               | 336                 | 1.887                      | 10/27/89    | (1,2)   |
| BIL-GL-12-6                                    | "               | 1.003       | 0.1335          | 1.066                               | 349                 | 1.952                      | "           | (1,2)   |
| BIL-GL-12-9                                    | "               | 1.002       | 0.1329          | 1.066                               | 313                 | 1.765                      | "           | (1,2)   |
| BIL-GL-12-12                                   | "               | 1.001       | 0.1333          | 1.066                               | 328                 | 1.840                      | "           | (1,2)   |
| BIL-GL-12-15                                   | "               | 1.001       | 0.1337          | 1.066                               | 345                 | 1.930                      | "           | (1,2)   |
| Average                                        |                 |             |                 |                                     |                     | 1.875                      |             |         |
| Std. Dev.                                      |                 |             |                 |                                     |                     | 0.075                      |             |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.11%

| SI Conversion                 |
|-------------------------------|
| Ultimate Shear Strength (MPa) |
| 13.01                         |
| 13.46                         |
| 12.17                         |
| 12.69                         |
| 13.31                         |
| Average                       |
| Std. Dev.                     |
| 12.93                         |
| 0.52                          |

TABLE G.10

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, 22°C (72°F) DRY

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                 | Specimen Orientation: Warp |                     |                       |             |         |
|------------------------------------------------|-----------------|--------------------------------------|-----------------|----------------------------|---------------------|-----------------------|-------------|---------|
| Material : EA-9396 A/B; W133 Graphite          |                 | Batch #1                             | Task #7         | Tested By: PM              |                     |                       |             |         |
| Specimen Number                                | Test Conditions | Width (in.)                          | Thickness (in.) | Span (in.)                 | Ultimate            |                       | Date Tested | Remarks |
|                                                |                 |                                      |                 |                            | Maximum Load (lbs.) | Shear Strength (Ksi.) |             |         |
| BI_-GR-17-3                                    | 72°F (DRY)      | 1.002                                | 0.1711          | 2.816                      | 1,188               | 5.196                 | 4/17/89     |         |
| BI_-GR-17-11                                   | "               | 1.002                                | 0.1771          | 2.816                      | 1,333               | 5.637                 | "           |         |
| BI_-GR-17-24                                   | "               | 1.000                                | 0.1764          | 2.816                      | 1,338               | 5.688                 | "           |         |
| BI_-GR-17-33                                   | "               | 1.000                                | 0.1817          | 2.816                      | 1,526               | 6.301                 | "           |         |
| BI_-GR-17-37                                   | "               | 0.999                                | 0.1738          | 2.816                      | 1,275               | 5.506                 | "           |         |
|                                                |                 |                                      |                 |                            |                     | Average               | 5.665       |         |
|                                                |                 |                                      |                 |                            |                     | Std. Dev.             | 0.403       |         |

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
| 35.82                         |       |
| 38.86                         |       |
| 39.22                         |       |
| 43.44                         |       |
| 37.96                         |       |
| Average                       | 39.06 |
| Std. Dev.                     | 2.78  |



TABLE G.11

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 22°C (72°F) DRY

| Test : Apparent Interlaminar Shear: ASTM-D2344 |                 |                            |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|----------------------------|-----------------|--------------------------------------|---------------------|----------------------------|-------------|---------|
| Material :                                     |                 | EA-9396 A/B; W133 Graphite |                 | Batch #2                             | Task #7             | Tested By: PM              |             |         |
| Specimen Number                                | Test Conditions | Width (in.)                | Thickness (in.) | Span (in.)                           | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |                            |                 |                                      | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| B/L-GR-18-1                                    | 72°F (DRY)      | 1.002                      | 0.1682          | 2.816                                | 1,077               | 4.794                      | 4/17/89     |         |
| B/L-GR-18-4                                    | "               | 1.000                      | 0.1683          | 2.816                                | 1,455               | 6.481                      | "           |         |
| B/L-GR-18-7                                    | "               | 1.002                      | 0.1806          | 2.816                                | 1,515               | 6.277                      | "           |         |
| B/L-GR-18-10                                   | "               | 1.002                      | 0.1703          | 2.816                                | 1,277               | 5.613                      | "           |         |
| B/L-GR-18-13                                   | "               | 1.000                      | 0.1889          | 2.816                                | 1,439               | 5.712                      | "           |         |
| Average                                        |                 |                            |                 |                                      |                     | 5.776                      |             |         |
| Std. Dev.                                      |                 |                            |                 |                                      |                     | 0.660                      |             |         |

| SI Conversion        |       |
|----------------------|-------|
| Ultimate             |       |
| Shear Strength (MPa) |       |
|                      | 33.05 |
|                      | 44.69 |
|                      | 43.28 |
|                      | 38.70 |
|                      | 39.39 |
| Average              | 39.82 |
| Std. Dev.            | 4.55  |

TABLE G.12

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 22°C (72°F) DRY

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     | Specimen Orientation: Warp |             |
|------------------------------------------------|-----------------|-------------|-----------------|--------------------------------------|---------------------|----------------------------|-------------|
| Material : EA-9396 A/B; W133 Graphite          |                 |             |                 | Batch #3                             | Task #7             | Tested By:                 | PM          |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                           | Ultimate            |                            | Date Tested |
|                                                |                 |             |                 |                                      | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |
| BIL-GR-19-1                                    | 72°F (DRY)      | 1.003       | 0.1676          | 2.816                                | 1,181               | 5.270                      | 4/17/89     |
| BIL-GR-19-4                                    | "               | 1.000       | 0.1771          | 2.816                                | 1,304               | 5.522                      | "           |
| BIL-GR-19-7                                    | "               | 1.001       | 0.1782          | 2.816                                | 1,459               | 6.136                      | "           |
| BIL-GR-19-10                                   | "               | 1.001       | 0.1689          | 2.816                                | 1,234               | 5.471                      | "           |
| BIL-GR-19-13                                   | "               | 1.002       | 0.1790          | 2.816                                | 1,397               | 5.839                      | "           |
|                                                |                 |             |                 |                                      | Average             | 5.648                      |             |
|                                                |                 |             |                 |                                      | Std. Dev.           | 0.341                      |             |
| SI Conversion                                  |                 |             |                 |                                      |                     |                            |             |
| Ultimate                                       |                 |             |                 |                                      |                     |                            |             |
| Shear Strength (MPa)                           |                 |             |                 |                                      |                     |                            |             |
|                                                |                 |             |                 |                                      |                     | 36.34                      |             |
|                                                |                 |             |                 |                                      |                     | 38.07                      |             |
|                                                |                 |             |                 |                                      |                     | 42.31                      |             |
|                                                |                 |             |                 |                                      |                     | 37.72                      |             |
|                                                |                 |             |                 |                                      |                     | 40.26                      |             |
|                                                |                 |             |                 |                                      | Average             | 38.94                      |             |
|                                                |                 |             |                 |                                      | Std. Dev.           | 2.35                       |             |

TABLE G.13

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS.  
GRAPHITE REINFORCEMENT, BATCH 1, 22°C (72°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     | Specimen Orientation:          |                     |
|------------------------------------------------|-----------------|-------------|-----------------|--------------------------------------|---------------------|--------------------------------|---------------------|
| Material : EA-9396 A/B; W133 Graphite          |                 |             |                 | Batch #1                             | Task #7             | Tested By:                     | DH                  |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                           | Maximum Load (lbs.) | Ultimate Shear Strength (Ksi.) | Date Tested Remarks |
| BIL-GR-17-4                                    | 72°F (WET)      | 1.001       | 0.1716          | 2.827                                | 1,001               | 4.369                          | 12/7/89 (1,2)       |
| BIL-GR-17-12                                   | "               | 1.001       | 0.1759          | 2.827                                | 1,129               | 4.808                          | " (1,2)             |
| BIL-GR-17-24                                   | "               | 0.999       | 0.1735          | 2.827                                | 1,062               | 4.597                          | " (1,2)             |
| BIL-GR-17-34                                   | "               | 1.000       | 0.1804          | 2.827                                | 1,305               | 5.424                          | " (1,2)             |
| BIL-GR-17-44                                   | "               | 1.001       | 0.1727          | 2.827                                | 1,047               | 4.543                          | " (1,2)             |
| Average                                        |                 |             |                 |                                      |                     | 4.748                          |                     |
| Std. Dev.                                      |                 |             |                 |                                      |                     | 0.409                          |                     |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.19%

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
|                               | 30.12 |
|                               | 33.15 |
|                               | 31.70 |
|                               | 37.40 |
|                               | 31.33 |
| Average                       | 32.74 |
| Std. Dev.                     | 2.82  |

TABLE G.14

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 22°C (72°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     | Specimen Orientation: Warp |             |         |
|------------------------------------------------|-----------------|-------------|-----------------|--------------------------------------|---------------------|----------------------------|-------------|---------|
| Material : EA-9396 A/B; W133 Graphite          |                 |             |                 | Batch #2                             |                     | Task #7                    |             |         |
| Tested By:                                     |                 |             |                 | DH                                   |                     |                            |             |         |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                           | Ultimate            |                            | Date Tested | Remarks |
|                                                |                 |             |                 |                                      | Maximum Load (lbs.) | Shear Strength (Ksi.)      |             |         |
| BIL-GR-18-2                                    | 72°F (WET)      | 1.002       | 0.1746          | 2.827                                | 1,048               | 4.495                      | 12/7/89     | (1,2)   |
| BIL-GR-18-5                                    | "               | 1.002       | 0.1821          | 2.827                                | 1,136               | 4.670                      | "           | (1,2)   |
| BIL-GR-18-8                                    | "               | 1.002       | 0.1773          | 2.827                                | 1,167               | 4.927                      | "           | (1,2)   |
| BIL-GR-18-11                                   | "               | 1.006       | 0.1809          | 2.827                                | 1,134               | 4.676                      | "           | (1,2)   |
| BIL-GR-18-14                                   | "               | 1.000       | 0.1887          | 2.827                                | 1,232               | 4.899                      | "           | (1,2)   |
|                                                |                 |             |                 |                                      |                     | Average                    | 4.733       |         |
|                                                |                 |             |                 |                                      |                     | Std. Dev.                  | 0.180       |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
 (2) Average weight gain = 2.32%

| SI Conversion  |       |
|----------------|-------|
| Ultimate       |       |
| Shear          |       |
| Strength (MPa) |       |
|                | 30.99 |
|                | 32.20 |
|                | 33.97 |
|                | 32.24 |
|                | 33.78 |
| Average        | 32.64 |
| Std. Dev.      | 1.24  |

TABLE G.15

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 22°C (72°F) WET

|                                                |                    |                |                    |                                      |                           |                             |                |         |
|------------------------------------------------|--------------------|----------------|--------------------|--------------------------------------|---------------------------|-----------------------------|----------------|---------|
| Test : Apparent Interlaminar Shear: ASTM-D2344 |                    |                |                    | (4pt loading at 1.4 pts. L/D = 16/1) |                           | Specimen Orientation: Warp  |                |         |
| Material : EA-9396 A/B; W133 Graphite          |                    |                |                    | Batch #3                             | Task #7                   | Tested By: DH               |                |         |
| Specimen:<br>Number                            | Test<br>Conditions | Width<br>(in.) | Thickness<br>(in.) | Span<br>(in.)                        | Ultimate                  |                             | Date<br>Tested | Remarks |
|                                                |                    |                |                    |                                      | Maximum<br>Load<br>(lbs.) | Shear<br>Strength<br>(Ksi.) |                |         |
| BIL-GR-19-2                                    | 72°F (WET)         | 1.000          | 0.1718             | 2.827                                | 1,036                     | 4.522                       | 12/7/89        | (1,2)   |
| BIL-GR-19-5                                    | "                  | 1.002          | 0.1741             | 2.827                                | 1,079                     | 4.641                       | "              | (1,2)   |
| BIL-GR-19-8                                    | "                  | 1.000          | 0.1733             | 2.827                                | 1,037                     | 4.486                       | "              | (1,2)   |
| BIL-GR-19-11                                   | "                  | 1.001          | 0.1758             | 2.827                                | 1,089                     | 4.644                       | "              | (1,2)   |
| BIL-GR-19-14                                   | "                  | 1.002          | 0.1776             | 2.827                                | 1,128                     | 4.754                       | "              | (1,2)   |
|                                                |                    |                |                    |                                      |                           | Average                     | 4.609          |         |
|                                                |                    |                |                    |                                      |                           | Std. Dev.                   | 0.107          |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H.  
to saturation.  
(2) Average weight gain = 2.24%

| SI Conversion |       |
|---------------|-------|
| Ultimate      |       |
| Shear         |       |
| Strength      |       |
| (MPa)         |       |
|               | 31.18 |
|               | 32.00 |
|               | 30.93 |
|               | 32.02 |
|               | 32.78 |
| Average       | 31.78 |
| Std. Dev.     | 0.74  |

TABLE G.16

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 1, 93°C (200°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     | Specimen Orientation: Warp     |                     |
|------------------------------------------------|-----------------|-------------|-----------------|--------------------------------------|---------------------|--------------------------------|---------------------|
| Material : EA-9396 A/B; W133 Graphite          |                 |             |                 | Batch #1                             | Task #7             | Tested By:                     | DH                  |
| Specimen Number                                | Test Conditions | Width (in.) | Thickness (in.) | Span (in.)                           | Maximum Load (lbs.) | Ultimate Shear Strength (Ksi.) | Date Tested Remarks |
| BIL-GR-17-5                                    | 200°F (WET)     | 1.001       | 0.1802          | 2.846                                | 564                 | 2.345                          | 12/7/89 (1,2)       |
| BIL-GR-17-13                                   | "               | 1.000       | 0.1716          | 2.846                                | 432                 | 1.890                          | " (1,2)             |
| BIL-GR-17-26                                   | "               | 0.999       | 0.1752          | 2.846                                | 470                 | 2.011                          | " (1,2)             |
| BIL-GR-17-35                                   | "               | 1.001       | 0.1792          | 2.846                                | 473                 | 1.975                          | " (1,2)             |
| BIL-GR-17-43                                   | "               | 1.001       | 0.1761          | 2.846                                | 490                 | 2.084                          | " (1,2)             |
| Average                                        |                 |             |                 |                                      |                     | 2.061                          |                     |
| Std. Dev.                                      |                 |             |                 |                                      |                     | 0.173                          |                     |

## Remarks:

- (1) Specimens aged @ 140°F/55-100% R.H. to saturation.
- (2) Average weight gain = 2.22%

| SI Conversion                 |
|-------------------------------|
| Ultimate Shear Strength (MPa) |
| 16.17                         |
| 13.03                         |
| 13.87                         |
| 13.62                         |
| 14.37                         |
| Average                       |
| Std. Dev.                     |
| 14.21                         |
| 1.19                          |

TABLE G.17

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 2, 93°C (200°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 |                            | (4pt loading at 1/4 pts. L/D = 16/1) |            | Specimen Orientation: Warp |                       |             |         |
|------------------------------------------------|-----------------|----------------------------|--------------------------------------|------------|----------------------------|-----------------------|-------------|---------|
| Material :                                     |                 | EA-9396 A/B; W133 Graphite | Batch #2                             | Task #7    | Tested By:                 | DH                    |             |         |
| Ultimate                                       |                 |                            |                                      |            |                            |                       |             |         |
| Specimen Number                                | Test Conditions | Width (in.)                | Thickness (in.)                      | Span (in.) | Maximum Load (lbs.)        | Shear Strength (Ksi.) | Date Tested | Remarks |
| BIL-GR-18-3                                    | 200°F (WET)     | 1.002                      | 0.1787                               | 2.846      | 565                        | 2.366                 | 12/7/89     | (1,2)   |
| BIL-GR-18-6                                    | "               | 1.004                      | 0.1816                               | 2.846      | 538                        | 2.212                 | "           | (1,2)   |
| BIL-GR-18-9                                    | "               | 1.002                      | 0.1725                               | 2.846      | 521                        | 2.260                 | "           | (1,2)   |
| BIL-GR-18-12                                   | "               | 0.999                      | 0.1832                               | 2.846      | 541                        | 2.215                 | "           | (1,2)   |
| BIL-GR-18-15                                   | "               | 1.000                      | 0.1873                               | 2.846      | 549                        | 2.197                 | "           | (1,2)   |
| Average                                        |                 |                            |                                      |            |                            | 2.250                 |             |         |
| Std. Dev.                                      |                 |                            |                                      |            |                            | 0.069                 |             |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.32%

| SI Conversion                 |       |
|-------------------------------|-------|
| Ultimate Shear Strength (MPa) |       |
| 16.31                         |       |
| 15.25                         |       |
| 15.58                         |       |
| 15.27                         |       |
| 15.15                         |       |
| Average                       | 15.51 |
| Std. Dev.                     | 0.47  |

TABLE G.18

INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR TEST RESULTS, BASELINE TESTS,  
GRAPHITE REINFORCEMENT, BATCH 3, 93°C (200°F) WET

| Test : Apparent Interlaminar Shear; ASTM-D2344 |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                 | Specimen Orientation: Warp |                     |                       |             |         |
|------------------------------------------------|-----------------|--------------------------------------|-----------------|----------------------------|---------------------|-----------------------|-------------|---------|
| Material : EA-9396 A/B; W133 Graphite          |                 | Batch #3                             | Task #7         | Tested By: DH              |                     |                       |             |         |
| Specimen Number                                | Test Conditions | Width (in.)                          | Thickness (in.) | Span (in.)                 | Ultimate            |                       |             | Remarks |
|                                                |                 |                                      |                 |                            | Maximum Load (lbs.) | Shear Strength (Ksi.) | Date Tested |         |
| BIL-GR-19-3                                    | 200°F (WET)     | 0.999                                | 0.1761          | 2.846                      | 662                 | 2.820                 | 12/7/89     | (1,2)   |
| BIL-GR-19-6                                    | "               | 1.002                                | 0.1757          | 2.846                      | 665                 | 2.833                 | "           | (1,2)   |
| BIL-GR-19-9                                    | "               | 1.000                                | 0.1716          | 2.846                      | 571                 | 2.493                 | "           | (1,2)   |
| BIL-GR-19-12                                   | "               | 1.001                                | 0.1774          | 2.846                      | 632                 | 2.667                 | "           | (1,2)   |
| BIL-GR-19-15                                   | "               | 1.002                                | 0.1716          | 2.846                      | 634                 | 2.765                 | "           | (1,2)   |
| Average                                        |                 |                                      |                 |                            |                     | 2.716                 |             |         |
| Std. Dev.                                      |                 |                                      |                 |                            |                     | 0.140                 |             |         |

Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. to saturation.  
(2) Average weight gain = 2.24%

| SI Conversion  |       |
|----------------|-------|
| Ultimate       |       |
| Shear          |       |
| Strength (MPa) |       |
|                | 19.44 |
|                | 19.53 |
|                | 17.19 |
|                | 18.39 |
|                | 19.06 |
| Average        | 18.72 |
| Std. Dev.      | 0.97  |



## APPENDIX H

### INDIVIDUAL SPECIMEN BEARING PROPERTIES, BASELINE

The four tables in this appendix present the detailed mechanical property test data measured during this program for each baseline specimen tested in bearing. A summary of these data was presented and discussed in Section 3.4.

TABLE H.1

INDIVIDUAL SPECIMEN BOLT-BEARING TEST RESULTS,  
GLASS REINFORCEMENT, DRY CONDITION

| Test :          |                 | Bolt-Bearing: ASTM-D953 |                 |                     |                               | Fiber Orientation : (0°/±45°/90°) <sub>s</sub> |                         |                                 |                          |                      |                          |             |         |
|-----------------|-----------------|-------------------------|-----------------|---------------------|-------------------------------|------------------------------------------------|-------------------------|---------------------------------|--------------------------|----------------------|--------------------------|-------------|---------|
| Material :      |                 | EA-9396 A/B; 7781 Glass |                 |                     |                               | Tested by : PM                                 |                         |                                 |                          |                      |                          |             |         |
|                 |                 | Batch #1 Task #10       |                 |                     |                               |                                                |                         |                                 |                          |                      |                          |             |         |
| Specimen Number | Test Conditions | Width (in.)             | Thickness (in.) | Hole Diameter (in.) | Load at 4% Hol Deform. (lbs.) | Maximum Load (lbs.)                            | Bearing Strength (Ksi.) | Maximum Bearing Strength (Ksi.) | % Elong. @ Max. Load (%) | Ultimate Load (lbs.) | % Elong. @ Ult. Load (%) | Date Tested | Remarks |
|                 |                 |                         |                 |                     |                               |                                                |                         |                                 |                          |                      |                          |             |         |
| BIL-GL-22-1     | 72°F (DRY)      | 1.498                   | 0.0631          | 0.2515              | 660                           | 900                                            | 41.59                   | 56.71                           | 12.80                    | 900                  | 12.00                    | 7/14/89     |         |
| BIL-GL-22-5     | "               | 1.499                   | 0.0649          | 0.2518              | 713                           | 846                                            | 43.62                   | 51.75                           | 12.00                    | 850                  | 12.30                    | "           |         |
| BIL-GL-22-7     | "               | 1.498                   | 0.0647          | 0.2517              | 686                           | 916                                            | 42.11                   | 56.23                           | 11.00                    | 920                  | 11.38                    | "           |         |
| Average         |                 |                         |                 |                     |                               | 42.44                                          | 54.93                   | 11.93                           | 11.89                    |                      |                          |             |         |
| Std. Dev.       |                 |                         |                 |                     |                               | 1.06                                           | 2.74                    | 0.90                            | 0.47                     |                      |                          |             |         |

Remarks:

(1) Type of failure:

- a) tension.
- b) shear-out
- c) cleavage-tension.
- d) bearing.

| SI Conversion          |       |
|------------------------|-------|
| Maximum                |       |
| Bearing Strength (MPa) | 391.0 |
|                        | 356.8 |
|                        | 387.7 |
| Average                | 378.5 |
| Std. Dev.              | 18.9  |

TABLE H.2  
INDIVIDUAL SPECIMEN BOLT-BEARING TEST RESULTS,  
GLASS REINFORCEMENT, WET CONDITION

| Test : Bolt-Bearing: ASTM-D953 |                 |                         |                 |                     |                        |          |                     |                         |                                 | Fiber Orientation : (0°/±45°/90°) |                          |             |          |
|--------------------------------|-----------------|-------------------------|-----------------|---------------------|------------------------|----------|---------------------|-------------------------|---------------------------------|-----------------------------------|--------------------------|-------------|----------|
| Material :                     |                 | EA-9396 A/B; 7781 Glass |                 | Batch #1            |                        | Task #10 |                     | Tested by : PM          |                                 |                                   |                          |             |          |
| Specimen Number                | Test Conditions | Width (in.)             | Thickness (in.) | Hole Diameter (in.) | Load at 4% Hol Deform. |          | Maximum Load (lbs.) | Bearing Strength (Ksi.) | Maximum Bearing Strength (Ksi.) | % Elong. @ Max. Load (%)          | % Elong. @ Ult. Load (%) | Date Tested | Remarks  |
|                                |                 |                         |                 |                     | (lbs.)                 | (lbs.)   |                     |                         |                                 |                                   |                          |             |          |
| BIL-GL-22-2                    | 72°F (WET)      | 1.498                   | 0.0651          | 0.2499              | 381                    | 555      | 23.42               | 34.12                   | 35.09                           | 9.36                              | NA                       | 2/26/90     | (1a,2,3) |
| BIL-GL-22-4                    | "               | 1.499                   | 0.0645          | 0.2505              | 375                    | 615      | 23.21               | 38.06                   | 2.63                            | 10.52                             | NA                       | "           | (1a,2,3) |
| BIL-GL-22-8                    | "               | 1.498                   | 0.0640          | 0.2512              | 292                    | 532      | 18.16               | 33.09                   | 21.60                           | 28.72                             | 28.72                    | "           | (1a,2,3) |
| Average                        |                 |                         |                 |                     |                        |          |                     |                         | 35.09                           | 16.20                             |                          |             |          |
| Std. Dev.                      |                 |                         |                 |                     |                        |          |                     |                         | 2.63                            | 10.86                             |                          |             |          |

## Remarks:

- (1) Type of failure:
  - a) tension.
  - b) shear-out
  - c) cleavage-tension.
  - d) bearing.
- (2) Specimens aged @ 140°F/95–100% R.H. for 148 days to saturation.
- (3) Average weight gain = 0.6418%

TABLE H.3

INDIVIDUAL SPECIMEN BOLT-BEARING TEST RESULTS,  
GRAPHITE REINFORCEMENT, DRY CONDITION

| Test :          |                 | Bolt-Bearing: ASTM-D953     |                 | Batch #1            |                       | Task #10            |                         | Fiber Orientation : (0°/±45°/90°) <sub>s</sub> |                          |
|-----------------|-----------------|-----------------------------|-----------------|---------------------|-----------------------|---------------------|-------------------------|------------------------------------------------|--------------------------|
| Material :      |                 | EA-9396 A/B ; W133 Graphite |                 | Load at             |                       | Tested by : PM      |                         |                                                |                          |
| Specimen Number | Test Conditions | Width (in.)                 | Thickness (in.) | Hole Diameter (in.) | 4% Hol Deform. (lbs.) | Maximum Load (lbs.) | Bearing Strength (Ksi.) | Maximum Bearing Strength (Ksi.)                |                          |
|                 |                 |                             |                 |                     |                       |                     |                         | % Elong. @ Max. Load (%)                       | % Elong. @ Ult. Load (%) |
| BIL-GR-43-1     | 72°F (DRY)      | 1.499                       | 0.1154          | 0.2502              | 1,482                 | 1,861               | 51.33                   | 64.44                                          | 1.50                     |
| BIL-GR-43-5     | "               | 1.499                       | 0.1232          | 0.2505              | 1,575                 | 2,204               | 51.03                   | 71.40                                          | 3.50                     |
| BIL-GR-43-7     | "               | 1.500                       | 0.1196          | 0.2508              | 2,179                 | 2,339               | 72.63                   | 77.99                                          | 5.25                     |
| Average         |                 |                             |                 |                     |                       |                     | 58.33                   | 71.28                                          | 3.42                     |
| Std. Dev.       |                 |                             |                 |                     |                       |                     | 12.38                   | 6.77                                           | 1.88                     |
|                 |                 |                             |                 |                     |                       |                     |                         |                                                | 10.09                    |
|                 |                 |                             |                 |                     |                       |                     |                         |                                                | 3.18                     |

Remarks:

(1) Type of failure:

- a) tension.
- b) shear-out
- c) cleavage-tension.
- d) bearing.

## SI Conversion

|           | Maximum                |                        |
|-----------|------------------------|------------------------|
|           | Bearing Strength (MPa) | Bearing Strength (MPa) |
|           | 353.9                  | 444.3                  |
|           | 351.9                  | 492.3                  |
|           | 500.8                  | 537.7                  |
| Average   | 402.2                  | 491.5                  |
| Std. Dev. | 85.4                   | 46.7                   |

TABLE H.4

INDIVIDUAL SPECIMEN BOLT-BEARING TEST RESULTS,  
GRAPHITE REINFORCEMENT, WET CONDITION

| Test :          |                 | Bolt-Bearing: ASTM-D953     |                 | Batch #1       |                       | Task #10            |                         | Fiber Orientation : (0°/±45°/90°) |                                 | Tested by : PM |                 |
|-----------------|-----------------|-----------------------------|-----------------|----------------|-----------------------|---------------------|-------------------------|-----------------------------------|---------------------------------|----------------|-----------------|
| Material :      |                 | EA-9396 A/B · W133 Graphite |                 | Load at        |                       | Hole                |                         | Maximum                           |                                 | % Elong.       |                 |
| Specimen Number | Test Conditions | Width (in.)                 | Thickness (in.) | Diameter (in.) | 4% Hol Deform. (lbs.) | Maximum Load (lbs.) | Bearing Strength (Ksi.) | Bearing Strength (Ksi.)           | Maximum Bearing Strength (Ksi.) | Load (%)       | % Elong. @ Ult. |
| BIL-GR-43-2     | 72°F (WET)      | 1.501                       | 0.1224          | 0.2512         | 930                   | 2,660               | 30.25                   | 86.51                             | 19.64                           | 2,660          | 19.64           |
| BIL-GR-43-4     | "               | 1.500                       | 0.1224          | 0.2509         | 1,040                 | 2,750               | 33.87                   | 89.55                             | 22.32                           | 2,700          | 23.20           |
| BIL-GR-43-6     | "               | 1.499                       | 0.1209          | 0.2510         | 1,125                 | 2,760               | 37.07                   | 90.95                             | 20.28                           | 2,725          | 22.08           |
|                 |                 |                             |                 |                |                       | Average             | 33.73                   | 89.00                             | 20.75                           | 21.64          |                 |
|                 |                 |                             |                 |                |                       | Std. Dev.           | 3.41                    | 2.27                              | 1.40                            | 1.82           |                 |

## Remarks:

(1) Type of failure:

- a) tension.
- b) shear-out
- c) cleavage-tension.
- d) bearing.

(2) Specimens aged @ 140°F/95-100% R.H. for 148 days to saturation.

(3) Average weight gain = 0.6129%

| SI Conversion          |                        |
|------------------------|------------------------|
|                        | Maximum                |
| Bearing Strength (MPa) | Bearing Strength (MPa) |
| 208.6                  | 596.5                  |
| 233.5                  | 617.4                  |
| 255.6                  | 627.1                  |
| Average                | 613.7                  |
| Std. Dev.              | 15.6                   |

# APPENDIX I INDIVIDUAL SPECIMEN GLASS TRANSITION TEMPERATURE MEASUREMENTS

This appendix presents the results of the glass transition temperature (T<sub>g</sub>) measurements on each individual specimen. The specimens were in the form of neat resin castings with approximate dimensions of 22 x 13 x 2 mm (7/8 x 1/2 x 1/16 inch). The measurements were performed by dynamic mechanical analysis (DMA) at a heating rate of 0.5°C/minute. Glass transition temperature was taken from the peak of the log E'' (loss modulus) vs. temperature curve. The tests were performed on a DuPont Model 983 DMA. Table I.1 summarizes the individual results and Figures I.1-I.18 illustrate the DMA curves for each specimen. The curves for specimen Nos. 1-2 (I.1) and 1-1 (I.10) are labelled to indicate the location at which the T<sub>g</sub> was identified for the dry and wet test conditions.

TABLE I.1  
INDIVIDUAL SPECIMEN GLASS TRANSITION TEMPERATURE

| Specimen<br>Number | Batch<br>Number | Test<br>Condition | Wt. Gain<br>(%) (1) | Glass Transition Temp.(2) |      |
|--------------------|-----------------|-------------------|---------------------|---------------------------|------|
|                    |                 |                   |                     | (°C)                      | (°F) |
| 1-2                | 1               | Dry               | N.A.                | 174                       | 345  |
| 1-4                | 1               | Dry               | N.A.                | 176                       | 349  |
| 1-6                | 1               | Dry               | N.A.                | 175                       | 347  |
| Avg.               |                 |                   |                     | 175                       | 347  |
| Std. Dev.          |                 |                   |                     | 1.0                       | 2.0  |
| 2-2                | 2               | Dry               | N.A.                | 176                       | 349  |
| 2-4                | 2               | Dry               | N.A.                | 176                       | 349  |
| 2-6                | 2               | Dry               | N.A.                | 177                       | 351  |
| Avg.               |                 |                   |                     | 176                       | 350  |
| Std. Dev.          |                 |                   |                     | 0.6                       | 1.0  |
| 3-2                | 3               | Dry               | N.A.                | 177                       | 351  |
| 3-4                | 3               | Dry               | N.A.                | 178                       | 352  |
| 3-6                | 3               | Dry               | N.A.                | 176                       | 349  |
| Avg.               |                 |                   |                     | 177                       | 351  |
| Std. Dev.          |                 |                   |                     | 1.0                       | 1.5  |
| 1-1                | 1               | Wet               | 9.2                 | 107                       | 225  |
| 1-3                | 1               | Wet               | 9.1                 | 106                       | 223  |
| 1-5                | 1               | Wet               | 9.1                 | 106                       | 223  |
| Avg.               |                 |                   |                     | 106                       | 224  |
| Std. Dev.          |                 |                   |                     | 0.6                       | 1.0  |
| 2-1                | 2               | Wet               | 8.7                 | 108                       | 226  |
| 2-3                | 2               | Wet               | 8.6                 | 111                       |      |
| 2-5                | 2               | Wet               | 8.9                 | 106                       | 223  |
| Avg.               |                 |                   |                     | 108                       | 227  |
| Std. Dev.          |                 |                   |                     | 2.5                       | 4.6  |
| 3-1                | 3               | Wet               | 8.8                 | 109                       | 228  |
| 3-3                | 3               | Wet               | 8.9                 | 107                       | 225  |
| 3-5                | 3               | Wet               | 8.7                 | 105                       | 221  |
| Avg.               |                 |                   |                     | 107                       | 225  |
| Std. Dev.          |                 |                   |                     | 2.0                       | 3.5  |

NOTES: (1) After aging at 60°C (140°F) and 95-100% R.H. until saturated.  
(2) Specimens cured for 45 minutes at 93°C (200°F).

Sample : EA 9396 1-2 DRY  
 Size : 21.81 x 13.50 x 2.11 mm  
 Method : DMA-STEP 2°  
 Comments: STEP 2°C

File : E: RUN1880.01  
 Operator: GALASKA  
 Run Date: 06/08/99 10:53

# DMA

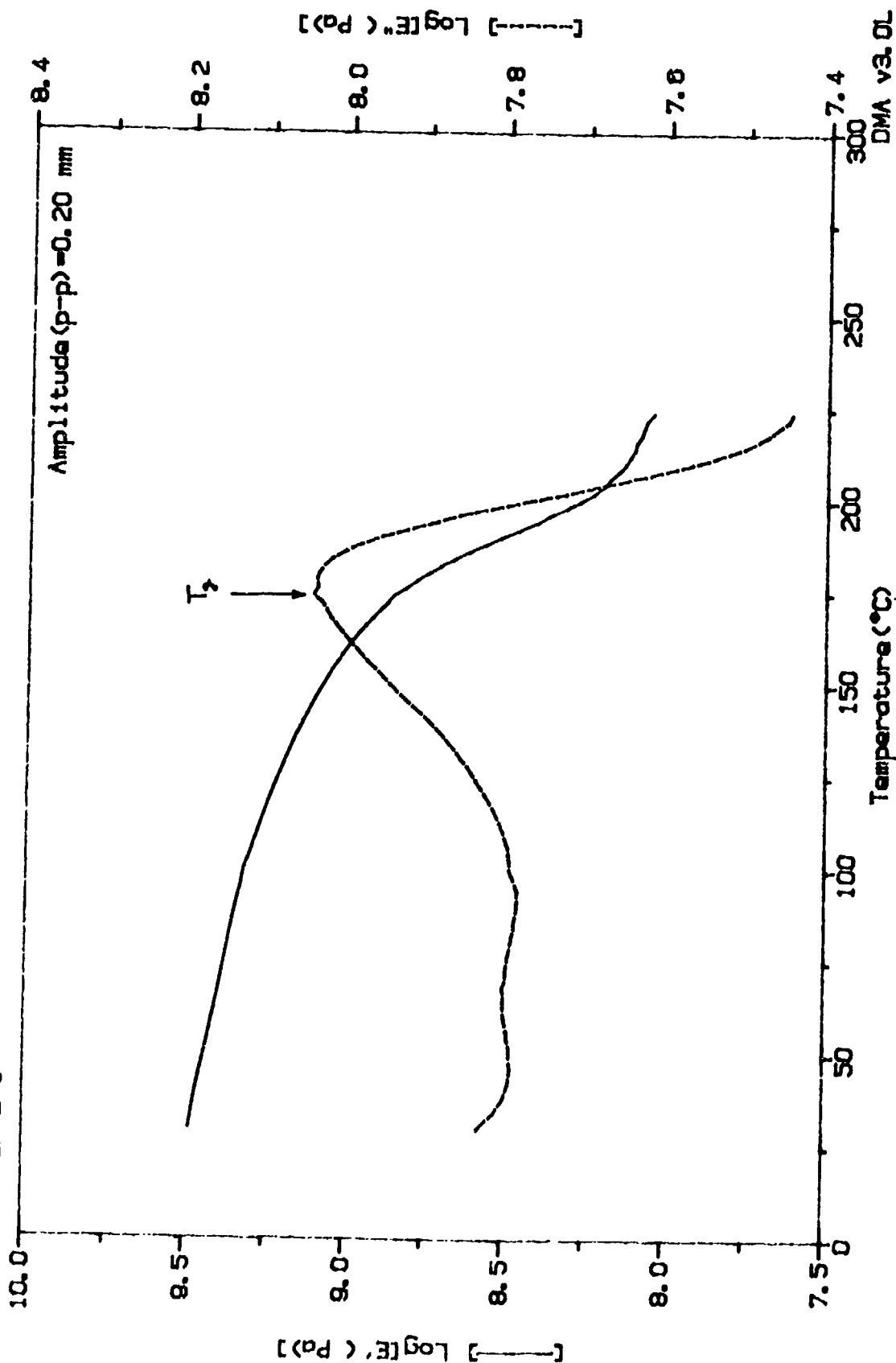


Figure I.1. Determination of T<sub>g</sub> for Specimen 1-2, Batch 1, Dry Condition.



Sample : EA 9398 1-4 DRY  
 Size : 22.05 x 13.77 x 2.15 mm  
 Method : DMA-STEP 2°  
 Comments: STEP 2°C

File : E: RUN1881.02  
 Operator: GALASKA  
 Run Date: 08/12/89 10:28

# DMA

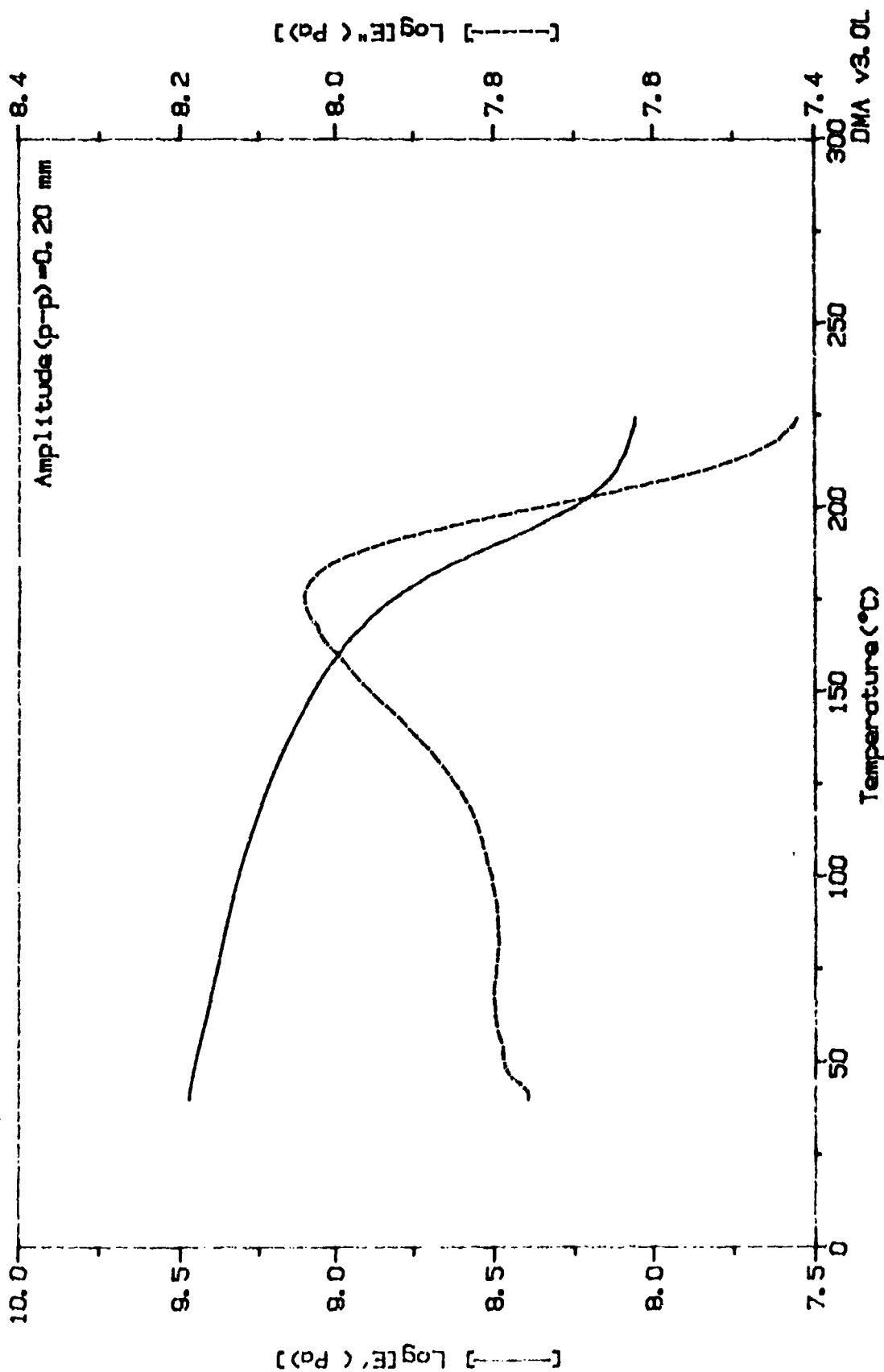


Figure I.2. Determination of Tg for Specimen 1-4, Batch 1, Dry Condition.

Sample : EA 9398 1-6 DRY  
 Size : 22.18 x 12.80 x 2.15 mm  
 Method : DMA-STEP 2°  
 Comment: STEP 2°C

# DMA

File : E: RUN1882.01  
 Operator: GALASKA  
 Run Date: 08/13/89 07:41

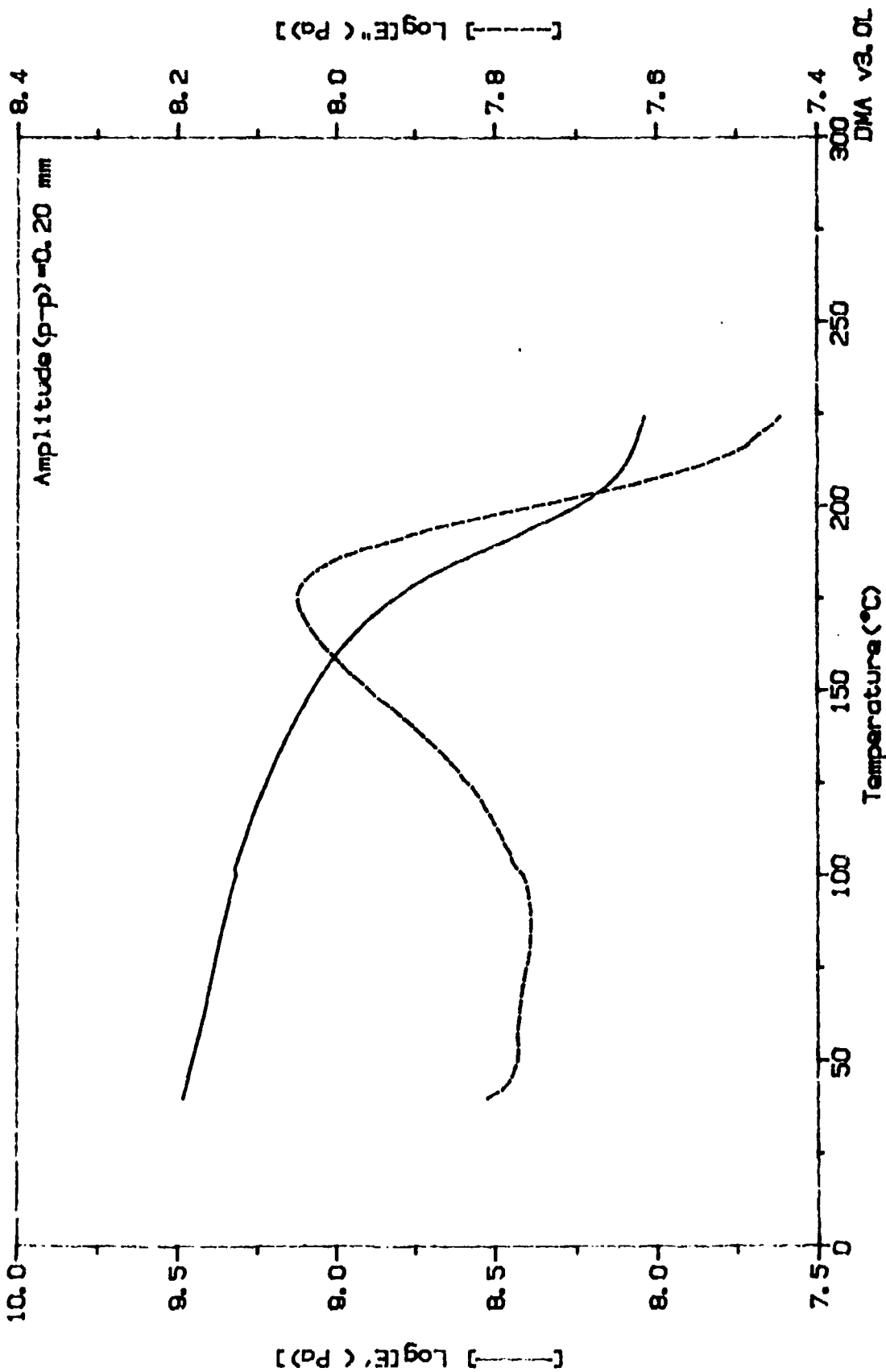


Figure I.3. Determination of Tg for Specimen 1-6, Batch 1, Dry Condition.

Sample : SA 9396 2-2 DRY  
 Size : 22.70 x 13.30 x 1.85 mm  
 Method : DMA-STEP 2°  
 Comment: STEP 2°C

File : E: RUN1883.01  
 Operator: GALASKA  
 Run Date: 06/13/89 18:05

DMA

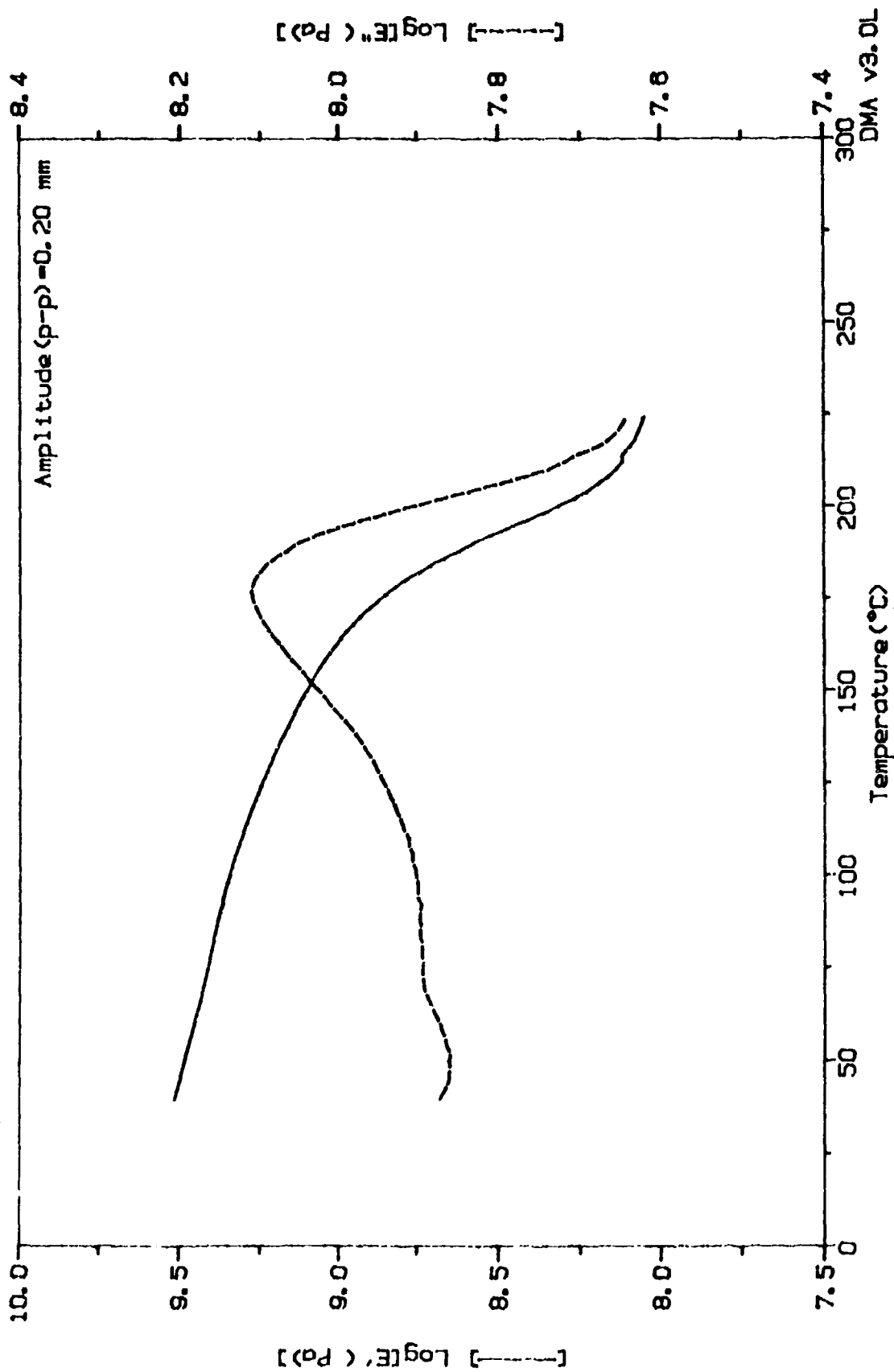


Figure 1.4. Determination of Tg for Specimen 2-2, Batch 2, Dry Condition.

Sample : EA 9396 2-4 DRY  
 Size : 22.89 x 14.01 x 2.00 mm  
 Method : DMA-STEP 2°  
 Comments: STEP 2°C

File : E:\RUN1884.01  
 Operator: GALASKA  
 Run Date: 06/14/89 07:28

# DMA

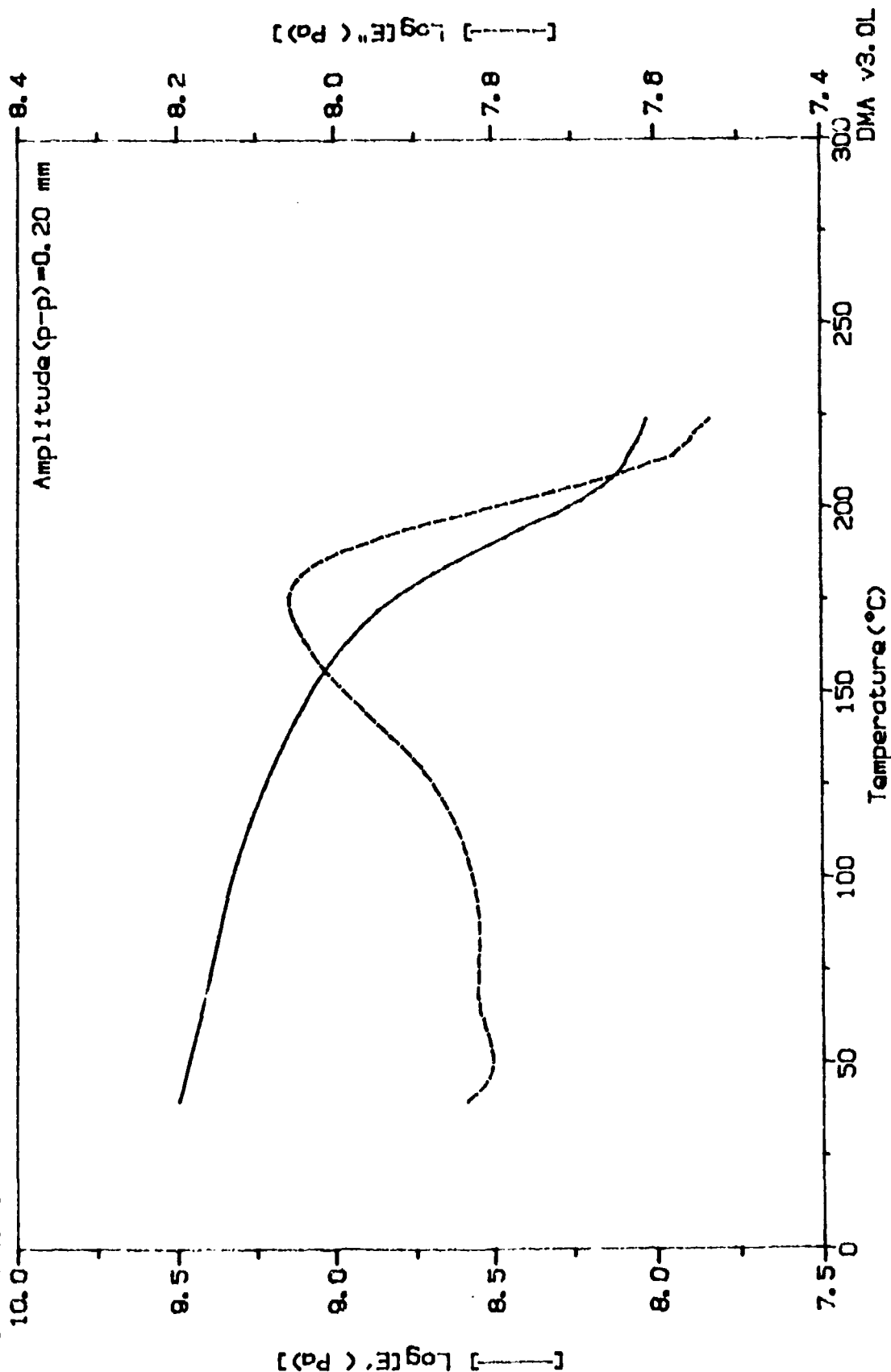


Figure 1.5. Determination of Tg for Specimen 2-4, Batch 2, Dry Condition.

Sample : EA 9398 2-8 DRY  
 Size : 23.18 x 13.17 x 1.95 mm  
 Method : DMA-STEP 2°  
 Comment: STEP 2°C

File : E: RUN1885.01  
 Operator: GALASKA  
 Run Date: 08/14/89 15:45

# DMA

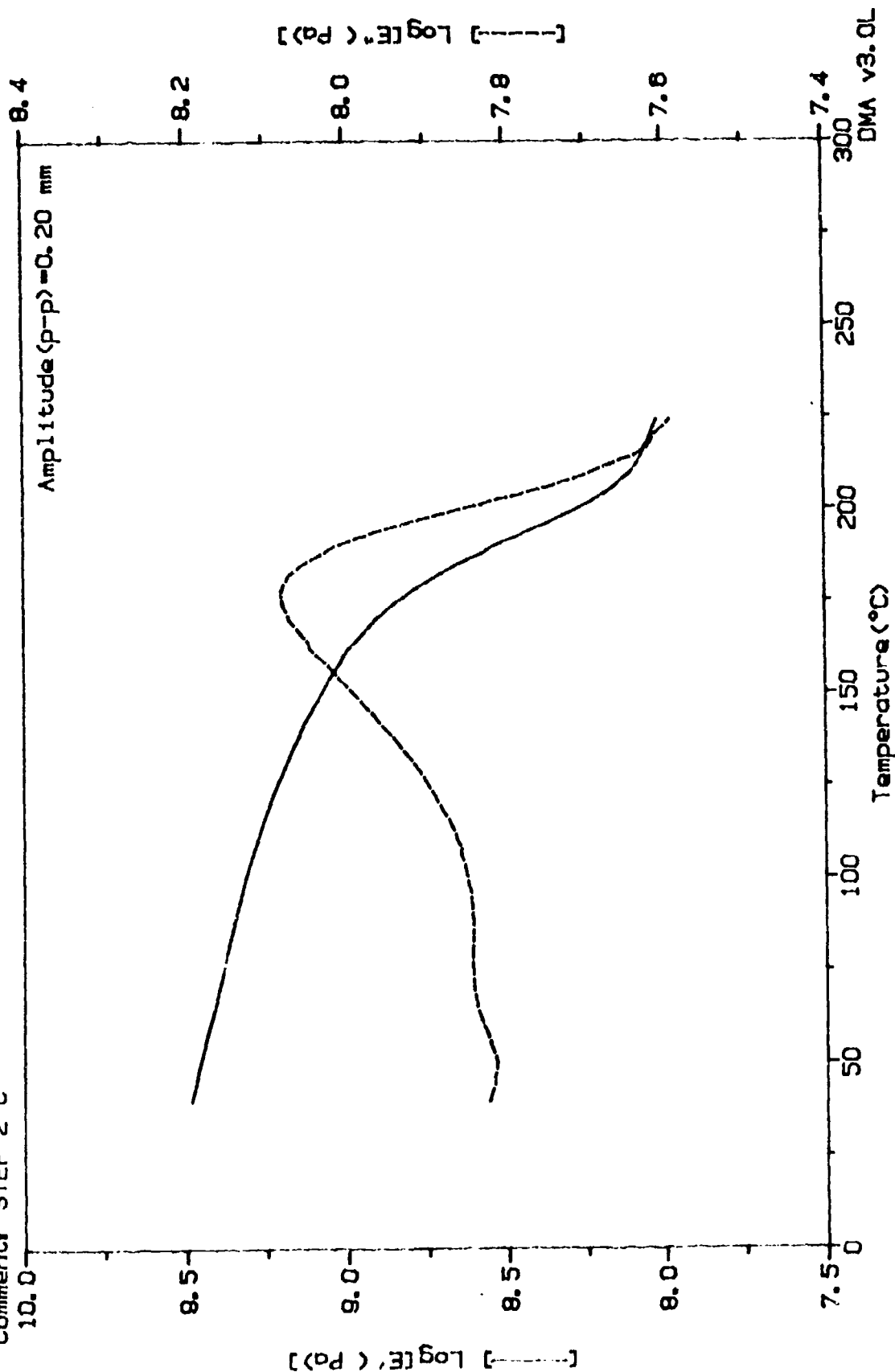


Figure 1.6. Determination of Tg for Specimen 2-6, Batch 2, Dry Condition.

Sample : EA 9398 3-2 DRY  
 Size : 23.59 x 14.68 x 1.94 mm  
 Method : DMA-STEP 2°  
 Comment: STEP 2°C

DMA

File : E1 RUN1888.01  
 Operator: GALASKA  
 Run Date: 06/15/89 07:27

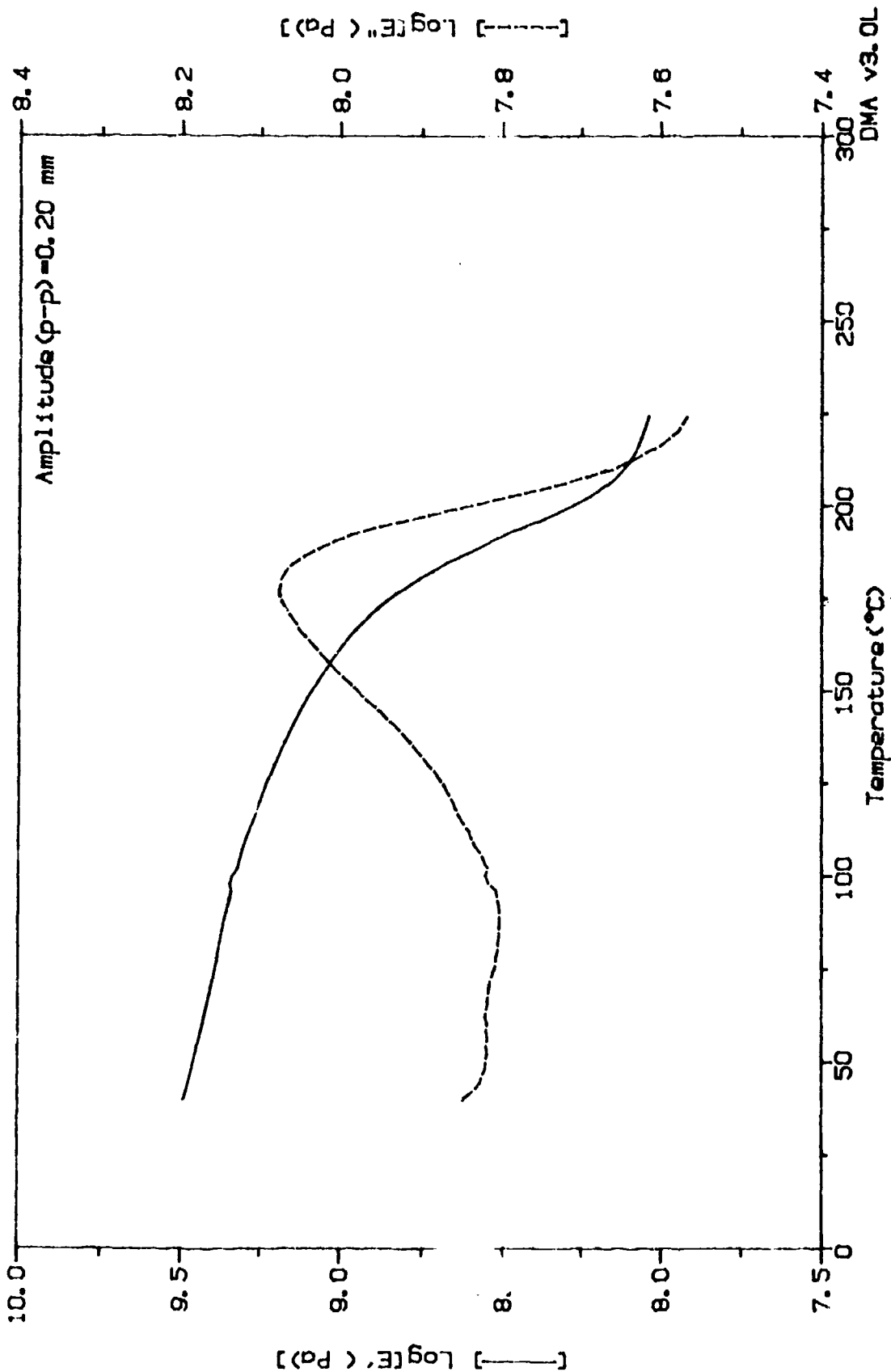


Figure 1.7. Determination of Tg for Specimen 3-2, Batch 3, Dry Condition.

Sample : EA 9396 3-4 DRY  
 Size : 23.86 x 11.79 x 2.01 mm  
 Method : DMA-STEP 2°  
 Comment: STEP 2°C

# DMA

File : E:RUN1987.01  
 Operator: GALASKA  
 Run Date: 06/15/89 15:08

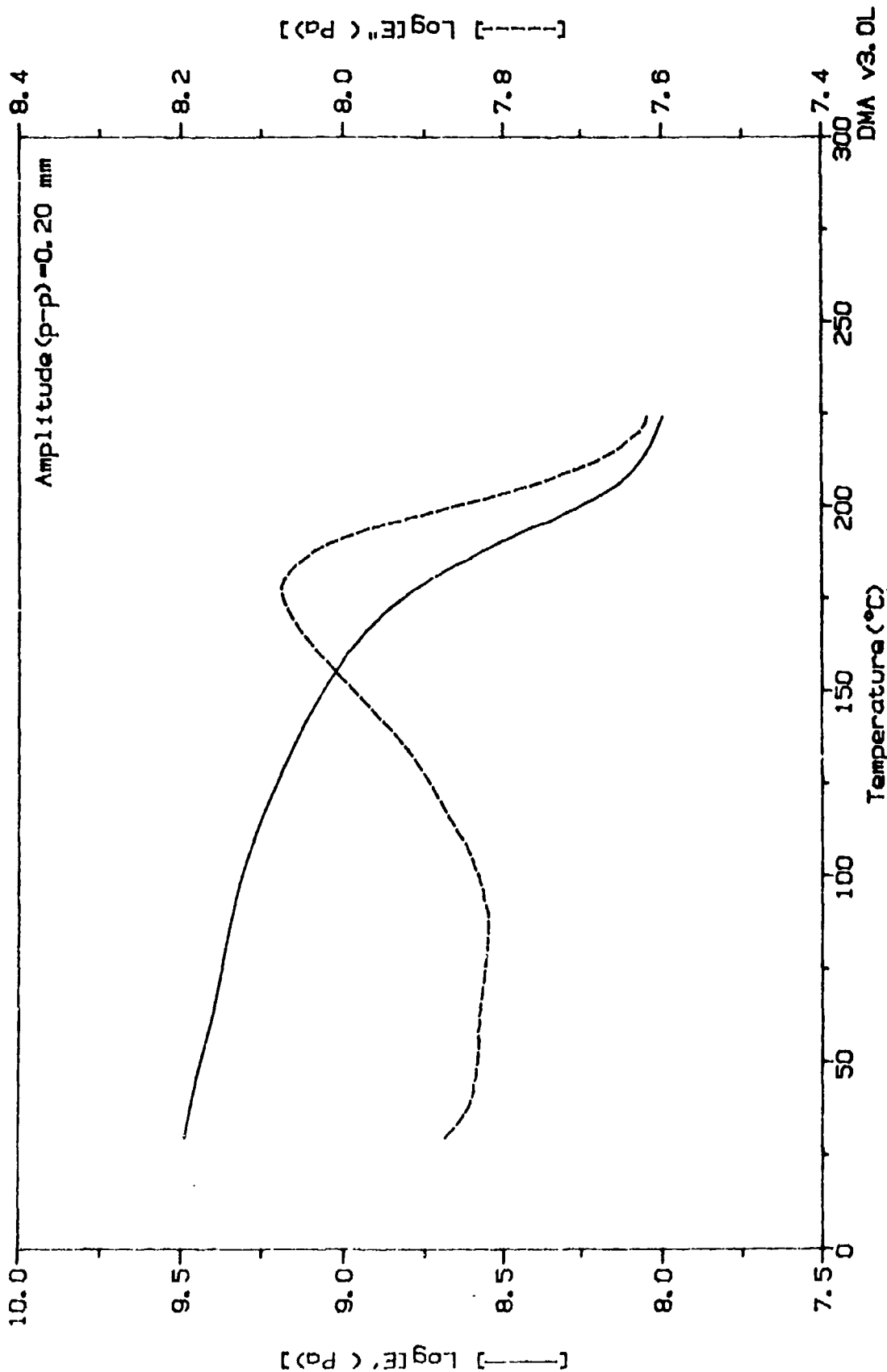


Figure 1.8. Determination of Tg for Specimen 3-4, Batch 3, Dry Condition.

Sample : EA 9396 3-6 DRY  
 Size : 24.21 x 13.75 x 2.37 mm  
 Method : DMA-STEP 2°  
 Comments : STEP 2°C

DMA

File : E:RUN1888.01  
 Operator: WEISSMAN  
 Run Date: 08/16/89 07.46

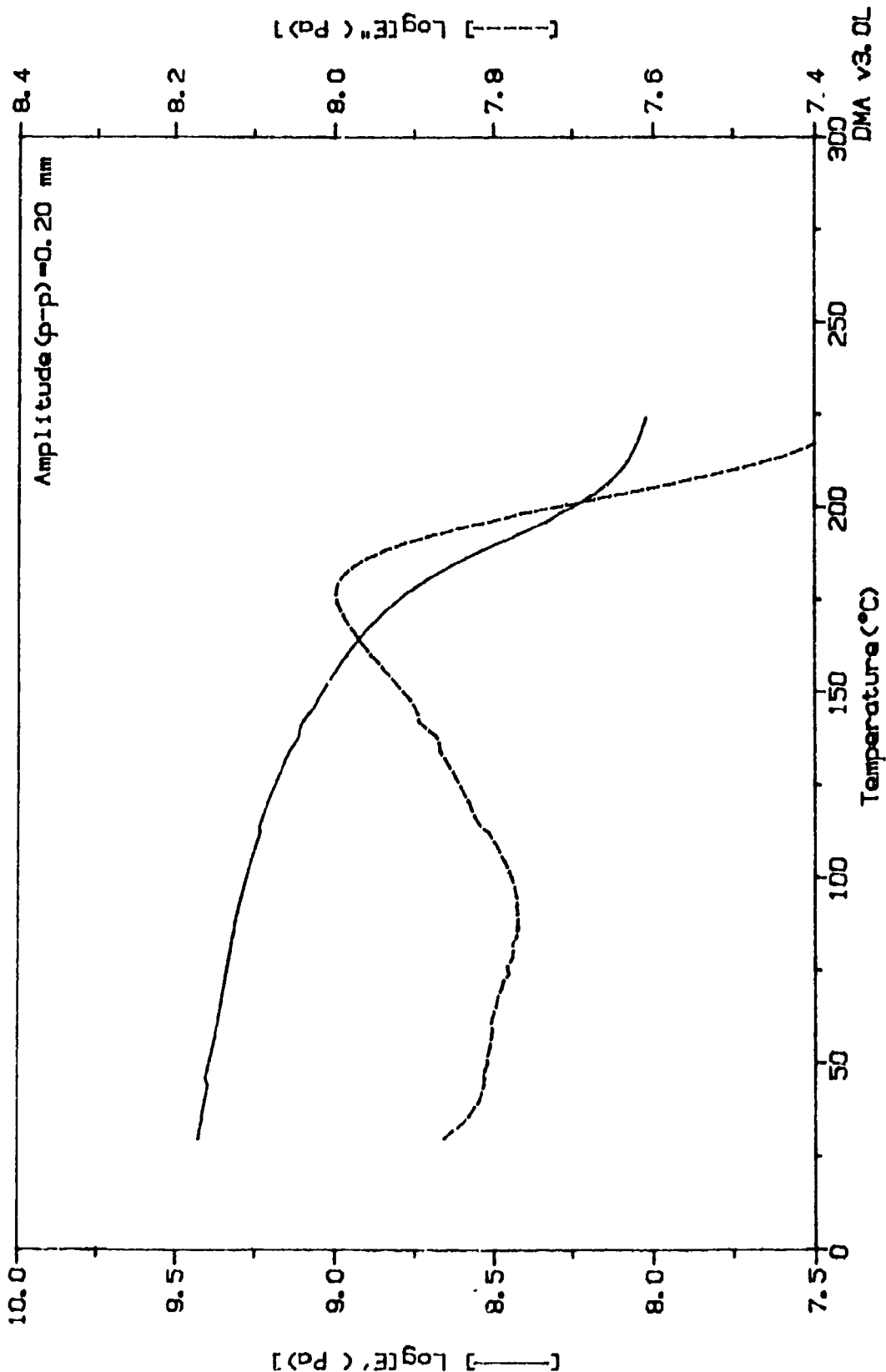


Figure I.9. Determination of Tg for Specimen 3-6, Batch 3, Dry Condition.



Sample : EA 9398 1-1 WET  
 Size : 24.40 x 13.77 x 2.21 mm  
 Method : DMA-STEP 2°  
 Comments : 2°C/STEP,NIT

File : E:RUN1917.01  
 Operator: GALASKA  
 Run Date: 07/20/89 14:09

DMA

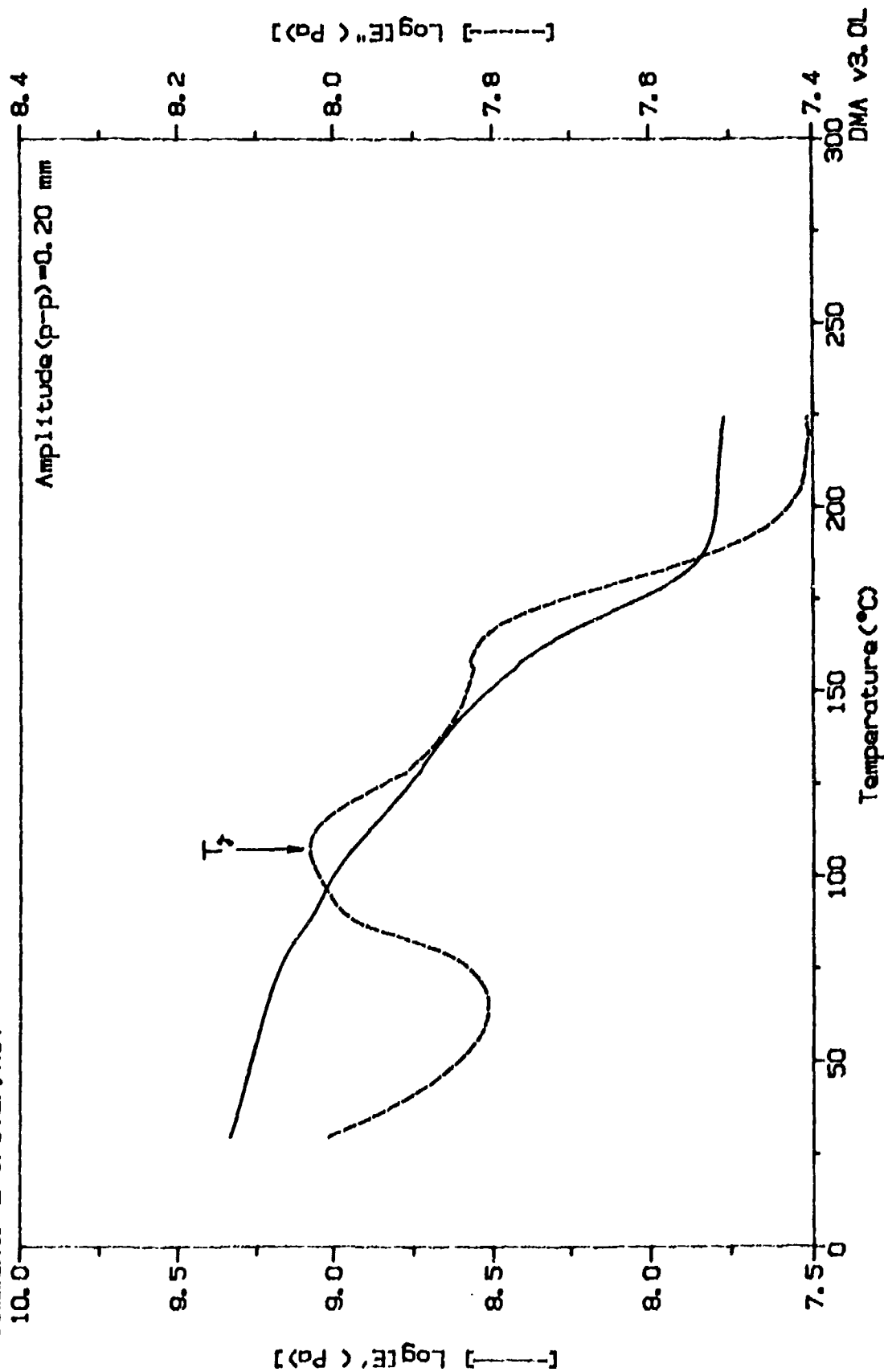


Figure 1.10. Determination of T<sub>g</sub> for Specimen 1-1, Batch 1, Wet Condition.

Sample : EA 9398 1-3 WET  
 Size : 24.61 x 13.42 x 2.25 mm  
 Method : DMA-STEP 2°  
 Comment: 2°C/STEP, NIT

# DMA

File : E1 RUN1918.01  
 Operator: GALASKA  
 Run Date: 07/21/89 08:26

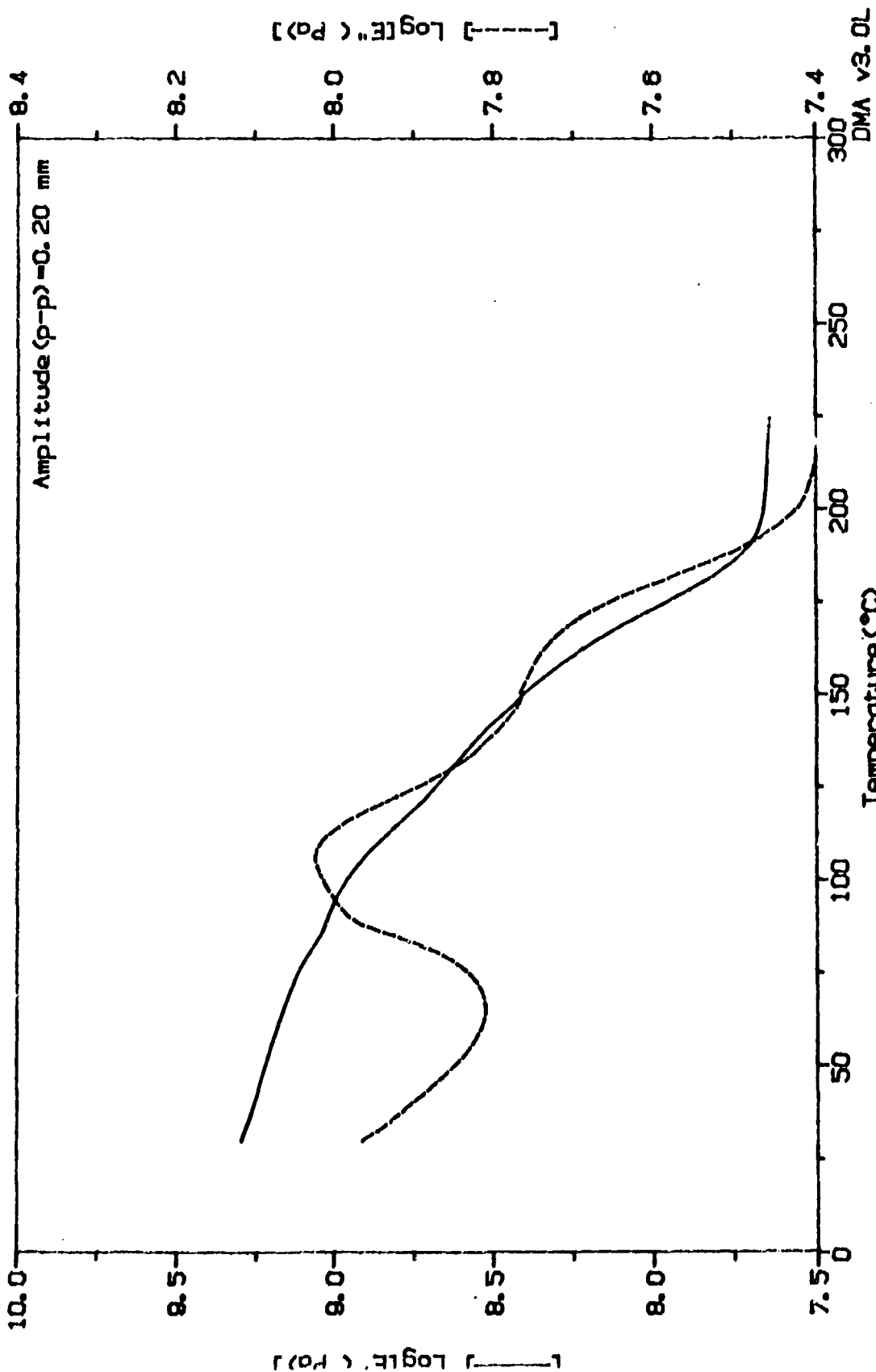


Figure I.11. Determination of  $T_g$  for Specimen 1-3, Batch 1, Wet Condition.

Sample : EA 9398 1-5 WET  
 Size : 24.87 x 13.42 x 2.23 mm  
 Method : DMA-STEP 2°  
 Comment: 2°C/STEP, NIT

# DMA

File : E, RUN1920.01  
 Operator: GALASKA  
 Run Date: 07/24/89 10:19

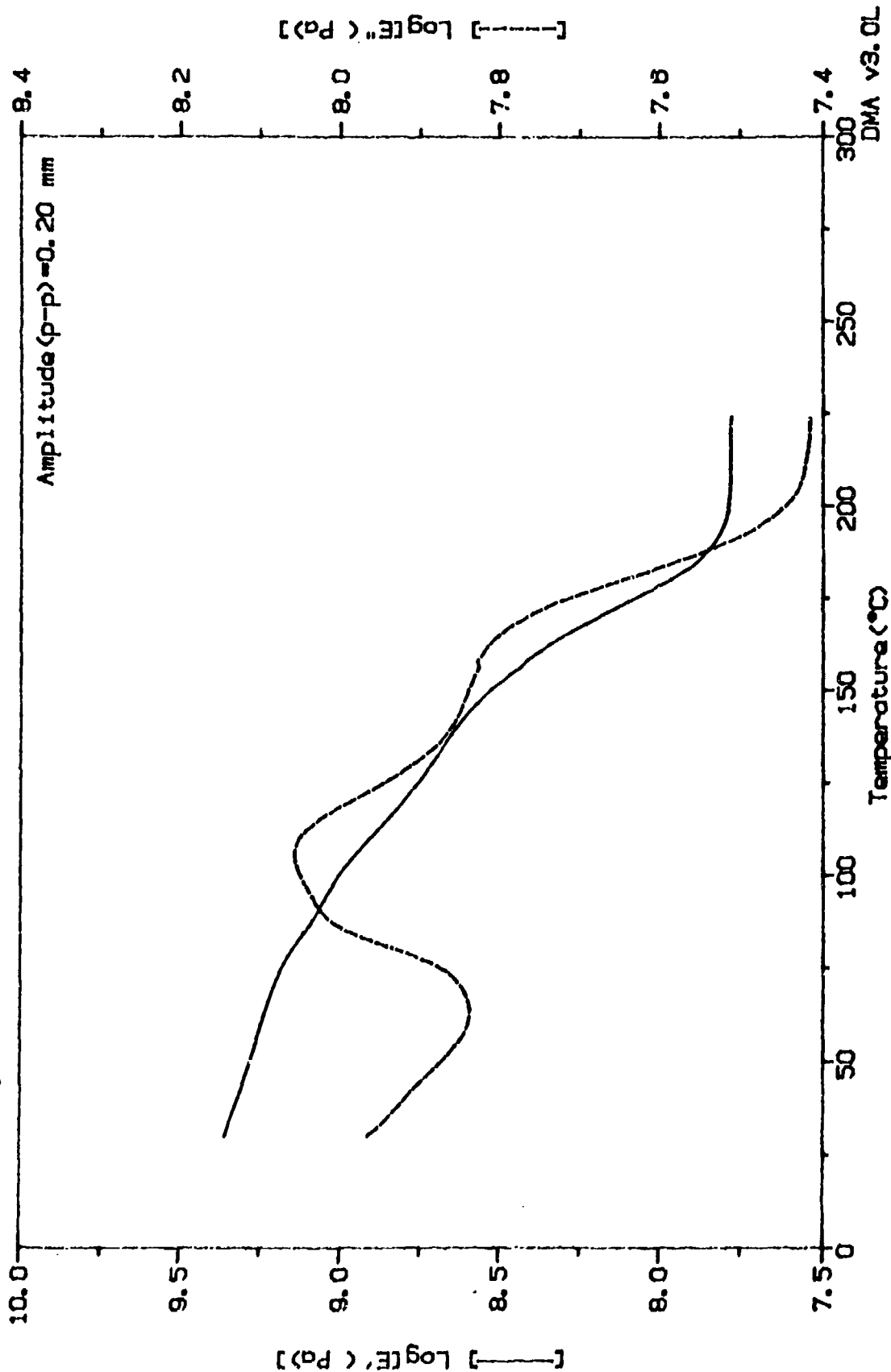


Figure I.12. Determination of T<sub>g</sub> for Specimen 1-5, Batch 1, Wet Condition.

Sample : EA 9398 2-1 WET  
 Size : 25.10 x 14.18 x 1.93 mm  
 Method : DMA-STEP 2°  
 Comments : 2°C/STEP.NIT

File : E:RUN1921.01  
 Operator: GALASKA  
 Run Date: 07/25/89 08:20

DMA

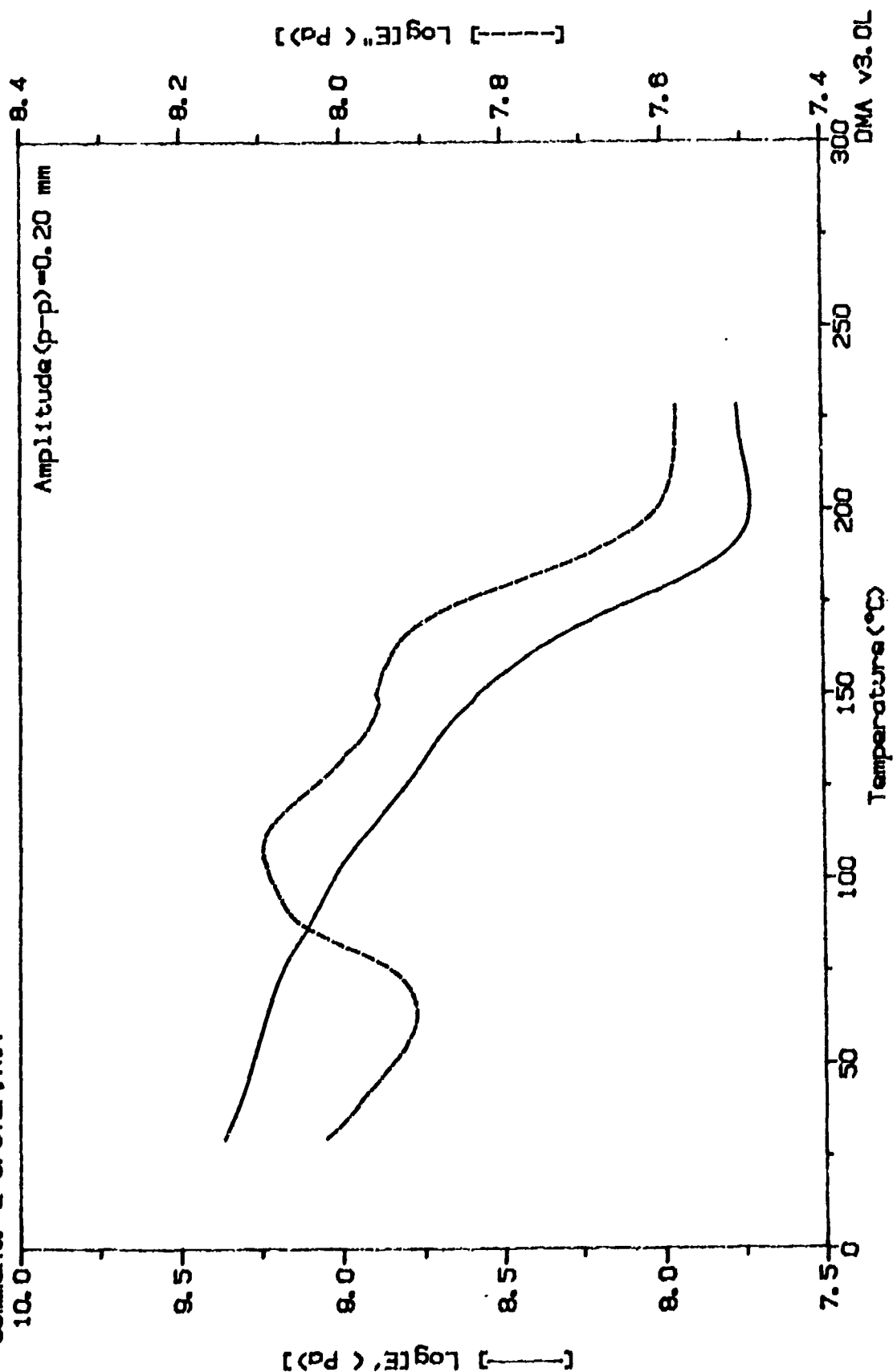


Figure I.13. Determination of Tg for Specimen 2-1, Batch 2, Wet Condition.

Sample : EA 9398 2-3 WET  
 Size : 25.32 x 13.36 x 1.92 mm  
 Method : DMA-STEP 2°  
 Comments : 2°C/STEP.NIT

# DMA

File : E:RUN1922.01  
 Operator: GALASKA  
 Run Date: 07/25/89 18:15

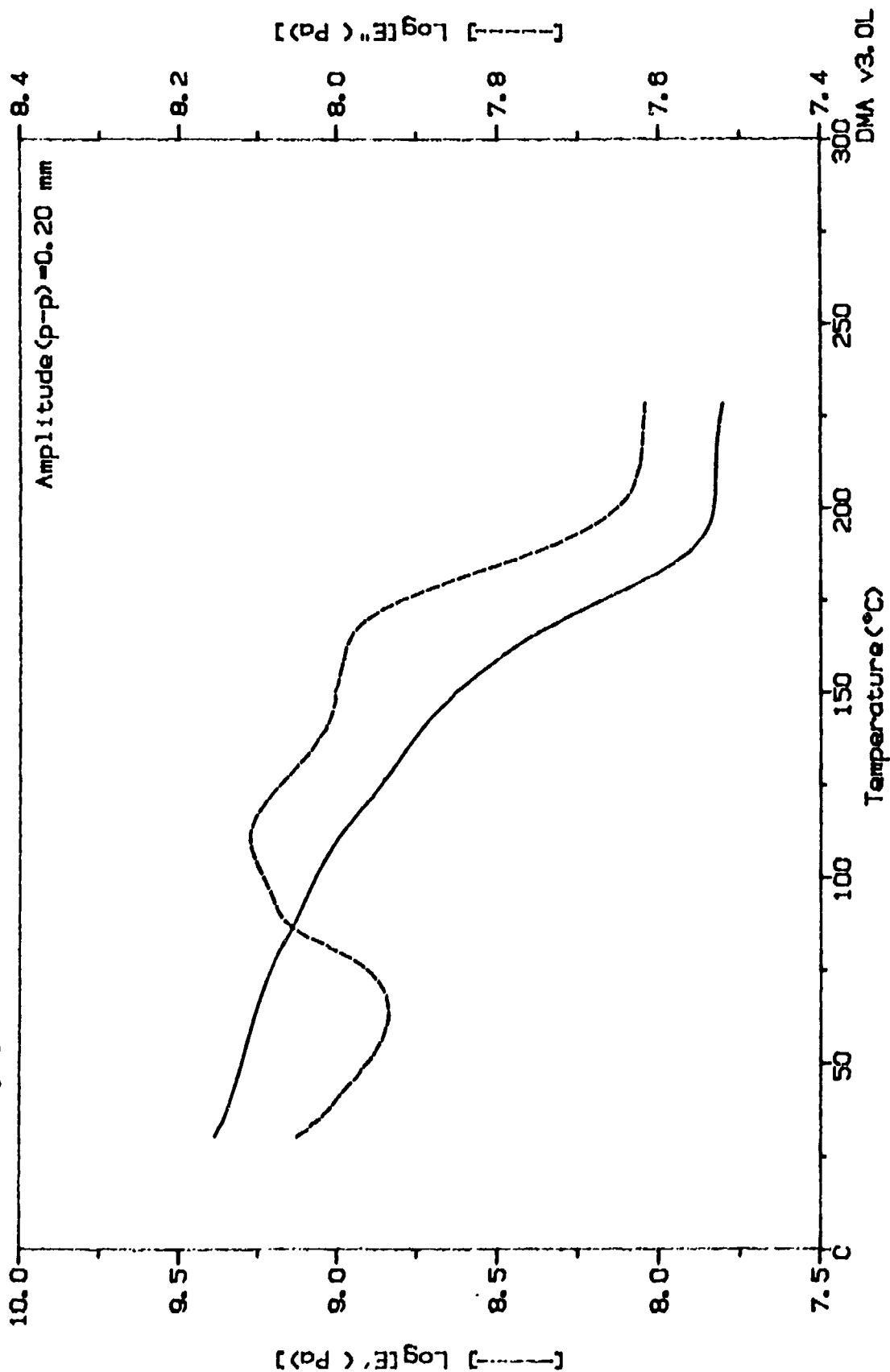


Figure 1.14. Determination of T<sub>g</sub> for Specimen 2-3, Batch 2, Wet Condition.

Sample : EA 9398 2-5 WET  
 Size : 25.52 x 13.60 x 2.03 mm  
 Method : DMA-STEP 2°  
 Comments : 2°C/STEP.NIT

File : E, RUN1923.01  
 Operator: GALASKA  
 Run Date: 07/26/89 08:27

# DMA

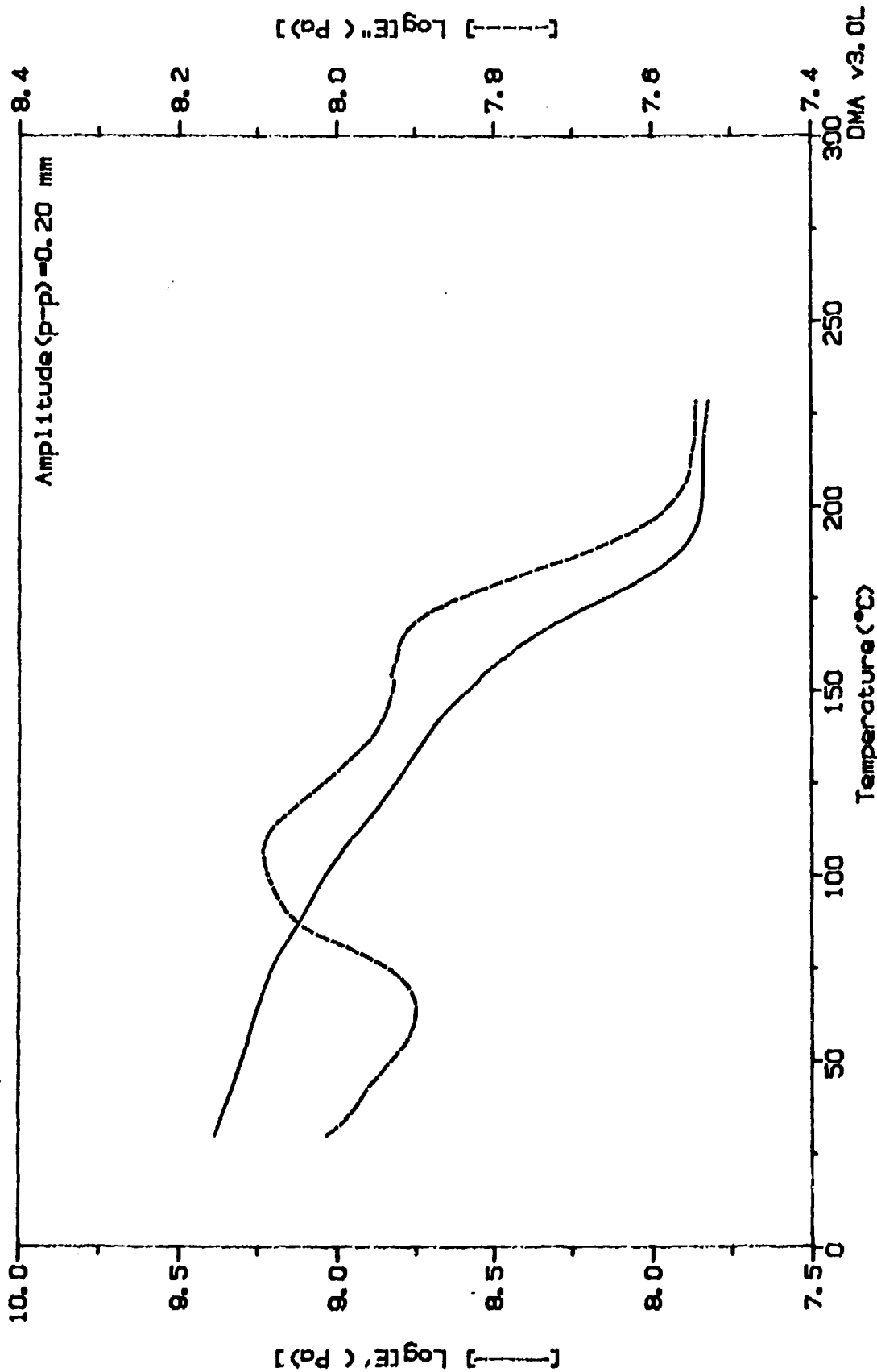


Figure I.15. Determination of T<sub>g</sub> for Specimen 2-5, Batch 2, Wet Condition.

Sample : EA 9398 3-1 WET  
 Size : 25.67 x 13.58 x 1.94 mm  
 Method : DMA-STEP 2°  
 Comments : 2°C/STEP.NIT

DMA

File : E:RUN1924.01  
 Operator: GALASKA  
 Run Date: 07/27/89 08.24

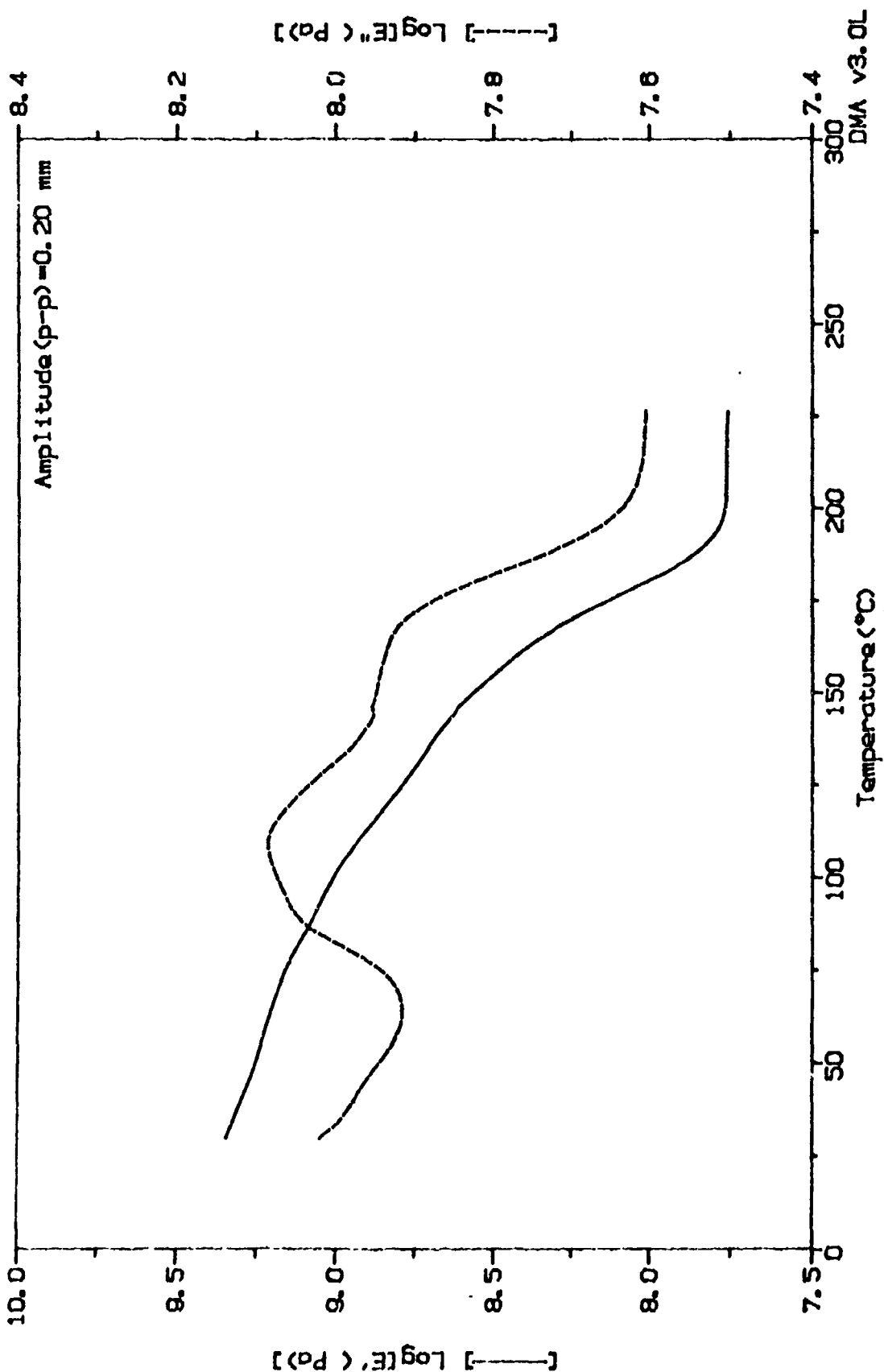


Figure I.16. Determination of Tg for Specimen 3-1, Batch 3, Wet Condition.

Sample : EA 9398 3-3 WET  
 Size : 24.37 x 14.76 x 2.13 mm  
 Method : DMA-STEP 2°  
 Comments : 2°C/STEP.NIT

File : E, RUN1925.01  
 Operator: GALASKA  
 Run Date: 07/27/89 18:25

# DMA

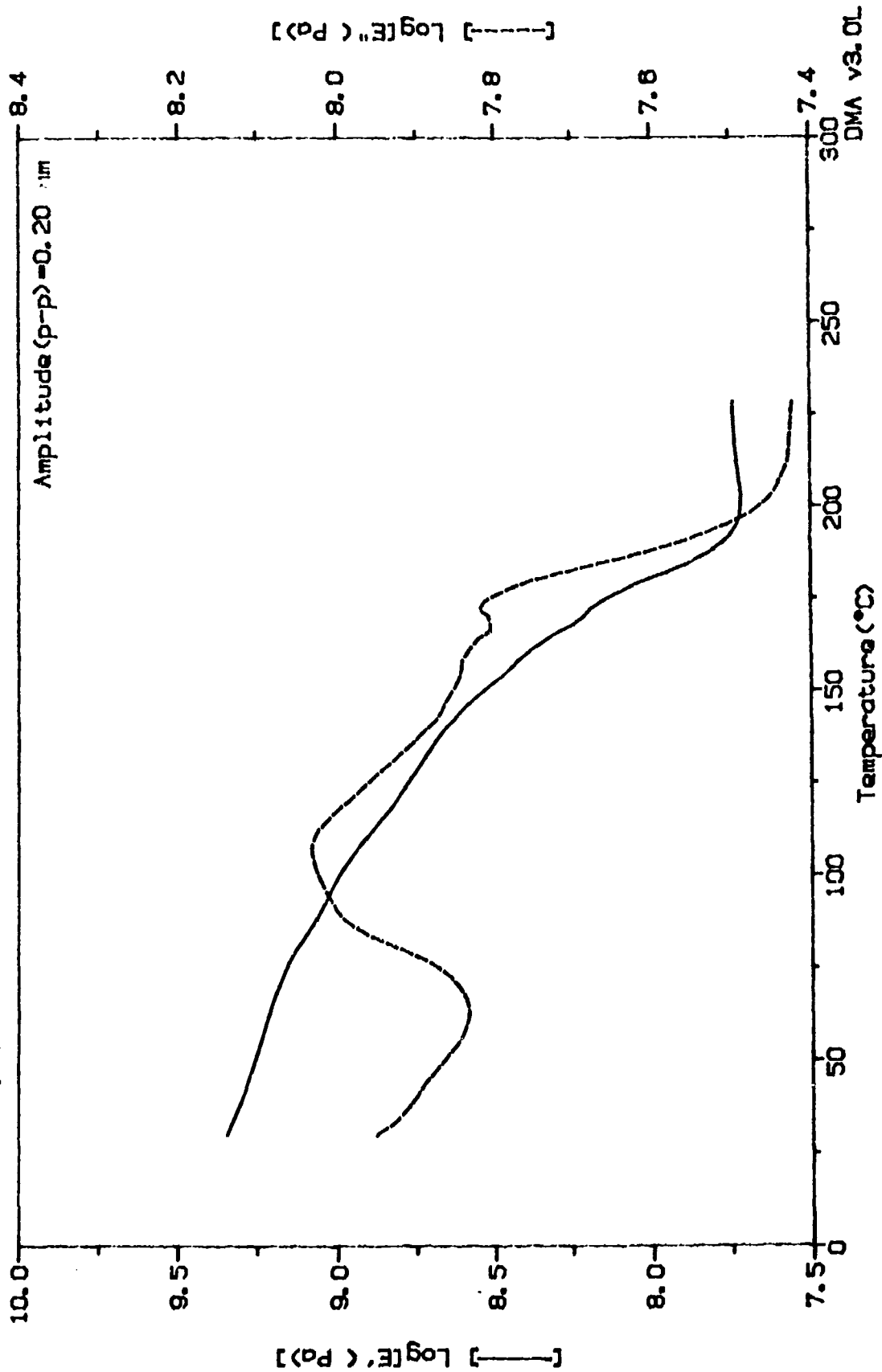


Figure I.17. Determination of  $T_g$  for Specimen 3-3, Batch 3, Wet Condition.



Sample : EA 9398 3-5 WET  
 Size : 24.80 x 14.80 x 2.38 mm  
 Method : DMA-STEP 2°  
 Comment: 2°C/STEP.NIT

File : E, RUN1926.01  
 Operator: GALASKA  
 Run Date: 07/31/89 08:38

# DMA

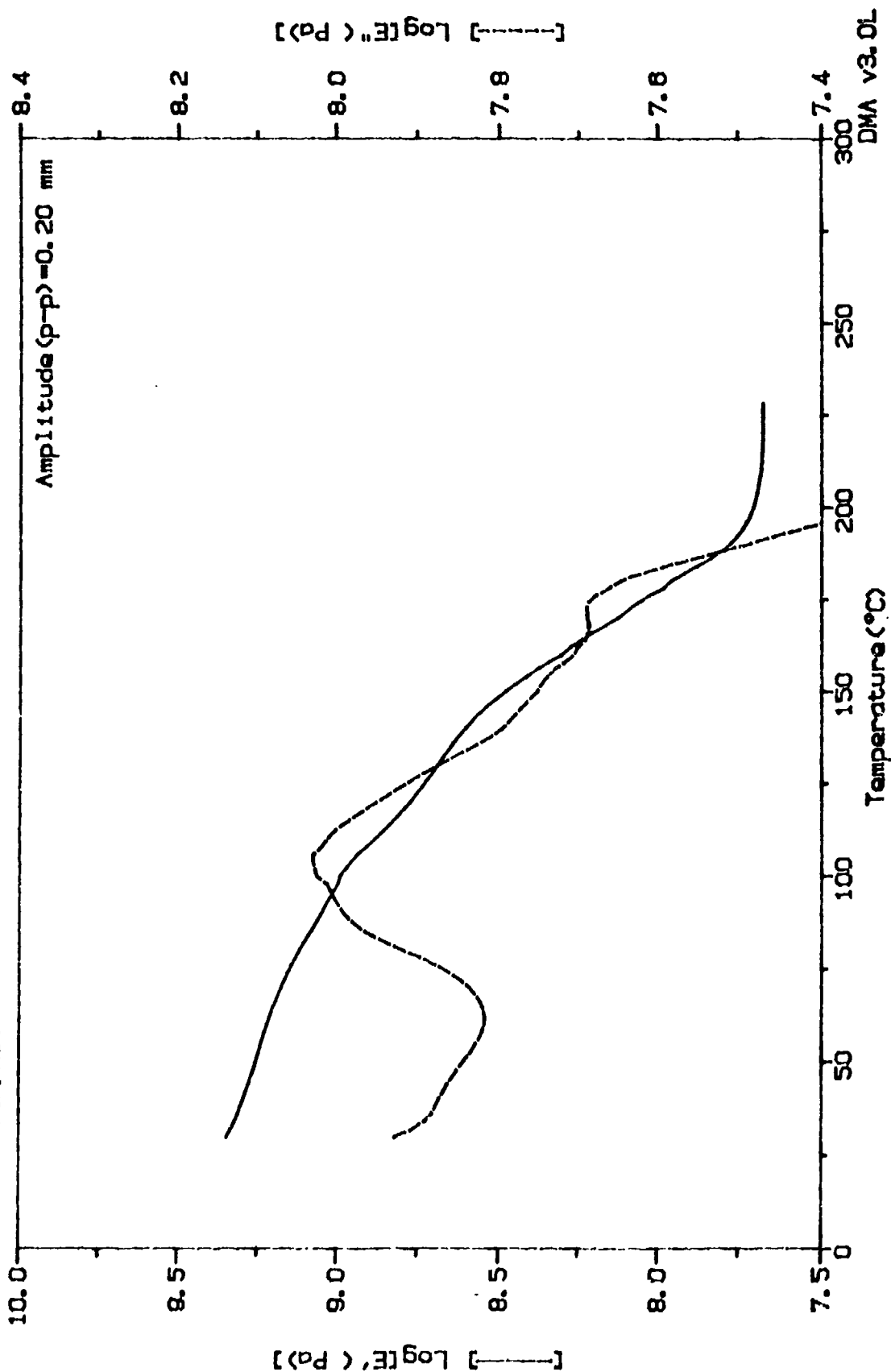


Figure I.18. Determination of T<sub>g</sub> for Specimen 3-5, Batch 3, Wet Condition.

**APPENDIX J**  
**INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR**  
**STRENGTHS, EFFECT OF CURE TIME/TEMPERATURE/**  
**PRESSURE VARIATIONS**

The six tables in this appendix present the detailed interlaminar shear strength data for specimens prepared with nonstandard cure schedules. These nonstandard cure schedules involved curing at temperatures and vacuum pressures both above and below the baseline levels of 93°C (200°F) and 635 mm (25 in.) Hg, respectively, or for other than the standard cure time of 45 minutes. A summary of these data was presented and discussed in Section 3.5.2.

TABLE J.1

EFFECT OF CURE VACUUM PRESSURE ON INTERLAMINAR SHEAR STRENGTH OF  
GLASS REINFORCED EA9396 COMPOSITE LAMINATES

| Test :          |                | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |             |                       | Specimen Orientation: Warp |             |
|-----------------|----------------|-----------------------------|-------------|-----------------|-------------------------------------|-------------|-----------------------|----------------------------|-------------|
| Material :      |                | EA-9396 A/B; 7781 Glass     |             |                 | Batch #4 Task #17                   |             |                       | Tested By: DH              |             |
| Specimen Number | Cure           |                             | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum     |                       | Interlaminar               |             |
|                 | Pressure (in.) | g. Vac.                     |             |                 |                                     | Load (lbs.) | Shear Strength (Ksi.) | Shear Strength (MPa)       | Date Tested |
| BIL-GL-27-A     | 10             | "                           | 0.500       | 0.1360          | 1.088                               | 435         | 4.798                 | 33.08                      | 12/11/89    |
| BIL-GL-27-C     | "              | "                           | 0.750       | 0.1340          | 1.072                               | 500         | 4.478                 | 30.87                      | "           |
|                 |                |                             |             |                 |                                     |             | Average               | 31.98                      |             |
|                 |                |                             |             |                 |                                     |             | Std. Dev.             | 1.56                       |             |
| BIL-GL-28-1     | 16             | "                           | 1.003       | 0.1292          | 1.050                               | 888         | 5.139                 | 35.44                      | 10/26/89    |
| BIL-GL-28-3     | "              | "                           | 1.003       | 0.1328          | 1.050                               | 925         | 5.208                 | 35.91                      | "           |
|                 |                |                             |             |                 |                                     |             | Average               | 35.67                      |             |
|                 |                |                             |             |                 |                                     |             | Std. Dev.             | 0.34                       |             |
| BIL-GL-29-1     | 23             | "                           | 1.002       | 0.1281          | 1.030                               | 801         | 4.680                 | 32.27                      | 10/31/89    |
| BIL-GL-29-3     | "              | "                           | 1.002       | 0.1290          | 1.030                               | 832         | 4.828                 | 33.29                      | "           |
| BIL-GL-29-C     | "              | "                           | 0.500       | 0.1300          | 1.040                               | 379         | 4.373                 | 30.15                      | 12/11/89    |
|                 |                |                             |             |                 |                                     |             | Average               | 31.90                      |             |
|                 |                |                             |             |                 |                                     |             | Std. Dev.             | 1.60                       |             |
| BIL-GL-38-1     | 27             | "                           | 0.997       | 0.1212          | 0.978                               | 922         | 5.723                 | 39.46                      | 12/4/89     |
| BIL-GL-38-3     | "              | "                           | 0.997       | 0.1224          | 0.978                               | 917         | 5.636                 | 38.86                      | "           |
| BIL-GL-38-5     | "              | "                           | 0.996       | 0.1211          | 0.978                               | 1,039       | 6.461                 | 44.55                      | "           |
|                 |                |                             |             |                 |                                     |             | Average               | 40.95                      |             |
|                 |                |                             |             |                 |                                     |             | Std. Dev.             | 3.13                       |             |

(1) All cures were at 93°C (200°F) for 45 minutes.

TABLE J.2

INTERLAMINAR SHEAR STRENGTH OF GRAPHITE REINFORCED EA9396  
COMPOSITE LAMINATES CURED 45 MINUTES AT 107°C (225°F)

| Test :          |                             | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     |                                    | Specimen Orientation: Warp |             |         |
|-----------------|-----------------------------|-----------------------------|-------------|-----------------|-------------------------------------|---------------------|------------------------------------|----------------------------|-------------|---------|
| Material :      |                             | EA-9396 A/B, W133 Graphite  |             |                 | Task #16                            |                     |                                    | Tested By: TOB             |             |         |
| Specimen Number | Cure Time & Temperature (1) | Test Conditions (2)         | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | interlaminar Shear Strength (Ksi.) | Shear Strength (MPa)       | Date Tested | Remarks |
| BIL-GR-5-1      | 45 min. @ 107°C (225°F)     | 22°C (72°F) (DRY)           | 0.997       | 0.1732          | 2.800                               | 1,448               | 6.289                              | 43.36                      | 1/23/89     |         |
| BIL-GR-5-3      | "                           | "                           | 1.000       | 0.1743          | 2.800                               | 1,496               | 6.437                              | 44.38                      | "           |         |
| BIL-GR-5-5      | "                           | "                           | 0.995       | 0.1681          | 2.800                               | 1,340               | 6.007                              | 41.42                      | "           |         |
| BIL-GR-5-7      | "                           | "                           | 0.998       | 0.1739          | 2.800                               | 1,386               | 5.993                              | 41.32                      | "           |         |
| BIL-GR-5-9      | "                           | "                           | 1.000       | 0.1717          | 2.800                               | 1,348               | 5.889                              | 40.61                      | "           |         |
| Average         |                             |                             |             |                 |                                     |                     | 6.123                              | 42.22                      |             |         |
| Std. Dev.       |                             |                             |             |                 |                                     |                     | 0.230                              | 1.58                       |             |         |
| BIL-GR-5-2      | 45 min. @ 107°C (225°F)     | 22°C (72°F) (WET)           | 0.997       | 0.1741          | 2.800                               | 1,107               | 4.783                              | 32.98                      | 5/25/89     |         |
| BIL-GR-5-4      | "                           | "                           | 0.997       | 0.1704          | 2.800                               | 1,028               | 4.538                              | 31.29                      | "           |         |
| BIL-GR-5-6      | "                           | "                           | 0.996       | 0.1740          | 2.800                               | 992                 | 4.295                              | 29.62                      | "           |         |
| BIL-GR-5-8      | "                           | "                           | 1.000       | 0.1740          | 2.800                               | 1,093               | 4.713                              | 32.49                      | "           |         |
| BIL-GR-5-10     | "                           | "                           | 0.996       | 0.1681          | 2.800                               | 977                 | 4.376                              | 30.17                      | "           |         |
| Average         |                             |                             |             |                 |                                     |                     | 4.541                              | 31.31                      |             |         |
| Std. Dev.       |                             |                             |             |                 |                                     |                     | 0.210                              | 1.44                       |             |         |

(1) Pressure during cure was nominal 635 mm (25 in.) Hg vacuum.

(2) Wet = wet-aged at 60°C (140°F)/95-100% R.H. until saturated.

TABLE J.3

INTERLAMINAR SHEAR STRENGTH OF GRAPHITE REINFORCED EA9396  
COMPOSITE LAMINATES CURED 30 MINUTES AT 93°C (200°F)

| Test :          |                              | Apparent Interlaminar Shear |             |                |            | (4pt loading at 1/4 pts. L/D = 8/1) |  |                       |                                   | Specimen Orientation: Warp |         |
|-----------------|------------------------------|-----------------------------|-------------|----------------|------------|-------------------------------------|--|-----------------------|-----------------------------------|----------------------------|---------|
| Material :      |                              | EA-9396 A/B; W133 Graphite  |             |                |            | Task #16                            |  |                       |                                   | Tested By: TOB             |         |
| Specimen Number | Cure Time & Temperature (1)  | Test Conditions (2)         | Width (in.) | Thicknes (in.) | Span (in.) | Maximum Load                        |  | Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Date Tested                | Remarks |
|                 |                              |                             |             |                |            | (lbs.)                              |  |                       |                                   |                            |         |
| BIL-GR-1-5      | 30 min. @ 22°C (72°F) (DRY)  |                             | 1.000       | 0.1809         | 2.800      | 1,526                               |  | 6.325                 | 43.61                             | 1/23/89                    |         |
| BIL-GR-1-9      | 93°C (200°F)                 | "                           | 0.998       | 0.1759         | 2.800      | 1,420                               |  | 6.065                 | 41.82                             | "                          |         |
| BIL-GR-1-14     | "                            | "                           | 0.998       | 0.1807         | 2.800      | 1,508                               |  | 6.271                 | 43.24                             | "                          |         |
|                 |                              |                             |             |                |            | Average                             |  | 6.220                 | 42.89                             |                            |         |
|                 |                              |                             |             |                |            | Std. Dev.                           |  | 0.137                 | 0.94                              |                            |         |
| BIL-GR-1-1      | 30 min. @ 22°C (72°F) (WET)  |                             | 1.001       | 0.1758         | 2.816      | 1,089                               |  | 4.640                 | 32.00                             | 4/24/89                    |         |
| BIL-GR-1-7      | 93°C (200°F)                 | "                           | 1.001       | 0.1804         | 2.816      | 1,027                               |  | 4.266                 | 29.41                             | "                          |         |
| BIL-GR-1-16     | "                            | "                           | 1.000       | 0.1793         | 2.816      | 1,051                               |  | 4.396                 | 30.31                             | "                          |         |
|                 |                              |                             |             |                |            | Average                             |  | 4.434                 | 30.57                             |                            |         |
|                 |                              |                             |             |                |            | Std. Dev.                           |  | 0.190                 | 1.31                              |                            |         |
| BIL-GR-1-4      | 30 min. @ 93°C (200°F) (WET) |                             | 1.001       | 0.1802         | 2.816      | 539                                 |  | 2.241                 | 15.45                             | 4/25/89                    |         |
| BIL-GR-1-10     | 93°C (200°F)                 | "                           | 0.999       | 0.1770         | 2.816      | 533                                 |  | 2.262                 | 15.59                             | "                          |         |
| BIL-GR-1-13     | "                            | "                           | 0.999       | 0.1804         | 2.816      | 557                                 |  | 2.319                 | 15.99                             | "                          |         |
|                 |                              |                             |             |                |            | Average                             |  | 2.274                 | 15.68                             |                            |         |
|                 |                              |                             |             |                |            | Std. Dev.                           |  | 0.040                 | 0.28                              |                            |         |

(1) Pressure during cure was nominal 635 mm (25 in.) Hg vacuum.

(2) Wet = wet-aged at 60°C (140°F)/95-100% R.H. until saturated.

TABLE J.4

INTERLAMINAR SHEAR STRENGTH OF GRAPHITE REINFORCED EA3396  
COMPOSITE LAMINATES CURED 30 MINUTES AT 82°C (180°F)

| Test :           |                              | Apparent Interlaminar Shear |             | (4pt loading at 1/4 pts. L/D = 8/1) |            |                     | Specimen Orientation: Warp               |             |         |  |
|------------------|------------------------------|-----------------------------|-------------|-------------------------------------|------------|---------------------|------------------------------------------|-------------|---------|--|
| Material :       |                              | EA-9396 A/B; W133 Graphite  |             |                                     | Task #16   |                     |                                          | Tested By:  |         |  |
| Specimen Number  | Cure Time & Temperature (1)  | Test Conditions (2)         | Width (in.) | Thickness (in.)                     | Span (in.) | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) (MPa) | Date Tested | Remarks |  |
| BIL-H7-5-ILS-5   | 30 min. @ 22°C (72°F) (DRY)  | "                           | 0.500       | 0.1700                              | 2.765      | 760                 | 6.706                                    | 46.24       | 2/16/88 |  |
| BIL-H7-5-ILS-14  | 82°C (180°F)                 | "                           | 0.500       | 0.1720                              | 2.765      | 688                 | 6.000                                    | 41.37       | "       |  |
| BIL-H7-5-ILS-25  | "                            | "                           | 0.502       | 0.1680                              | 2.765      | 674                 | 5.994                                    | 41.33       | "       |  |
|                  |                              |                             |             |                                     |            | Average             | 6.233                                    | 42.98       |         |  |
|                  |                              |                             |             |                                     |            | Std. Dev.           | 0.409                                    | 2.82        |         |  |
| BIL-H7-5-ILS-8   | 30 min. @ 22°C (72°F) (WET)  | "                           | 0.499       | 0.1730                              | 2.765      | 504                 | 4.379                                    | 30.19       | 3/9/88  |  |
| BIL-H7-5-ILS-17  | 82°C (180°F)                 | "                           | 0.498       | 0.1730                              | 2.765      | 472                 | 4.109                                    | 28.33       | "       |  |
| BIL-H7-5-ILS-21  | "                            | "                           | 0.501       | 0.1720                              | 2.765      | 520                 | 4.526                                    | 31.21       | "       |  |
|                  |                              |                             |             |                                     |            | Average             | 4.338                                    | 29.91       |         |  |
|                  |                              |                             |             |                                     |            | Std. Dev.           | 0.211                                    | 1.46        |         |  |
| BIL-H7-5-ILS-3   | 30 min. @ 93°C (200°F) (WET) | "                           | 0.501       | 0.1690                              | 2.765      | 205                 | 1.816                                    | 12.52       | 3/9/88  |  |
| BIL-H7-5-ILS-9   | 82°C (180°F)                 | "                           | 0.499       | 0.1720                              | 2.765      | 233                 | 2.036                                    | 14.04       | "       |  |
| BIL-H7-5-ILS- 19 | "                            | "                           | 0.499       | 0.1720                              | 2.765      | 212                 | 1.853                                    | 12.77       | "       |  |
|                  |                              |                             |             |                                     |            | Average             | 1.901                                    | 13.11       |         |  |
|                  |                              |                             |             |                                     |            | Std. Dev.           | 0.118                                    | 0.81        |         |  |

- (1) Pressure during cure was nominal 635 mm (25 in.) Hg vacuum.  
 (2) Wet = wet-aged at 60°C (140°F)/95-100% R.H. until saturated.

TABLE J.5

INTERLAMINAR SHEAR STRENGTH OF GRAPHITE REINFORCED EA9396  
COMPOSITE LAMINATES CURED 45 MINUTES AT 79°C (175°F)

| Test :          |                             | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     |                                          | Specimen Orientation: Warp |         |  |
|-----------------|-----------------------------|-----------------------------|-------------|-----------------|-------------------------------------|---------------------|------------------------------------------|----------------------------|---------|--|
| Material :      |                             | EA-9396 A/B; W133 Graphite  |             |                 | Task #16                            |                     |                                          | Tested By: TOB             |         |  |
| Specimen Number | Cure Time & Temperature (1) | Test Conditions (2)         | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) (MPa) | Date Tested                | Remarks |  |
| BIL-GR-4(R)-1   | 45 min. @ 79°C (175°F)      | 22°C (72°F) (DRY)           | 0.996       | 0.1746          | 2.800                               | 1,270               | 5.477                                    | 37.77                      | 1/23/89 |  |
| BIL-GR-4(R)-3   | "                           | "                           | 0.995       | 0.1723          | 2.800                               | 1,354               | 5.925                                    | 40.85                      | "       |  |
| BIL-GR-4(R)-5   | "                           | "                           | 0.996       | 0.1659          | 2.800                               | 1,230               | 5.584                                    | 38.50                      | "       |  |
| BIL-GR-4(R)-7   | "                           | "                           | 0.997       | 0.1757          | 2.800                               | 1,310               | 5.606                                    | 38.66                      | "       |  |
| BIL-GR-4(R)-9   | "                           | "                           | 0.996       | 0.1732          | 2.800                               | 1,287               | 5.596                                    | 38.58                      | "       |  |
| Average         |                             |                             |             |                 |                                     |                     | 5.638                                    | 38.87                      |         |  |
| Std. Dev.       |                             |                             |             |                 |                                     |                     | 0.169                                    | 1.16                       |         |  |
| BIL-GR-4(R)-2   | 45 min. @ 79°C (175°F)      | 22°C (72°F) (WET)           | 0.998       | 0.1741          | 2.800                               | 962                 | 4.153                                    | 28.63                      | 5/25/89 |  |
| BIL-GR-4(R)-4   | "                           | "                           | 0.997       | 0.1712          | 2.800                               | 937                 | 4.119                                    | 28.40                      | "       |  |
| BIL-GR-4(R)-6   | "                           | "                           | 0.997       | 0.1763          | 2.800                               | 933                 | 3.983                                    | 27.46                      | "       |  |
| BIL-GR-4(R)-8   | "                           | "                           | 0.998       | 0.1740          | 2.800                               | 930                 | 4.019                                    | 27.71                      | "       |  |
| BIL-GR-4(R)-10  | "                           | "                           | 0.997       | 0.1675          | 2.800                               | 849                 | 3.813                                    | 26.29                      | "       |  |
| Average         |                             |                             |             |                 |                                     |                     | 4.017                                    | 27.70                      |         |  |
| Std. Dev.       |                             |                             |             |                 |                                     |                     | 0.134                                    | 0.92                       |         |  |

(1) Pressure during cure was nominal 635 mm (25 in.) Hg vacuum.

(2) Wet = wet-aged at 60°C (140°F)/95-100% R.H. until saturated.

TABLE J.6

INTERLAMINAR SHEAR STRENGTH OF GRAPHITE REINFORCED EA9396  
COMPOSITE LAMINATES CURED 7 DAYS AT 22°C (72°F)

| Test :          |                                    | Apparent Interlaminar Shear |             |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |  |                                    |       | Specimen Orientation: Warp |         |
|-----------------|------------------------------------|-----------------------------|-------------|-----------------|------------|-------------------------------------|--|------------------------------------|-------|----------------------------|---------|
| Material :      |                                    | EA-9396 A/B; W133 Graphite  |             |                 |            | Task #16                            |  |                                    |       | Tested By:                 |         |
| Specimen Number | Cure Time & Temperature (1)        | Test Conditions (2)         | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 |  | Interlaminar Shear Strength (Ksi.) |       | Date Tested                | Remarks |
|                 |                                    |                             |             |                 |            |                                     |  |                                    |       |                            |         |
| BIL-GR-20-1     | 7 days @ 22°C (72°F) (DRY)         |                             | 1.004       | 0.1814          | 2.816      | 979                                 |  | 4.031                              | 27.79 | 5/25/89                    |         |
| BIL-GR-20-4     | 22°C (72°F) plus additional 3 mos. | "                           | 1.005       | 0.1753          | 2.816      | 1,216                               |  | 5.179                              | 35.71 | "                          |         |
| BIL-GR-20-5     | dry storage or wet-aging (Note 3)  | "                           | 1.004       | 0.1728          | 2.816      | 1,227                               |  | 5.306                              | 36.59 | "                          |         |
| BIL-GR-20-8     | "                                  | "                           | 1.005       | 0.1760          | 2.816      | 1,196                               |  | 5.074                              | 34.98 | "                          |         |
| BIL-GR-20-9     | "                                  | "                           | 1.005       | 0.1771          | 2.816      | 1,117                               |  | 4.708                              | 32.46 | "                          |         |
| BIL-GR-20-12    | "                                  | "                           | 1.005       | 0.1758          | 2.816      | 1,222                               |  | 5.188                              | 35.77 | "                          |         |
| BIL-GR-20-13    | "                                  | "                           | 1.005       | 0.1735          | 2.816      | 1,282                               |  | 5.515                              | 38.03 | "                          |         |
| BIL-GR-20-16    | "                                  | "                           | 0.998       | 0.1730          | 2.816      | 1,167                               |  | 5.071                              | 34.97 | "                          |         |
|                 |                                    |                             |             |                 |            | Average                             |  | 5.009                              | 34.54 |                            |         |
|                 |                                    |                             |             |                 |            | Std. Dev.                           |  | 0.457                              | 3.15  |                            |         |
| BIL-GR-20-3     | 7 days @ 22°C (72°F) (WET)         |                             | 1.004       | 0.1747          | 2.816      | 823                                 |  | 3.519                              | 24.26 | 5/25/89                    |         |
| BIL-GR-20-7     | 22°C (72°F) plus additional 3 mos. | "                           | 1.005       | 0.1728          | 2.816      | 880                                 |  | 3.804                              | 26.23 | "                          |         |
| BIL-GR-20-11    | dry storage or wet-aging (Note 3)  | "                           | 1.005       | 0.1797          | 2.816      | 734                                 |  | 3.050                              | 21.03 | "                          |         |
| BIL-GR-20-15    | "                                  | "                           | 1.005       | 0.1741          | 2.816      | 814                                 |  | 3.491                              | 24.07 | "                          |         |
| BIL-GR-20-17    | "                                  | "                           | 1.004       | 0.1761          | 2.816      | 749                                 |  | 3.176                              | 21.90 | "                          |         |
|                 |                                    |                             |             |                 |            | Average                             |  | 3.408                              | 23.50 |                            |         |
|                 |                                    |                             |             |                 |            | Std. Dev.                           |  | 0.299                              | 2.06  |                            |         |

(1) Pressure during cure was nominal 635 mm (25 in.) Hg vacuum.

(2) Wet = wet-aged at 60°C (140°F)/95-100% R.H. until saturated.

(3) Vacuum pressure was applied only during first four hours of cure.



**APPENDIX K**  
**INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR STRENGTH,**  
**EFFECT OF EXPOSURE TO 177°C (350°F)**

The two tables in this appendix present the detailed interlaminar shear strength data for specimens exposed to 177°C (350°F). A summary of these data was presented and discussed in Section 3.12.1.

TABLE K.1

EFFECT OF ELEVATED TEMPERATURE EXPOSURE ON INTERLAMINAR SHEAR STRENGTH OF  
GLASS REINFORCED EA9396 COMPOSITE LAMINATES

| Test :          | Apparent Interlaminar Shear  |                     |             |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     |                                    |                                   | Specimen Orientation:     |             | Warp    |
|-----------------|------------------------------|---------------------|-------------|-----------------|-------------------------------------|---------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|
| Material :      | EA-9396 A/B; 7781 Glass      |                     |             |                 | Batch #1                            | Task #8             | Tested By:                         |                                   | TOB & DH                  |             |         |
| Specimen Number | Exposure Condition           | Test Conditions (3) | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |
| BIL-GL-13(R)-6  | 2 hrs. @ 22°C (72°F) (DRY)   | "                   | 1.002       | 0.1334          | 1.063                               | 986                 | 5.528                              | 38.12                             | NA                        | 4/19/89     | (1)     |
| BIL-GL-13(R)-16 | 177°C (350°F)                | "                   | 0.999       | 0.1322          | 1.063                               | 951                 | 5.397                              | 37.21                             | NA                        | "           | (1)     |
| BIL-GL-13(R)-38 | "                            | "                   | 1.000       | 0.1352          | 1.063                               | 1,084               | 6.016                              | 41.48                             | NA                        | "           | (1)     |
|                 |                              |                     |             |                 |                                     | Average             | 5.647                              | 38.94                             |                           |             |         |
|                 |                              |                     |             |                 |                                     | Std. Dev.           | 0.326                              | 2.25                              |                           |             |         |
| BIL-GL-13(R)-8  | 2 hrs. @ 93°C (200°F) (WET)  | "                   | 1.001       | 0.1352          | 1.080                               | 326                 | 1.807                              | 12.46                             | 1.98                      | 10/30/89    | (1)     |
| BIL-GL-13(R)-18 | 177°C (350°F)                | "                   | 1.005       | 0.1329          | 1.080                               | 350                 | 1.965                              | 13.55                             | 2.04                      | "           | (1)     |
| BIL-GL-13(R)-40 | "                            | "                   | 1.002       | 0.1365          | 1.080                               | 370                 | 2.029                              | 13.99                             | 2.10                      | "           | (1)     |
|                 |                              |                     |             |                 |                                     | Average             | 1.934                              | 13.33                             | 2.04                      |             |         |
|                 |                              |                     |             |                 |                                     | Std. Dev.           | 0.114                              | 0.79                              | 0.06                      |             |         |
| BIL-GL-13(R)-7  | 16 hrs. @ 22°C (72°F) (DRY)  | "                   | 1.001       | 0.1329          | 1.063                               | 1,038               | 5.850                              | 40.34                             | NA                        | 4/19/89     | (2)     |
| BIL-GL-13(R)-17 | 177°C (350°F)                | "                   | 1.002       | 0.1349          | 1.063                               | 1,079               | 5.985                              | 41.27                             | NA                        | "           | (2)     |
| BIL-GL-13(R)-39 | (Note 4)                     | "                   | 1.000       | 0.1373          | 1.063                               | 1,135               | 6.201                              | 42.76                             | NA                        | "           | (2)     |
|                 |                              |                     |             |                 |                                     | Average             | 6.012                              | 41.45                             |                           |             |         |
|                 |                              |                     |             |                 |                                     | Std. Dev.           | 0.177                              | 1.22                              |                           |             |         |
| BIL-GL-13(R)-9  | 16 hrs. @ 93°C (200°F) (WET) | "                   | 1.000       | 0.1316          | 1.080                               | 314                 | 1.790                              | 12.34                             | 2.20                      | 10/30/89    | (2)     |
| BIL-GL-13(R)-19 | 177°C (350°F)                | "                   | 1.001       | 0.1326          | 1.080                               | 336                 | 1.899                              | 13.09                             | 2.27                      | "           | (2)     |
| BIL-GL-13(R)-41 | (Note 4)                     | "                   | 1.001       | 0.1369          | 1.080                               | 381                 | 2.085                              | 14.38                             | 2.29                      | "           | (2)     |
|                 |                              |                     |             |                 |                                     | Average             | 1.924                              | 13.27                             | 2.25                      |             |         |
|                 |                              |                     |             |                 |                                     | Std. Dev.           | 0.150                              | 1.03                              | 0.05                      |             |         |

(1) Specimens turned slightly brown as result of exposure.

(2) Specimens turned dark brown as result of exposure.

(3) Wet = wet-aging at 60°C (140°F)/95-100% R. H. until saturated.

(4) Three segments of 6+6+4 hours.

TABLE K.2

## EFFECT OF ELEVATED TEMPERATURE EXPOSURE ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE REINFORCED EA9396 COMPOSITE LAMINATES

| Test :          |  | Apparent Interlaminar Shear  |  | (4pt loading at 1/4 pts. L/D = 16/1) |  | Specimen Orientation: |  | Warp            |  |            |  |                     |  |                                          |  |                           |  |             |  |         |  |
|-----------------|--|------------------------------|--|--------------------------------------|--|-----------------------|--|-----------------|--|------------|--|---------------------|--|------------------------------------------|--|---------------------------|--|-------------|--|---------|--|
| Material :      |  | EA-9396 A/B; W133 Graphite   |  | Batch #1                             |  | Task #8               |  | Tested By:      |  |            |  |                     |  |                                          |  |                           |  |             |  |         |  |
| Specimen Number |  | Exposure Condition           |  | Test Conditions (1)                  |  | Width (in.)           |  | Thickness (in.) |  | Span (in.) |  | Maximum Load (lbs.) |  | Interlaminar Shear Strength (Ksi.) (MPa) |  | Wt. Gain During Aging (%) |  | Date Tested |  | Remarks |  |
| BIL-GR-17-6     |  | 2 hrs. @ 22°C (72°F) (DRY)   |  | "                                    |  | 1.000                 |  | 0.1819          |  | 2.816      |  | 1,220               |  | 5.028                                    |  | 34.67                     |  | NA          |  | 4/19/89 |  |
| BIL-GR-17-16    |  | 177°C (350°F)                |  | "                                    |  | 1.003                 |  | 0.1752          |  | 2.816      |  | 1,119               |  | 4.776                                    |  | 32.93                     |  | NA          |  | "       |  |
| BIL-GR-17-38    |  | "                            |  | "                                    |  | 1.000                 |  | 0.1726          |  | 2.816      |  | 1,197               |  | 5.201                                    |  | 35.86                     |  | NA          |  | "       |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Average             |  | 5.002                                    |  | 34.49                     |  |             |  |         |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Std. Dev.           |  | 0.214                                    |  | 1.47                      |  |             |  |         |  |
| BIL-GR-17-8     |  | 2 hrs. @ 93°C (200°F) (WET)  |  | "                                    |  | 1.001                 |  | 0.1825          |  | 2.846      |  | 510                 |  | 2.094                                    |  | 14.44                     |  | 2.42        |  | 12/7/89 |  |
| BIL-GR-17-18    |  | 177°C (350°F)                |  | "                                    |  | 1.002                 |  | 0.1829          |  | 2.846      |  | 453                 |  | 1.854                                    |  | 12.78                     |  | 2.49        |  | "       |  |
| BIL-GR-17-40    |  | "                            |  | "                                    |  | 1.002                 |  | 0.1742          |  | 2.846      |  | 471                 |  | 2.024                                    |  | 13.95                     |  | 2.15        |  | "       |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Average             |  | 1.990                                    |  | 13.72                     |  | 2.35        |  |         |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Std. Dev.           |  | 0.123                                    |  | 0.85                      |  | 0.18        |  |         |  |
| BIL-GR-17-7     |  | 16 hrs. @ 22°C (72°F) (DRY)  |  | "                                    |  | 1.003                 |  | 0.1802          |  | 2.816      |  | 1,244               |  | 5.163                                    |  | 35.60                     |  | NA          |  | 4/19/89 |  |
| BIL-GR-17-17    |  | 177°C (350°F)                |  | "                                    |  | 1.000                 |  | 0.1829          |  | 2.816      |  | 1,343               |  | 5.507                                    |  | 37.97                     |  | NA          |  | "       |  |
| BIL-GR-17-39    |  | (Note 2)                     |  | "                                    |  | 0.999                 |  | 0.1731          |  | 2.816      |  | 1,177               |  | 5.107                                    |  | 35.21                     |  | NA          |  | "       |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Average             |  | 5.259                                    |  | 36.26                     |  |             |  |         |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Std. Dev.           |  | 0.216                                    |  | 1.49                      |  |             |  |         |  |
| BIL-GR-17-9     |  | 16 hrs. @ 93°C (200°F) (WET) |  | "                                    |  | 1.000                 |  | 0.1770          |  | 2.846      |  | 438                 |  | 1.856                                    |  | 12.80                     |  | 2.31        |  | 12/7/89 |  |
| BIL-GR-17-19    |  | 177°C (350°F)                |  | "                                    |  | 1.002                 |  | 0.1851          |  | 2.846      |  | 454                 |  | 1.836                                    |  | 12.66                     |  | 2.49        |  | "       |  |
| BIL-GR-17-41    |  | (Note 2)                     |  | "                                    |  | 1.002                 |  | 0.1762          |  | 2.846      |  | 484                 |  | 2.056                                    |  | 14.18                     |  | 2.24        |  | "       |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Average             |  | 1.916                                    |  | 13.21                     |  | 2.35        |  |         |  |
|                 |  |                              |  |                                      |  |                       |  |                 |  |            |  | Std. Dev.           |  | 0.122                                    |  | 0.84                      |  | 0.13        |  |         |  |

(1) Wet = wet-aging at 60°C (140°F)/95-100% R.H. until saturated.

(2) Three segments of 6+6+4 hours.

**APPENDIX L**  
**INDIVIDUAL SPECIMEN INTERLAMINAR SHEAR STRENGTH,**  
**EFFECT OF RESIN/FIBER CONTENT**

The 12 tables in this appendix present the detailed interlaminar shear strength data for specimens prepared with nonstandard fiber contents. All of the laminates from which these specimens were machined were cured in accordance with the baseline cure schedule. The reduced fiber contents were achieved by varying the resin/reinforcement ratios during impregnation and the bleeder ratio during bagging. The laminate preparation details were described in Appendix B.3. A summary of these data was presented and discussed in Section 3.8.

TABLE L.1  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GLASS REINFORCED  
EA 9396 COMPOSITE LAMINATES

| Test :          |                   | Apparent Interlaminar Shear |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |                             |       | Specimen Orientation:     |             | Warp    |  |
|-----------------|-------------------|-----------------------------|-----------------|------------|-------------------------------------|-----------------------------|-------|---------------------------|-------------|---------|--|
| Material :      |                   | EA-9396 A/B; 7781 Glass     |                 |            | Batch #4 Task #12                   |                             |       | Tested By:                |             | DH & PM |  |
| Specimen Number | Test Conditions   | Width (in.)                 | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 | Interlaminar Shear Strength |       | Wt. Gain During Aging (%) | Date Tested | Remarks |  |
|                 |                   |                             |                 |            |                                     | (Ksi.)                      | (MPa) |                           |             |         |  |
| BIL-GL-31-1     | 22°C (72°F) (DRY) | 1.002                       | 0.1387          | 1.100      | 981                                 | 5.295                       | 36.51 | NA                        | 10/30/89    | (1)     |  |
| BIL-GL-31-3     | "                 | 1.002                       | 0.1327          | 1.100      | 943                                 | 5.320                       | 36.68 | NA                        | "           | (1)     |  |
| BIL-GL-31-5     | "                 | 1.000                       | 0.1398          | 1.100      | 979                                 | 5.250                       | 36.20 | NA                        | "           | (1)     |  |
|                 |                   |                             |                 |            |                                     | Average                     | 5.288 | 36.46                     |             |         |  |
|                 |                   |                             |                 |            |                                     | Std. Dev.                   | 0.035 | 0.24                      |             |         |  |
| BIL-GL-31-2     | 22°C (72°F) (WET) | 1.002                       | 0.1339          | 1.069      | 532                                 | 2.974                       | 20.50 | 1.88                      | 10/30/89    | (1,2)   |  |
| BIL-GL-31-4     | "                 | 1.002                       | 0.1324          | 1.069      | 575                                 | 3.251                       | 22.41 | 1.87                      | "           | (1,2)   |  |
|                 |                   |                             |                 |            |                                     | Average                     | 3.112 | 21.46                     | 1.87        |         |  |
|                 |                   |                             |                 |            |                                     | Std. Dev.                   | 0.196 | 1.35                      | 0.00        |         |  |

Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 55.4

Resin Content (wt. %) = 26.2

Void content (vol. %) = 5.0

Specific Gravity = 1.94

(2) Specimens aged @ 140°F/95-100% R.H. for 79 days.

TABLE L.2

EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GLASS  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          |                   | Apparent Interlaminar Shear |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |                             |       | Specimen Orientation: |             | Warp    |
|-----------------|-------------------|-----------------------------|-----------------|------------|-------------------------------------|-----------------------------|-------|-----------------------|-------------|---------|
| Material :      |                   | EA-9396 A/B; 7781 Glass     |                 |            | Batch #4 Task #12                   |                             |       | Tested By:            |             | DH & PM |
| Specimen Number | Test Conditions   | Width (in.)                 | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 | Interlaminar Shear Strength |       | Wt. Gain              |             | Remarks |
|                 |                   |                             |                 |            |                                     | (Ksi.)                      | (MPa) | During Aging (%)      | Date Tested |         |
| BIL-GL-30-1     | 22°C (72°F) (DRY) | 1.003                       | 0.1397          | 1.080      | 1,018                               | 5.449                       | 37.57 | NA                    | 10/30/89    | (1)     |
| BIL-GL-30-3     | "                 | 1.002                       | 0.1312          | 1.080      | 973                                 | 5.551                       | 38.27 | NA                    | "           | (1)     |
| BIL-GL-30-5     | "                 | 1.003                       | 0.1392          | 1.080      | 1,044                               | 5.608                       | 38.67 | NA                    | "           | (1)     |
|                 |                   |                             |                 |            |                                     | Average                     | 5.536 | 38.17                 |             |         |
|                 |                   |                             |                 |            |                                     | Std. Dev.                   | 0.081 | 0.56                  |             |         |
| BIL-GL-30-2     | 22°C (72°F) (WET) | 1.002                       | 0.1337          | 1.069      | 570                                 | 3.191                       | 22.00 | 1.88                  | 1/22/90     | (1,2)   |
| BIL-GL-30-4     | "                 | 1.003                       | 0.1345          | 1.069      | 570                                 | 3.169                       | 21.85 | 1.85                  | "           | (1,2)   |
|                 |                   |                             |                 |            |                                     | Average                     | 3.180 | 21.93                 | 1.86        |         |
|                 |                   |                             |                 |            |                                     | Std. Dev.                   | 0.016 | 0.11                  | 0.02        |         |

## Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 54.3

Resin Content (wt. %) = 26.7

Void content (vol. %) = 6.1

Specific Gravity = 1.89

(2) Specimens aged @ 140°F/95-100% R.H. for 79 days.

TABLE L.3

EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GLASS  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          |                   | Apparent Interlaminar Shear |                 | (4pt loading at 1/4 pts. L/D = 8/1) |                     | Specimen Orientation:       |       | Warp                      |             |         |
|-----------------|-------------------|-----------------------------|-----------------|-------------------------------------|---------------------|-----------------------------|-------|---------------------------|-------------|---------|
| Material :      |                   | EA-9396 A/B; 7781 Glass     |                 | Batch #4 Task #12                   |                     | Tested By:                  |       | DH & PM                   |             |         |
| Specimen Number | Test Conditions   | Width (in.)                 | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Interlaminar Shear Strength |       | Wt. Gain During Aging (%) | Date Tested | Remarks |
|                 |                   |                             |                 |                                     |                     | (Ksi.)                      | (MPa) |                           |             |         |
| BIL-GL-33-1     | 22°C (72°F) (DRY) | 1.001                       | 0.1756          | 1.462                               | 1,126               | 4.804                       | 33.13 | NA                        | 10/30/89    | (1)     |
| BIL-GL-33-3     | "                 | 1.001                       | 0.1378          | 1.100                               | 1,042               | 5.666                       | 39.06 | NA                        | "           | (1)     |
| BIL-GL-33-5     | "                 | 1.001                       | 0.1382          | 1.100                               | 1,108               | 6.007                       | 41.42 | NA                        | "           | (1)     |
|                 |                   |                             |                 |                                     |                     | Average                     | 5.492 | 37.87                     |             |         |
|                 |                   |                             |                 |                                     |                     | Std. Dev.                   | 0.620 | 4.27                      |             |         |
| BIL-GL-33-2     | 22°C (72°F) (WET) | 1.001                       | 0.1456          | 1.206                               | 476                 | 2.449                       | 16.89 | 2.17                      | 1/22/90     | (1,2)   |
| BIL-GL-33-4     | "                 | 1.000                       | 0.1413          | 1.206                               | 659                 | 3.498                       | 24.12 | 2.09                      | "           | (1,2)   |
|                 |                   |                             |                 |                                     |                     | Average                     | 2.974 | 20.50                     | 2.13        |         |
|                 |                   |                             |                 |                                     |                     | Std. Dev.                   | 0.741 | 5.11                      | 0.06        |         |

## Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 52.3

Resin Content (wt. %) = 28.4

Void content (vol. %) = 6.4

Specific Gravity = 1.86

(2) Specimens aged @ 140°F/95-100% R.H. for 79 days.

TABLE L.4

EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GLASS  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :             |                    | Apparent interlaminar shear |                    | (4pt loading at 1/4 pts. L/D = 8/1) |                           | Specimen Orientation: Warp                     |                           |
|--------------------|--------------------|-----------------------------|--------------------|-------------------------------------|---------------------------|------------------------------------------------|---------------------------|
| Material :         |                    | EA-9396 A/B; 7781 Glass     |                    | Batch #4 Task #12                   |                           | Tested By: PM                                  |                           |
| Specimen<br>Number | Test<br>Conditions | Width<br>(in.)              | Thickness<br>(in.) | Span<br>(in.)                       | Maximum<br>Load<br>(lbs.) | Interlaminar<br>Shear Strength<br>(Ksi.) (MPa) | Date<br>Tested<br>Remarks |
| BIL-GL-10-21       | 22°C (72°F) (DRY)  | 1.000                       | 0.1605             | 1.286                               | 1,206                     | 5.636 38.86                                    | 5/26/89 (1)               |
| BIL-GL-10-22       | "                  | 0.998                       | 0.1616             | 1.286                               | 1,174                     | 5.460 37.64                                    | " (1)                     |
| BIL-GL-10-23       | "                  | 0.997                       | 0.1622             | 1.286                               | 1,155                     | 5.357 36.93                                    | " (1)                     |
| BIL-GL-10-24       | "                  | 0.997                       | 0.1587             | 1.286                               | 1,167                     | 5.532 38.14                                    | " (1)                     |
| Average            |                    |                             |                    |                                     |                           | 5.496 37.89                                    |                           |
| Std. Dev.          |                    |                             |                    |                                     |                           | 0.118 0.81                                     |                           |

## Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 45.6

Resin Content (wt. %) = 35.2

Void Content (vol. %) = 4.7

Specific Gravity = 1.79



TABLE L.5

EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GLASS  
REINFORCED EA 9396 COMPOSITE LAMINATES

|                 |                             |             |                 |            |                                     |                                          |                       |         |      |
|-----------------|-----------------------------|-------------|-----------------|------------|-------------------------------------|------------------------------------------|-----------------------|---------|------|
| Test :          | Apparent Interlaminar Shear |             |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |                                          | Specimen Orientation: |         | Fill |
| Material :      | EA-9396 A/B; 7781 Glass     |             |                 |            | Batch #5 Task #12                   |                                          | Tested By:            |         | DRB  |
| Specimen Number | Test Conditions             | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 | Interlaminar Shear Strength (Ksi.) (MPa) | Date Tested           | Remarks |      |
| BIL-GL-54-2     | 22°C (72°F) (DRY)           | 0.998       | 0.1788          | 1.600      | 1,098                               | 4.617 31.83                              | 10/7/91               | (1)     |      |
| BIL-GL-54-6     | "                           | 0.999       | 0.1997          | 1.600      | 1,253                               | 4.709 32.47                              | "                     | (1)     |      |
| BIL-GL-54-8     | "                           | 0.999       | 0.2064          | 1.600      | 1,407                               | 5.116 35.28                              | "                     | (1)     |      |
| Average         |                             |             |                 |            |                                     | 4.814                                    | 33.19                 |         |      |
| Std. Dev.       |                             |             |                 |            |                                     | 0.266                                    | 1.83                  |         |      |

## Remarks:

## (1) Physical Properties:

Fiber Content (vol. %) = 35.8

Resin Content (wt. %) = 43.6

Void content (vol. %) = 8.8

Specific Gravity = 1.62

TABLE L.6  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GLASS  
REINFORCED EA 9396 COMPOSITE LAMINATES

|                 |                             |             |                                     |            |                       |                                          |             |         |
|-----------------|-----------------------------|-------------|-------------------------------------|------------|-----------------------|------------------------------------------|-------------|---------|
| Test :          | Apparent Interlaminar Shear |             | (4pt loading at 1/4 pts. L/D = 8/1) |            | Specimen Orientation: |                                          | Fill        |         |
| Material :      | EA-9396 A/B; 7781 Glass     |             | Batch #5 Task #12                   |            | Tested By:            |                                          | DRB         |         |
| Specimen Number | Test Conditions             | Width (in.) | Thickness (in.)                     | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength (Ksi.) (MPa) | Date Tested | Remarks |
| BIL-GL-53-6     | 22°C (72°F) (DRY)           | 0.999       | 0.2218                              | 1.600      | 1,521                 | 5.150 35.51                              | 10/7/91     | (1)     |
| BIL-GL-53-8     | "                           | 0.998       | 0.2252                              | 1.600      | 1,473                 | 4.915 33.89                              | "           | (1)     |
| Average         |                             |             |                                     |            |                       | 5.033 34.70                              |             |         |
| Std. Dev.       |                             |             |                                     |            |                       | 0.166 1.15                               |             |         |

Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 33.9

Resin Content (wt. %) = 45.6

Void content (vol. %) = 9.3

Specific Gravity = 1.59

TABLE L.7

EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          | Apparent Interlaminar Shear | {4pt loading at 1/4 pts. L/D = 16/1} |                 |            |                     | Specimen Orientation:                    |                           | Warp                |
|-----------------|-----------------------------|--------------------------------------|-----------------|------------|---------------------|------------------------------------------|---------------------------|---------------------|
| Material :      | EA-9396 A/B: W133 Graphite  | Batch #4                             | Task #12        | Tested By: |                     | DH & PM                                  |                           |                     |
| Specimen Number | Test Conditions             | Width (in.)                          | Thickness (in.) | Span (in.) | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) (MPa) | Wt. Gain During Aging (%) | Date Tested Remarks |
| BIL-GR-51-1     | 22°C (72°F) (DRY)           | 1.002                                | 0.1721          | 2.789      | 1,348               | 5.863                                    | 40.42                     | 11/1/89 (1)         |
| BIL-GR-51-3     | "                           | 1.002                                | 0.1746          | 2.789      | 1,401               | 6.006                                    | 41.41                     | " (1)               |
| BIL-GR-51-5     | "                           | 1.001                                | 0.1733          | 2.789      | 1,325               | 5.729                                    | 39.50                     | " (1)               |
|                 |                             |                                      |                 |            | Average             | 5.866                                    | 40.44                     |                     |
|                 |                             |                                      |                 |            | Std. Dev.           | 0.139                                    | 0.96                      |                     |
| BIL-GR-51-2     | 22°C (72°F) (WET)           | 1.001                                | 0.1742          | 2.832      | 990                 | 4.258                                    | 29.36                     | 2/23/90 (1,2)       |
| BIL-GR-51-4     | "                           | 1.002                                | 0.1753          | 2.832      | 1,009               | 4.308                                    | 29.71                     | " (1,2)             |
|                 |                             |                                      |                 |            | Average             | 4.283                                    | 29.53                     | 2.30                |
|                 |                             |                                      |                 |            | Std. Dev.           | 0.035                                    | 0.24                      | 0.02                |

## Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 55.8

Resin Content (wt. %) = 32.5

Void content (vol. %) = 6.5

Specific Gravity = 1.47

(2) Specimens aged @ 140°F/95-100% R.H. for 112 days.

TABLE L.8  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |                 |            |             | Specimen Orientation: |           | Warp        |         |                      |
|-----------------|-----------------------------|--------------------------------------|-----------------|------------|-------------|-----------------------|-----------|-------------|---------|----------------------|
| Material :      | EA-9396 A/B; W133 Graphite  | Batch #4                             | Task #12        | Tested By: |             | DH & PM               |           |             |         |                      |
| Specimen Number | Test Conditions             | Width (in.)                          | Thickness (in.) | Span (in.) | Maximum     | Interlaminar          | Aging (%) | Date Tested | Remarks |                      |
|                 |                             |                                      |                 |            | Load (lbs.) | Shear Strength (Ksi.) |           |             |         | Shear Strength (MPa) |
| BIL-GR-52-1     | 22°C (72°F) (DRY)           | 1.001                                | 0.1714          | 2.789      | 1,231       | 5.381                 | 37.10     | NA          | 11/1/89 | (1)                  |
| BIL-GR-52-3     | "                           | 1.002                                | 0.1791          | 2.789      | 1,492       | 6.235                 | 42.99     | NA          | "       | (1)                  |
| BIL-GR-52-5     | "                           | 1.002                                | 0.1757          | 2.789      | 1,397       | 5.951                 | 41.03     | NA          | "       | (1)                  |
|                 |                             |                                      |                 |            | Average     | 5.856                 | 40.38     |             |         |                      |
|                 |                             |                                      |                 |            | Std. Dev.   | 0.435                 | 3.00      |             |         |                      |
| BIL-GR-52-2     | 22°C (72°F) (WET)           | 1.002                                | 0.1778          | 2.832      | 1,099       | 4.627                 | 31.90     | 2.29        | 2/23/90 | (1,2)                |
| BIL-GR-52-4     | "                           | 1.002                                | 0.1773          | 2.832      | 1,149       | 4.851                 | 33.45     | 2.29        | "       | (1,2)                |
|                 |                             |                                      |                 |            | Average     | 4.739                 | 32.67     | 2.29        |         |                      |
|                 |                             |                                      |                 |            | Std. Dev.   | 0.158                 | 1.09      | 0.00        |         |                      |

Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 54.7

Resin Content (wt. %) = 33.6

Void content (vol. %) = 6.4

Specific Gravity = 1.47

(2) Specimens aged @ 140°F/95-100% R.H. for 112 days.

TABLE L.9  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |                 |            | Specimen Orientation: |                             |         | Warp             |             |         |
|-----------------|-----------------------------|--------------------------------------|-----------------|------------|-----------------------|-----------------------------|---------|------------------|-------------|---------|
| Material :      | EA-9396 A/B; W133 Graphite  | Batch #4                             | Task #12        | Tested By: |                       |                             | DH & PM |                  |             |         |
| Specimen Number | Test Conditions             | Width (in.)                          | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength |         | During Aging (%) | Date Tested | Remarks |
|                 |                             |                                      |                 |            |                       | (Ksi.)                      | (MPa)   |                  |             |         |
| BIL-GR-53-1     | 22°C (72°F) (DRY)           | 1.001                                | 0.1826          | 3.017      | 1,509                 | 6.192                       | 42.69   | NA               | 11/1/89     | (1)     |
| BIL-GR-53-3     | "                           | 1.001                                | 0.1957          | 3.017      | 1,615                 | 6.183                       | 42.63   | NA               | "           | (1)     |
| BIL-GR-53-5     | "                           | 1.001                                | 0.1865          | 3.017      | 1,640                 | 6.589                       | 45.43   | NA               | "           | (1)     |
|                 |                             |                                      |                 |            |                       | Average                     | 6.321   | 43.58            |             |         |
|                 |                             |                                      |                 |            |                       | Std. Dev.                   | 0.232   | 1.60             |             |         |
| BIL-GR-53-2     | 22°C (72°F) (WET)           | 1.000                                | 0.1866          | 3.033      | 1,185                 | 4.763                       | 32.84   | 2.58             | 2/23/90     | (1,2)   |
| BIL-GR-53-4     | "                           | 1.002                                | 0.1895          | 3.033      | 1,305                 | 5.155                       | 35.54   | 2.62             | "           | (1,2)   |
|                 |                             |                                      |                 |            |                       | Average                     | 4.959   | 34.19            | 2.60        |         |
|                 |                             |                                      |                 |            |                       | Std. Dev.                   | 0.277   | 1.91             | 0.03        |         |

Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 50.1

Resin Content (wt. %) = 39.0

Void content (vol. %) = 4.9

Specific Gravity = 1.46

(2) Specimens aged @ 140°F/95-100% R.H. for 112 days.

TABLE L.10  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |                 |            | Specimen Orientation: |                       | Warp        |         |                      |                           |
|-----------------|-----------------------------|--------------------------------------|-----------------|------------|-----------------------|-----------------------|-------------|---------|----------------------|---------------------------|
| Material :      | EA-9396 A/B; W133 Graphite  | Batch #4                             | Task #12        | Tested By: |                       | DH & PM               |             |         |                      |                           |
| Specimen Number | Test Conditions             | Width (in.)                          | Thickness (in.) | Span (in.) | Maximum               | Interlaminar          | Date Tested | Remarks |                      |                           |
|                 |                             |                                      |                 |            | Load (lbs.)           | Shear Strength (Ksi.) |             |         | Shear Strength (MPa) | Wt. Gain During Aging (%) |
| BiL-GR-54-1     | 22°C (72°F) (DRY)           | 0.999                                | 0.1853          | 3.017      | 1,561                 | 6.324                 | 43.61       | NA      | 11/1/89              | (1)                       |
| BiL-GR-54-3     | "                           | 1.000                                | 0.1931          | 3.017      | 1,684                 | 6.541                 | 45.10       | NA      | "                    | (1)                       |
| BiL-GR-54-5     | "                           | 1.000                                | 0.1883          | 3.017      | 1,549                 | 6.170                 | 42.54       | NA      | "                    | (1)                       |
|                 |                             |                                      |                 |            | Average               | 6.345                 | 43.75       |         |                      |                           |
|                 |                             |                                      |                 |            | Std. Dev.             | 0.186                 | 1.28        |         |                      |                           |
| BiL-GR-54-2     | 22°C (72°F) (WET)           | 1.001                                | 0.1901          | 3.033      | 1,300                 | 5.124                 | 35.33       | 2.73    | 2/23/90              | (1,2)                     |
| BiL-GR-54-4     | "                           | 1.001                                | 0.1921          | 3.033      | 1,311                 | 5.113                 | 35.26       | 2.72    | "                    | (1,2)                     |
|                 |                             |                                      |                 |            | Average               | 5.119                 | 35.29       | 2.72    |                      |                           |
|                 |                             |                                      |                 |            | Std. Dev.             | 0.007                 | 0.05        | 0.00    |                      |                           |

Remarks:

(1) Physical Properties:

Fiber Content (vol. %) = 49.8

Resin Content (wt. %) = 39.0

Void content (vol. %) = 4.7

Specific Gravity = 1.47

(2) Specimens aged @ 140°F/95-100% R.H. for 112 days.

TABLE L.11  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA 9396 COMPOSITE LAMINATES

| Test :          |                   | Apparent Interlaminar Shear |                 | (4pt loading at 1/4 pts. L/D = 12/1) |                     | Specimen Orientation:                    |                     |
|-----------------|-------------------|-----------------------------|-----------------|--------------------------------------|---------------------|------------------------------------------|---------------------|
| Material :      |                   | EA-9396 A/B; W133 Graphite  |                 | Batch #5 Task #12                    |                     | Tested By:                               |                     |
| Specimen Number | Test Conditions   | Width (in.)                 | Thickness (in.) | Span (in.)                           | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) (MPa) | Date Tested Remarks |
| BIL-GR-84-2     | 22°C (72°F) (DRY) | 1.004                       | 0.2329          | 2.920                                | 1,446               | 4.638 31.98                              | 10/7/91 (1)         |
| BIL-GR-84-6     | "                 | 1.003                       | 0.2402          | 2.920                                | 1,450               | 4.513 31.12                              | " (1)               |
| BIL-GR-84-8     | "                 | 1.003                       | 0.2394          | 2.920                                | 1,442               | 4.503 31.05                              | " (1)               |
| Average         |                   |                             |                 |                                      |                     | 4.552 31.38                              |                     |
| Std. Dev.       |                   |                             |                 |                                      |                     | 0.075 0.52                               |                     |

Remarks:

(\*) Physical Properties:

Fiber Content (vol. %) = 42.3

Resin Content (wt. %) = 45.6

Void content (vol. %) = 7.5

Specific Gravity = 1.39

TABLE L.12  
EFFECT OF FIBER CONTENT ON INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA 9396 COMPOSITE LAMINATES

|                 |                             |             |                 |                                      |                     |                                    |                                   |             |         |
|-----------------|-----------------------------|-------------|-----------------|--------------------------------------|---------------------|------------------------------------|-----------------------------------|-------------|---------|
| Test :          | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 12/1) |                     | Specimen Orientation:              |                                   | Fill        |         |
| Material :      | EA-9396 A/B; W133 Graphite  |             |                 | Batch #5 Task #12                    |                     | Tested By:                         |                                   | DRB         |         |
| Specimen Number | Test Conditions             | Width (in.) | Thickness (in.) | Span (in.)                           | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Date Tested | Remarks |
| BIL-GR-79-2     | 22°C (72°F) (DRY)           | 1.001       | 0.2433          | 2.920                                | 1,690               | 5.206                              | 35.90                             | 10/7/91     | (1)     |
| BIL-GR-79-6     | "                           | 0.999       | 0.2572          | 2.920                                | 1,668               | 4.868                              | 33.57                             | "           | (1)     |
| BIL-GR-79-8     | "                           | 1.002       | 0.2582          | 2.920                                | 1,555               | 4.509                              | 31.09                             | "           | (1)     |
| Average         |                             |             |                 |                                      |                     | 4.861                              | 33.52                             |             |         |
| Std. Dev.       |                             |             |                 |                                      |                     | 0.349                              | 2.40                              |             |         |

Remarks:

- (1) Physical Properties:  
 Fiber Content (vol. %) = 40.5  
 Resin Content (wt. %) = 48.8  
 Void content (vol. %) = 5.5  
 Specific Gravity = 1.41



# EFFECT OF FIBER CONTENT ON COMPRESSION STRENGTH OF GLASS REINFORCED EA 9396 COMPOSITE LAMINATES

Remarks:

(1) Specimen failed within the 1/2 inch gage section.

(a) Shear crimping

(b) Shear fracture

(2) Specimen failed outside gage section.

(3) Test speed = 0.05 in/min.

**(4) Physical Properties:**

Fiber Content (vol. %) = 33.9

Resin Content (wt. %) = 45.6

**Void Content (vol. %) = 9.3**

Specific Gravity = 1.59

| SI Conversion                                |                                        |                                             |  |
|----------------------------------------------|----------------------------------------|---------------------------------------------|--|
| Ultimate<br>Compressive<br>Strength<br>(MPa) | Initial<br>Tangent<br>Modulus<br>(GPa) | Ultimate<br>Strain<br>( $\mu\text{cm/cm}$ ) |  |
| 193.4                                        | 16.72                                  | 12,312                                      |  |
| 240.6                                        | 16.73                                  | 13,879                                      |  |
| 237.2                                        | 16.20                                  | 15,535                                      |  |
| 274.4                                        | 19.02                                  | 14,927                                      |  |
| 250.3                                        | 16.37                                  | 14,209                                      |  |
| 232.1                                        | 17.19                                  | 13,535                                      |  |
| 238.0                                        | 17.04                                  | 14,066                                      |  |
| 26.5                                         | 1.03                                   | 1,124                                       |  |
| Average                                      |                                        |                                             |  |
| Std. Dev.                                    |                                        |                                             |  |

TABLE L. 14

EFFECT OF FIBER CONTENT ON COMPRESSION STRENGTH OF GLASS REINFORCED  
EA 9396 COMPOSITE LAMINATES

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation: |                                |                                | Fill            |             |          |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|--------------------|--------------------------------|--------------------------------|-----------------|-------------|----------|
| Material :      |                 | EA-9396 A/B; 7781 Glass       |                 |                     |                             | Tested By:         |                                |                                | DRB             |             |          |
|                 |                 | Batch #5                      |                 |                     |                             | Task #12           |                                |                                |                 |             |          |
|                 |                 |                               |                 |                     |                             |                    |                                |                                |                 |             |          |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                    | Initial Tangent Modulus (Msi.) | Ultimate Strain ( $\mu$ in/in) | Poisson's Ratio | Date Tested | Remarks  |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) |                    |                                |                                |                 |             |          |
| BIL-GL-54-1     | 72°F (DRY)      | 0.998                         | 0.1806          | 6,587               | 36.56                       |                    | 2.447                          | 14,634                         |                 | 11/13/90    | (1a,3,4) |
| BIL-GL-54-3     | "               | 0.997                         | 0.1847          | 6,868               | 37.29                       |                    | 2.901                          | 15,828                         | 0.181           | 11/14/90    | (1a,3,4) |
| BIL-GL-54-5     | "               | 0.998                         | 0.1966          | 7,549               | 38.47                       |                    | 2.403                          | 17,849                         |                 | 11/13/90    | (1b,3,4) |
| BIL-GL-54-7     | "               | 0.992                         | 0.2050          | 7,515               | 36.95                       |                    | 2.656                          | 17,007                         |                 | "           | (1b,3,4) |
| BIL-GL-54-9     | "               | 0.998                         | 0.2032          | 7,136               | 35.19                       |                    | 2.860                          | 15,857                         | 0.158           | 11/14/90    | (1a,3,4) |
| BIL-GL-54-11    | "               | 0.991                         | 0.1892          | 6,873               | 36.65                       |                    | 2.989                          | 12,173                         |                 | 11/13/90    | (1a,3,4) |
|                 |                 |                               |                 | Average             | 36.85                       |                    | 2.709                          | 15,558                         | 0.170           |             |          |
|                 |                 |                               |                 | Std. Dev.           | 1.07                        |                    | 0.246                          | 1,991                          | 0.017           |             |          |

TABLE L. 15

EFFECT OF FIBER CONTENT ON COMPRESSION STRENGTH OF GRAPHITE REINFORCED  
EA 9396 COMPOSITE LAMINATES

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             | Fiber Orientation:     |                |            |                 | Fill        |          |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|----------------|------------|-----------------|-------------|----------|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Batch #5               | Task #12       | Tested By: |                 | DRB         |          |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Initial        |            | Poisson's Ratio | Date Tested | Remarks  |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain (in/in) |            |                 |             |          |
| BIL-GR-79-1     | 72°F (DRY)      | 0.997                         | 0.2335          | 10.835              | 46.53                       | 5.470                  | 10.557         | 11/16/90   |                 |             | (1a,3,4) |
| BIL-GR-79-3     | "               | 1.001                         | 0.2519          | 11.738              | 46.57                       | 5.751                  | 7.860          | 11/19/90   | 0.021           |             | (1a,3,4) |
| BIL-GR-79-5     | "               | 0.995                         | 0.2565          | 11.201              | 43.90                       | 4.252                  | 12.340         | 11/16/90   |                 |             | (1a,3,4) |
| BIL-GR-79-7     | "               | 1.001                         | 0.2615          | 11.118              | 42.47                       | 5.549                  | 7.490          | "          |                 |             | (1a,3,4) |
| BIL-GR-79-9     | "               | 0.999                         | 0.2507          | 9.038               | 36.09                       | 5.388                  | 6.800          | 11/19/90   | 0.213           |             | (1a,3,4) |
| BIL-GR-79-11    | "               | 1.000                         | 0.2322          | 12.456              | 53.64                       | 6.036                  | 9.106          | 11/16/90   |                 |             | (1a,3,4) |
| Average         |                 |                               |                 |                     | 44.87                       | 5.408                  | 9.026          | 0.117      |                 |             |          |
| Std. Dev.       |                 |                               |                 |                     | 5.77                        | 0.612                  | 2.098          | 0.136      |                 |             |          |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
  - (a) Shear crimping
  - (b) Shear fracture
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Physical Properties:
  - Fiber Content (vol. %) = 40.5
  - Resin Content (wt. %) = 48.8
  - Void Content (vol. %) = 5.5
  - Specific Gravity = 1.41

| SI Conversion                       |                       |                |                         |
|-------------------------------------|-----------------------|----------------|-------------------------|
| Ultimate Compressive Strength (MPa) | Initial               |                | Ultimate Strain (in/in) |
|                                     | Tangent Modulus (GPa) | Strain (in/in) |                         |
| 320.8                               | 37.72                 | 10.557         |                         |
| 321.1                               | 39.66                 | 7.860          |                         |
| 302.7                               | 29.32                 | 12.340         |                         |
| 292.8                               | 38.26                 | 7.490          |                         |
| 249.8                               | 37.15                 | 6.800          |                         |
| 369.9                               | 41.62                 | 9.106          |                         |
| Average                             | 37.29                 | 9.026          |                         |
| Std. Dev.                           | 4.22                  | 2.098          |                         |

TABLE L. 16

EFFECT OF FIBER CONTENT ON COMPRESSION STRENGTH OF GRAPHITE REINFORCED  
EA 9396 COMPOSITE LAMINATES

| Test :          |                 | IITRI Compression; ASTM-D3410 |                 |                     |                             |                        |                       | Fiber Orientation: |                 |             |          |     |  |
|-----------------|-----------------|-------------------------------|-----------------|---------------------|-----------------------------|------------------------|-----------------------|--------------------|-----------------|-------------|----------|-----|--|
| Material :      |                 | EA-9396 A/B; W133 Graphite    |                 |                     |                             | Batch #5               |                       | Task #12           |                 | Tested By:  |          | DRB |  |
| Specimen Number | Test Conditions | Width (in.)                   | Thickness (in.) | Maximum Load (lbs.) | Ultimate                    |                        | Initial               |                    | Poisson's Ratio | Date Tested | Remarks  |     |  |
|                 |                 |                               |                 |                     | Compressive Strength (Ksi.) | Tangent Modulus (Msi.) | Strain ( $\mu$ in/in) |                    |                 |             |          |     |  |
| BIL-GR-84-1     | 72°F (DRY)      | 1.002                         | 0.2254          | 11,357              | 50.30                       | 6.101                  | 8,945                 |                    |                 | 11/20/90    | (1a,3,4) |     |  |
| BIL-GR-84-3     | "               | 1.003                         | 0.2395          | 10,933              | 45.49                       | 5.687                  | 9,473                 | 0.037              |                 | "           | (1b,3,4) |     |  |
| BIL-GR-84-5     | "               | 1.003                         | 0.2458          | 10,900              | 44.19                       | 5.599                  | 6,533                 |                    |                 | 11/19/90    | (1b,3,4) |     |  |
| BIL-GR-84-7     | "               | 1.003                         | 0.2435          | 8,975               | 36.75                       | 4.665                  | 7,647                 |                    |                 | "           | (1a,3,4) |     |  |
| BIL-GR-84-9     | "               | 1.004                         | 0.2460          | 10,854              | 43.97                       | 5.378                  | 8,042                 | 0.007              |                 | 11/20/90    | (1a,3,4) |     |  |
| BIL-GR-84-11    | "               | 1.004                         | 0.2309          | 8,901               | 38.40                       | 5.276                  | 7,500                 |                    |                 | 11/19/90    | (1b,3,4) |     |  |
|                 |                 |                               |                 | Average             | 43.18                       | 5.451                  | 8,023                 | 0.022              |                 |             |          |     |  |
|                 |                 |                               |                 | Std. Dev.           | 4.94                        | 0.480                  | 1,057                 | 0.021              |                 |             |          |     |  |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
  - (a) Shear crimping
  - (b) Shear fracture
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Physical Properties:
  - Fiber Content (vol. %) = 42.3
  - Resin Content (wt. %) = 45.6
  - Void Content (vol. %) = 7.5
  - Specific Gravity = 1.39

| SI Conversion              |                       |                                |       |
|----------------------------|-----------------------|--------------------------------|-------|
| Ultimate                   |                       | Initial                        |       |
| Compressive Strength (MPa) | Tangent Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) |       |
| 346.8                      | 42.06                 | 8,945                          |       |
| 313.7                      | 39.21                 | 9,473                          |       |
| 304.7                      | 38.60                 | 6,533                          |       |
| 253.4                      | 32.16                 | 7,647                          |       |
| 303.2                      | 37.08                 | 8,042                          |       |
| 264.7                      | 36.38                 | 7,500                          |       |
| Average                    | 297.8                 | 37.58                          | 8,023 |
| Std. Dev.                  | 34.0                  | 3.31                           | 1,057 |

## APPENDIX M

### INDIVIDUAL SPECIMEN PROPERTIES, EFFECT OF STORAGE TIME AND TEMPERATURE

The tables and figures in this appendix present the detailed mechanical, physical, thermophysical, and chemical property data measured during this program. The data include HPLC spectra, viscosity measurements on both parts A and B, DSC analyses, FTIR spectra, Rheometrics viscosity profiles, and interlaminar shear strengths. Each of these specific types of data are presented separately in sections M.1 through M.6 of this appendix. These data are summarized in Section 3.7.

#### M.1 HPLC SPECTRA

Figures M.1 through M.6 present the HPLC spectra obtained during the program. It can be seen from Figures M.1(b) that part B of the EA9396 resin system produced no significant features. As a result, no further HPLC tests were performed on part B. Table M.1 summarizes the pertinent features and test parameters for each of the tests represented by Figures M.1 through M.6. It will be observed, both in Figures M.4 and M.6 as well as in Table M.1, that the retention times for the 12- and 24-month tests are about twice what they are in the other tests. This is due to the fact that the flow rate during the test was only half what it was in the other tests, thereby doubling the retention times.

In each case the test samples were prepared for analysis by making a 1% solution by weight in dioxane and filtering the solution through a 0.5-micron PTFE filter to remove insolubles.

#### M.2 BROOKFIELD VISCOSITY MEASUREMENTS

Viscosity measurements were made on both parts A and B of the EA9396 resin system using a Brookfield type RV Viscometer. This viscometer comes with a set of seven spindles to cover a wide range of viscosities. Spindle No. 7 was used for viscosity measurements of Part A, while Spindle No. 3 was used for Part B.

The samples that were tested were tested in the cans they were received in from Hysol. In the case of Part A, this was a quart can, while Part B was in a pint can. In each case the cans were not large enough to accommodate the spindle guard so this was removed during the viscosity measurements. While this is not in strict accordance with

the recommended procedure, since all of the tests were performed in the same way, the measurements do provide a consistent comparison of the material for each aging time from its initial receipt until the final measurement after 36 months of storage. In all cases the spindles were immersed to the recommended depths. Table M.2 lists the results of all the viscosity measurements made on both Parts A and B. These results were summarized and discussed in Section 3.7 (see Table 31 in particular).

### M.3 HEAT OF REACTION TESTS (DSC)

Dynamic scanning calorimetric (DSC) tests were conducted on EA9396 in the as-received condition and after storage times of up to 24 months at various temperatures. From these tests the heat released during cure is obtained. Resin samples of approximately 5 mg were heated at a rate of 10°C (18°F)/min in these tests. Figures M.7 through M.22 present the DSC curves from each of these tests and the heat release during cure in these tests is tabulated in Table M.3.

If one considers only the heat release data for the 6-24 month storage times, there is a relatively consistent decrease in heat release as aging time increases and the decrease is greatest for the highest temperature storage condition.

### M.4 FTIR SPECTRA

Figures M.23 through M.54 present the FTIR spectra obtained during the program. The tests were carried out using a Nicolet FTIR instrument. Spectra were obtained on both Parts A and B of the EA9396 resin system after storage times of up to 24 months at various temperatures. Samples were deposited on NaCl plates to perform the FTIR tests. No attempt has been made to interpret these spectra.

### M.5 RHEOMETRIC VISCOSITY PROFILES

A Rheometrics Solids Analyzer (RSA-II) was used to measure the changing viscosity of EA9396 during cure. The test was carried out using approximately 0.1 gm samples in a parallel plate arrangement. The plates were positioned about 0.36 mm apart and oscillated at a frequency of 1 Hz. The motion of the plates was to slightly open and close in a tensile mode rather than to rotate with respect to one another in a torsional mode. The amount of motion represented a cyclic strain of 1.0% ( $\pm 0.0036$  mm) about the midpoint.

Both dynamic viscosity ( $\eta'$ ) and loss viscosity ( $\eta''$ ) were measured in these tests. Since the dynamic viscosity is the most commonly used measure of material viscosity, only these charts are included in this section. Several points should be cited in regard to these data. First, the viscosity values plotted in the accompanying charts are not quantitative. The parallel plate arrangement was a novel way to use the RSA instrument. Normally the tests are carried out using a shear sandwich type arrangement. The low viscosity of the EA9396 system precluded use of the shear sandwich arrangement because the minimum gap setting was 0.5 mm and the material ran out of the fixture during the test. While the parallel plate approach was nonstandard, the viscosity vs. temperature curve was very similar to that obtained with the shear sandwich fixture. For this reason it is felt that so long as all of the tests were carried out in the same manner, comparisons of test results would be valid (i.e., temperatures at which minimum viscosity and gel occur). Second, due to compliance limitations of the RSA instrument, data recorded after gel are meaningless.

Figures M.55 through M.70 present the viscosity profiles obtained after various storage times up to 2 years and at storage temperatures up to 49°C (120°F). Pertinent features from these figures were listed in Table 29 of Section 3.7.

## M.6 INTERLAMINAR SHEAR STRENGTH

Tables M.4-M.19 list the individual specimen interlaminar shear strength properties of laminates made with EA9396 resin that had been in storage for up to two years at temperatures up to 49°C (120°F). These data are summarized and discussed in Section 3.7 (Table 32 in particular).

TABLE M.1  
HPLC TEST PARAMETERS AND RESULTS

| Sample Age | Flow Rate (ml/min) | Solvent Gradient (1) | Retention Time (min.) |                      |                      |
|------------|--------------------|----------------------|-----------------------|----------------------|----------------------|
|            |                    |                      | 22°C (72°F) Storage   | 38°C (100°F) Storage | 40°C (120°F) Storage |
| Initial    | 1.0                | A                    | 18.88                 | ---                  | ---                  |
| 1 Month    | 1.0                | A                    | ---                   | 18.48                | 18.44                |
| 6 Months   | 1.0                | A                    | 20.14                 | 20.16                | 21.15                |
| 12 Months  | 0.5                | A                    | 39.24 (2)             | 37.68 (2)            | 37.92 (2)            |
| 18 Months  | 1.0                | A                    | 18.73                 | 18.43                | 18.81                |
| 24 Months  | 0.5                | B                    | 40.87 (2)             | 41.22 (2)            | 41.36 (2)            |

NOTE:

(1) A: Time      % Water      % Dioxane

|    |    |    |
|----|----|----|
| 0  | 00 | 50 |
| 10 | 50 | 50 |
| 40 | 30 | 70 |
| 50 | 30 | 70 |

B: 50% Water/50% Dioxane throughout test.

(2) These retention times are higher than the others by a factor of 2 because the flow rate during the test was half the flow rate in the other tests. This caused the retention times to be doubled. Thus, these test results are equivalent to those obtained for the other sample ages.



TABLE M.2  
BROOKFIELD VISCOSITY MEASUREMENTS ON EA9396  
AS A FUNCTION OF STORAGE TIME AT  
VARIOUS TEMPERATURES

| Date of Measurement | Storage Time(1) | Storage Temperature |      | Viscosity (Poise) |        |
|---------------------|-----------------|---------------------|------|-------------------|--------|
|                     |                 | (°C)                | (°F) | Part A            | Part B |
| 11/9/88             | As received     | N.A.                |      | 840               | 1      |
| 12/19/88            | 1 month         | 38                  | 100  | 840               | 0.75   |
|                     |                 | 49                  | 120  | 880               | 0.75   |
| 2/9/89              | 3 months        | 22                  | 72   | 920               | 1      |
| 5/16/89             | 6 months        | 22                  | 72   | 720               | 1      |
| 7/20/89             | 8 months        | 38                  | 100  | 840               | 1      |
|                     |                 | 49                  | 120  | 880               | 1      |
| 11/16/89            | 12 months       | 22                  | 72   | 720               | 1      |
|                     |                 | 38                  | 100  | 960               | 1      |
|                     |                 | 49                  | 120  | 1000              | 1      |
| 5/16/90             | 18 months       | 22                  | 72   | 1120              | 1      |
|                     |                 | 38                  | 100  | 1080              | 0.9    |
|                     |                 | 49                  | 120  | 2380              | 0.9    |
| 8/22/90             | 21 months       | 49                  | 120  | 3440              | 0.75   |
| 11/17/90            | 24 months       | 22                  | 72   | 820               | 1      |
|                     |                 | 38                  | 100  | 840               | 1      |
|                     |                 | 49                  | 120  | 6500              | 1      |
| 5/16/91             | 30 months       | 22                  | 72   | 776               | ---    |
|                     |                 | 38                  | 100  | 2340              | ---    |
|                     |                 | 49                  | 120  | >20,000(2)        | ---    |
| 11/15/91            | 36 months       | 22                  | 72   | 800               | ---    |
|                     |                 | 38                  | 100  | 4600              | ---    |
| 6/15/92             | 43 months       | 22                  | 72   | 1000              | ---    |
|                     |                 | 38                  | 100  | >20,000 (2)       | ---    |
| 1/7/93              | 50 months       | 22                  | 72   | 1000              | ---    |
|                     |                 | 38                  | 100  | (3)               | ---    |

NOTES:

- (1) Storage times are nominal, after receipt of material. Material was manufactured three months before receipt.
- (2) This material was no longer processible into laminates and further storage was discontinued.
- (3) Material had hard crust on surface.

**TABLE M.3**  
**EFFECT OF LONG-TERM STORAGE ON HEAT**  
**RELEASE DURING CURE**

| Storage Time | Heat Release During Cure (J/gm) |                         |                         |                                  |
|--------------|---------------------------------|-------------------------|-------------------------|----------------------------------|
|              | 22°C (72°F)<br>Storage          | 38°C (100°F)<br>Storage | 49°C (120°F)<br>Storage | Average of All<br>3 Temperatures |
| 1 Month      | 576.2                           | 588.8                   | 576.4                   | 580.5                            |
| 3 Months     | 572.9                           |                         |                         |                                  |
| 6 Months     | 633.8                           | 593.5                   | 624.6                   | 617.3                            |
| 12 Months    | 613.4                           | 589.5                   | 601.6                   | 601.5                            |
| 18 Months    | 615.4                           | 564.6                   | 586.8                   | 588.9                            |
| 24 Months    | 599.6                           | 575.6                   | 560.6                   | 578.6                            |

TABLE M.4  
EFFECT OF RESIN STORAGE FOR 1 MONTH AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 | Specimen Orientation: |                     | Warp                               |                                   |                           |             |         |
|-----------------|-----------------------------|--------------------------------------|-------------|-----------------|-----------------------|---------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|
| Material :      | EA-9396 A/B; W133 Graphite  | Batch #1                             | Task #13    | Tested By:      |                       |                     | DRB                                |                                   |                           |             |         |
| Specimen Number | Storage Condition           | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.)            | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |
| BIL-GR-6-1      | 1 month @ 22°C (72°F)       | 22°C (72°F) (DRY)                    | 0.996       | 0.1662          | 2.800                 | 1,182               | 5.354                              | 36.92                             | NA                        | 1/22/89     |         |
| BIL-GR-6-3      | 22°C (72°F)                 | "                                    | 0.997       | 0.1711          | 2.800                 | 1,258               | 5.530                              | 38.13                             | NA                        | "           |         |
| BIL-GR-6-5      | "                           | "                                    | 0.993       | 0.1664          | 2.800                 | 1,160               | 5.265                              | 36.30                             | NA                        | "           |         |
|                 |                             |                                      |             |                 |                       | Average             | 5.383                              | 37.12                             |                           |             |         |
|                 |                             |                                      |             |                 |                       | Std. Dev.           | 0.135                              | 0.93                              |                           |             |         |
| BIL-GR-6-2      | 1 month @ 22°C (72°F) (WET) |                                      | 0.999       | 0.1687          | 2.800                 | 810                 | 3.606                              | 24.86                             | 3.86                      | 4/24/89     | (1)     |
| BIL-GR-6-4      | 22°C (72°F)                 | "                                    | 0.998       | 0.1691          | 2.800                 | 855                 | 3.801                              | 26.21                             | 3.96                      |             | (1)     |
|                 |                             |                                      |             |                 |                       | Average             | 3.704                              | 25.54                             | 3.91                      |             |         |
|                 |                             |                                      |             |                 |                       | Std. Dev.           | 0.138                              | 0.95                              | 0.07                      |             |         |

(1) Specimens aged by water immersion 140°F.

TABLE M.5  
EFFECT OF RESIN STORAGE FOR 1 MONTH AT 38°C (100°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                        | Apparent Interlaminar Shear |             | (4pt loading at 1/4 pts. L/D = 16/1) |            |                     | Specimen Orientation:       |       | Warp             |             |
|-----------------|------------------------|-----------------------------|-------------|--------------------------------------|------------|---------------------|-----------------------------|-------|------------------|-------------|
| Material :      |                        | EA-9396 A/B; W133 Graphite  |             | Batch #1                             | Task #13   | Tested By:          |                             |       | DRB              |             |
| Specimen Number | Storage Condition      | Test Condition              | Width (in.) | Thickness (in.)                      | Span (in.) | Maximum Load (lbs.) | Interlaminar Shear Strength |       | Wt. Gain         |             |
|                 |                        |                             |             |                                      |            |                     | (Ksi.)                      | (MPa) | During Aging (%) | Date Tested |
| BIL-GR-2-1      | 1 month @ 38°C (100°F) | 22°C (72°F) (DRY)           | 1.003       | 0.1683                               | 2.800      | 1,380               | 6.131                       | 42.28 | NA               | 1/22/89     |
| BIL-GR-2-3      | "                      | "                           | 1.001       | 0.1741                               | 2.800      | 1,438               | 6.186                       | 42.65 | NA               | "           |
| BIL-GR-2-5      | "                      | "                           | 1.002       | 0.1695                               | 2.800      | 1,400               | 6.180                       | 42.61 | NA               | "           |
| Average         |                        |                             |             |                                      |            |                     | 6.166                       | 42.51 |                  |             |
| Std. Dev.       |                        |                             |             |                                      |            |                     | 0.030                       | 0.21  |                  |             |
| BIL-GR-2-2      | 1 month @ 38°C (100°F) | 22°C (72°F) (WET)           | 0.998       | 0.1709                               | 2.816      | 1,078               | 4.742                       | 32.69 | 2.71             | 4/24/89 (1) |
| BIL-GR-2-4      | "                      | "                           | 0.998       | 0.1724                               | 2.816      | 1,099               | 4.790                       | 33.03 | 2.69             | " (1)       |
| Average         |                        |                             |             |                                      |            |                     | 4.766                       | 32.86 | 2.70             |             |
| Std. Dev.       |                        |                             |             |                                      |            |                     | 0.034                       | 0.24  | 0.01             |             |

(1) Specimens aged by water immersion @ 140°F.

TABLE M.6  
EFFECT OF RESIN STORAGE FOR 1 MONTH AT 49°C (120°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                        | Apparent Interlaminar Shear |             |                 |            | (4pt loading at 1/4 pts. L/D = 16/1) |                             |              |             | Specimen Orientation: |     | Warp    |
|-----------------|------------------------|-----------------------------|-------------|-----------------|------------|--------------------------------------|-----------------------------|--------------|-------------|-----------------------|-----|---------|
| Material :      |                        | EA-9396 A/B; W133 Graphite  |             |                 |            | Batch #1 Task #13                    |                             |              |             | Tested By:            |     | DRB     |
| Specimen Number | Storage Condition      | Test Condition              | Width (in.) | Thickness (in.) | Span (in.) | Maximum                              |                             | Interlaminar |             | Wt. Gain              |     | Remarks |
|                 |                        |                             |             |                 |            | Load (lbs.)                          | Shear Strength (Ksi.) (MPa) | Aging (%)    | Date Tested |                       |     |         |
| BIL-GR-3-1      | 1 month @ 49°C (120°F) | 22°C (72°F) (DRY)           | 0.983       | 0.1727          | 2.800      | 1,267                                | 5.597                       | 38.59        | NA          | 1/23/89               |     |         |
| BIL-GR-3-3      | "                      | "                           | 0.983       | 0.1760          | 2.800      | 1,332                                | 5.774                       | 39.81        | NA          | "                     |     |         |
| BIL-GR-3-5      | "                      | "                           | 0.983       | 0.1745          | 2.800      | 1,309                                | 5.723                       | 39.46        | NA          | "                     |     |         |
|                 |                        |                             |             |                 |            | Average                              | 5.698                       | 39.29        |             |                       |     |         |
|                 |                        |                             |             |                 |            | Std. Dev.                            | 0.091                       | 0.63         |             |                       |     |         |
| BIL-GR-3-2      | 1 month @ 49°C (120°F) | 22°C (72°F) (WET)           | 0.983       | 0.1747          | 2.816      | 987                                  | 4.307                       | 29.70        | 2.81        | 4/24/89               | (1) |         |
| BIL-GR-3-4      | "                      | "                           | 0.979       | 0.1764          | 2.816      | 1,001                                | 4.347                       | 29.97        | 3.00        | "                     | (1) |         |
|                 |                        |                             |             |                 |            | Average                              | 4.327                       | 29.84        | 2.91        |                       |     |         |
|                 |                        |                             |             |                 |            | Std. Dev.                            | 0.028                       | 0.19         | 0.13        |                       |     |         |

(\*) Specimens aged by water immersion @ 140°F.

TABLE M.7  
EFFECT OF RESIN STORAGE FOR 3 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                      | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     |                                    | Specimen Orientation:             |                  |             |
|-----------------|----------------------|-----------------------------|-------------|-----------------|--------------------------------------|---------------------|------------------------------------|-----------------------------------|------------------|-------------|
| Material :      |                      | EA-9396 A/B; W133 Graphite  |             |                 | Batch #1 Task #13                    |                     |                                    | Tested By: DRB                    |                  |             |
| Specimen Number | Storage Condition    | Test Condition              | Width (in.) | Thickness (in.) | Span (in.)                           | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain         |             |
|                 |                      |                             |             |                 |                                      |                     |                                    |                                   | During Aging (%) | Date Tested |
| BIL-GR-30-1     | 3 mos. @ 22°C (72°F) | (DRY)                       | 1.002       | 0.1660          | 2.678                                | 1,246               | 5.617                              | 38.73                             | NA               | 2/22/89     |
| BIL-GR-30-3     | 22°C (72°F)          | "                           | 1.003       | 0.1689          | 2.678                                | 1,289               | 5.706                              | 39.34                             | NA               | "           |
| BIL-GR-30-5     | "                    | "                           | 1.002       | 0.1672          | 2.678                                | 1,167               | 5.222                              | 36.01                             | NA               | "           |
|                 |                      |                             |             |                 |                                      | Average             | 5.515                              | 38.03                             |                  |             |
|                 |                      |                             |             |                 |                                      | Std. Dev.           | 0.257                              | 1.78                              |                  |             |
| BIL-GR-30-2     | 3 mos. @ 22°C (72°F) | (WET)                       | 1.003       | 0.1683          | 2.816                                | 999                 | 4.441                              | 30.62                             | 1.53             | (1)         |
| BIL-GR-30-4     | 22°C (72°F)          | "                           | 1.003       | 0.1688          | 2.816                                | 1,057               | 4.684                              | 32.30                             | 1.58             | (1)         |
|                 |                      |                             |             |                 |                                      | Average             | 4.562                              | 31.46                             | 1.56             |             |
|                 |                      |                             |             |                 |                                      | Std. Dev.           | 0.172                              | 1.19                              | 0.04             |             |

(1) Specimens aged by water immersion @ 140°F.

TABLE M.8  
EFFECT OF RESIN STORAGE FOR 6 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                            | Apparent Interlaminar Shear |             |                 |            | (4pt loading at 1/4 pts. L/D = 16/1) |                             |       |                  | Specimen Orientation: |             | Warp     |
|-----------------|----------------------------|-----------------------------|-------------|-----------------|------------|--------------------------------------|-----------------------------|-------|------------------|-----------------------|-------------|----------|
| Material :      |                            | EA-9396 A/B; W133 Graphite  |             |                 |            | Batch #1 Task #13                    |                             |       |                  | Tested By:            |             | TOB & DH |
| Specimen Number | Storage Condition          | Test Condition              | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                  | Interlaminar Shear Strength |       | Wt. Gain         |                       | Date Tested | Remarks  |
|                 |                            |                             |             |                 |            |                                      | (Ksi.)                      | (MPa) | During Aging (%) |                       |             |          |
| BIL-GR-49-1     | 6 mos. @ 22°C (72°F)       | 22°C (72°F) (DRY)           | 1.005       | 0.1888          | 2.816      | 1,499                                | 5.928                       | 40.87 | NA               |                       | 5/25/89     |          |
| BIL-GR-49-3     | 22°C (72°F)                | "                           | 1.005       | 0.1925          | 2.816      | 1,698                                | 6.586                       | 45.41 | NA               |                       | "           |          |
| BIL-GR-49-5     | "                          | "                           | 1.005       | 0.1892          | 2.816      | 1,526                                | 6.019                       | 41.50 | NA               |                       | "           |          |
|                 |                            |                             |             |                 |            |                                      | Average                     | 6.178 | 42.60            |                       |             |          |
|                 |                            |                             |             |                 |            |                                      | Std. Dev.                   | 0.356 | 2.46             |                       |             |          |
| BIL-GR-49-2     | 6 mos. @ 22°C (72°F) (WET) | 22°C (72°F) (WET)           | 1.005       | 0.1975          | 3.159      | 1,159                                | 4.379                       | 30.20 | 2.66             |                       | 12/12/89    | (1)      |
| BIL-GR-49-4     | 22°C (72°F)                | "                           | 1.005       | 0.1962          | 3.159      | 1,166                                | 4.435                       | 30.58 | 2.70             |                       | "           | (1)      |
|                 |                            |                             |             |                 |            |                                      | Average                     | 4.407 | 30.39            | 2.68                  |             |          |
|                 |                            |                             |             |                 |            |                                      | Std. Dev.                   | 0.039 | 0.27             | 0.03                  |             |          |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.9  
EFFECT OF RESIN STORAGE FOR 6 MONTHS AT 38°C (100°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test : Apparent Interlaminar Shear    |                       | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 |            | Specimen Orientation: |                                    | Warp                              |                           |             |         |
|---------------------------------------|-----------------------|--------------------------------------|-------------|-----------------|------------|-----------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|
| Material : EA-9396 A/B; W133 Graphite |                       | Batch #1                             | Task #13    |                 | Tested By: |                       | TOB & DH                           |                                   |                           |             |         |
| Specimen Number                       | Storage Condition     | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |
| BIL-GR-48-1                           | 6 mos. @ 38°C (100°F) | 22°C (72°F) (DRY)                    | 1.006       | 0.1838          | 2.816      | 1,462                 | 5.929                              | 40.88                             | NA                        | 5/25/89     |         |
| BIL-GR-48-3                           | "                     | "                                    | 1.006       | 0.1994          | 2.816      | 1,591                 | 5.950                              | 41.02                             | NA                        | "           |         |
| BIL-GR-43-5                           | "                     | "                                    | 1.005       | 0.1818          | 2.816      | 1,639                 | 6.727                              | 46.38                             | NA                        | "           |         |
|                                       |                       |                                      |             |                 |            | Average               | 6.202                              | 42.76                             |                           |             |         |
|                                       |                       |                                      |             |                 |            | Std. Dev.             | 0.455                              | 3.13                              |                           |             |         |
| BIL-GR-48-2                           | 6 mos. @ 38°C (100°F) | 22°C (72°F) (WET)                    | 1.005       | 0.1943          | 3.159      | 1,229                 | 4.720                              | 32.55                             | 2.62                      | 12/12/89    | (1)     |
| BIL-GR-48-4                           | "                     | "                                    | 1.004       | 0.1974          | 3.159      | 1,230                 | 4.655                              | 32.09                             | 2.60                      | "           | (1)     |
|                                       |                       |                                      |             |                 |            | Average               | 4.687                              | 32.32                             | 2.61                      |             |         |
|                                       |                       |                                      |             |                 |            | Std. Dev.             | 0.046                              | 0.32                              | 0.01                      |             |         |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.



TABLE M.10  
EFFECT OF RESIN STORAGE FOR 6 MONTHS AT 49°C (120°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                       | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |             |                       | Specimen Orientation: |           |             | Warp     |
|-----------------|-----------------------|-----------------------------|-------------|-----------------|--------------------------------------|-------------|-----------------------|-----------------------|-----------|-------------|----------|
| Material :      |                       | EA-9396 A/B; W133 Graphite  |             |                 | Batch #1 Task #13                    |             |                       | Tested By:            |           |             | TOB & DH |
| Specimen Number | Storage Condition     | Test Condition              | Width (in.) | Thickness (in.) | Span (in.)                           | Maximum     |                       | Interlaminar          |           | Wt. Gain    |          |
|                 |                       |                             |             |                 |                                      | Load (lbs.) | Shear Strength (Ksi.) | Shear Strength (MPa)  | Aging (%) | Date Tested | Remarks  |
| BIL-GR-47-1     | 6 mos. @ 49°C (120°F) | 22°C (72°F) (DRY)           | 1.007       | 0.1873          | 2.816                                | 1,559       | 6.199                 | 42.74                 | NA        | 5/25/89     |          |
| BIL-GR-47-3     | "                     | "                           | 1.007       | 0.1923          | 2.816                                | 1,640       | 6.353                 | 43.80                 | NA        | "           |          |
| BIL-GR-47-5     | "                     | "                           | 1.006       | 0.1825          | 2.816                                | 1,493       | 6.099                 | 42.05                 | NA        | "           |          |
|                 |                       |                             |             |                 |                                      | Average     | 6.217                 | 42.87                 |           |             |          |
|                 |                       |                             |             |                 |                                      | Std. Dev.   | 0.128                 | 0.86                  |           |             |          |
| BIL-GR-47-2     | 6 mos. @ 49°C (120°F) | 22°C (72°F) (WET)           | 1.004       | 0.1975          | 3.159                                | 1,128       | 4.266                 | 29.42                 | 2.79      | 12/12/89    | (1)      |
| BIL-GR-47-4     | "                     | "                           | 1.005       | 0.2018          | 3.159                                | 1,143       | 4.227                 | 29.14                 | 2.78      | "           | (1)      |
|                 |                       |                             |             |                 |                                      | Average     | 4.247                 | 29.28                 | 2.79      |             |          |
|                 |                       |                             |             |                 |                                      | Std. Dev.   | 0.028                 | 0.19                  | 0.01      |             |          |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.11  
EFFECT OF RESIN STORAGE FOR 12 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                             | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. L/D = 16/1) |                     |                                    | Specimen Orientation:             |                           |             | Warp    |    |
|-----------------|-----------------------------|-----------------------------|-------------|-----------------|--------------------------------------|---------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|----|
| Material :      |                             | EA-9396 A/B; W133 Graphite  |             |                 | Batch #1                             | Task #13            | Tested By:                         |                                   |                           |             |         | DH |
| Specimen Number | Storage Condition           | Test Condition              | Width (in.) | Thickness (in.) | Span (in.)                           | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |    |
| BIL-GR-60-1     | 12 mos. @ 22°C (72°F)       | 22°C (72°F) (DRY)           | 0.998       | 0.1700          | 2.807                                | 1,161               | 5.132                              | 35.39                             | NA                        | 5/25/99     |         |    |
| BIL-GR-60-3     | 22°C (72°F)                 | "                           | 0.997       | 0.1791          | 2.807                                | 1,324               | 5.561                              | 38.34                             | NA                        | "           |         |    |
| BIL-GR-60-5     | "                           | "                           | 0.994       | 0.1762          | 2.807                                | 1,257               | 5.383                              | 37.11                             | NA                        | "           |         |    |
|                 |                             |                             |             |                 |                                      | Average             | 5.359                              | 36.95                             |                           |             |         |    |
|                 |                             |                             |             |                 |                                      | Std. Dev.           | 0.215                              | 1.49                              |                           |             |         |    |
| BIL-GR-60-2     | 12 mos. @ 22°C (72°F) (WET) | 22°C (72°F) (WET)           | 0.997       | 0.1768          | 2.832                                | 978                 | 4.161                              | 28.69                             | 2.59                      | 12/12/89    | (1)     |    |
| BIL-GR-60-4     | 22°C (72°F)                 | "                           | 0.997       | 0.1773          | 2.832                                | 1,066               | 4.523                              | 31.19                             | 2.59                      | "           | (1)     |    |
|                 |                             |                             |             |                 |                                      | Average             | 4.342                              | 29.94                             | 2.59                      |             |         |    |
|                 |                             |                             |             |                 |                                      | Std. Dev.           | 0.256                              | 1.76                              | 0.00                      |             |         |    |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.12  
EFFECT OF RESIN STORAGE FOR 12 MONTHS AT 38°C (100°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                        | Apparent Interlaminar Shear          |             |                 |            | Specimen Orientation: |                       |                      |           | Warp     |     |
|-----------------|------------------------|--------------------------------------|-------------|-----------------|------------|-----------------------|-----------------------|----------------------|-----------|----------|-----|
| Material :      |                        | EA-9396 A/B; W133 Graphite           |             |                 |            | Tested By:            |                       |                      |           | DH       |     |
|                 |                        | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 |            |                       |                       |                      |           |          |     |
|                 |                        | Batch #1 Task #13                    |             |                 |            |                       |                       |                      |           |          |     |
| Specimen Number | Storage Condition      | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.) | Maximum               |                       | Interlaminar         |           | Wt. Gain |     |
|                 |                        |                                      |             |                 |            | Load (lbs.)           | Shear Strength (Ksi.) | Shear Strength (MPa) | Aging (%) | During   |     |
| BIL-GR-59-1     | 12 mos. @ 38°C (100°F) | 22°C (72°F) (DRY)                    | 0.998       | 0.1677          | 2.807      | 1,410                 | 6.319                 | 43.57                | NA        | 12/6/89  |     |
| BIL-GR-59-3     | "                      | "                                    | 0.997       | 0.1768          | 2.807      | 1,482                 | 6.306                 | 43.48                | NA        | "        |     |
| BIL-GR-59-5     | "                      | "                                    | 0.997       | 0.1727          | 2.807      | 1,468                 | 6.394                 | 44.09                | NA        | "        |     |
|                 |                        |                                      |             |                 |            | Average               | 6.340                 | 43.71                |           |          |     |
|                 |                        |                                      |             |                 |            | Std. Dev.             | 0.048                 | 0.33                 |           |          |     |
| BIL-GR-59-2     | 12 mos. @ 38°C (100°F) | 22°C (72°F) (WET)                    | 0.998       | 0.1750          | 2.832      | 1,109                 | 4.762                 | 32.84                | 2.55      | 2/23/90  | (1) |
| BIL-GR-59-4     | "                      | "                                    | 0.998       | 0.1761          | 2.832      | 1,111                 | 4.741                 | 32.69                | 2.54      | "        | (1) |
|                 |                        |                                      |             |                 |            | Average               | 4.752                 | 32.76                | 2.54      |          |     |
|                 |                        |                                      |             |                 |            | Std. Dev.             | 0.015                 | 0.10                 | 0.01      |          |     |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.13  
EFFECT OF RESIN STORAGE FOR 12 MONTHS AT 49°C (120°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          | Apparent Interlaminar Shear |                   | (4pt loading at 1/4 pts. L/D = 16/1) |                 |            | Specimen Orientation: |                                    | Warp             |             |         |     |
|-----------------|-----------------------------|-------------------|--------------------------------------|-----------------|------------|-----------------------|------------------------------------|------------------|-------------|---------|-----|
| Material :      | EA-9396 A/B; W133 Graphite  |                   | Batch #1                             | Task #13        | Tested By: |                       | DH                                 |                  |             |         |     |
| Specimen Number | Storage Condition           | Test Condition    | Width (in.)                          | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Wt. Gain                           |                  | Date Tested | Remarks |     |
|                 |                             |                   |                                      |                 |            |                       | Interlaminar Shear Strength (Ksi.) | During Aging (%) |             |         |     |
| BIL-GR-61-1     | 12 mos. @ 49°C (120°F)      | 22°C (72°F) (DRY) | 0.996                                | 0.1699          | 2.807      | 1,362                 | 6.037                              | 41.62            | NA          | 12/6/89 |     |
| BIL-GR-61-3     | "                           | "                 | 0.999                                | 0.1810          | 2.807      | 1,469                 | 6.093                              | 42.01            | NA          | "       |     |
| BIL-GR-61-5     | "                           | "                 | 1.001                                | 0.1754          | 2.807      | 1,491                 | 6.369                              | 43.91            | NA          | "       |     |
|                 |                             |                   |                                      |                 |            |                       | Average                            | 6.166            | 42.52       |         |     |
|                 |                             |                   |                                      |                 |            |                       | Std. Dev.                          | 0.178            | 1.23        |         |     |
| BIL-GR-61-2     | 12 mos. @ 49°C (120°F)      | 22°C (72°F) (WET) | 0.996                                | 0.1770          | 2.832      | 883                   | 3.757                              | 25.90            | 4.21        | 2/23/90 | (1) |
| BIL-GR-61-4     | "                           | "                 | 1.001                                | 0.1801          | 2.832      | 915                   | 3.807                              | 26.25            | 4.29        | "       | (1) |
|                 |                             |                   |                                      |                 |            |                       | Average                            | 3.782            | 26.07       | 4.25    |     |
|                 |                             |                   |                                      |                 |            |                       | Std. Dev.                          | 0.035            | 0.24        | 0.05    |     |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.14  
EFFECT OF RESIN STORAGE FOR 18 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 | Specimen Orientation: |                     | Warp                               |                                   |                  |             |         |
|-----------------|-----------------------------|--------------------------------------|-------------|-----------------|-----------------------|---------------------|------------------------------------|-----------------------------------|------------------|-------------|---------|
| Material :      | EA-9396 A/B; W133 Graphite  | Batch #1                             | Task #13    | Tested By:      | PM & DRB              |                     |                                    |                                   |                  |             |         |
| Specimen Number | Storage Condition           | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.)            | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain         |             | Remarks |
|                 |                             |                                      |             |                 |                       |                     |                                    |                                   | During Aging (%) | Date Tested |         |
| BIL-GR-74-1     | 18 mos. @ 22°C (72°F)       | (DRY)                                | 1.000       | 0.1730          | 2.827                 | 1,318               | 5.714                              | 39.40                             | NA               | 6/12/90     |         |
| BIL-GR-74-3     | 22°C (72°F)                 | "                                    | 1.004       | 0.1820          | 2.827                 | 1,590               | 6.526                              | 45.00                             | NA               | "           |         |
| BIL-GR-74-5     | "                           | "                                    | 1.003       | 0.1770          | 2.827                 | 1,450               | 6.126                              | 42.24                             | NA               | "           |         |
|                 |                             |                                      |             |                 |                       |                     | Average                            | 6.122                             | 42.21            |             |         |
|                 |                             |                                      |             |                 |                       |                     | Std. Dev.                          | 0.406                             | 2.80             |             |         |
| BIL-GR-74-2     | 18 mos. @ 22°C (72°F) (WET) |                                      | 1.002       | 0.1800          | 2.848                 | 1,073               | 4.462                              | 30.76                             | 2.64             | 10/16/90    | (1)     |
| BIL-GR-74-4     | 22°C (72°F)                 | "                                    | 1.003       | 0.1800          | 2.848                 | 1,152               | 4.786                              | 33.00                             | 2.66             | "           | (1)     |
|                 |                             |                                      |             |                 |                       |                     | Average                            | 4.624                             | 31.88            | 2.65        |         |
|                 |                             |                                      |             |                 |                       |                     | Std. Dev.                          | 0.229                             | 1.58             | 0.01        |         |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.15  
EFFECT OF RESIN STORAGE FOR 18 MONTHS AT 38°C (200°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                        | Apparent Interlaminar Shear |             |                 | (4pt loading at 1/4 pts. LD = 16/1) |                     |                                    | Specimen Orientation:             |                           | Warp        |         |
|-----------------|------------------------|-----------------------------|-------------|-----------------|-------------------------------------|---------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|
| Material :      |                        | EA-9396 A/B; W133 Graphite  |             |                 | Batch #1 Task #13                   |                     |                                    | Tested By:                        |                           | PM & DRB    |         |
| Specimen Number | Storage Condition      | Test Condition              | Width (in.) | Thickness (in.) | Span (in.)                          | Maximum Load (lbs.) | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |
| BIL-GR-73-1     | 18 mos. @ 38°C (100°F) | 22°C (72°F) (DRY)           | 1.000       | 0.1700          | 2.827                               | 1,465               | 6.463                              | 44.56                             | NA                        | 6/12/90     |         |
| BIL-GR-73-3     | "                      | "                           | 1.000       | 0.1850          | 2.827                               | 1,545               | 6.264                              | 43.19                             | NA                        | "           |         |
| BIL-GR-73-5     | "                      | "                           | 0.993       | 0.1730          | 2.827                               | 1,510               | 6.553                              | 45.18                             | NA                        | "           |         |
|                 |                        |                             |             |                 |                                     | Average             | 6.427                              | 44.31                             |                           |             |         |
|                 |                        |                             |             |                 |                                     | Std. Dev.           | 0.148                              | 1.02                              |                           |             |         |
| BIL-GR-73-2     | 18 mos. @ 38°C (100°F) | 22°C (72°F) (WET)           | 1.000       | 0.1760          | 2.848                               | 1,222               | 5.207                              | 35.90                             | 2.64                      | 10/16/90    | (1)     |
| BIL-GR-73-4     | "                      | "                           | 1.000       | 0.1760          | 2.848                               | 1,215               | 5.178                              | 35.70                             | 2.66                      | "           | (1)     |
|                 |                        |                             |             |                 |                                     | Average             | 5.192                              | 35.80                             | 2.65                      |             |         |
|                 |                        |                             |             |                 |                                     | Std. Dev.           | 0.021                              | 0.15                              | 0.01                      |             |         |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.16  
EFFECT OF RESIN STORAGE FOR 18 MONTHS AT 49°C (120°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test            | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 |            | Specimen Orientation: |                                  | Warp             |             |              |
|-----------------|-----------------------------|--------------------------------------|-------------|-----------------|------------|-----------------------|----------------------------------|------------------|-------------|--------------|
| Material        | EA-9396 A/B; W133 Graphite  | Batch #1                             | Task #13    | Tested By:      |            |                       | PM & DRB                         |                  |             |              |
| Specimen Number | Storage Condition           | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strer. (Ksi.) | During Aging (%) | Date Tested | Remarks      |
| BIL-GR-72-1     | 18 mos. @ 49°C (120°F)      | 22°C (72°F) (DRY)                    | 0.999       | 0.1750          | 2.827      | 1.555                 | 6.671                            | 46.00            | NA          | 6/12/90      |
| BIL-GR-72-3     | "                           | "                                    | 1.000       | 0.1800          | 2.827      | 1.605                 | 6.688                            | 46.11            | NA          | "            |
| BIL-GR-72-5     | "                           | "                                    | 1.000       | 0.1750          | 2.827      | 1.595                 | 6.836                            | 47.13            | NA          | "            |
|                 |                             |                                      |             |                 |            | Average               | 6.731                            | 46.41            |             |              |
|                 |                             |                                      |             |                 |            | Std. Dev.             | 0.091                            | 0.63             |             |              |
| BIL-GR-72-2     | 18 mos. @ 49°C (120°F)      | 22°C (72°F) (WET)                    | 0.995       | 0.1780          | 2.848      | 1.251                 | 5.298                            | 36.53            | 2.64        | 10/16/90 (1) |
| BIL-GR-72-4     | "                           | "                                    | 1.000       | 0.1770          | 2.848      | 1.190                 | 5.042                            | 34.77            | 2.66        | " (1)        |
|                 |                             |                                      |             |                 |            | Average               | 5.170                            | 35.65            | 2.65        |              |
|                 |                             |                                      |             |                 |            | Std. Dev.             | 0.180                            | 1.24             | 0.01        |              |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.17  
EFFECT OF RESIN STORAGE FOR 24 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test            | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 |            | Specimen Orientation: |                                    | Warp                              |           |             |         |
|-----------------|-----------------------------|--------------------------------------|-------------|-----------------|------------|-----------------------|------------------------------------|-----------------------------------|-----------|-------------|---------|
| Material        | EA-9396 A/B; W133 Graphite  | Batch #1                             | Task #13    | Tested By:      |            | Wt. Gain              |                                    | DRB                               |           |             |         |
| Specimen Number | Storage Condition           | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Aging (%) | Date Tested | Remarks |
| BIL-GR-85-1     | 24 mos. @ 22°C (72°F)       | (DRY)                                | 1.002       | 0.1798          | 2.940      | 1,567                 | 6.523                              | 44.98                             | NA        | 1/4/91      |         |
| BIL-GR-85-3     | 22°C (72°F)                 | "                                    | 1.002       | 0.1821          | 2.940      | 1,650                 | 6.782                              | 46.76                             | NA        | "           |         |
| BIL-GR-85-5     | "                           | "                                    | 1.002       | 0.1738          | 2.940      | 1,587                 | 6.835                              | 47.13                             | NA        | "           |         |
|                 |                             |                                      |             |                 |            | Average               | 6.713                              | 46.29                             |           |             |         |
|                 |                             |                                      |             |                 |            | Std. Dev.             | 0.167                              | 1.15                              |           |             |         |
| BIL-GR-85-2     | 24 mos. @ 22°C (72°F) (WET) |                                      | 1.002       | 0.1806          | 2.940      | 1,120                 | 4.642                              | 32.01                             | 2.65      | 6/14/91     | (1)     |
| BIL-GR-85-4     | 22°C (72°F)                 | "                                    | 1.002       | 0.1790          | 2.940      | 1,110                 | 4.642                              | 32.00                             | 2.62      | "           | (1)     |
|                 |                             |                                      |             |                 |            | Average               | 4.642                              | 32.00                             | 2.63      |             |         |
|                 |                             |                                      |             |                 |            | Std. Dev.             | 0.000                              | 0.00                              | 0.02      |             |         |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.



TABLE M.18  
EFFECT OF RESIN STORAGE FOR 24 MONTHS AT 38°C (100°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test            | Apparent Interlaminar Shear |                   | (4pt loading at 1/4 pts. L/D = 16/1) |                 |            | Specimen Orientation: |                                    | Warp                              |                           |             |         |
|-----------------|-----------------------------|-------------------|--------------------------------------|-----------------|------------|-----------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|
| Material :      | EA-9396 A/B; W133 Graphite  |                   | Batch #1                             | Task #13        |            | Tested By:            |                                    | DRB                               |                           |             |         |
| Specimen Number | Storage Condition           | Test Condition    | Width (in.)                          | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |
| BIL-GR-86-1     | 24 mos. @ 38°C (100°F)      | 22°C (72°F) (DRY) | 1.003                                | 0.1845          | 2.940      | 1,520                 | 6.160                              | 42.48                             | NA                        | 1/4/91      |         |
| BIL-GR-86-3     | "                           | "                 | 1.002                                | 0.1904          | 2.940      | 1,445                 | 5.681                              | 39.17                             | NA                        | "           |         |
| BIL-GR-86-5     | "                           | "                 | 1.002                                | 0.1829          | 2.940      | 1,410                 | 5.770                              | 39.79                             | NA                        | "           |         |
|                 |                             |                   | Average                              |                 |            | 5.870                 |                                    | 40.48                             |                           |             |         |
|                 |                             |                   | Std. Dev.                            |                 |            | 0.255                 |                                    | 1.76                              |                           |             |         |
| BIL-GR-86-2     | 24 mos. @ 38°C (100°F)      | 22°C (72°F) (WET) | 1.002                                | 0.1885          | 2.940      | 1,060                 | 4.209                              | 29.02                             | 2.80                      | 6/14/91     | (1)     |
| BIL-GR-86-4     | "                           | "                 | 1.002                                | 0.1887          | 2.940      | 990                   | 3.927                              | 27.08                             | 2.80                      | "           | (1)     |
|                 |                             |                   | Average                              |                 |            | 4.068                 |                                    | 28.05                             | 2.80                      |             |         |
|                 |                             |                   | Std. Dev.                            |                 |            | 0.199                 |                                    | 1.38                              | 0.00                      |             |         |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.19  
EFFECT OF RESIN STORAGE FOR 24 MONTHS AT 49°C (120°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test            | Apparent Interlaminar Shear | (4pt loading at 1/4 pts. L/D = 16/1) |             |                 |            | Specimen Orientation: |                                    | Warp                              |                           |             |         |
|-----------------|-----------------------------|--------------------------------------|-------------|-----------------|------------|-----------------------|------------------------------------|-----------------------------------|---------------------------|-------------|---------|
| Material        | EA-9396 A/B; W133 Graphite  | Batch #1                             | Task #13    | Tested By:      |            | DRB                   |                                    |                                   |                           |             |         |
| Specimen Number | Storage Condition           | Test Condition                       | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain During Aging (%) | Date Tested | Remarks |
| BIL-GR-87-1     | 24 mos. @ 49°C (120°F)      | 22°C (72°F) (DRY)                    | 1.004       | 0.1882          | 2.940      | 1,580                 | 6.271                              | 43.24                             | NA                        | 1/4/91      |         |
| BIL-GR-87-3     | "                           | "                                    | 1.005       | 0.1861          | 2.940      | 1,595                 | 6.396                              | 44.10                             | NA                        | "           |         |
| BIL-GR-87-5     | "                           | "                                    | 1.003       | 0.1798          | 2.940      | 1,465                 | 6.093                              | 42.01                             | NA                        | "           |         |
|                 |                             |                                      |             |                 |            | Average               | 6.253                              | 43.12                             |                           |             |         |
|                 |                             |                                      |             |                 |            | Std. Dev.             | 0.152                              | 1.05                              |                           |             |         |
| BIL-GR-87-2     | 24 mos. @ 49°C (120°F)      | 22°C (72°F) (WET)                    | 1.005       | 0.1860          | 2.940      | 1,150                 | 4.614                              | 31.81                             | 2.82                      | 6/14/91     | (1)     |
| BIL-GR-87-4     | "                           | "                                    | 1.005       | 0.1856          | 2.940      | 1,130                 | 4.544                              | 31.33                             | 2.84                      | "           | (1)     |
|                 |                             |                                      |             |                 |            | Average               | 4.579                              | 31.57                             | 2.83                      |             |         |
|                 |                             |                                      |             |                 |            | Std. Dev.             | 0.050                              | 0.34                              | 0.01                      |             |         |

(1) Specimens aged @ 140°F/95-100% R.H. to saturation.

TABLE M.20  
EFFECT OF RESIN STORAGE FOR 43 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                             | Apparent Interlaminar Shear |             | (4pt loading at 1/4 pts. L/D = 16/1) |            |                     | Specimen Orientation:       |       | Warp        |             |
|-----------------|-----------------------------|-----------------------------|-------------|--------------------------------------|------------|---------------------|-----------------------------|-------|-------------|-------------|
| Material :      |                             | EA-9396 A/B; W133 Graphite  |             | Batch #1 Task #13                    |            |                     | Tested By:                  |       | PM          |             |
| Specimen Number | Storage Condition           | Test Condition              | Width (in.) | Thickness (in.)                      | Span (in.) | Maximum Load (lbs.) | Interlaminar Shear Strength |       | Date Tested | Remarks     |
|                 |                             |                             |             |                                      |            |                     | (Ksi.)                      | (MPa) |             |             |
| Wt. Gain        |                             |                             |             |                                      |            |                     |                             |       |             |             |
| BIL-GR-89-1     | 43 mos. @ 22°C (72°F) (DRY) | "                           | 0.998       | 0.1632                               | 2.685      | 1,446               | 6.659                       | 45.91 | NA          | 7/20/92     |
| BIL-GR-89-3     | 22°C (72°F)                 | "                           | 1.001       | 0.1699                               | 2.685      | 1,499               | 6.611                       | 45.58 | NA          | "           |
| BIL-GR-89-5     | "                           | "                           | 1.001       | 0.1645                               | 2.685      | 1,442               | 6.568                       | 45.29 | NA          | "           |
| Average         |                             |                             |             |                                      |            |                     | 6.612                       | 45.59 |             |             |
| Std. Dev.       |                             |                             |             |                                      |            |                     | 0.045                       | 0.31  |             |             |
| BIL-GR-89-2     | 43 mos. @ 22°C (72°F) (WET) | "                           | 1.001       | 0.1648                               | 2.690      | 1,080               | 4.910                       | 33.86 | 2.87        | 2/19/93 (1) |
| BIL-GR-89-4     | 22°C (72°F)                 | "                           | 0.999       | 0.1691                               | 2.690      | 1,106               | 4.910                       | 33.86 | 2.85        | " (1)       |
| Average         |                             |                             |             |                                      |            |                     | 4.910                       | 33.86 | 2.86        |             |
| Std. Dev.       |                             |                             |             |                                      |            |                     | 0.000                       | 0.00  | 0.01        |             |

(1) Specimens aged by water immersion at 140°F.

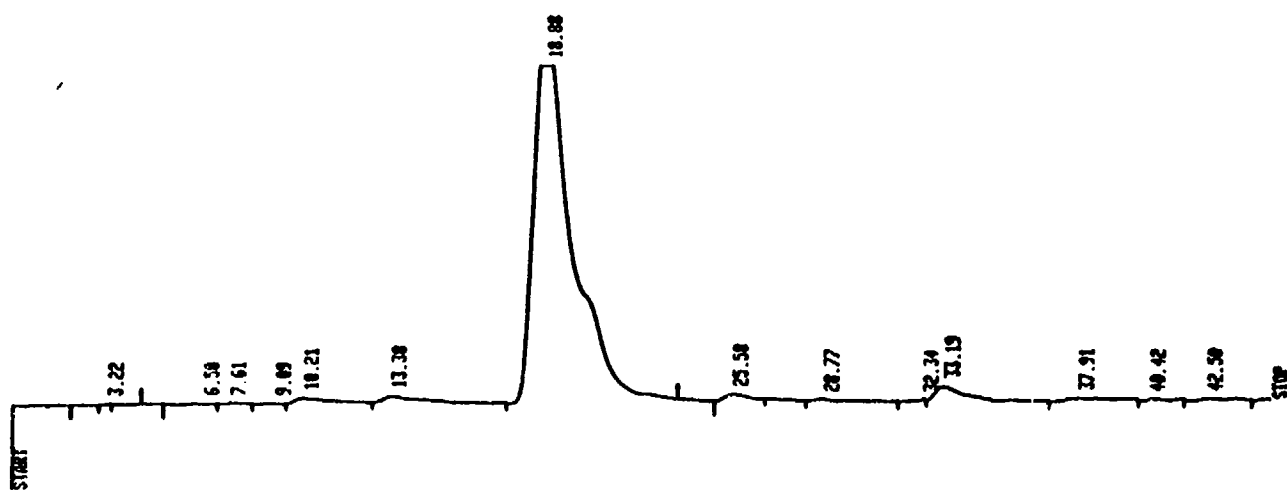
TABLE M.21  
EFFECT OF RESIN STORAGE FOR 43 MONTHS AT 38°C (100°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                        | Apparent Interlaminar Shear |             | (4pt loading at 1/4 pls. L/D = 16/1) |            |             | Specimen Orientation: |                                    | Warp                              |             |         |
|-----------------|------------------------|-----------------------------|-------------|--------------------------------------|------------|-------------|-----------------------|------------------------------------|-----------------------------------|-------------|---------|
| Material :      |                        | EA-9396 A/B; W133 Graphite  |             | Batch #1 Task #13                    |            |             | Tested By:            |                                    | PM                                |             |         |
| Specimen Number | Storage Condition      | Test Condition              | Width (in.) | Thickness (in.)                      | Span (in.) | Maximum     |                       | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Wt. Gain    |         |
|                 |                        |                             |             |                                      |            | Load (lbs.) | During Aging (%)      |                                    |                                   | Date Tested | Remarks |
| BIL-GR-90-1     | 43 mos. @ 38°C (100°F) | 22°C (72°F) (DRY)           | 1.001       | 0.1683                               | 2.685      | 1,479       | 6.584                 | 45.40                              | NA                                | 7/20/92     |         |
| BIL-GR-90-3     | "                      | "                           | 1.000       | 0.1709                               | 2.685      | 1,497       | 6.570                 | 45.30                              | NA                                | "           |         |
| BIL-GR-90-5     | "                      | "                           | 1.000       | 0.1698                               | 2.685      | 1,513       | 6.683                 | 46.08                              | NA                                | "           |         |
|                 |                        |                             |             |                                      |            | Average     | 6.612                 | 45.59                              |                                   |             |         |
|                 |                        |                             |             |                                      |            | Std. Dev.   | 0.062                 | 0.42                               |                                   |             |         |
| BIL-GR-90-2     | 43 mos. @ 38°C (100°F) | 22°C (72°F) (WET)           | 1.001       | 0.1720                               | 2.690      | 1,146       | 4.992                 | 34.42                              | 3.08                              | 2/19/93     | (1)     |
| BIL-GR-90-4     | "                      | "                           | 1.001       | 0.1705                               | 2.690      | 1,074       | 4.720                 | 32.54                              | 2.95                              | "           | (1)     |
|                 |                        |                             |             |                                      |            | Average     | 4.856                 | 33.48                              | 3.02                              |             |         |
|                 |                        |                             |             |                                      |            | Std. Dev.   | 0.193                 | 1.33                               | 0.09                              |             |         |

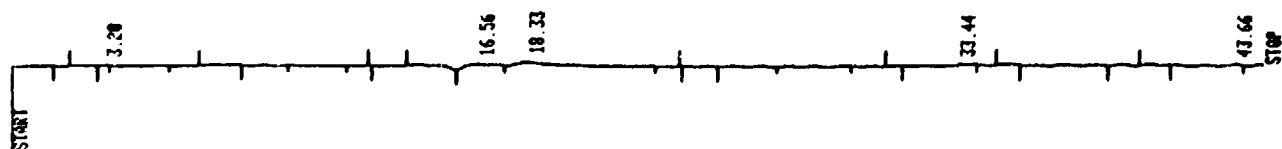
(1) Specimens aged by water immersion at 140°F.

TABLE M.22  
EFFECT OF RESIN STORAGE FOR 50 MONTHS AT 22°C (72°F) ON  
INTERLAMINAR SHEAR STRENGTH OF GRAPHITE  
REINFORCED EA9396 COMPOSITE LAMINATE

| Test :          |                       | Apparent Interlaminar Shear |             | (4pt loading at 1/4 pts. L/D = 16/1) |            | Specimen Orientation: |                                    | Warp                              |             |         |
|-----------------|-----------------------|-----------------------------|-------------|--------------------------------------|------------|-----------------------|------------------------------------|-----------------------------------|-------------|---------|
| Material :      |                       | EA-9396 A/B; W133 Graphite  |             | Batch #1 Task #13                    |            | Tested By:            |                                    | PM                                |             |         |
| Specimen Number | Storage Condition     | Test Condition              | Width (in.) | Thickness (in.)                      | Span (in.) | Maximum Load (lbs.)   | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Date Tested | Remarks |
| BIL-GR-91-1     | 50 mos. @ 22°C (72°F) | 22°C (72°F) (DRY)           | 1.000       | 0.1764                               | 2.842      | 1,490                 | 6.335                              | 43.68                             | 2/19/93     |         |
| BIL-GR-91-2     | "                     | "                           | 1.000       | 0.1793                               | 2.842      | 1,500                 | 6.275                              | 43.27                             | "           |         |
| BIL-GR-91-3     | "                     | "                           | 1.001       | 0.1795                               | 2.842      | 1,454                 | 6.069                              | 41.84                             | "           |         |
| BIL-GR-91-4     | "                     | "                           | 1.000       | 0.1784                               | 2.842      | 1,608                 | 6.759                              | 46.61                             | "           |         |
| BIL-GR-91-5     | "                     | "                           | 1.001       | 0.1746                               | 2.842      | 1,467                 | 6.295                              | 43.41                             | "           |         |
|                 |                       |                             |             |                                      |            |                       | Average                            | 6.347                             | 43.76       |         |
|                 |                       |                             |             |                                      |            |                       | Std. Dev.                          | 0.253                             | 1.74        |         |

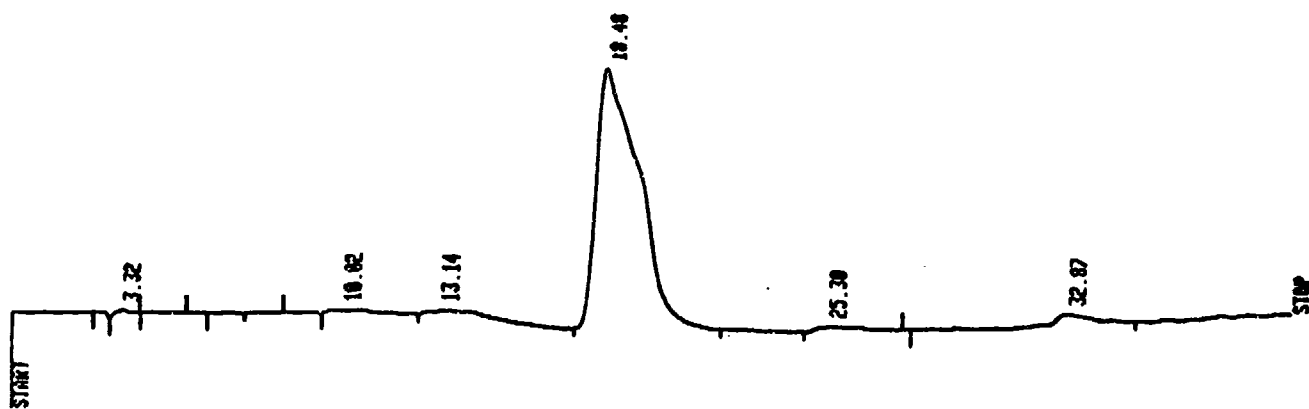


(a) Part A

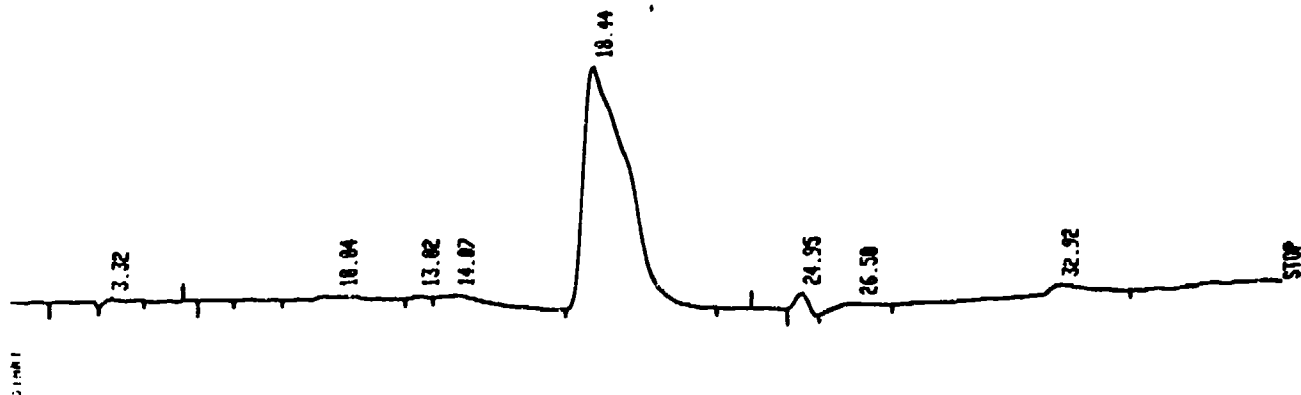


(b) Part B

Figure M.1. Initial HPLC Spectra for EA9396 Parts A and B.

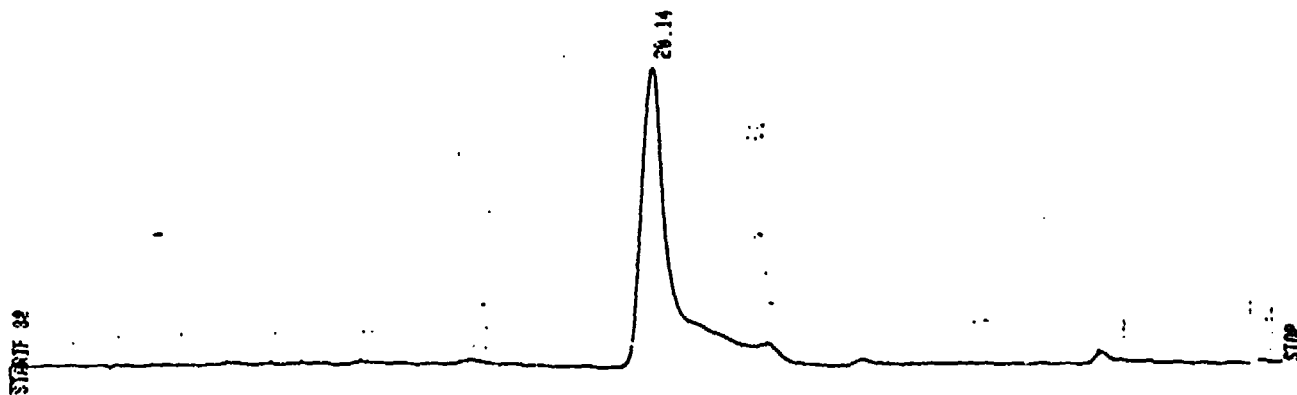


(a) Stored 1 month at 38°C (100°F).

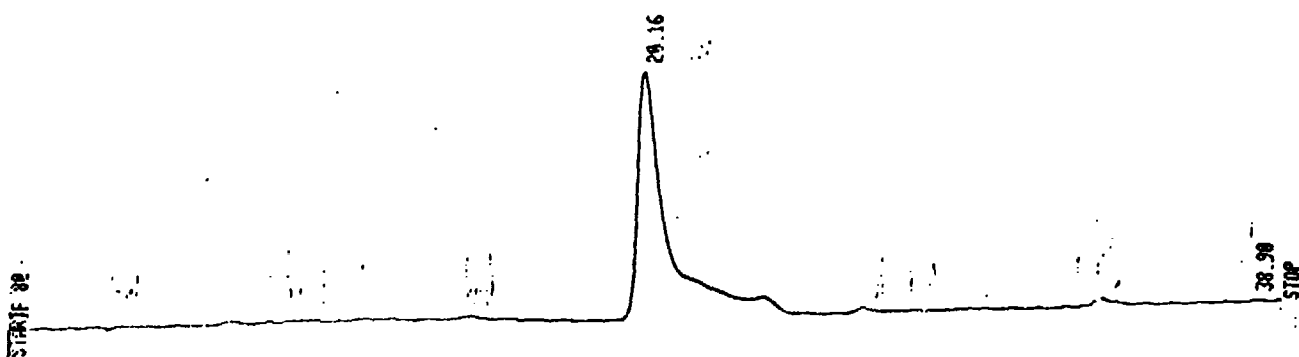


(b) Stored 1 month at 49°C (120°F).

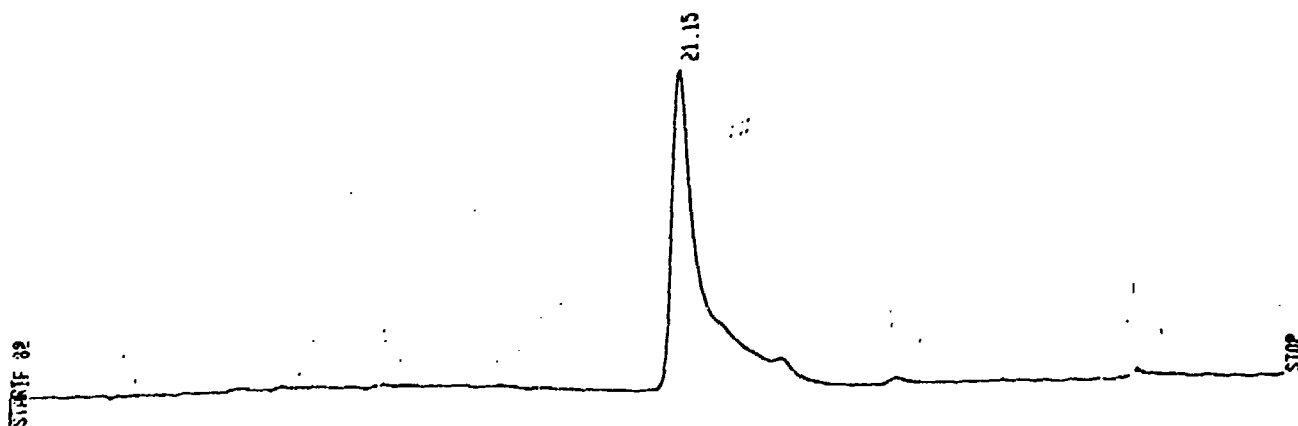
Figure M.2. HPLC Spectra for EA9396, Part A After One Month Storage.



(a) Stored 6 months at 22°C (72°F).



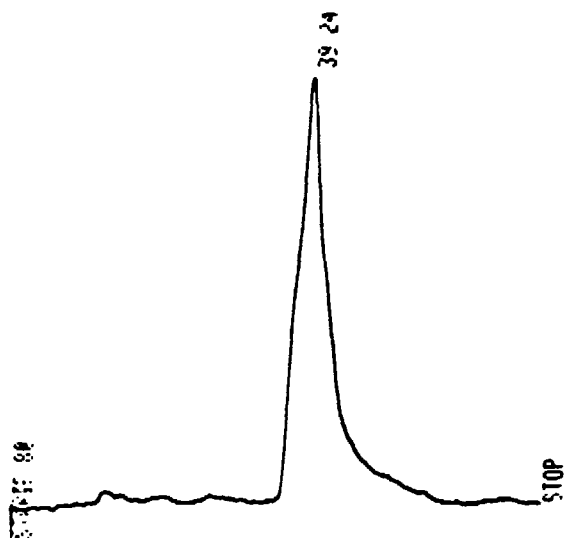
(b) Stored 6 months at 38°C (100°F).



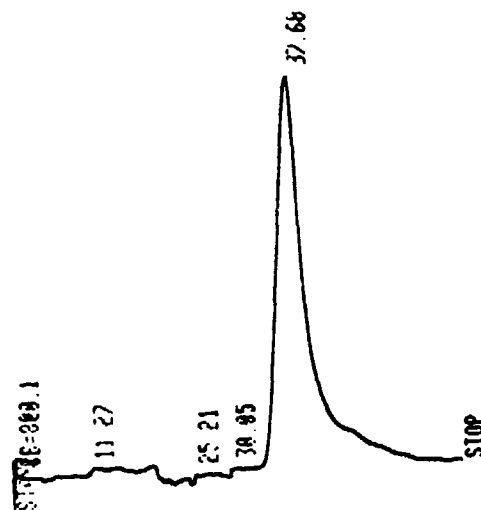
(c) Stored 6 months at 49°C (120°F).

Figure M.3. HPLC Spectra for EA9396, Part A After Six Months Storage.

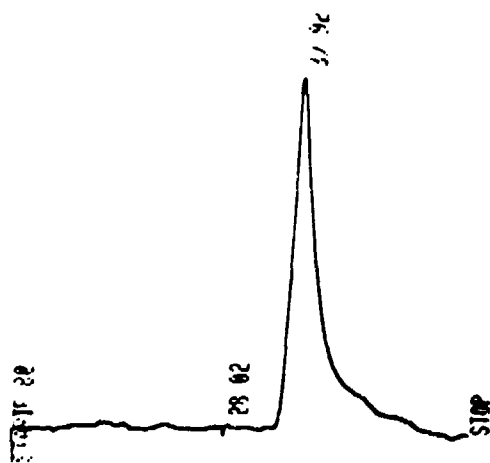




(a) Stored 12 Months at 22°C (72°F).

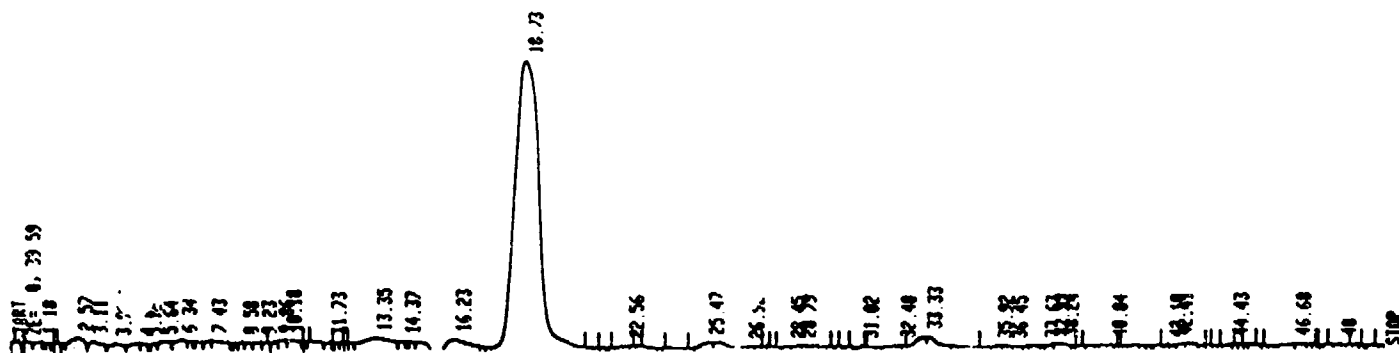


(b) Stored 12 Months at 38°C (100°F).

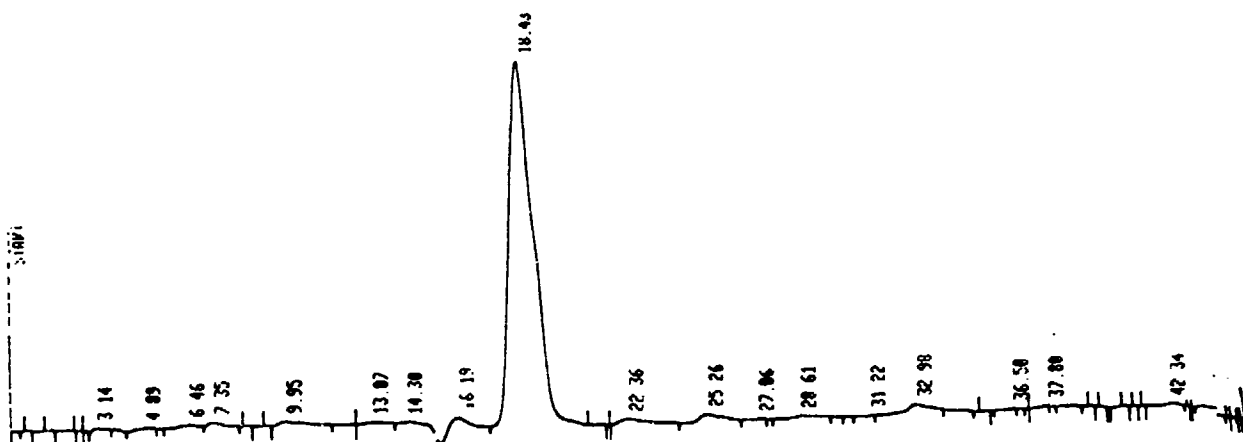


(c) Stored 12 Months at 49°C (120°F).

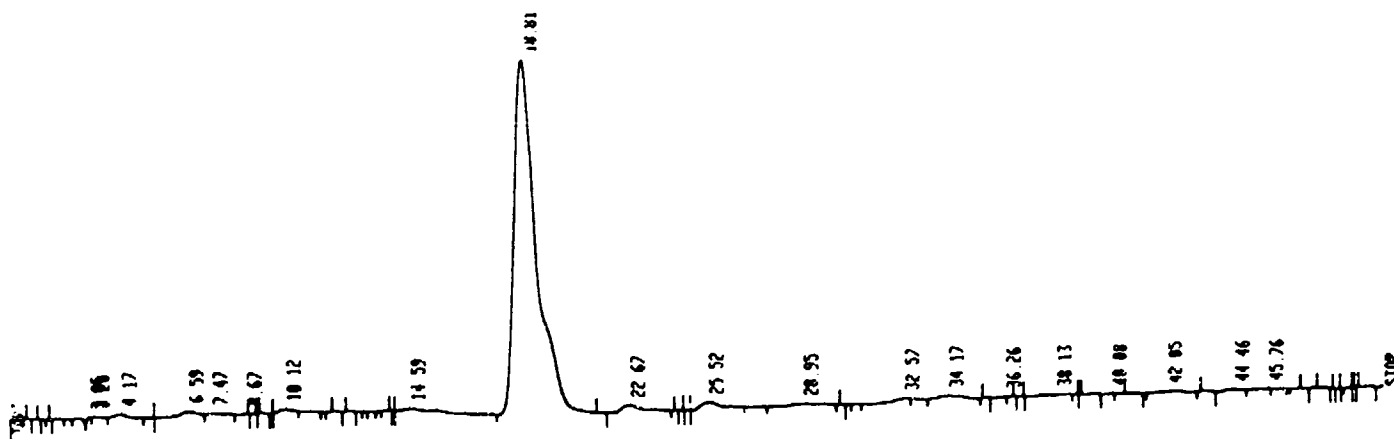
Figure M.4. HPLC Spectra for EA9396, Part A After 12 Months Storage.



(a) Stored 18 months at 22°C (72°F).

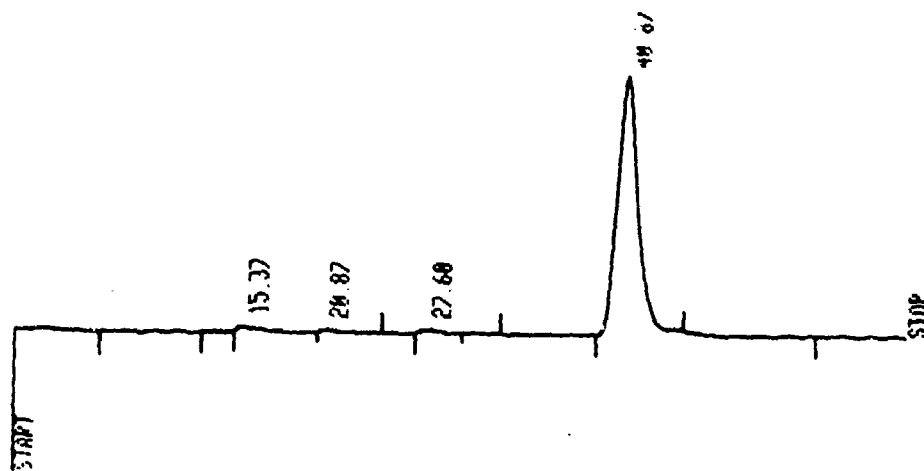


(b) Stored 18 months at 38°C (100°F).

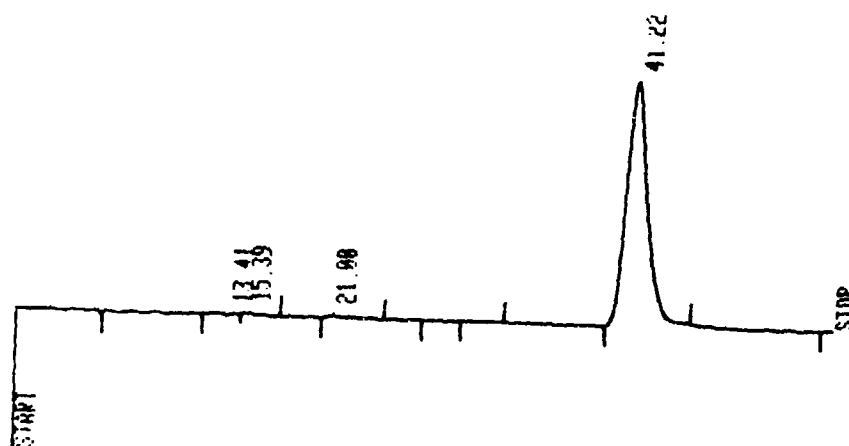


(c) Stored 18 months at 49°C (120°F).

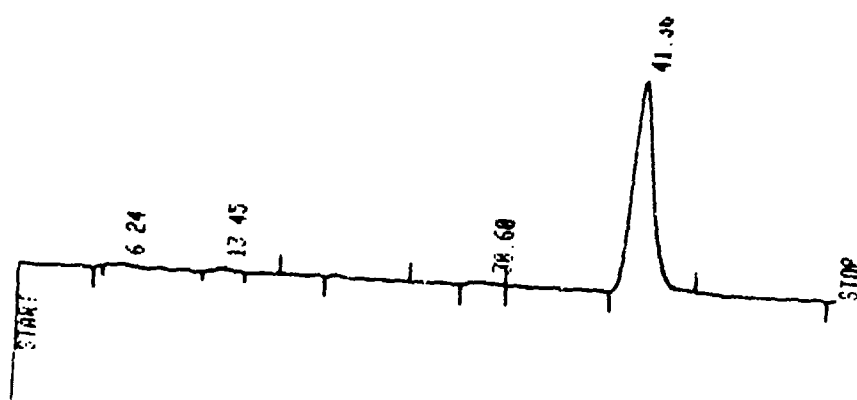
Figure M.5. HPLC Spectra of EA9396, Part A After 18 Months Storage.



(a) Stored 24 months at 22°C (72°F).



(b) Stored 24 months at 38°C (100°F).



(c) Stored 24 months at 49°C (120°F).

Figure M.6. HPLC Spectra of EA9396, Part A After 24 Months Storage.

Sample: EA 9398 (unaged) REPEAT  
Size: 5.2460 mg  
Method: BMI-Tg & HR  
Comment: 10°C/min

100.0 J 72°F

DSC

File: DSC0334.01  
Operator: GALASKA  
Run Date: 12/19/88 13:50

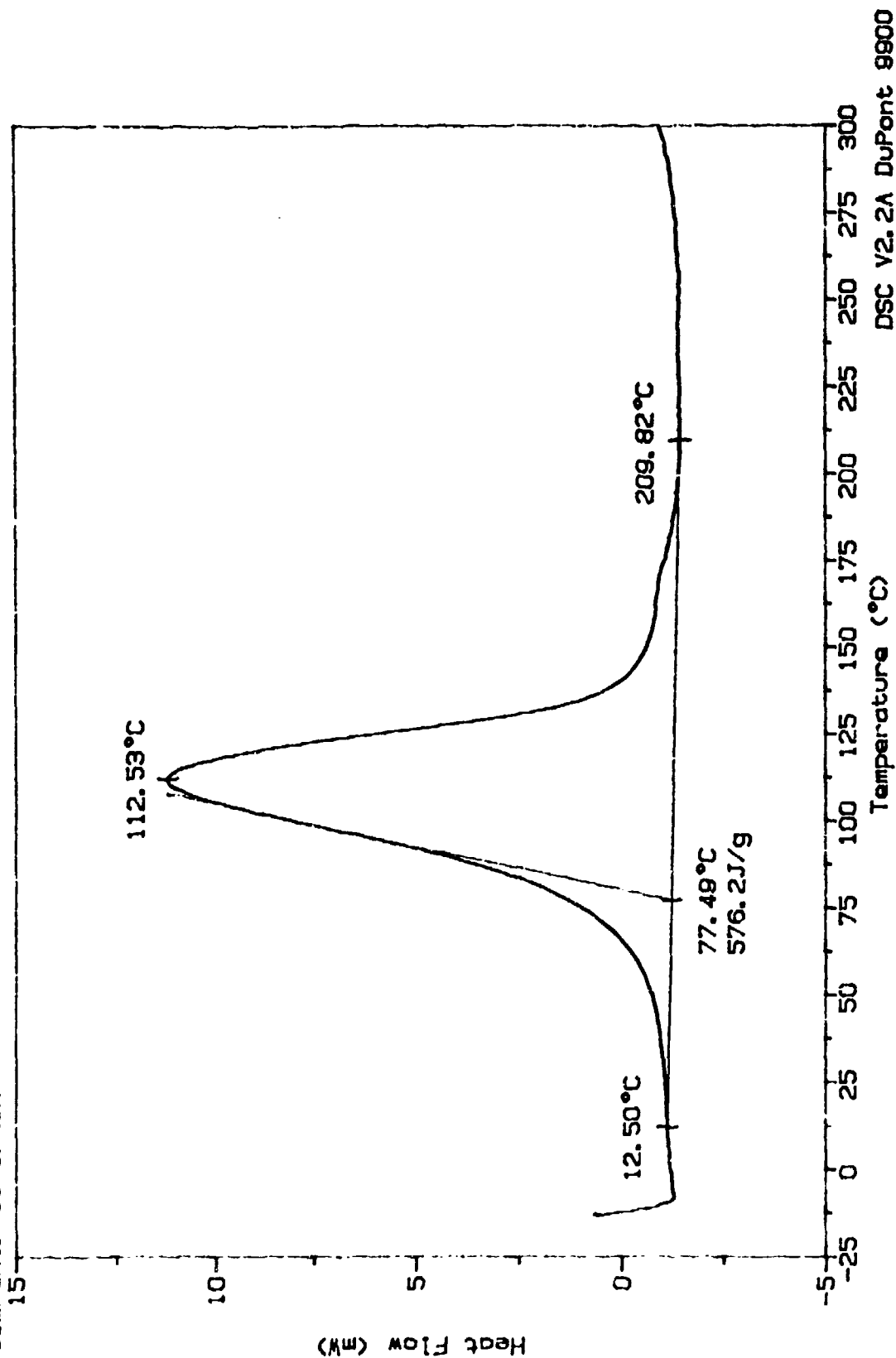


Figure M.7. Heat Release Curve for EA9396 Stored at 22°C (72°F) for 1 Month.

Sample: EA 9396 (1 mth @ 100°F)  
Size: 5.3540 mg  
Method: BMI-Ig & HR  
Comments: 10°C/min

DSC

File: DSC0392.01  
Operator: GALASKA  
Run Date: 12/19/88 09:40

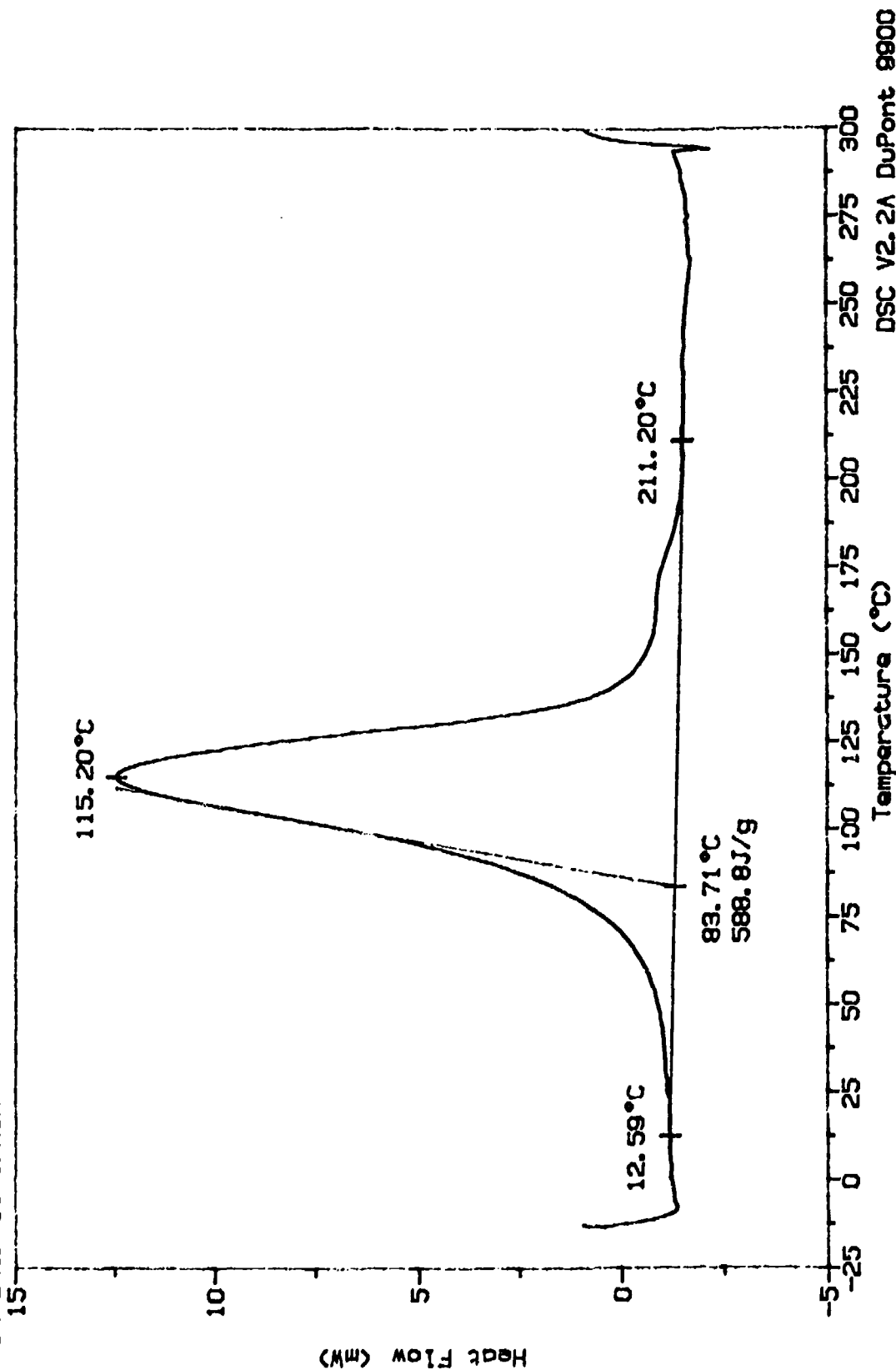


Figure M.8. Heat Release Curve for EA9396 Stored at 38°C (100°F) for 1 Month.

Sample: EA 9396 (1 mth @ 120°F)  
Size: 5.4340 mg  
Method: BMI-Tg & HR  
Comments: 10°C/min

DSC

File: DSC0333.01  
Operator: GALASKA  
Run Date: 12/19/88 12:08

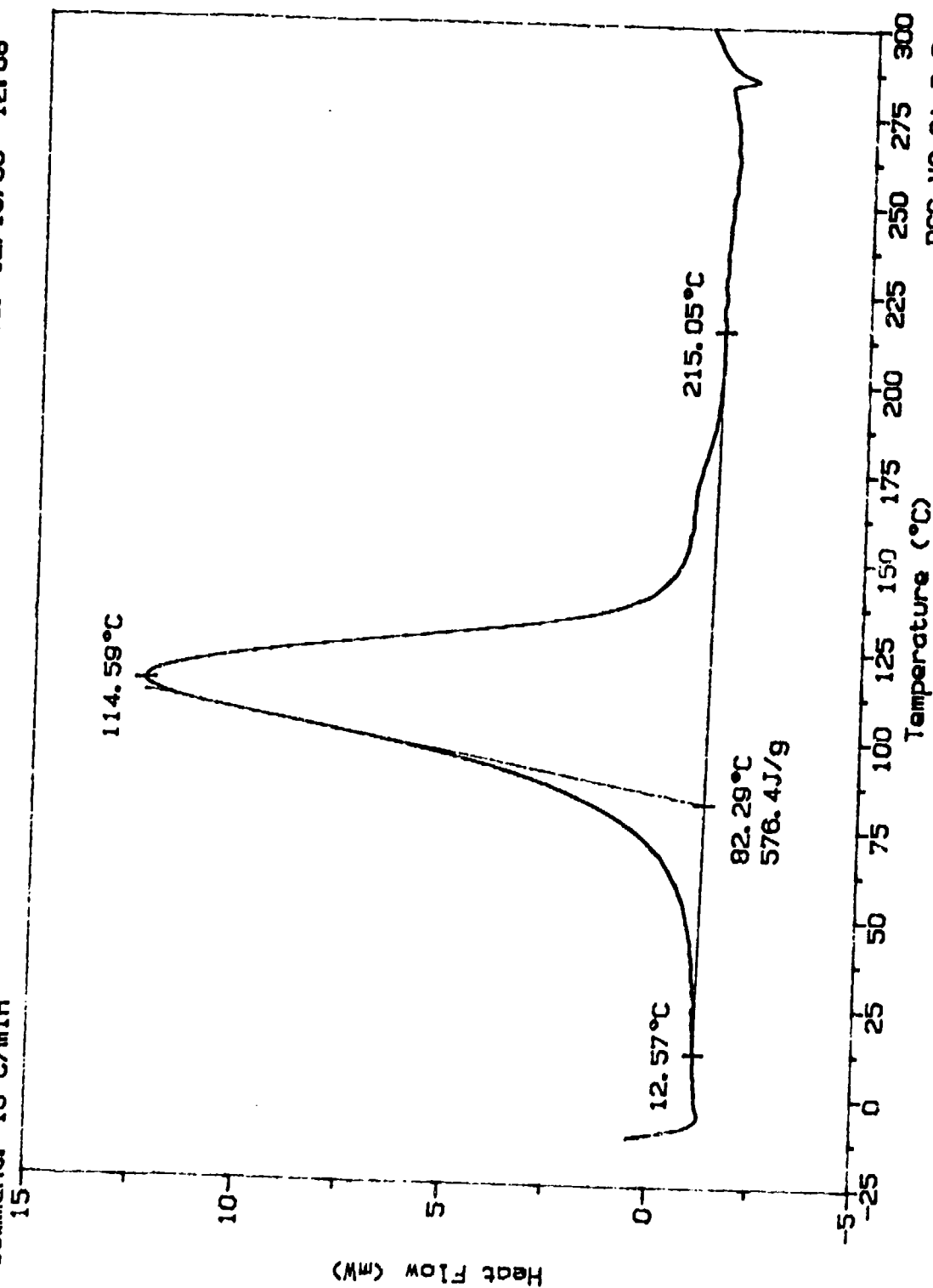


Figure M.9. Heat Release Curve for EA9396 Stored at 49°C (120°F) for 1 Month.

Sample: EA 9386 (3 mth @ RT)

Size: 5.1680 mg

Method: BMI-Tg & HR

Comments: 10°C/MIN-NIT

DSC

File: E1DSC0387.01

Operator: GALASKA

Run Date: 02/09/99 10:43

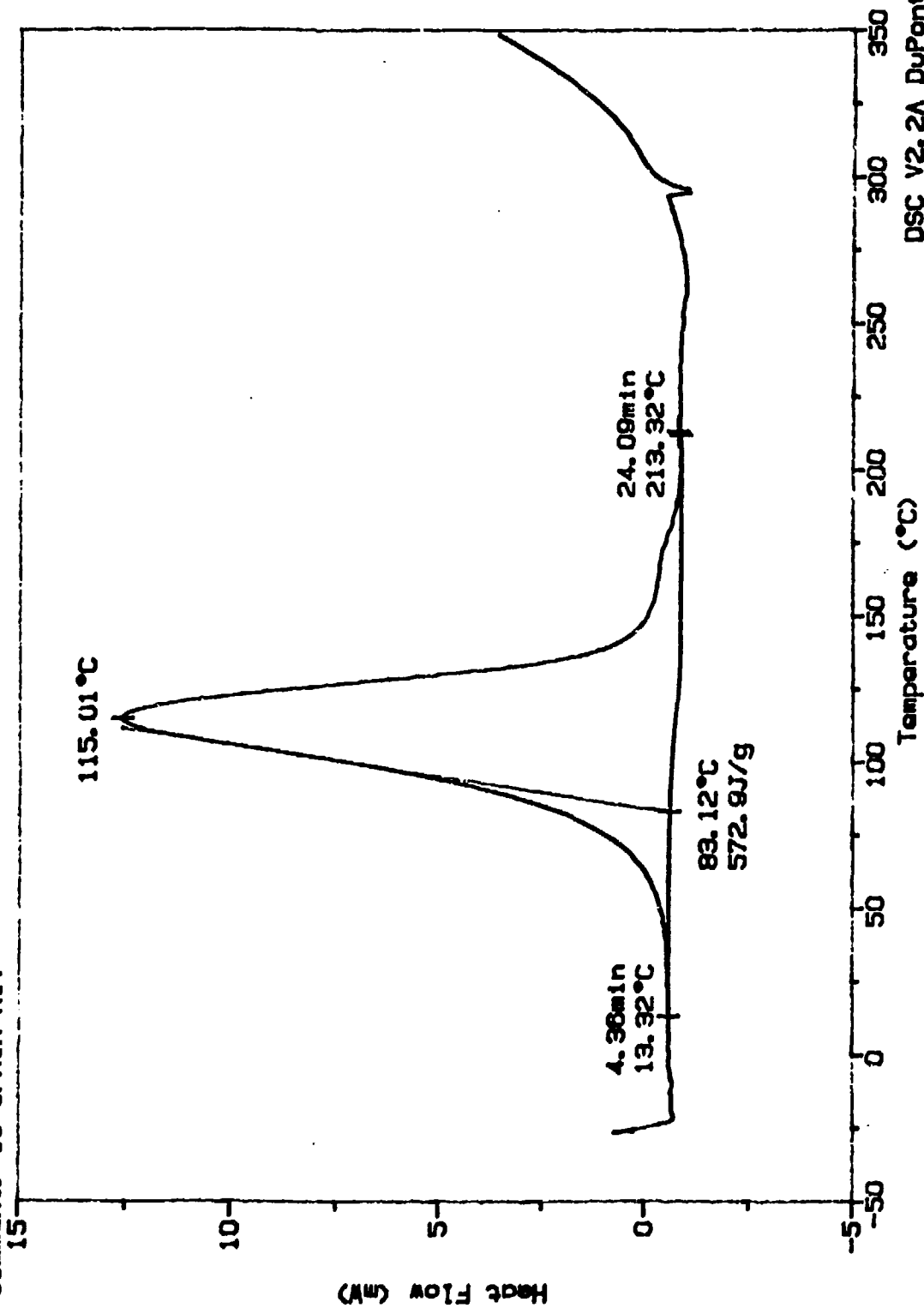


Figure M.10. Heat Release Curve for EA9396 Stored at 22°C (72°F) for 3 Months.

Sample: EA 9396 8 mth @ RT  
Size: 5.2100 mg  
Method: DSC-DYNAMIC TO 300°C  
Comments: 10°C/MIN, N2

DSC

File: DSC0547.01  
Operator: GALASKA  
Run Date: 18-May-89 14:27

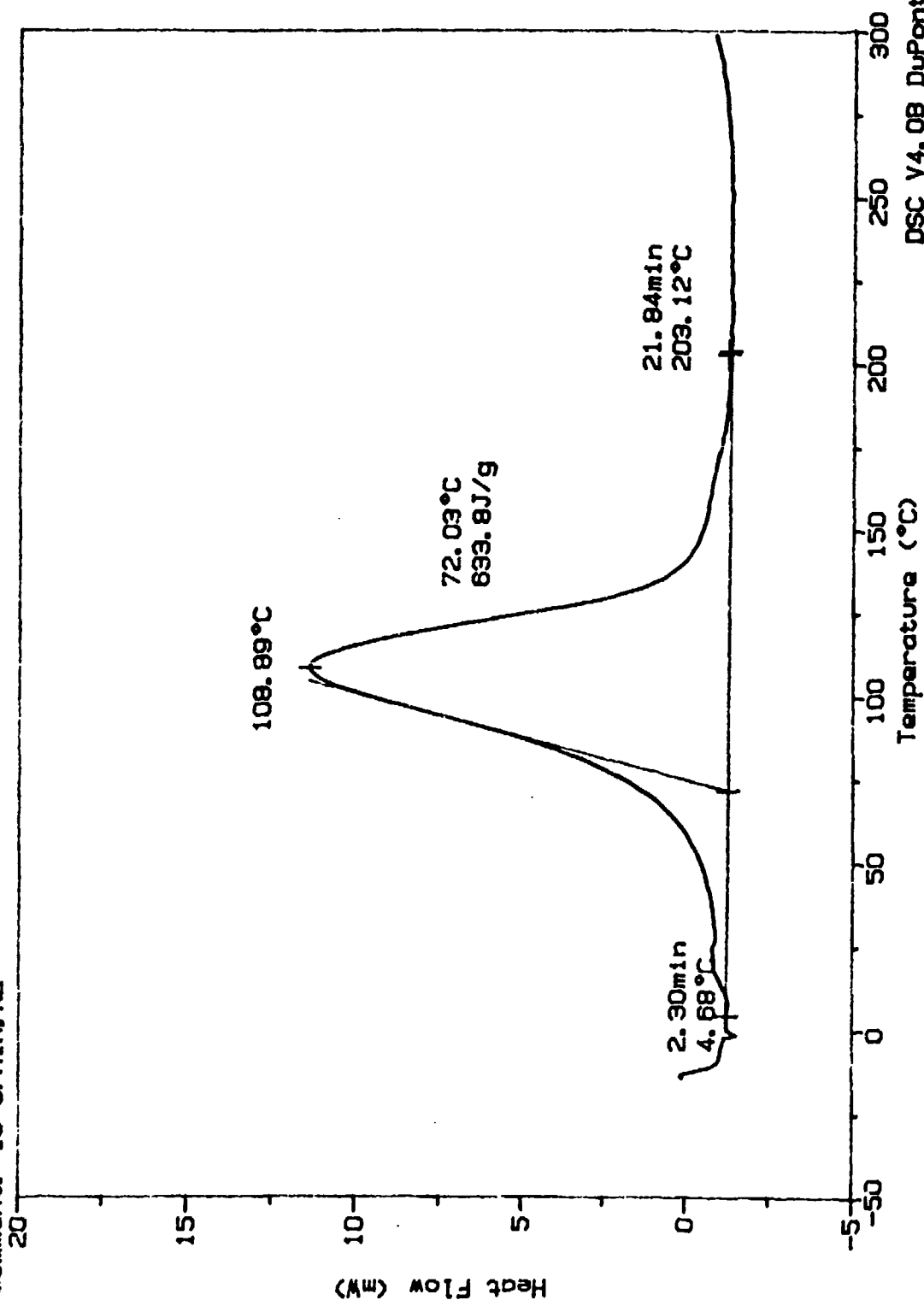


Figure M.11. Heat Release Curve for EA9396 Stored at 22°C (72°F) for 6 Months.



Sample: EA 9396 6 mth @ 100°F  
Size: 5.1780 mg  
Method: DSC-DYNAMIC TO 300°C  
Comment: 10°C/MIN, N2

DSC

File: DSC0548.01  
Operator: GALASKA  
Run Date: 16-May-89 12:32

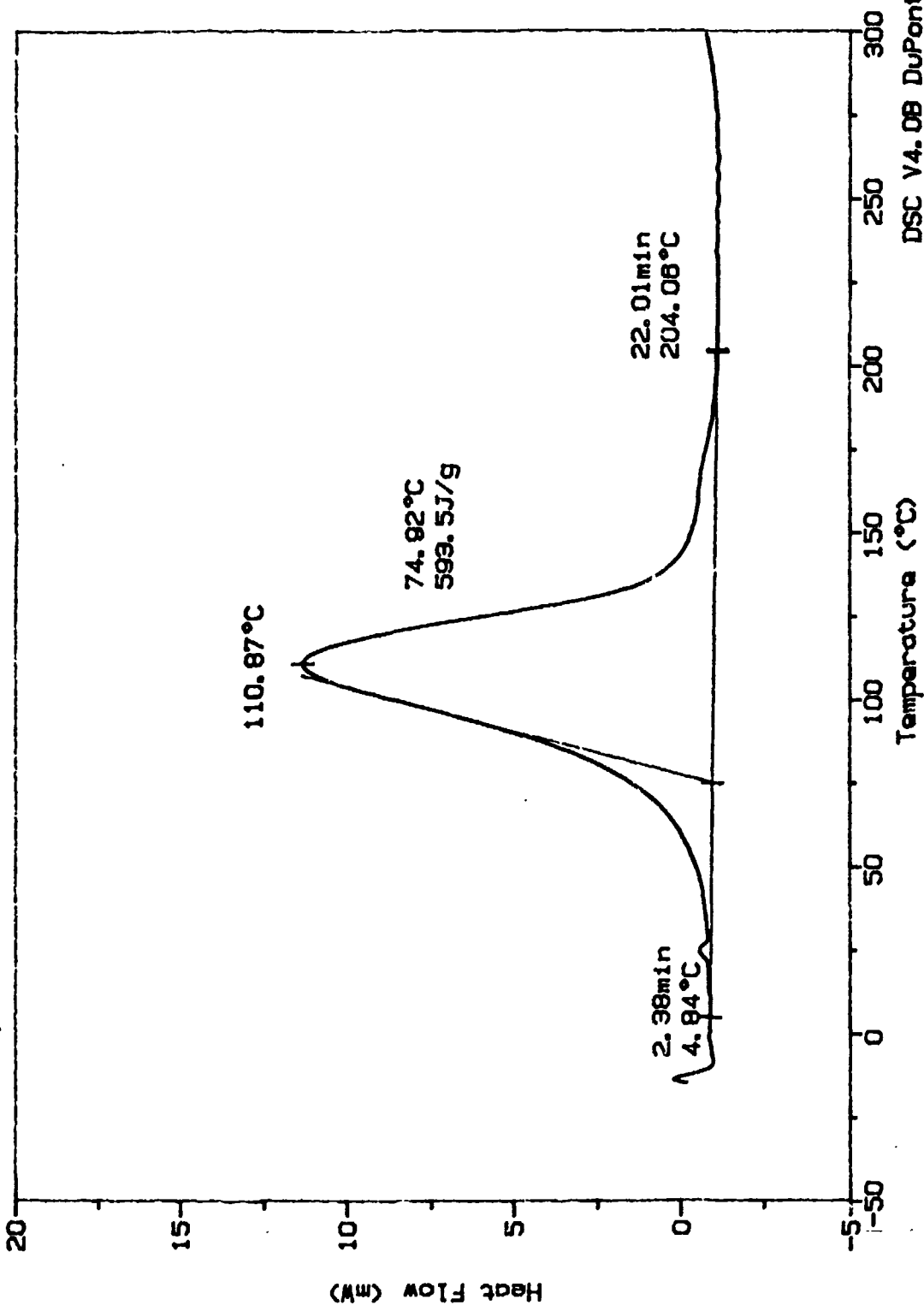


Figure M.12. Heat Release Curve for EA9396 Stored at 38°C (100°F) for 6 Months.

Sample: EA 9396 8 mth @ 120°F  
Size: 8.5940 mg  
Method: DSC-DYNAMIC TO 300°C  
Comment: 10°C/MIN, N2

DSC

File: DSC0545.01  
Operator: GALASKA  
Run Date: 18-May-88 11:24

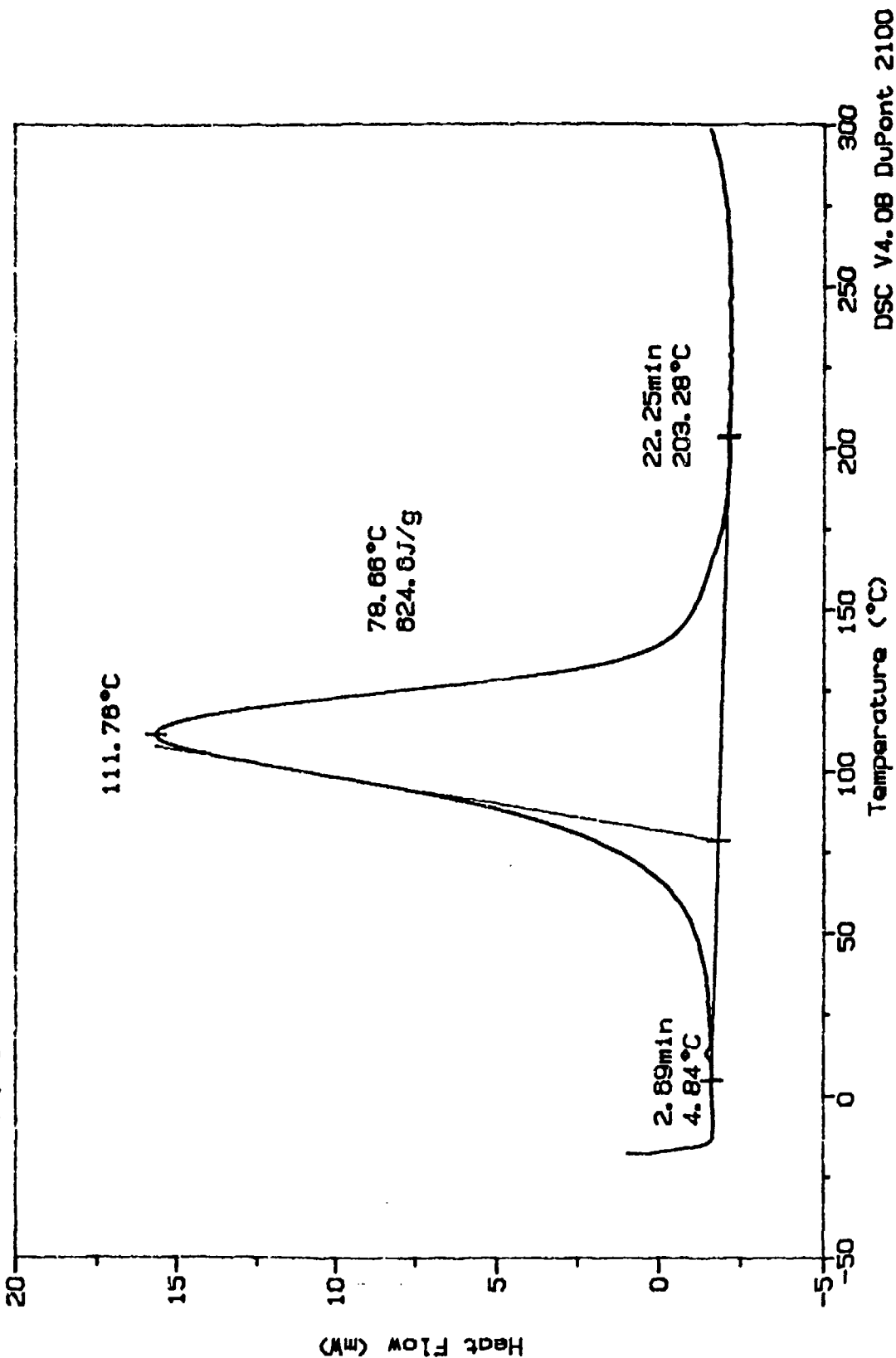


Figure M.13. Heat Release Curve for EA9396 Stored at 49°C (120°F) for 6 Months.

Sample: EA 9396 1 yr 0 RT  
Size: 4.6700 mg  
Method: DSC-HI-TEMP  
Comment: 10°/MIN. NIT

DSC

File: DSC0970.01  
Operator: GALASKA  
Run Date: 17-Nov-89 09:07

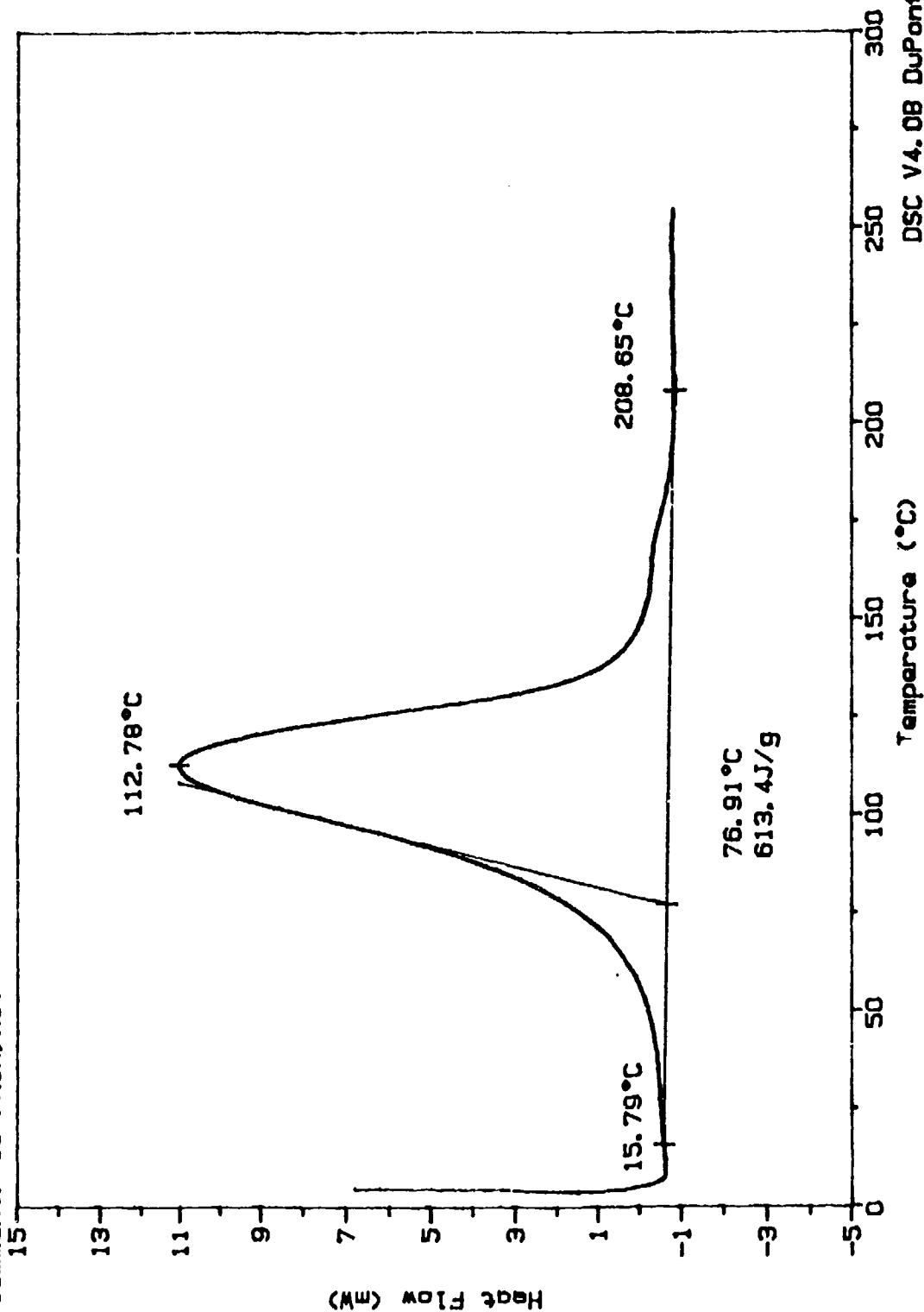


Figure M.14. Heat Release Curve for EA9396 Stored at 22°C (72°F) for 12 Months.

Sample: EA 9398 1 yr @ 100°F  
Size: 5.7120 mg  
Method: DSC-HI-TEMP  
Comments: 10°/MIN,NIT

DSC

File: DSC0972.01  
Operator: GALASKA  
Run Date: 17-Nov-89 10.50

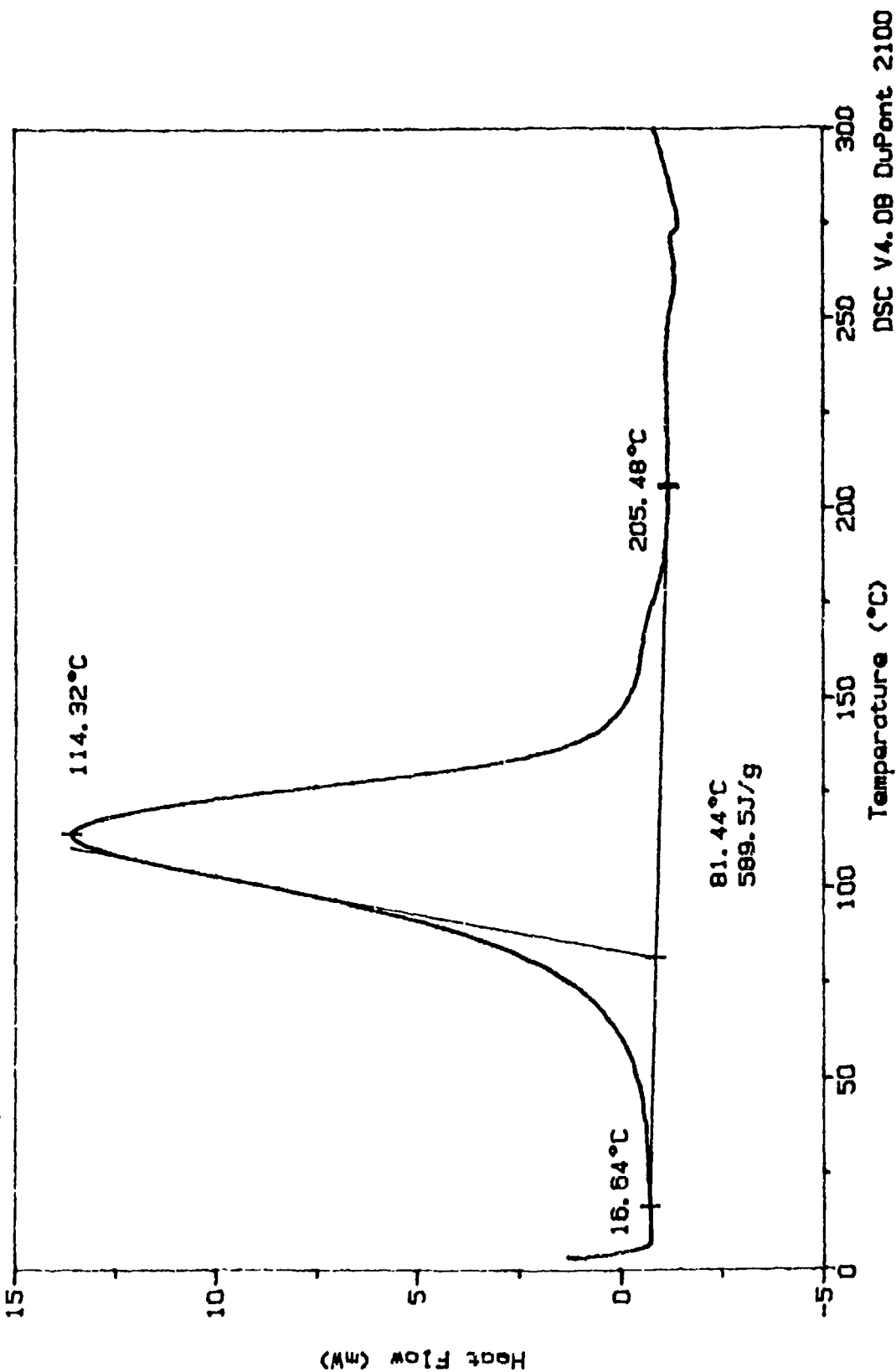


Figure M.15. Heat Release Curve for EA9396 Stored at 38°C (100°F) for 12 Months.

Sample: EA 9396 1 yr @ 120°F  
 Size: 5.0580 mg  
 Method: DSC-HI-TEMP  
 Comment: 10°/MIN.NIT

DSC

File: DSC0971.D1  
 Operator: GALASKA  
 Run Date: 17-Nov-89 10:06

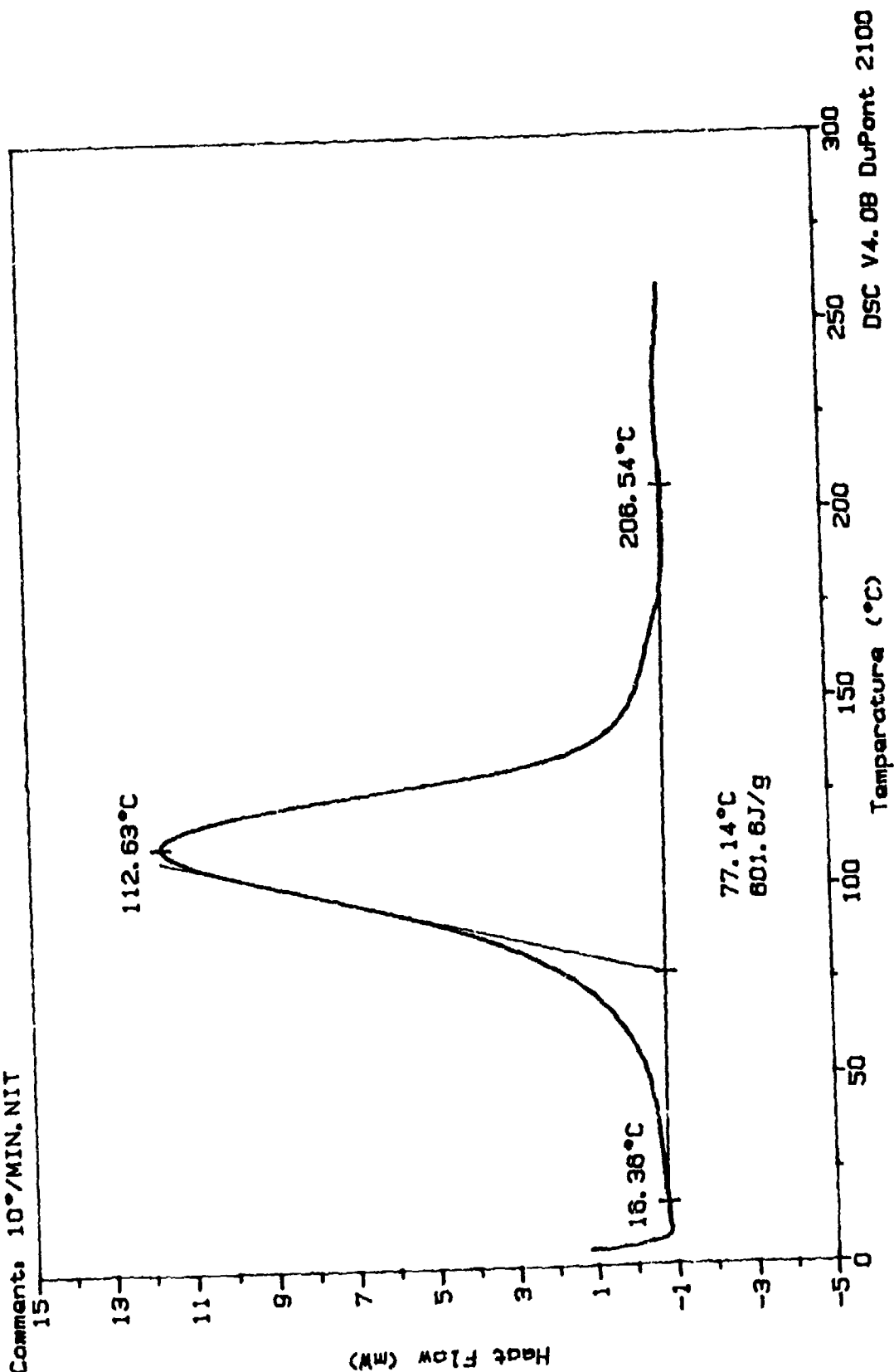


Figure M.16. Heat Release Curve for EA9396 Stored at 49°C (120°F) for 12 Months.

Sample: EA 9396 18 m RT  
Size: 6.7880 mg  
Method: DSC-HIGH TEMP  
Comment: 10°C/MIN

DSC

File: DSC1151.01  
Operator: GALASKA  
Run Date: 21-May-90 11:14

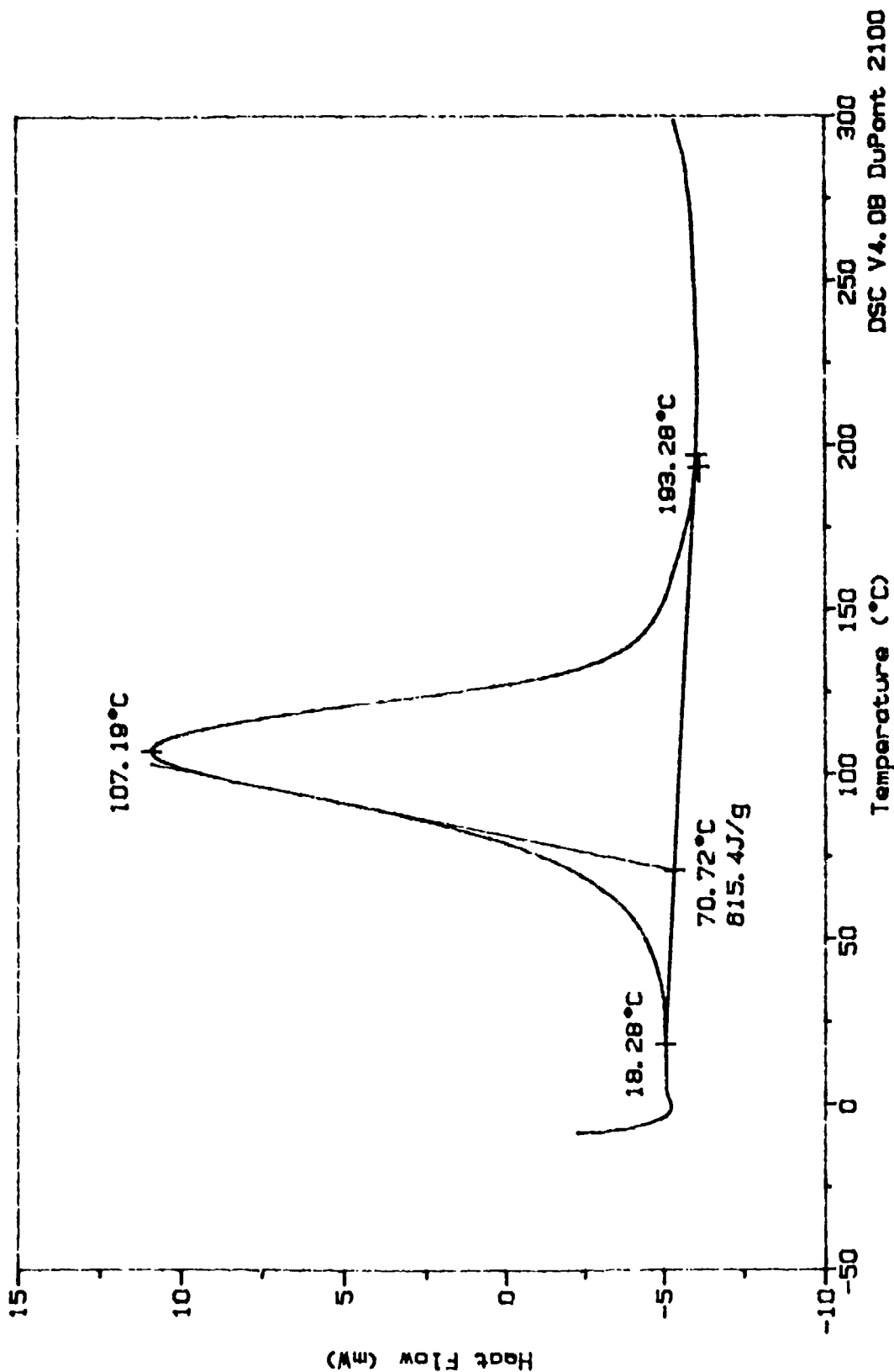


Figure M.17. Heat Release Curve for EA9396 Stored at 22°C (72°F) for 18 Months.

Sample: EA 9396 18 m @ 100°F  
Size: 7.0800 mg  
Method: DSC-HIGH TEMP  
Comment: 10°C/MIN

DSC

File: DSC1152.01  
Operator: CALASKA  
Run Date: 21-May-90 13:41

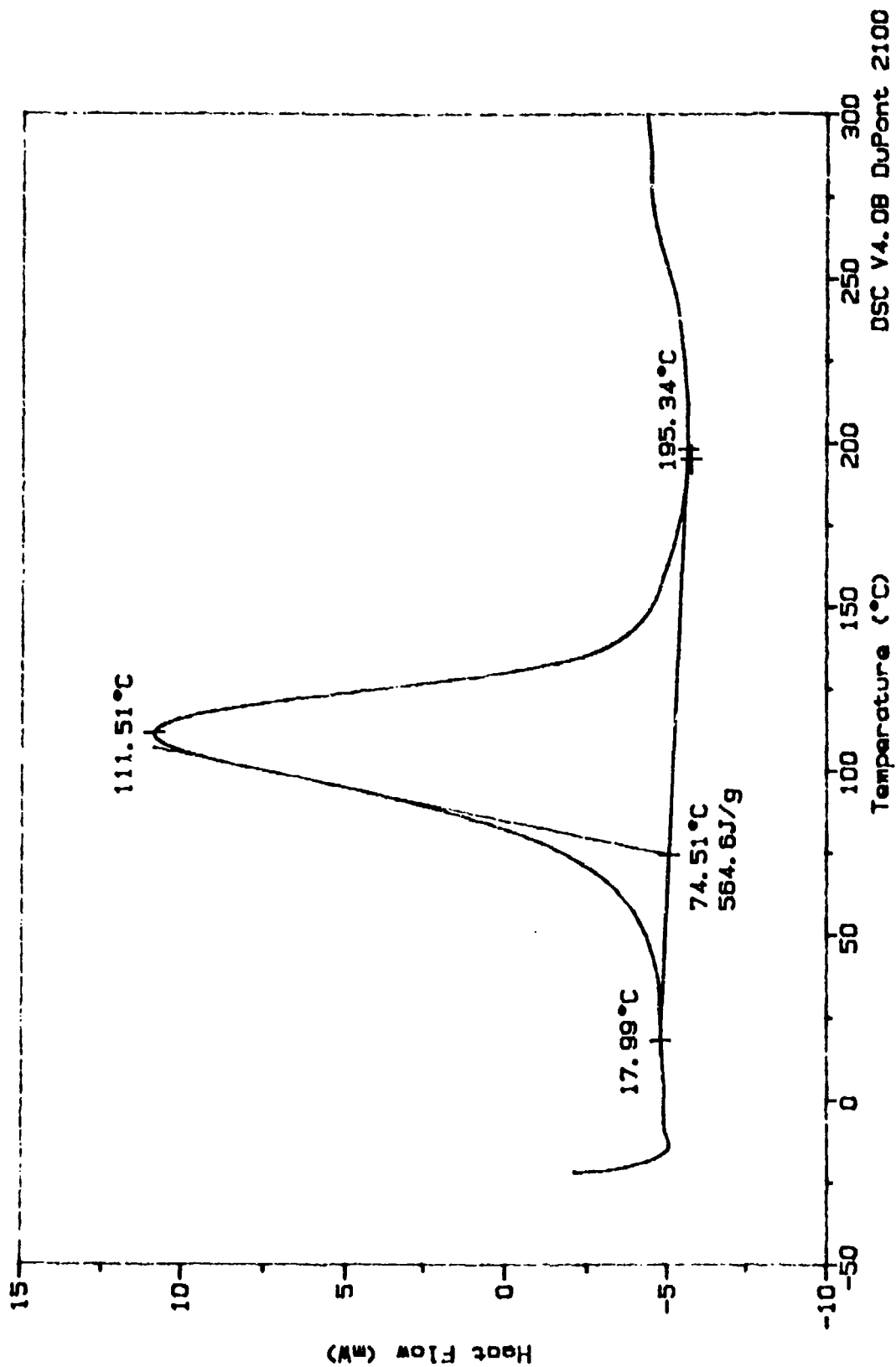


Figure M.18. Heat Release Curve for EA9396 Stored at 38°C (100°F) for 18 Months.

Sample: EA 9396 18 m @ 120°F  
Size: 6.2500 mg  
Method: DSC-HIGH TEMP  
Comment: 10°C/MIN

DSC

File: DSC1153.01  
Operator: GALASKA  
Run Date: 21-May-90 15:23

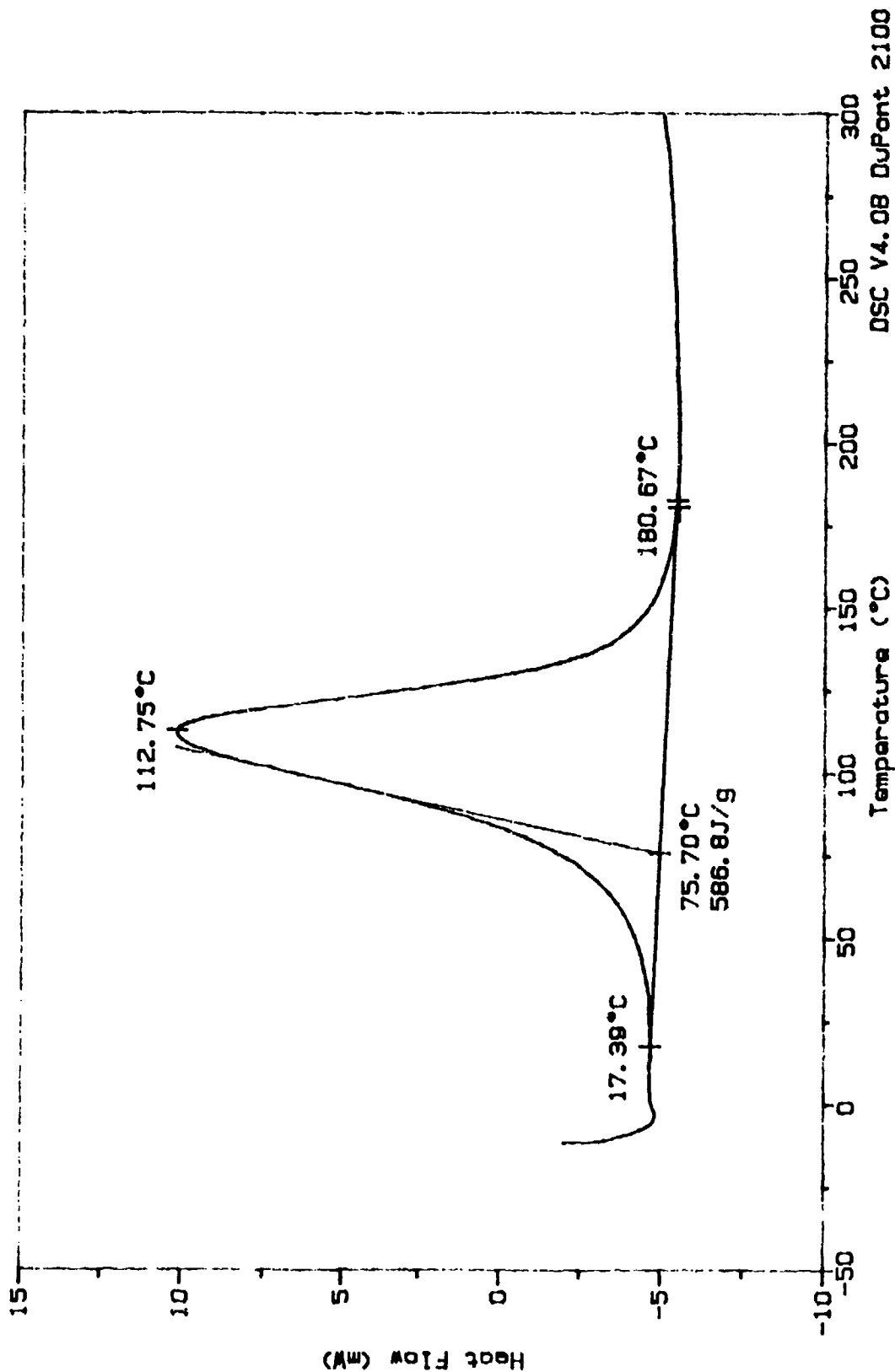


Figure M.19. Heat Release Curve for EA9396 Stored at 49°C (120°F) for 18 Months.



Sample: EA 9396 2 YR @ RT  
Size: 5.3760 mg  
Method: BMI-TG & HR  
Comment: 10°C/MIN.NIT

DSC

File: NDSC178.01  
Operator: GALASKA  
Run Date: 20-Nov-90 09:00

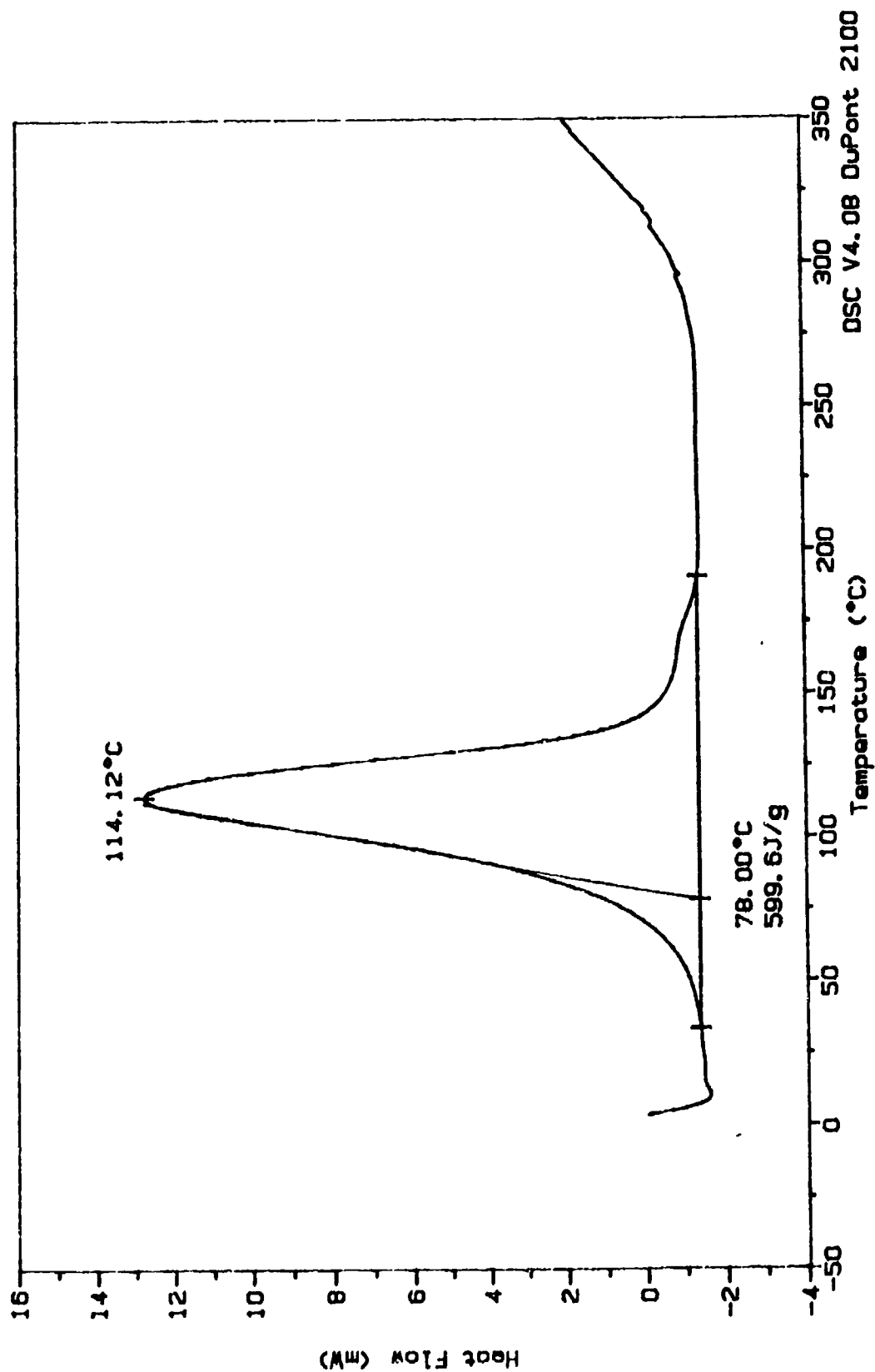


Figure M.20. Heat Release Curve for EA9396 Stored at 22°C (72°F) for 24 Months.

Sample: EA 9396 2 YR @ 100°F  
Size: 4.1800 mg  
Method: BMI-TG & HR  
Comment: 10°C/MIN.NIT

DSC

File: NOSC179.01  
Operator: GALASKA  
Run Date: 20-Nov-90 10:25

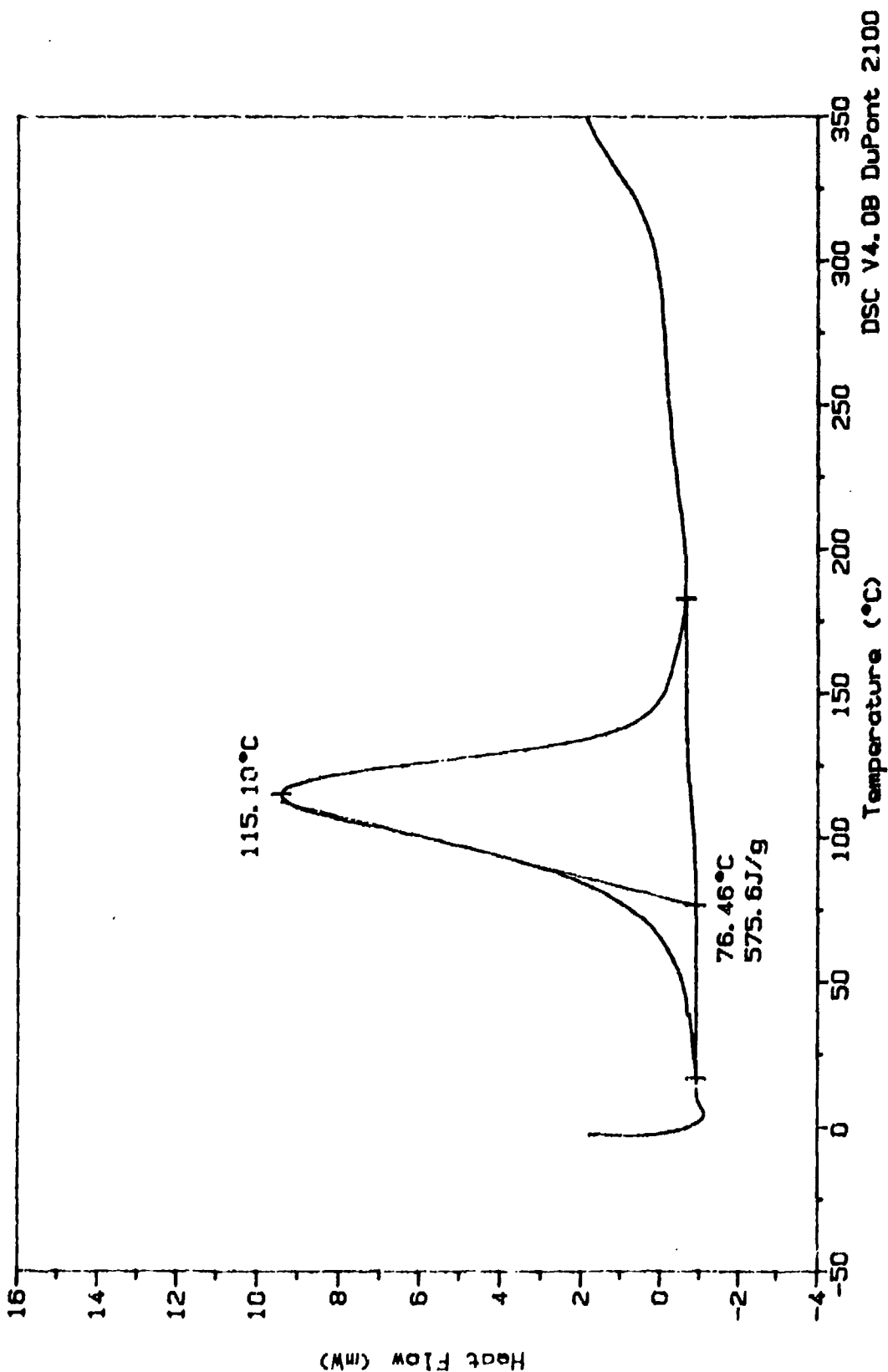


Figure M.21. Heat Release Curve for EA9396 Stored at 38°C (100°F) for 24 Months.

Sample: EA 9396 2 YR @ 120°F  
Size: 4.9140 mg  
Method: BMI-TG & HR  
Comments: 10°C/MIN, NIT

DSC

File: NDSC180.01  
Operator: GALASKA  
Run Date: 20-Nov-90 11:22

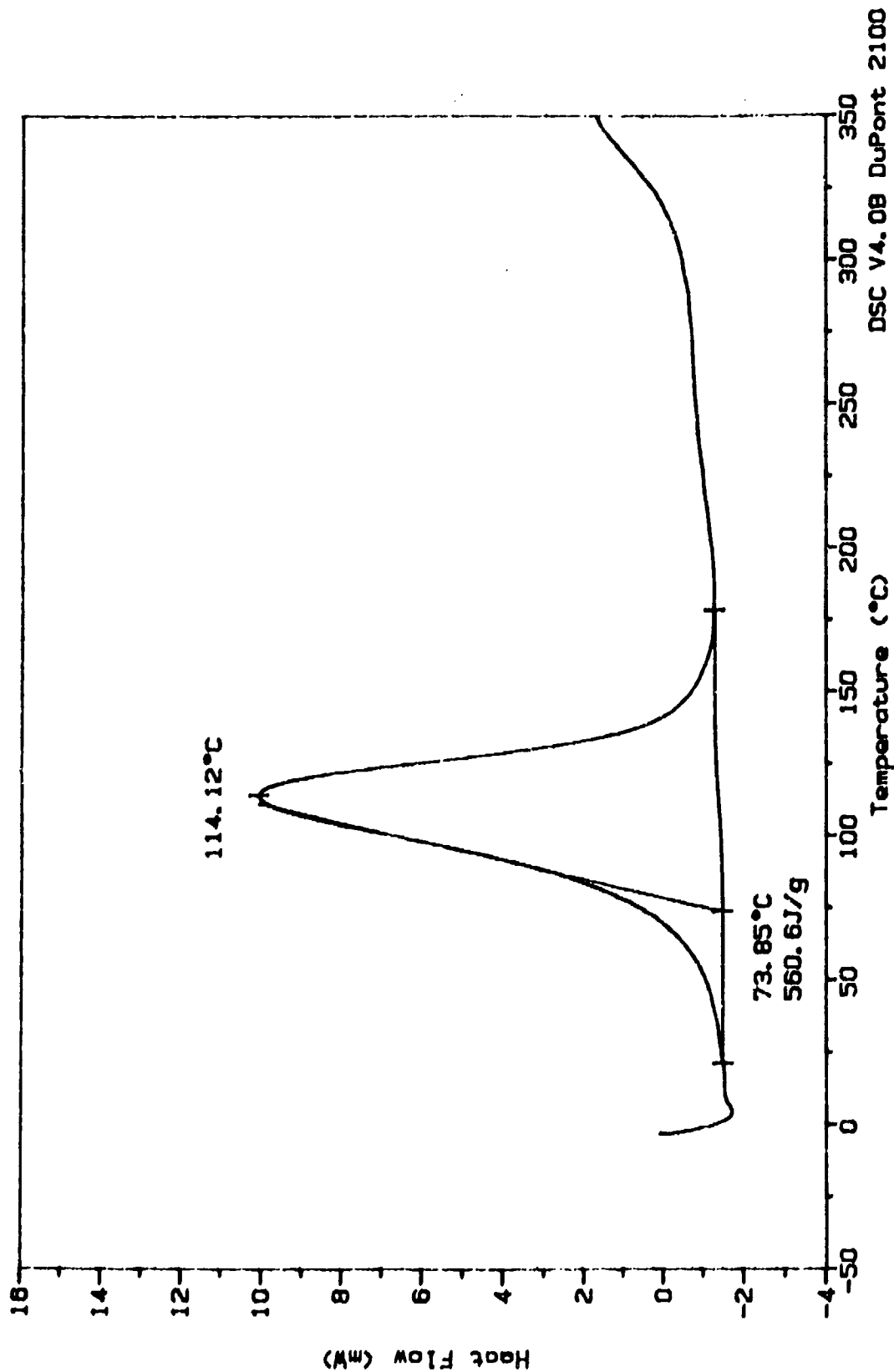


Figure M.22. Heat Release Curve for EA9396 Stored at 49°C (120°F) for 24 Months.

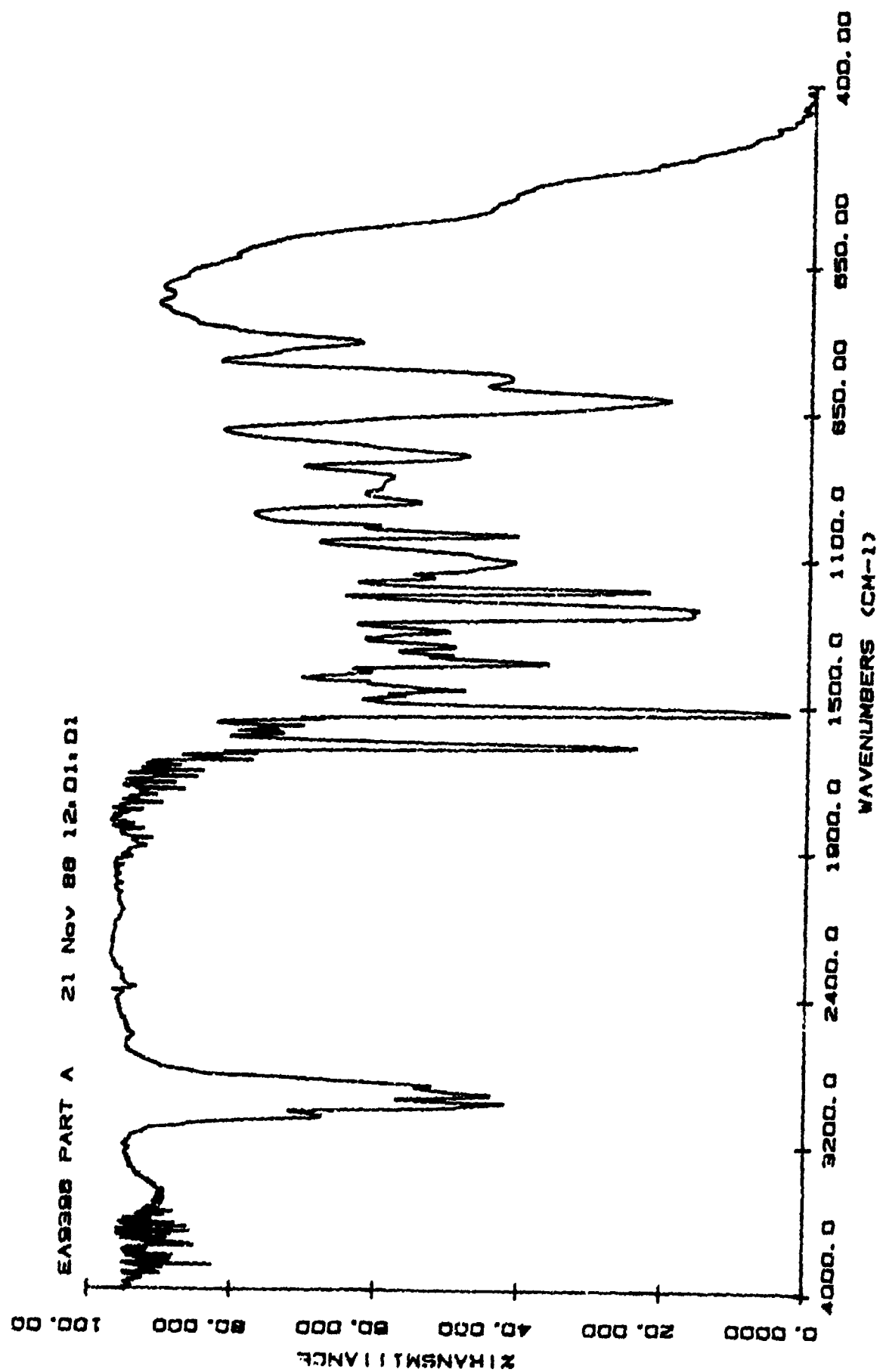


Figure M.23. FTIR Spectra for EA9396, Part A, Initial.

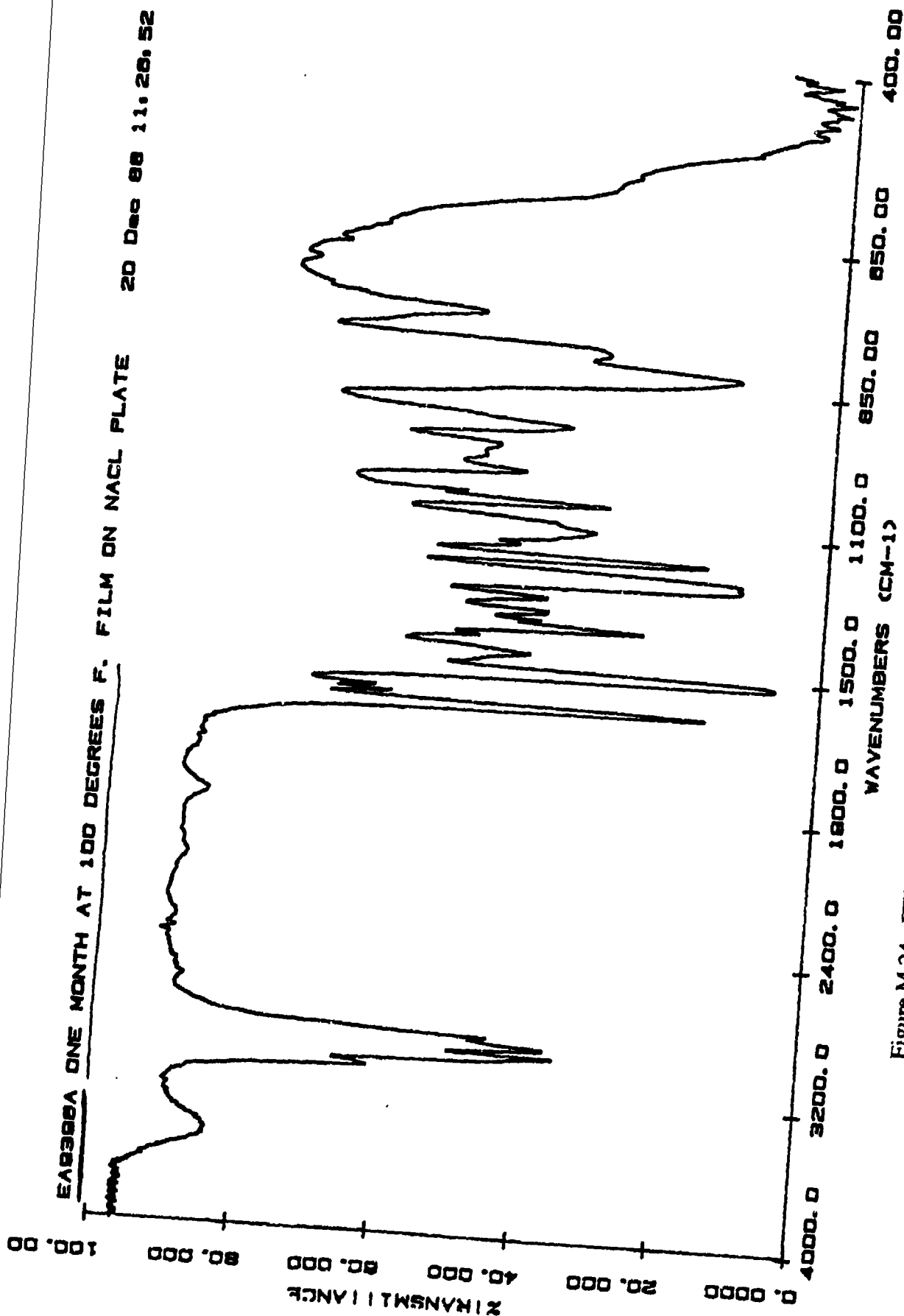


Figure M.24. FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 1 Month.

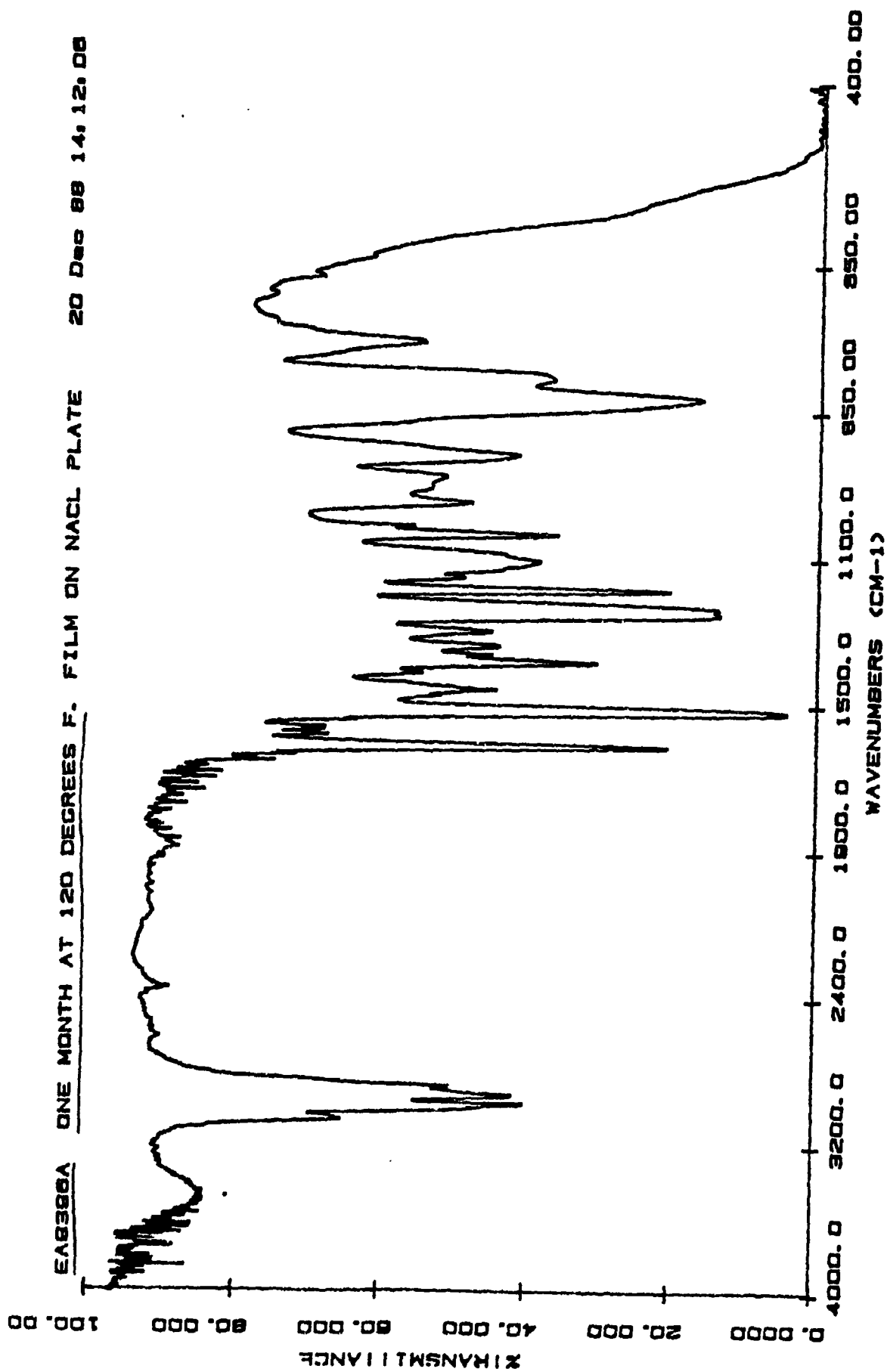


Figure M.25. FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 1 Month.

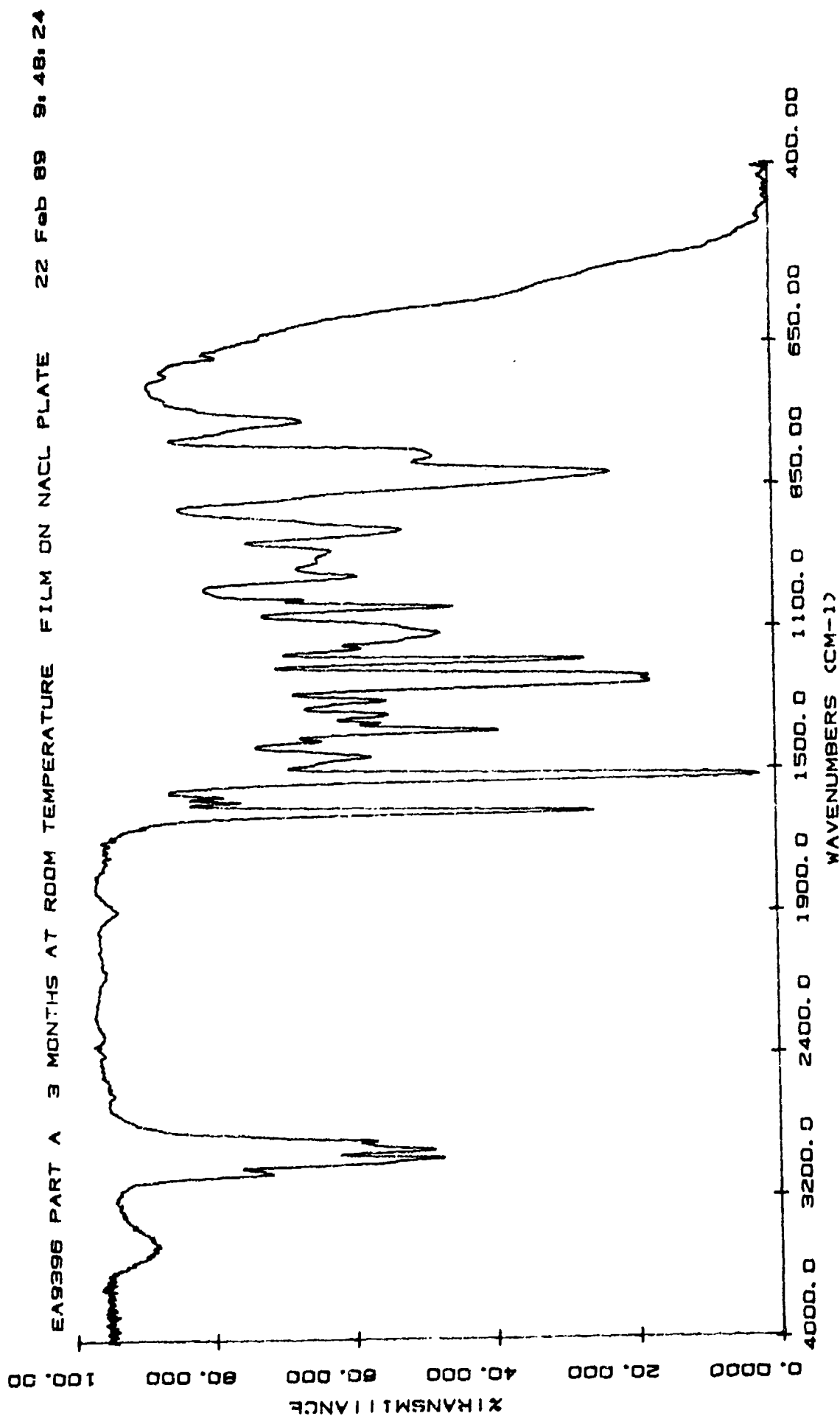


Figure M.26. FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 3 Months.

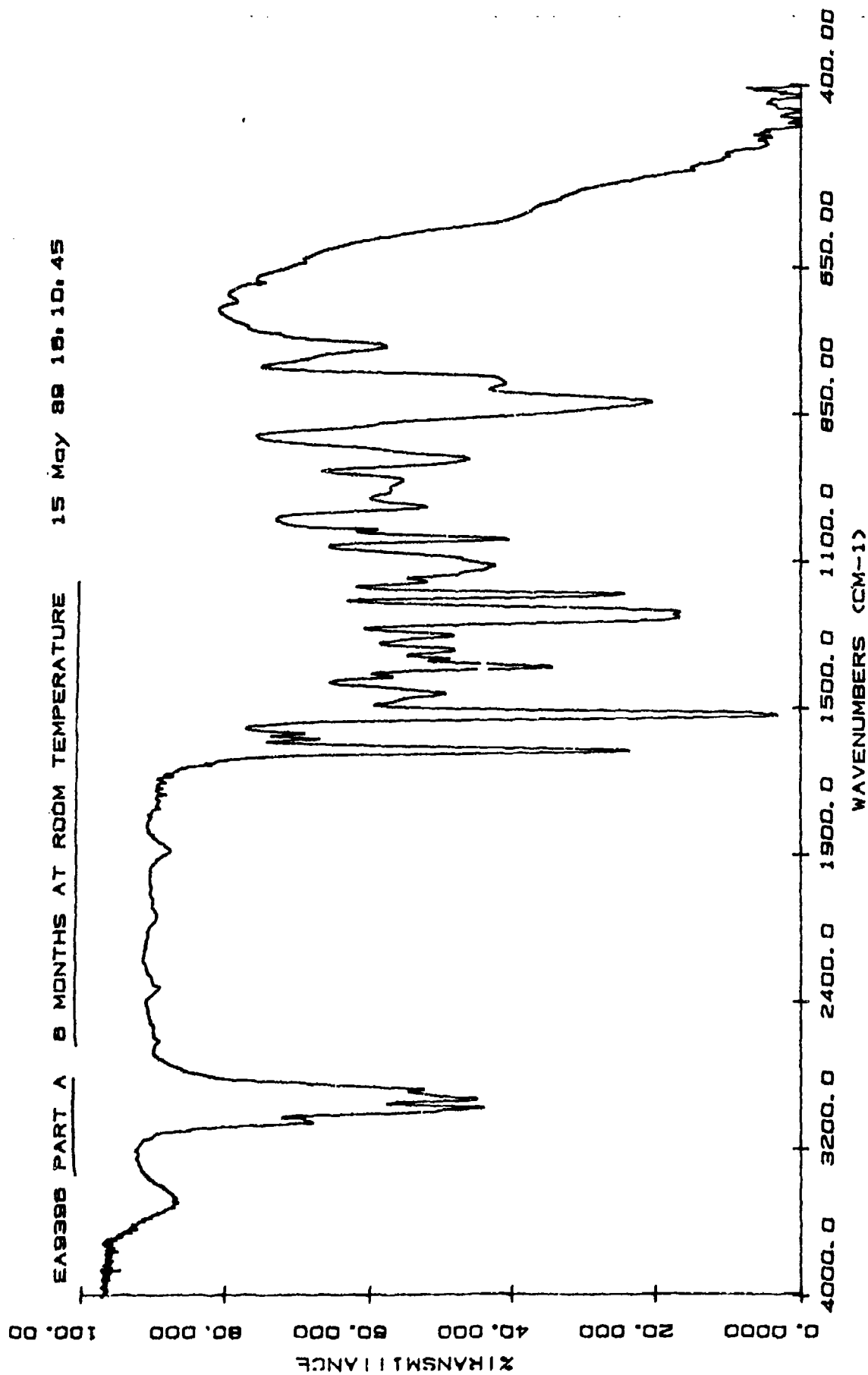


Figure M.27. FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 6 Months.



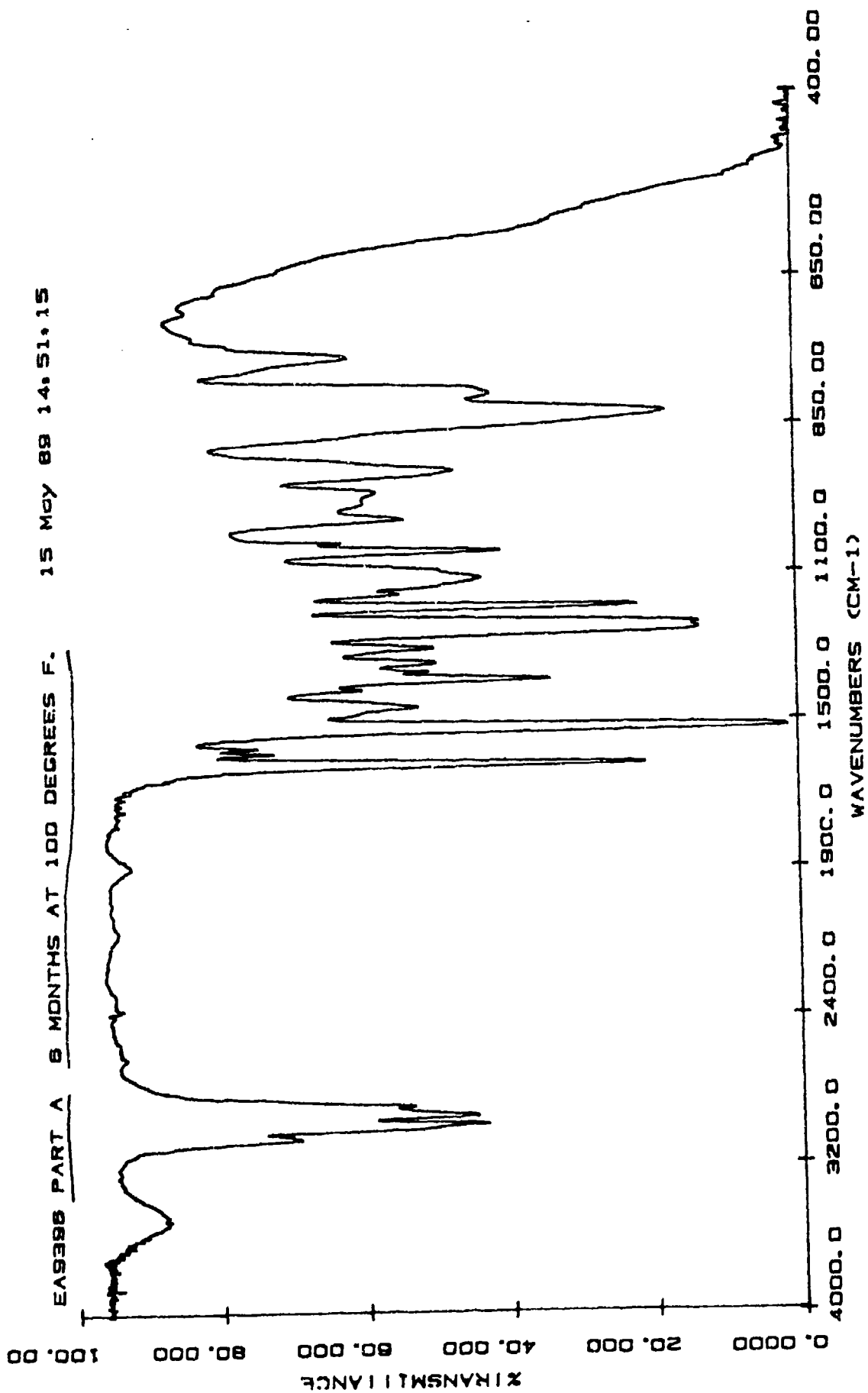


Figure M.28. FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 6 Months.

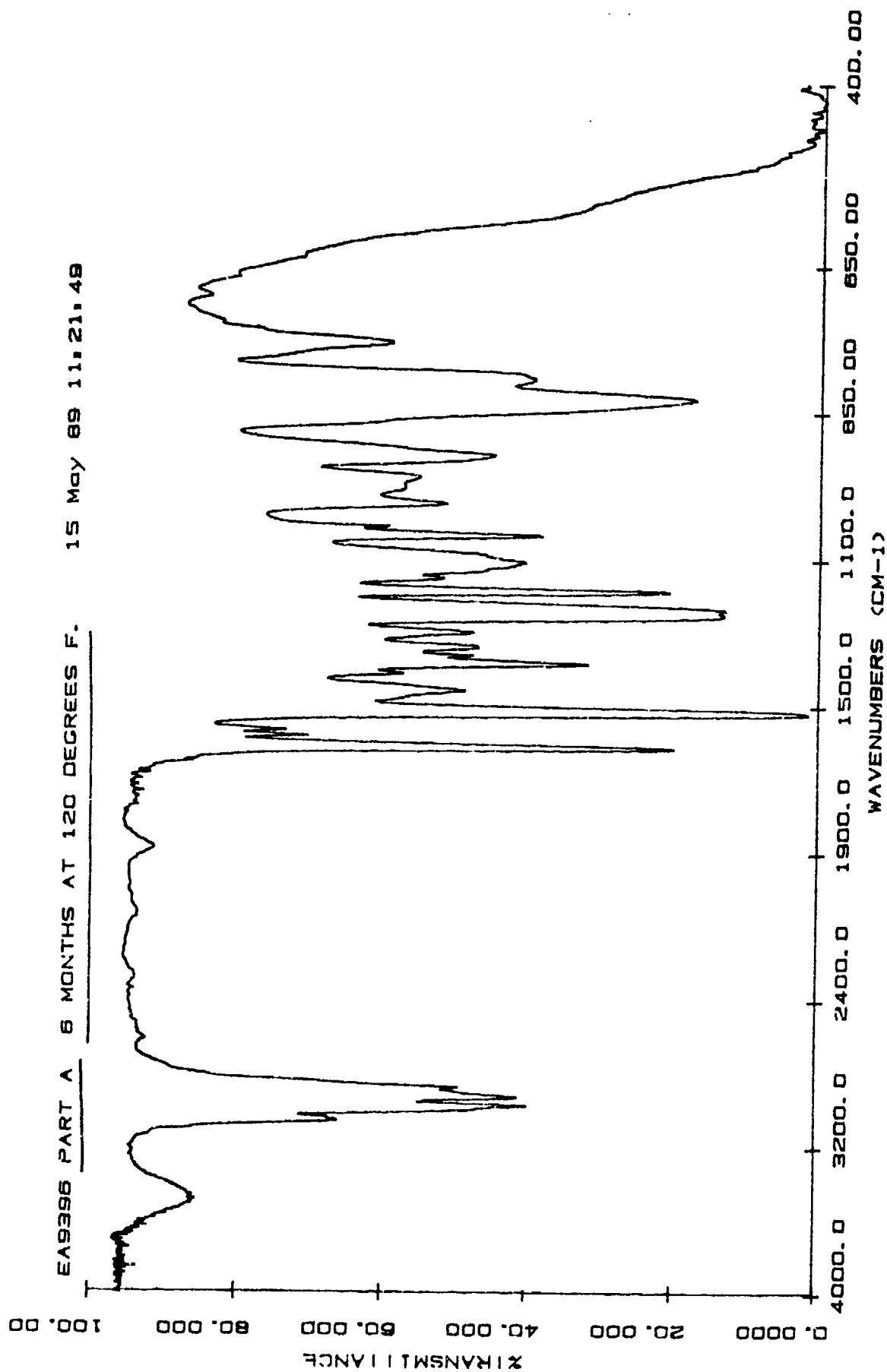


Figure M.29. FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 6 Months.

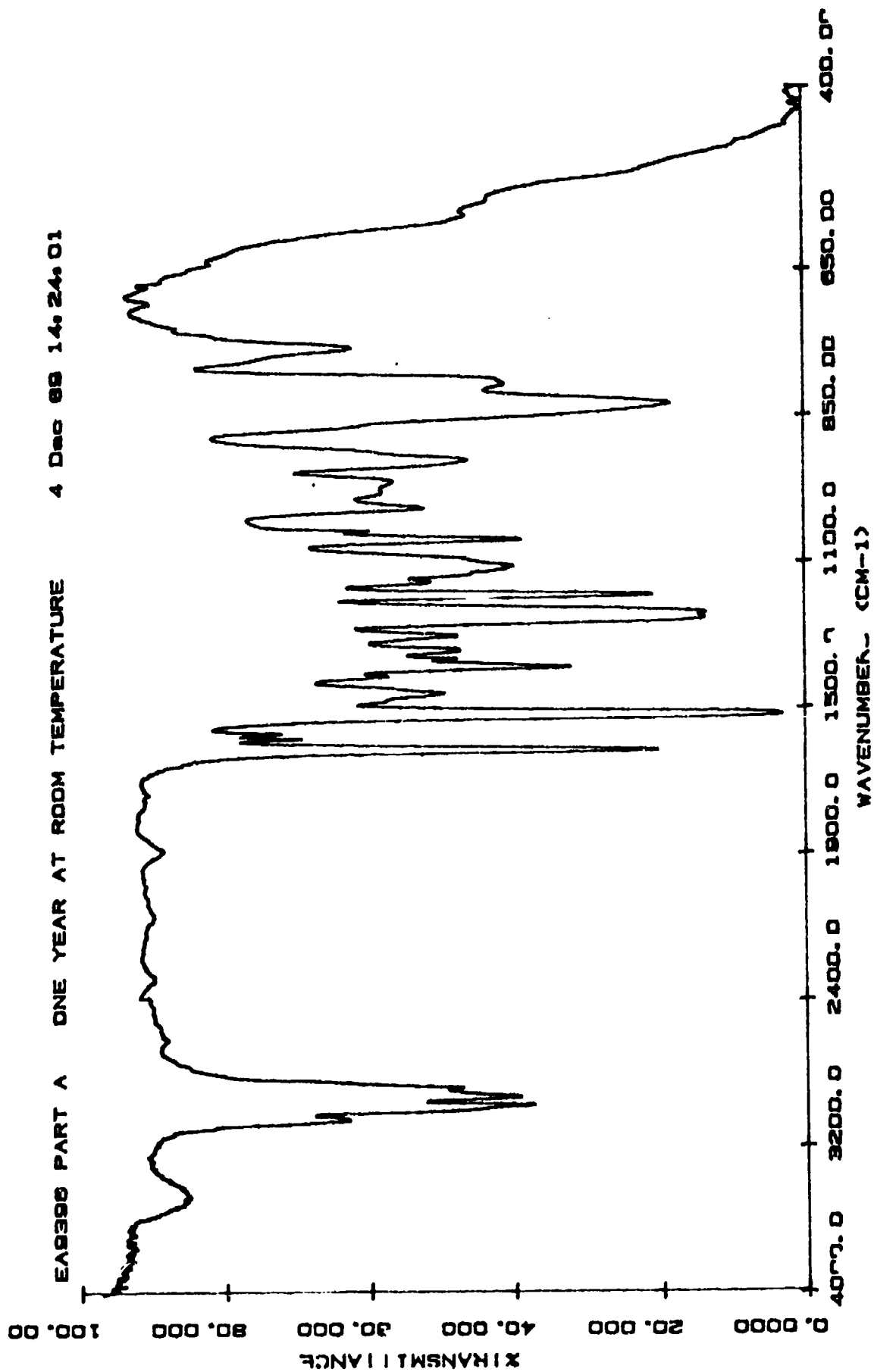


Figure M.30. FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 12 Months.

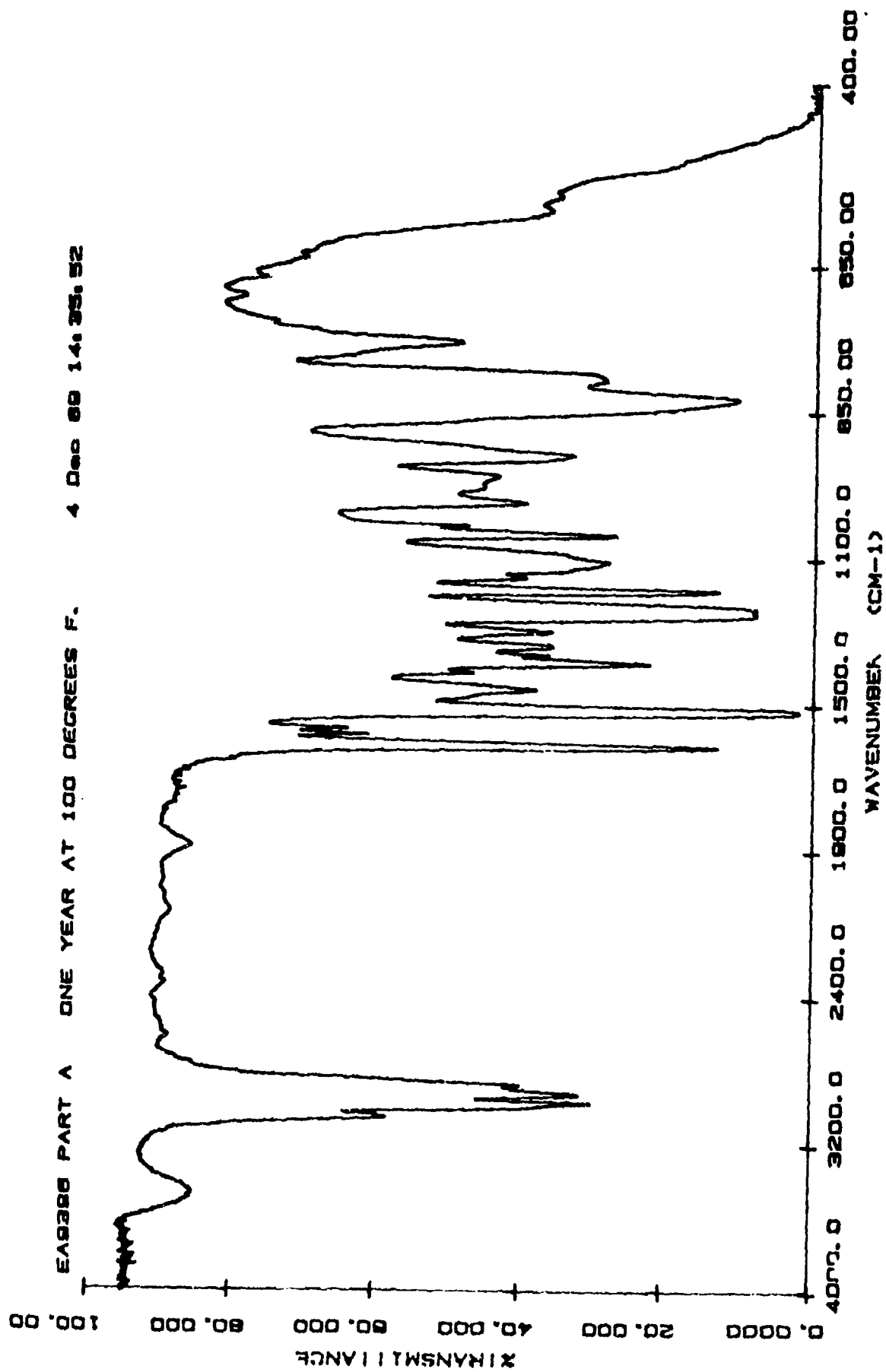


Figure M.31. FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 12 Months.

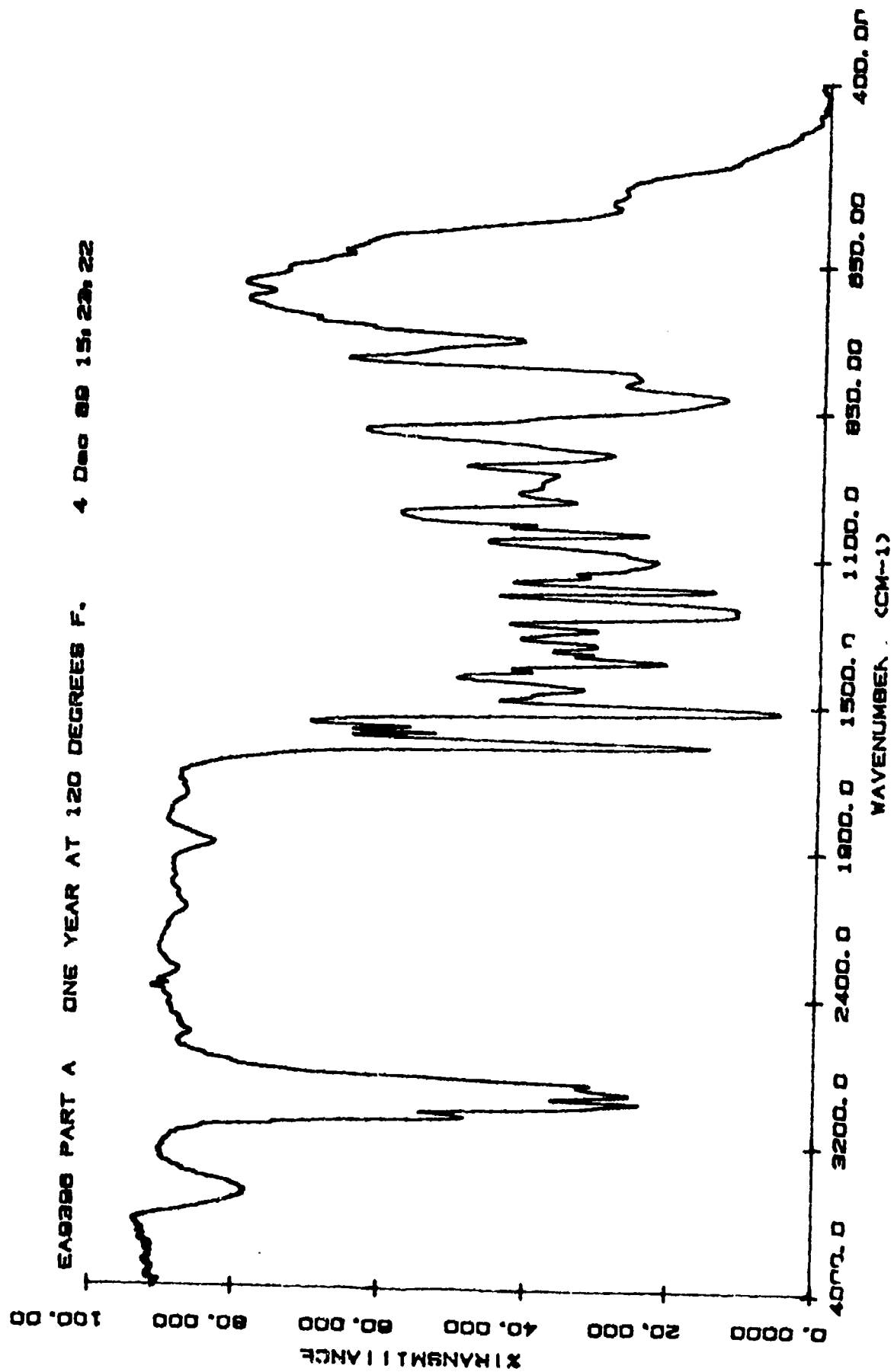


Figure M.32. FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 12 Months.

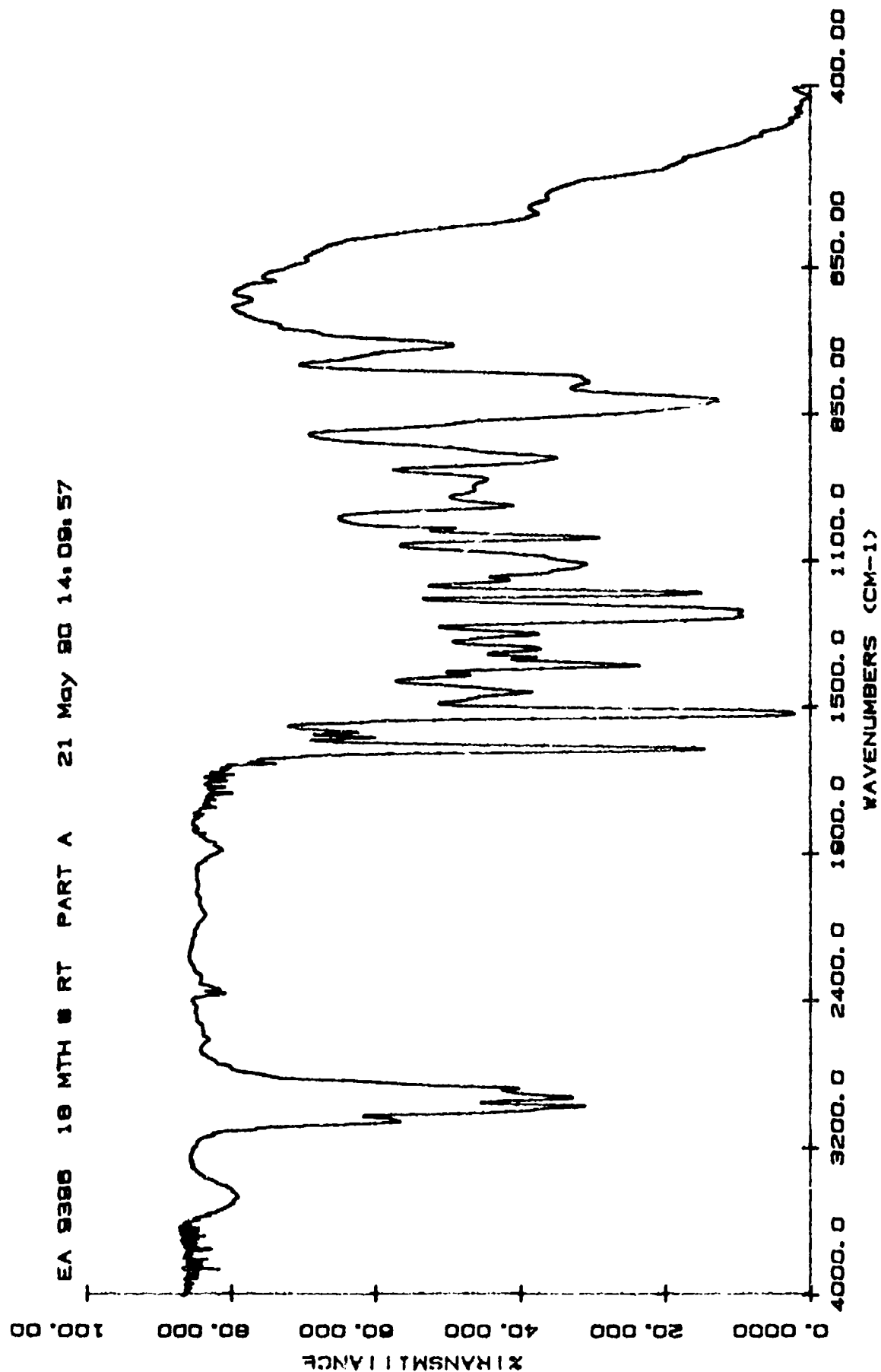


Figure M.33. FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 18 Months.

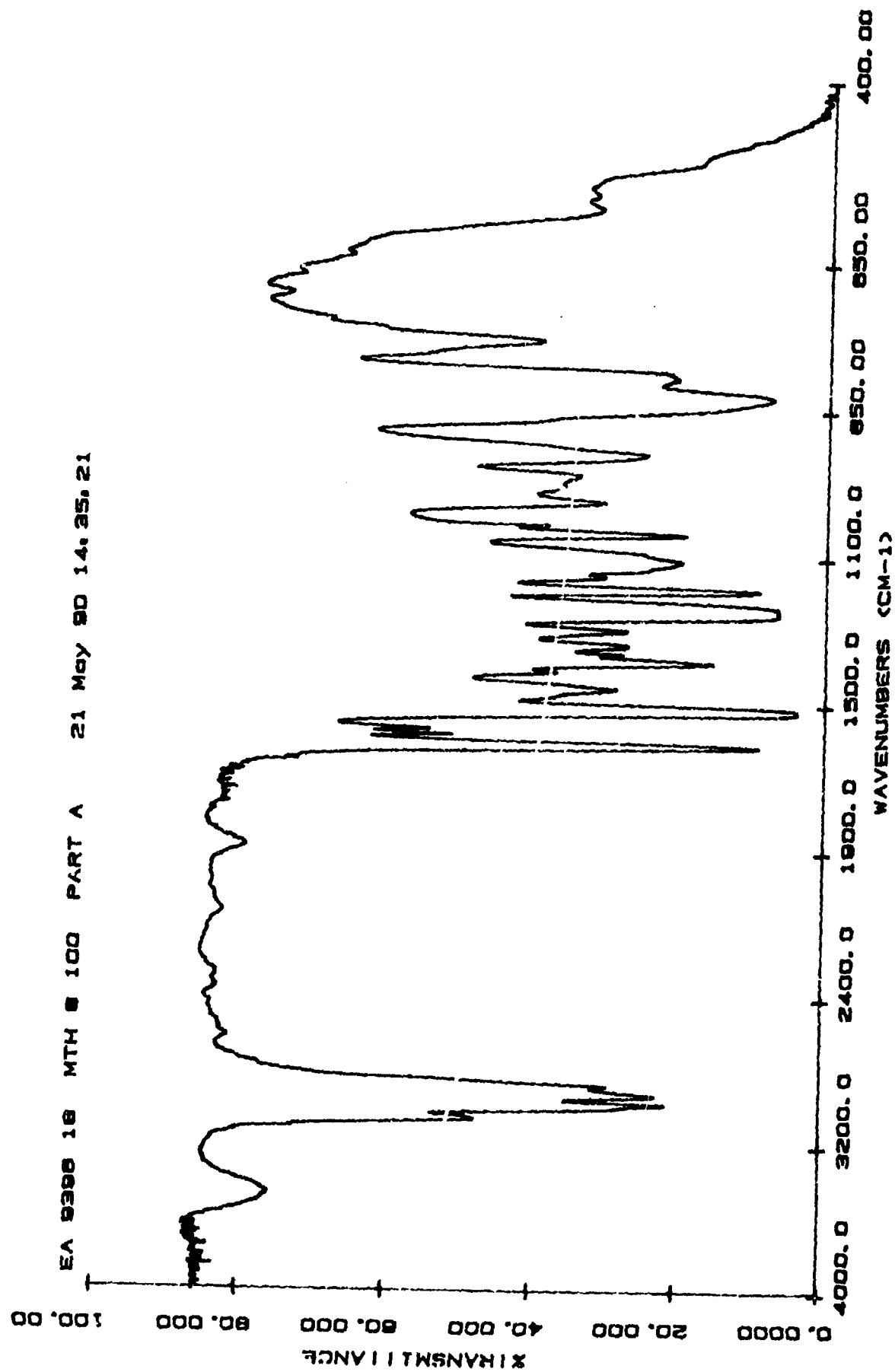


Figure M.34. FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 18 Months.

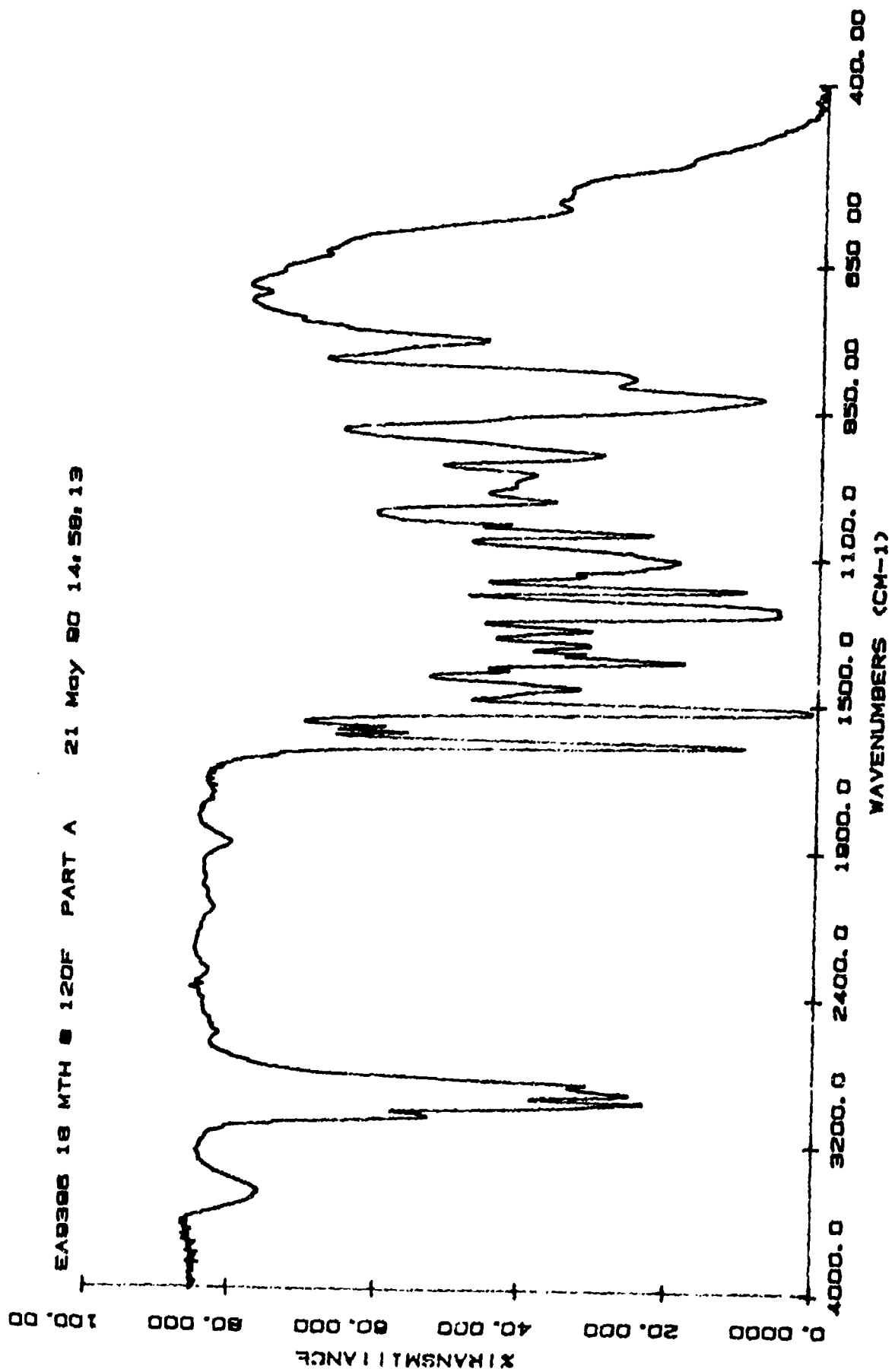


Figure M.35. FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 18 Months.



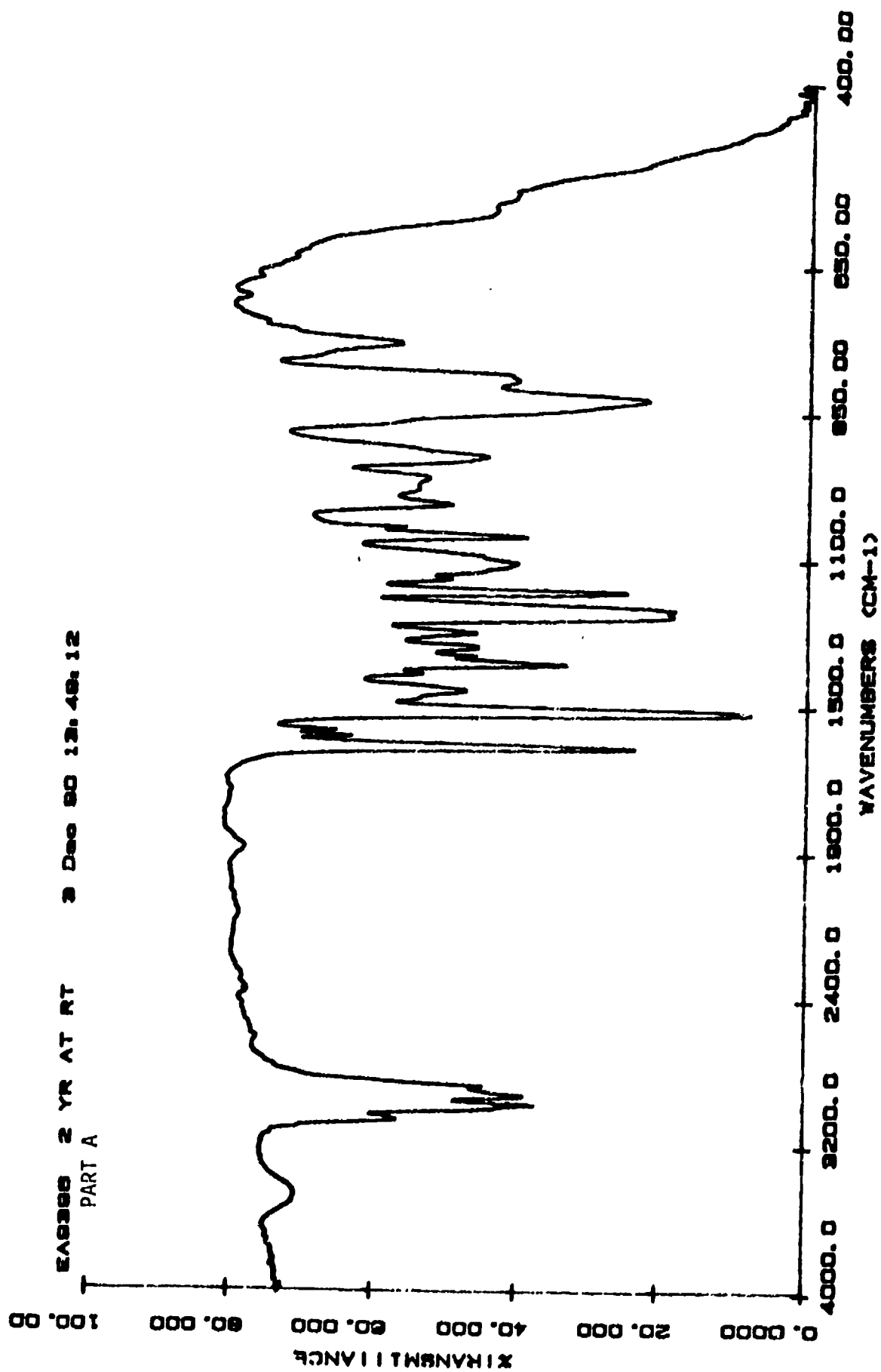
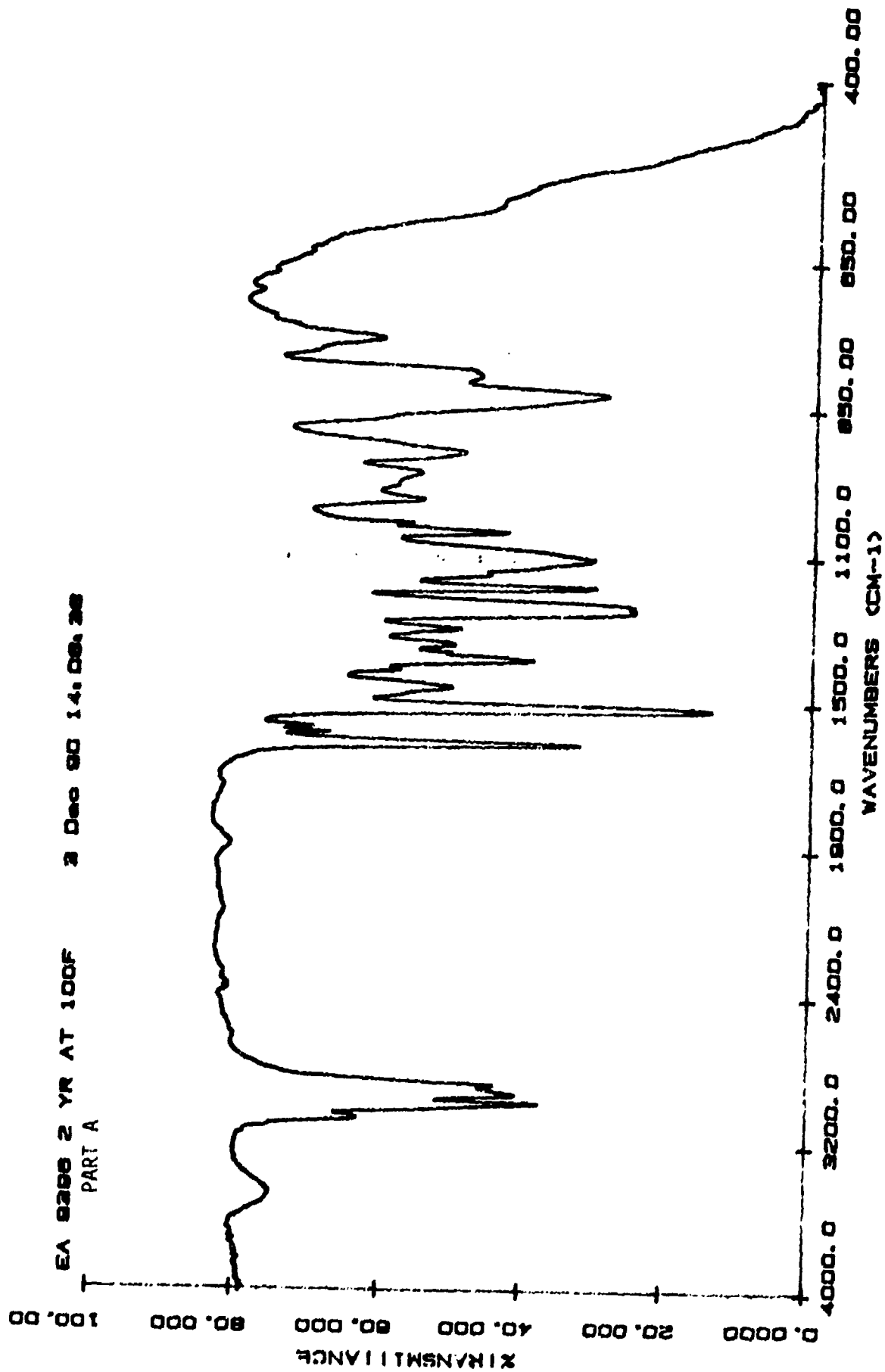


Figure M.36. FTIR Spectra for EA9396, Part A, Stored at 22°C (72°F) for 24 Months.



M-62

Figure M.37. FTIR Spectra for EA9396, Part A, Stored at 38°C (100°F) for 24 Months.

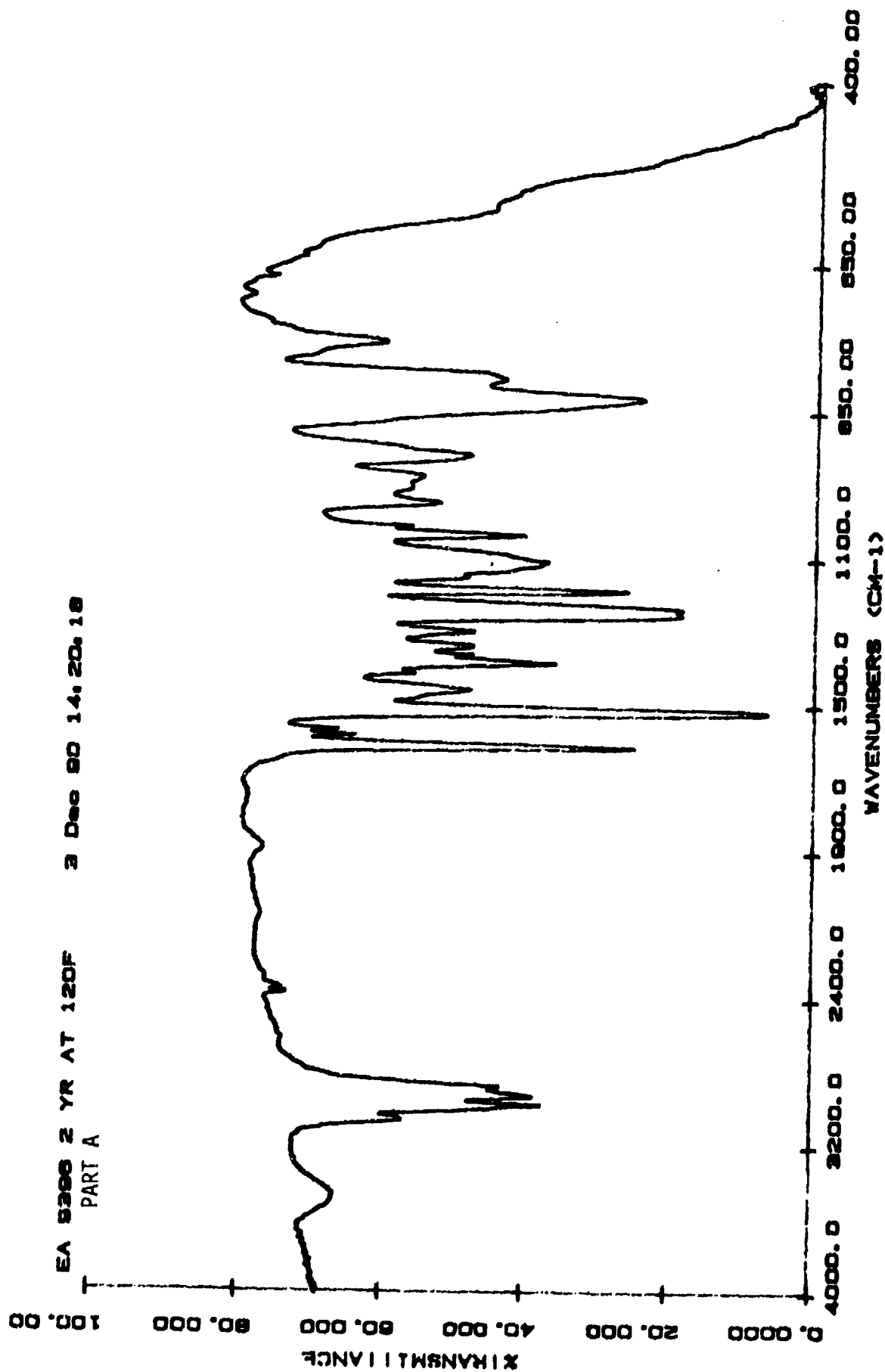


Figure M.38. FTIR Spectra for EA9396, Part A, Stored at 49°C (120°F) for 24 Months.

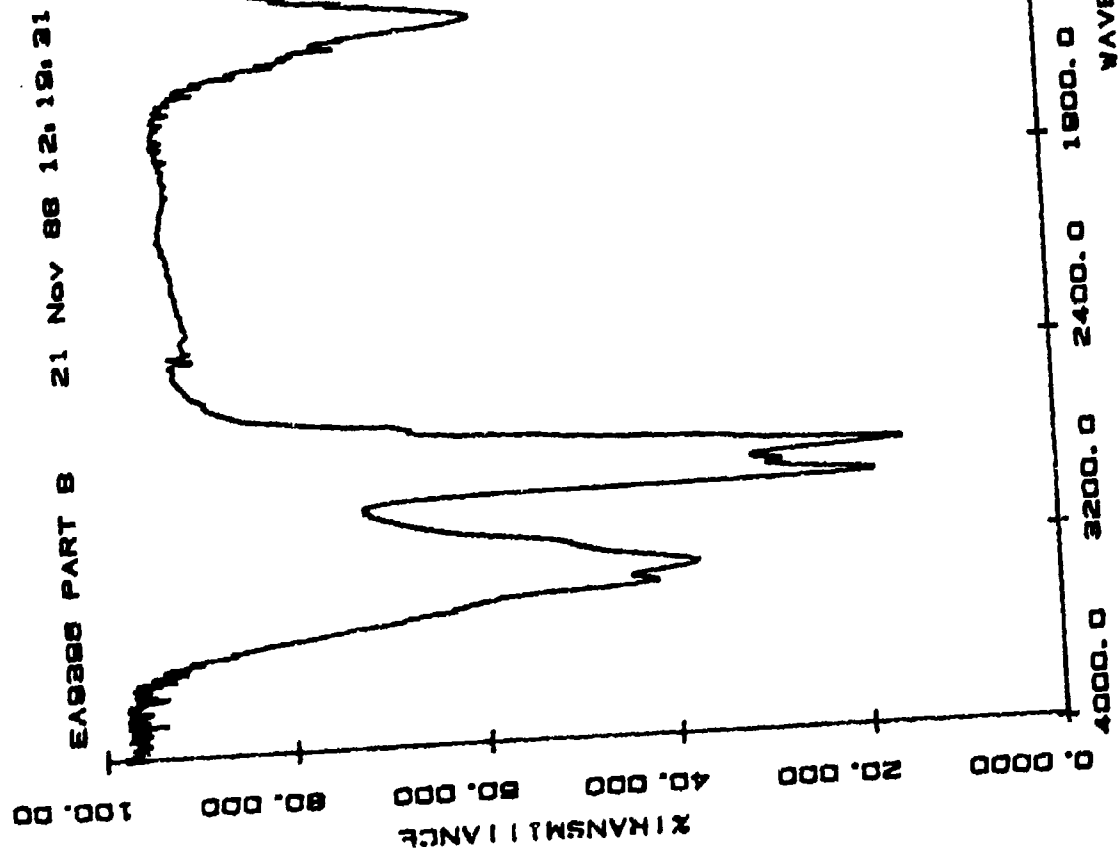


Figure M.39. FTIR Spectra for EA9396, Part B, Initial.

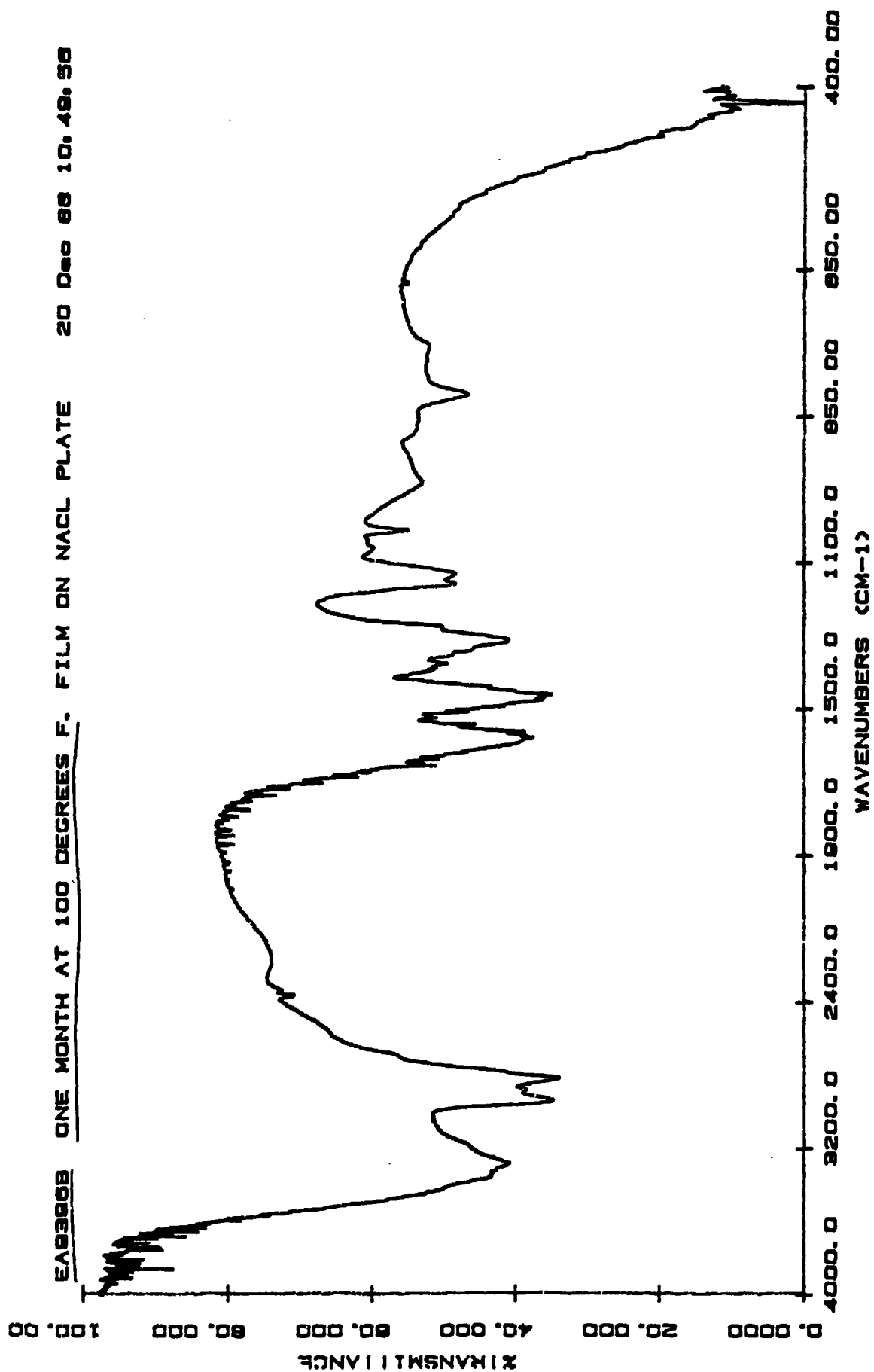


Figure M.40. FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 1 Month.

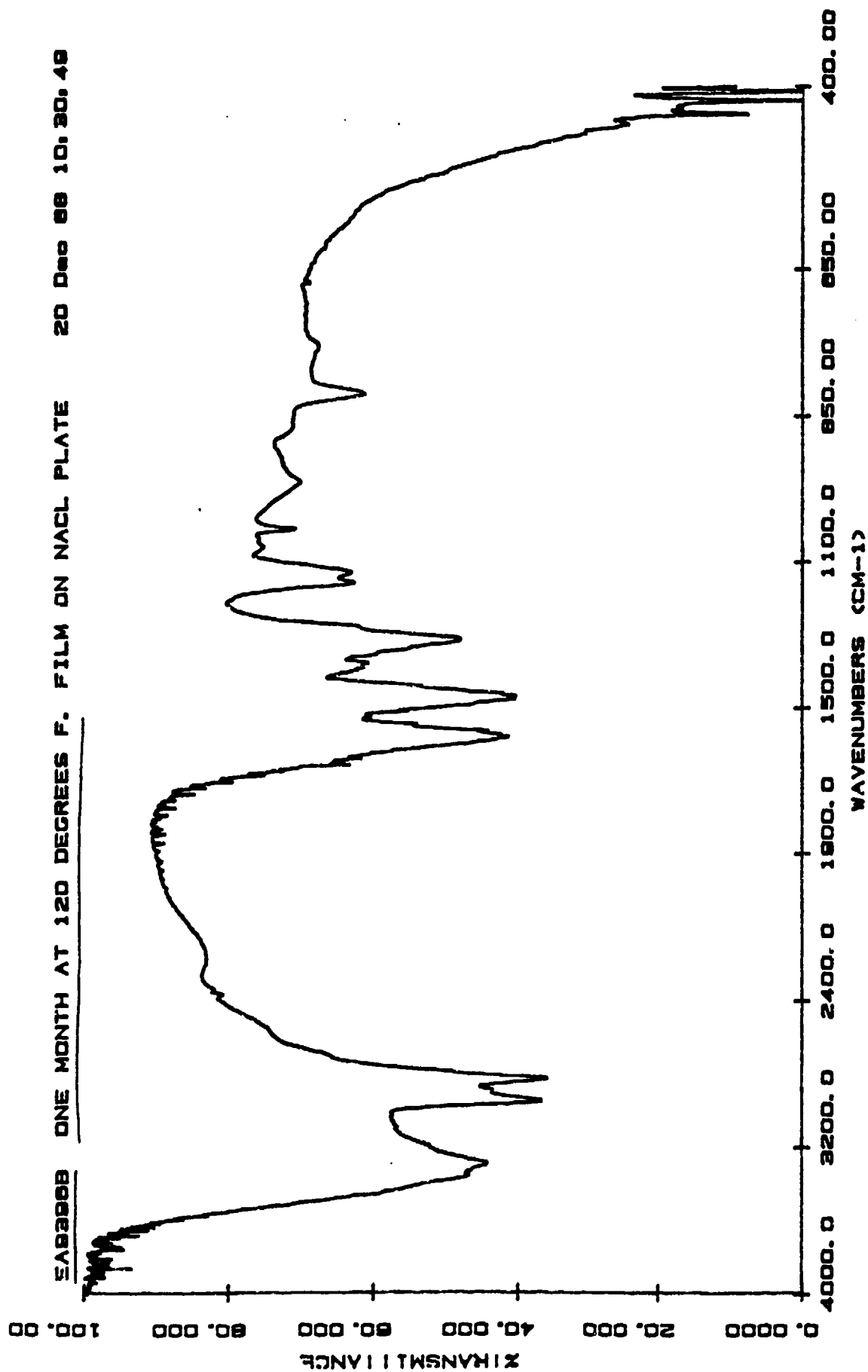


Figure M.41. FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 1 Month.

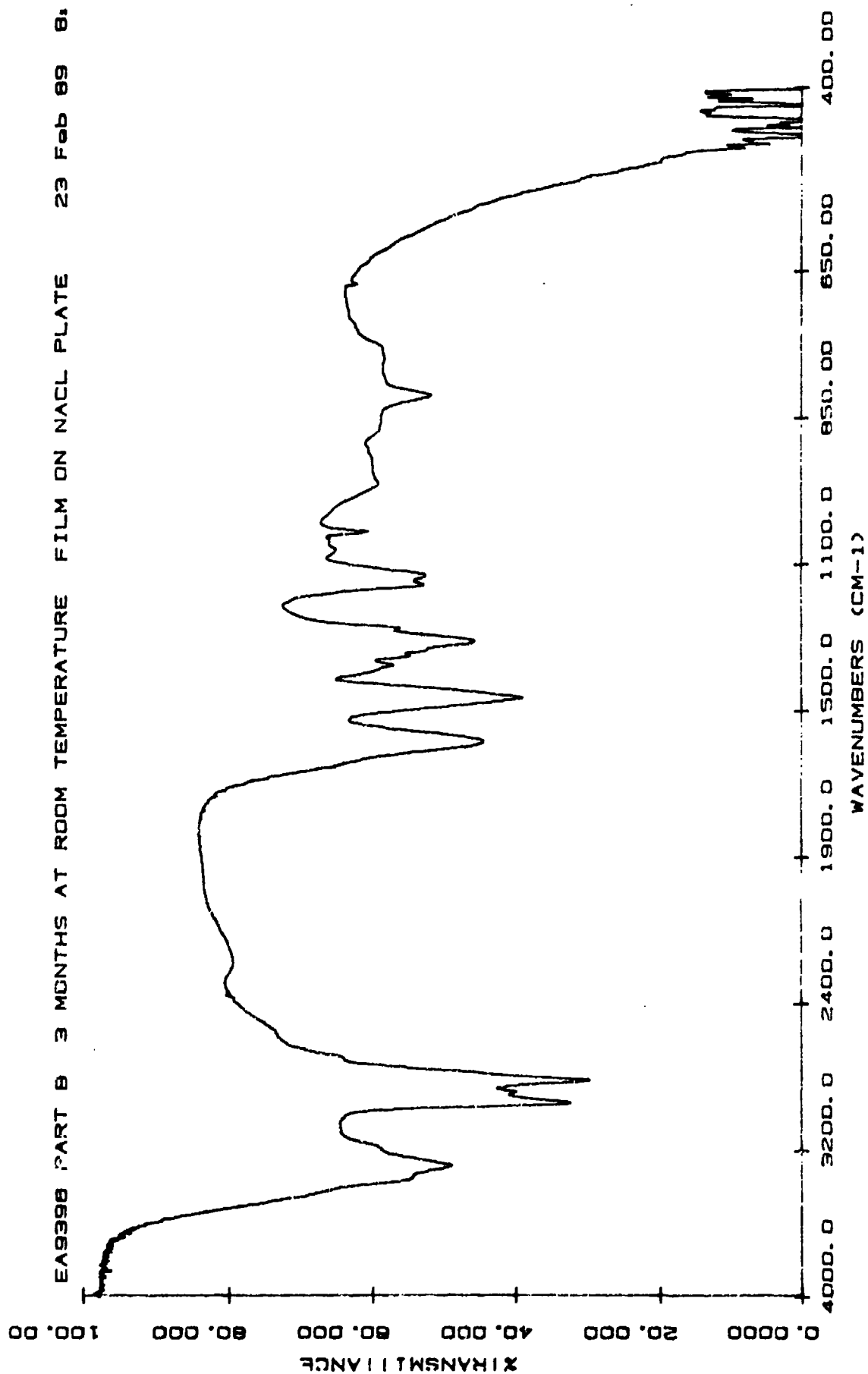


Figure M.42. FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 3 Months.

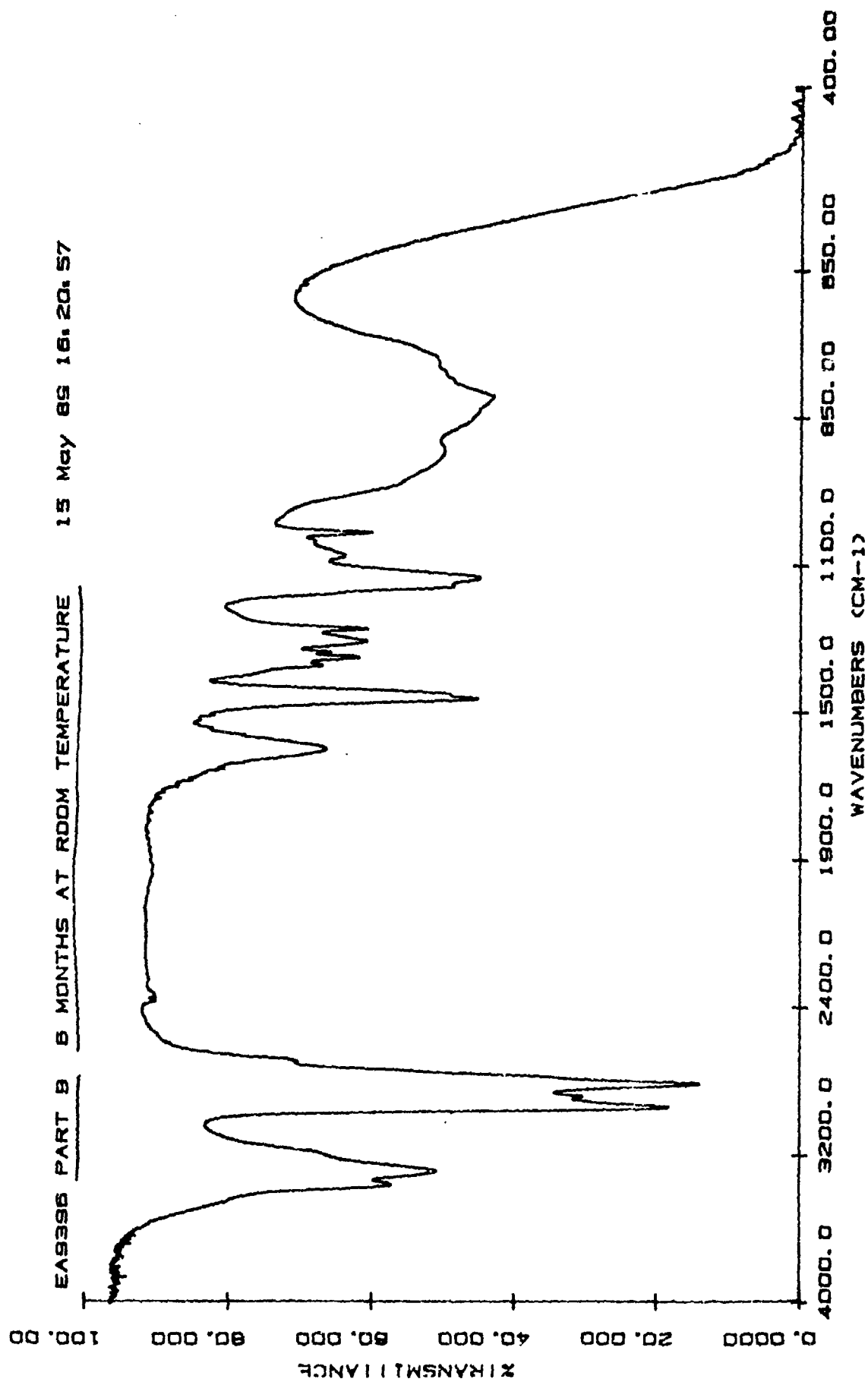


Figure M.43. FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 6 Months.



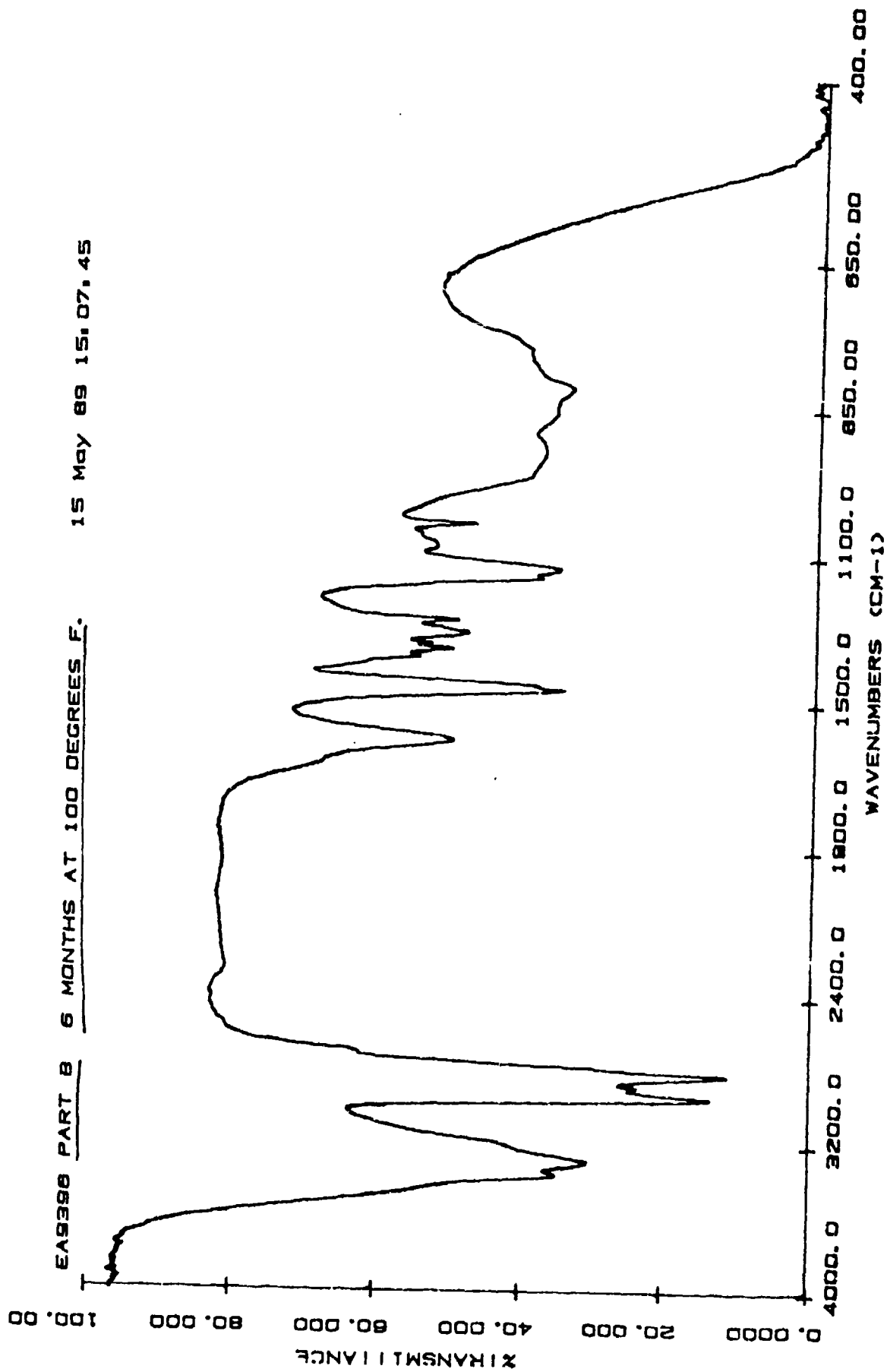


Figure M.44. FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 6 Months.

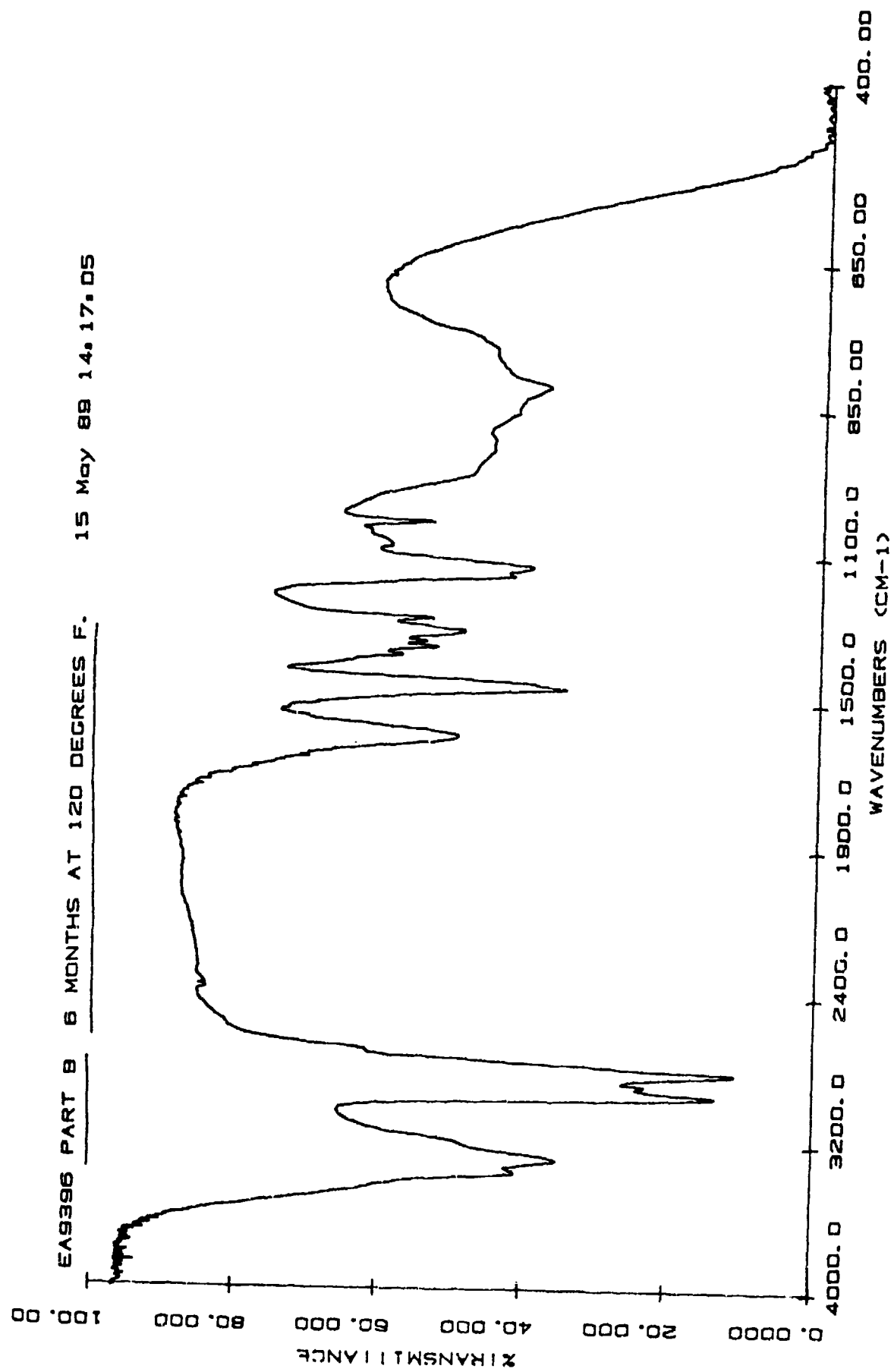


Figure M.45. FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 6 Months.

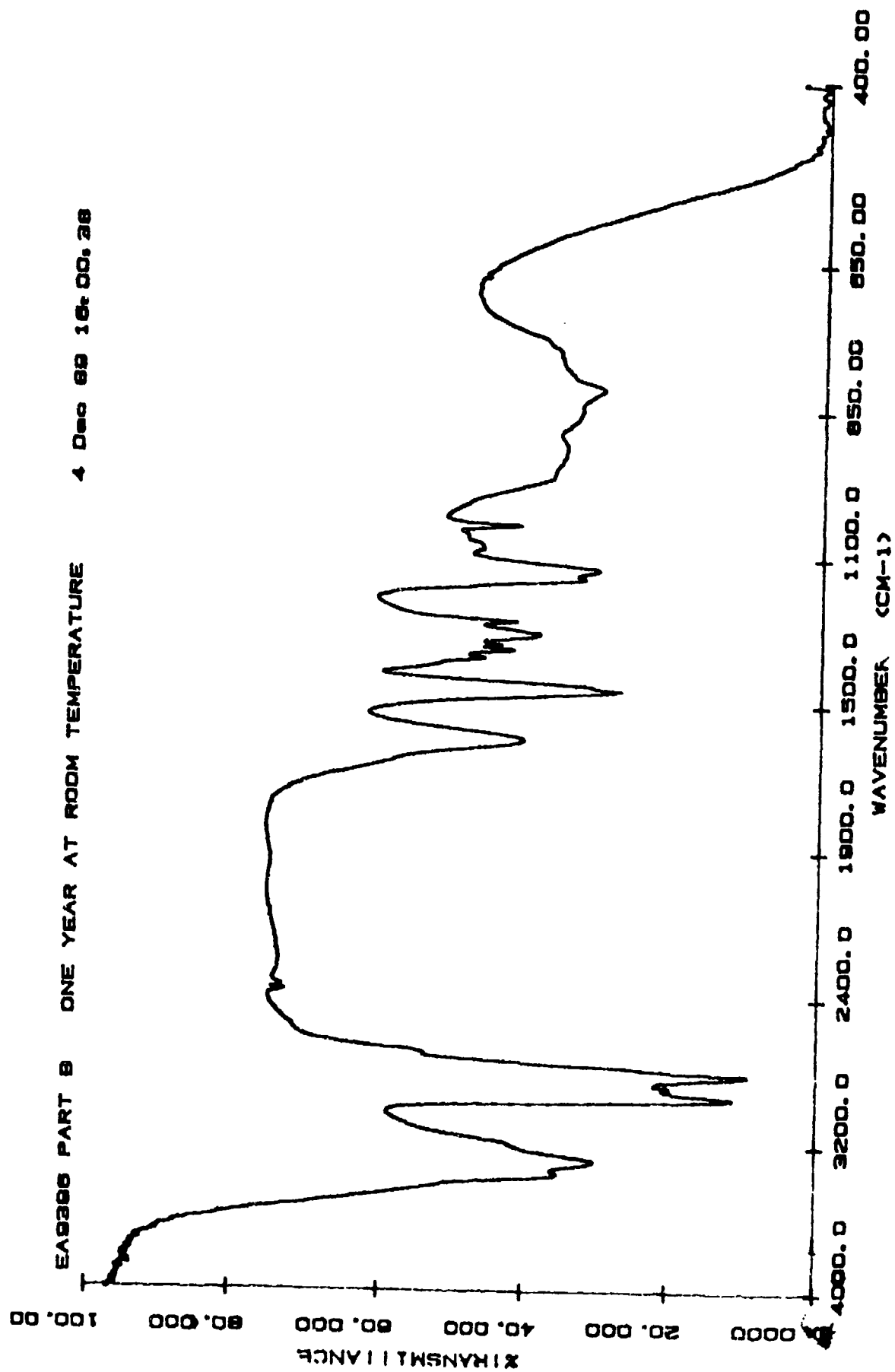


Figure M.46. FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 12 Months.

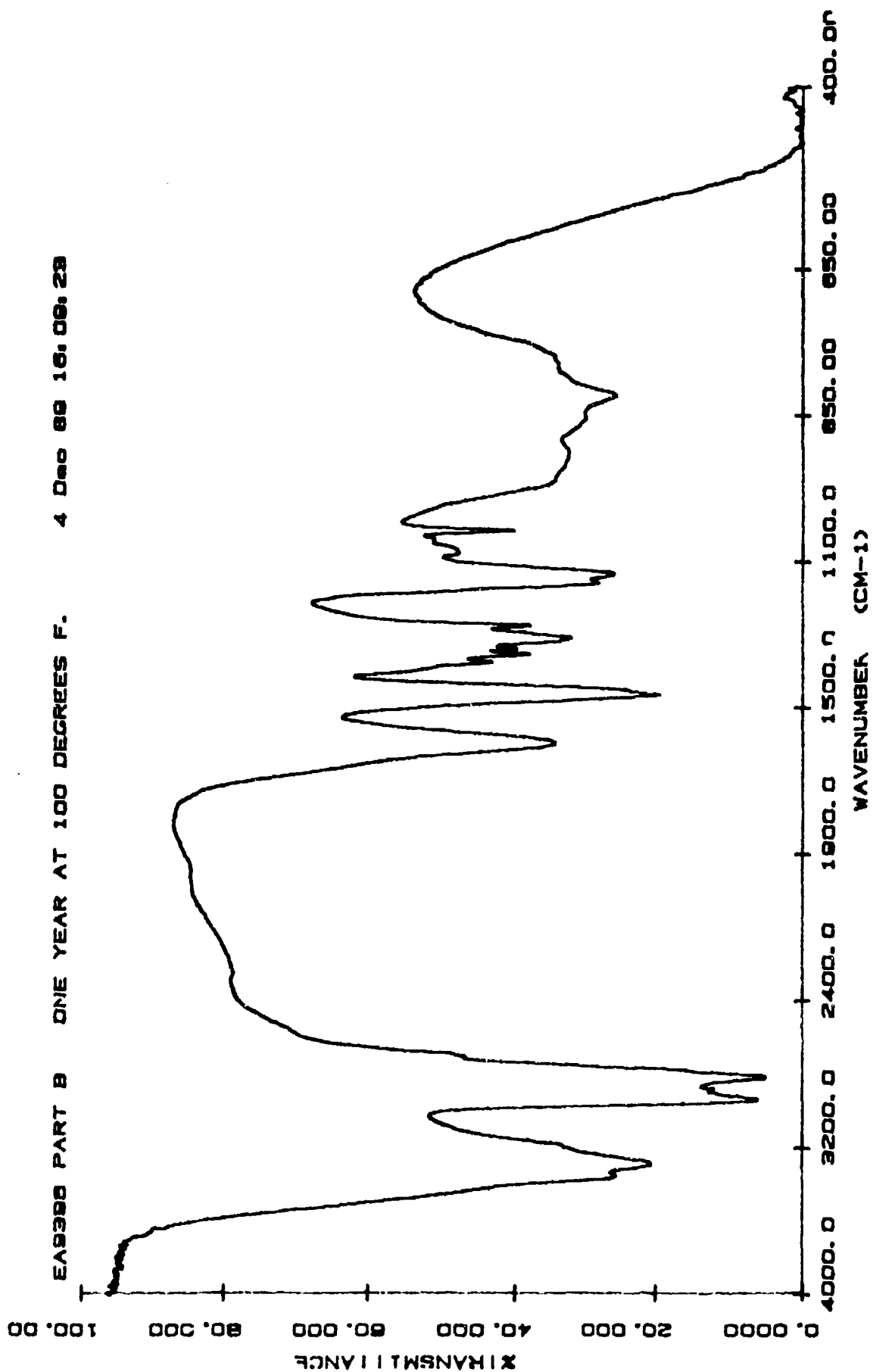


Figure M.47. FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 12 Months.

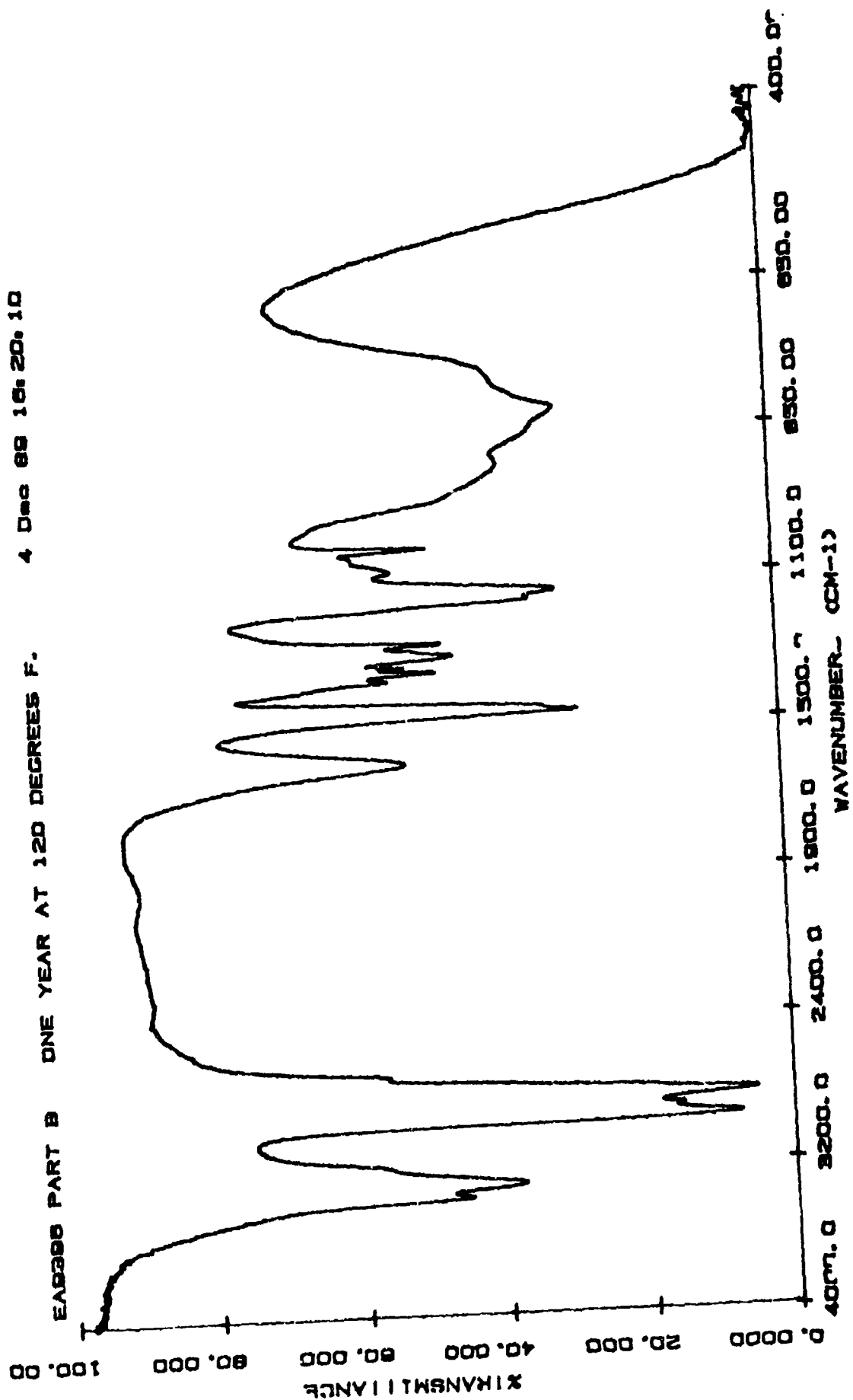


Figure M.48. FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 12 Months.

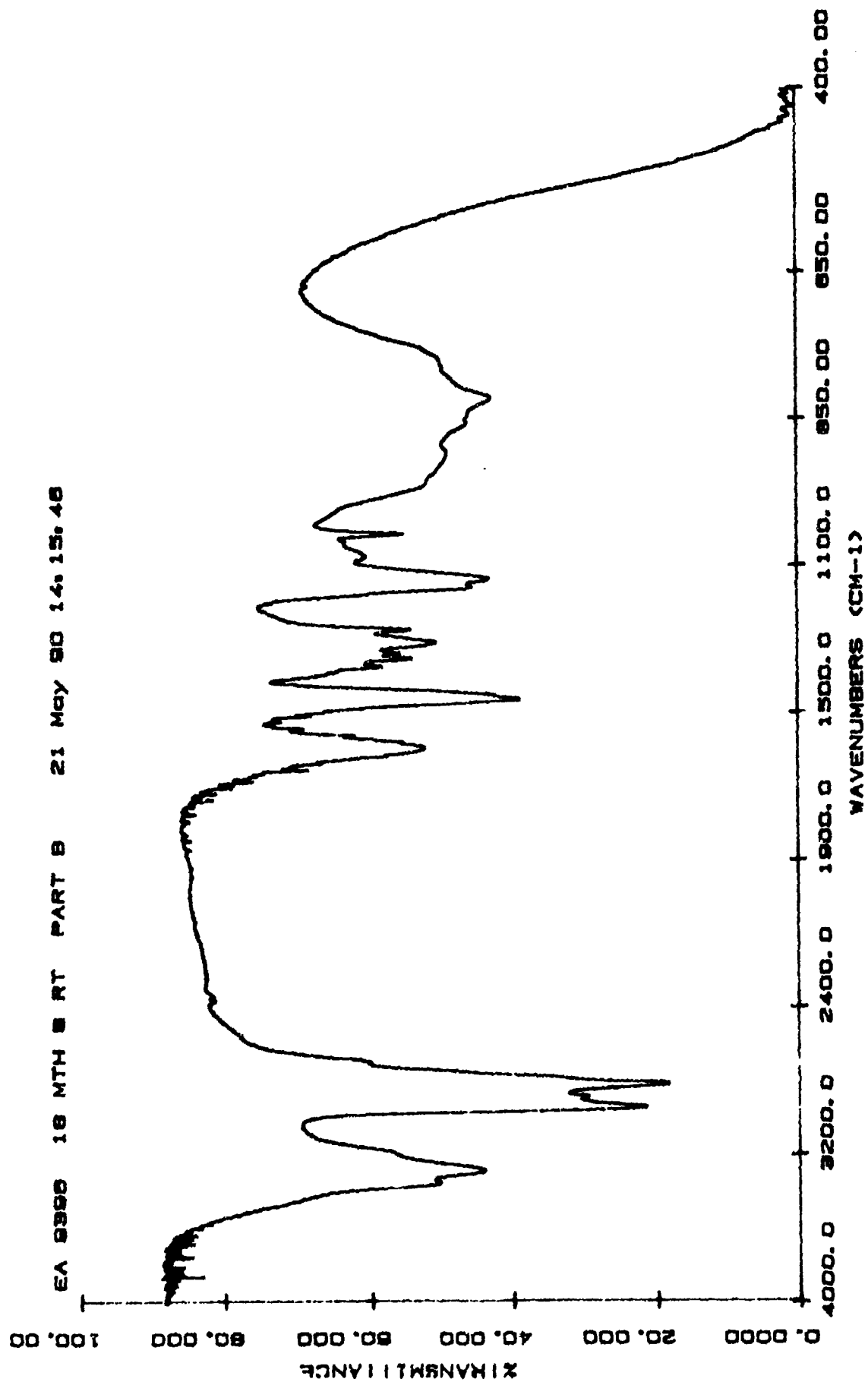


Figure M.49. FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 18 Months.

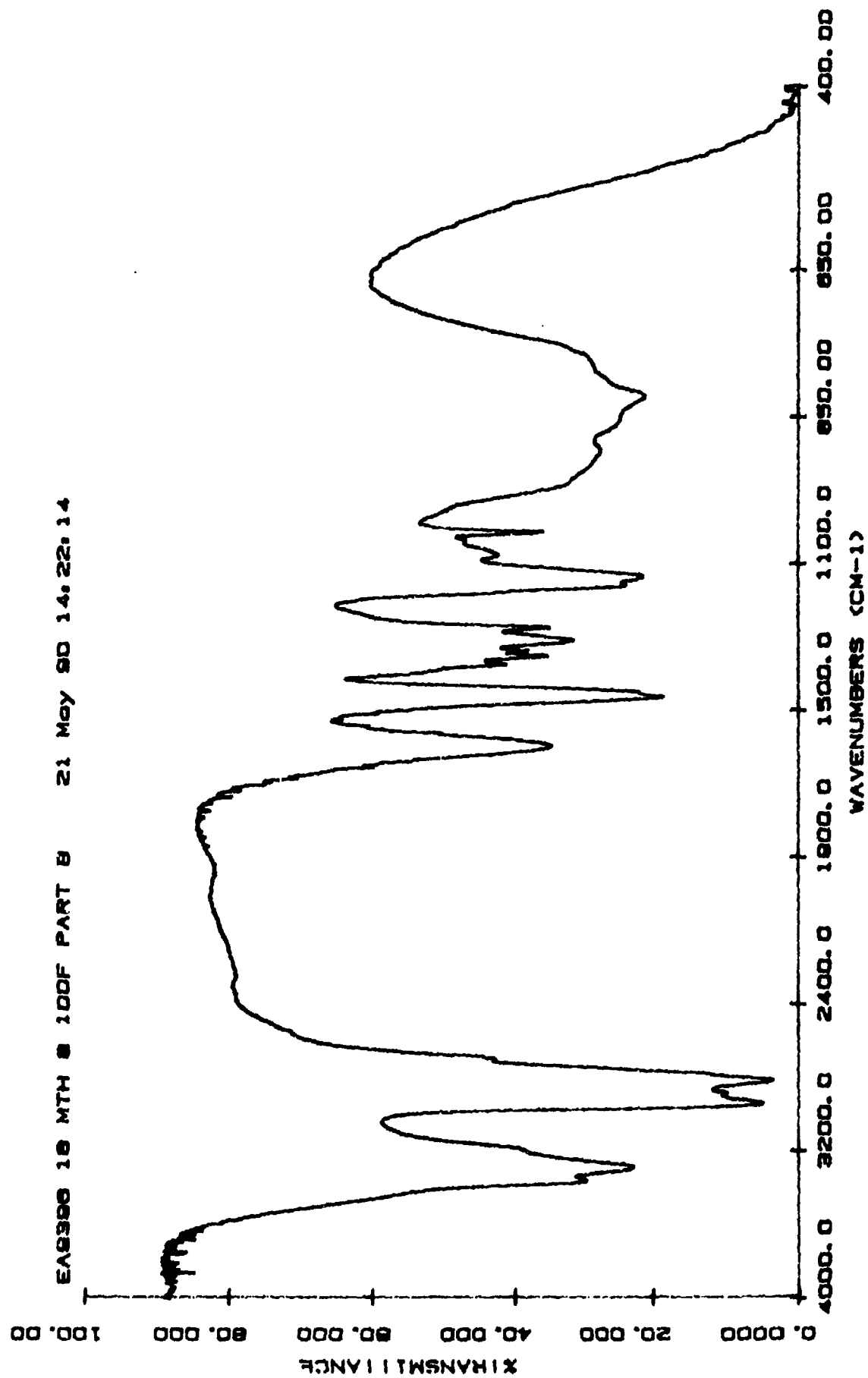


Figure M.50. FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 18 Months.

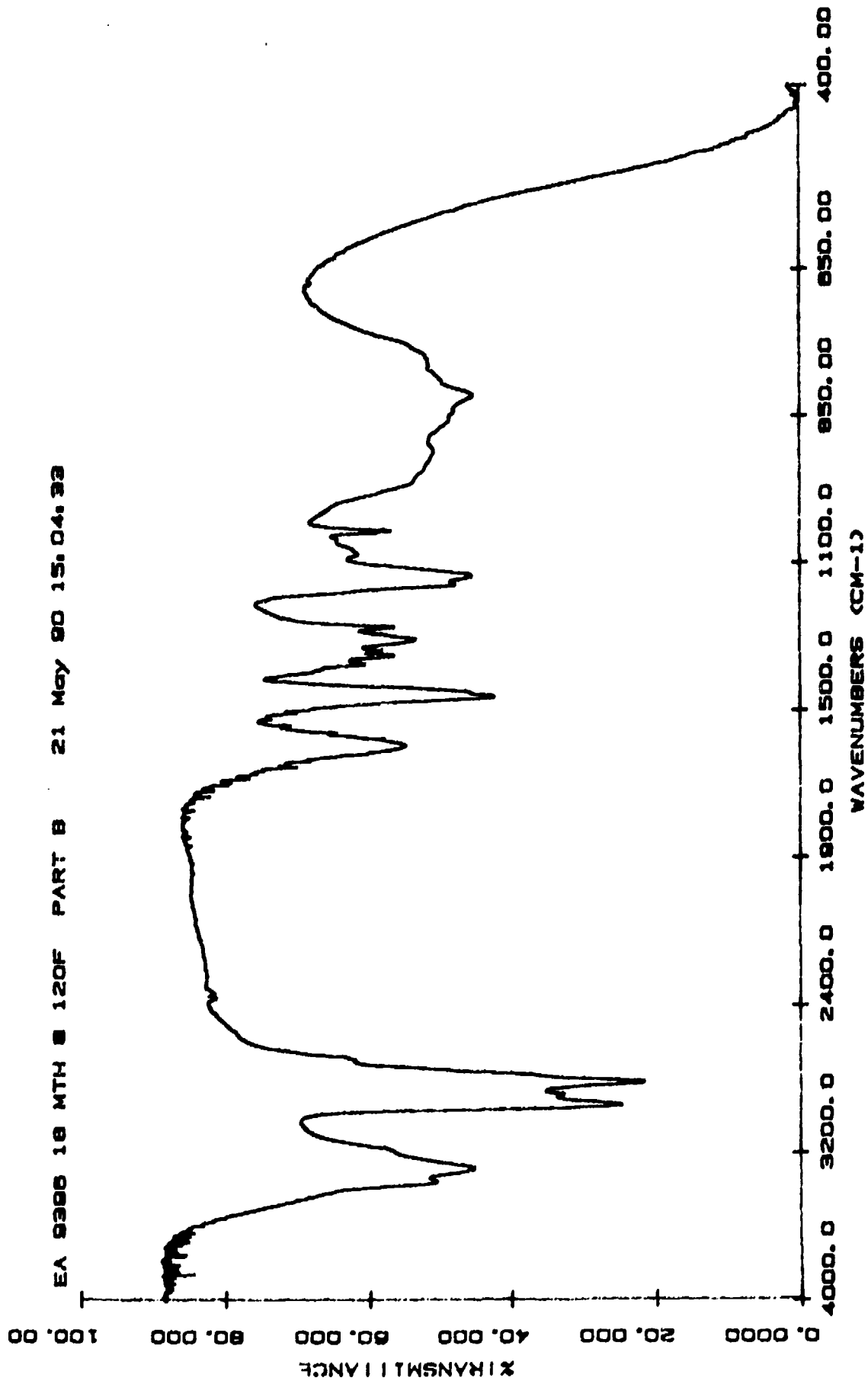


Figure M.51. FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 18 Months.



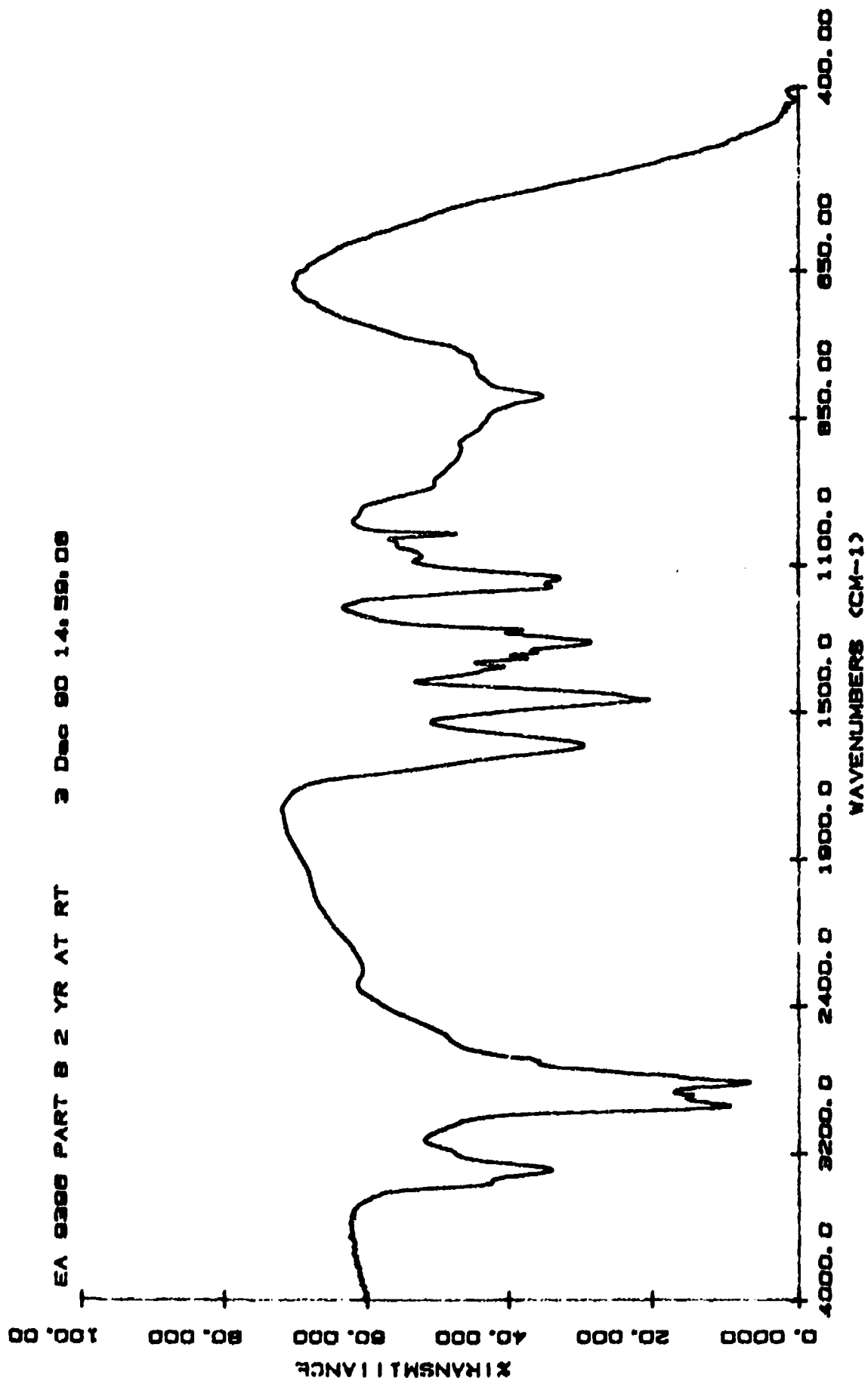


Figure M.52. FTIR Spectra for EA9396, Part B, Stored at 22°C (72°F) for 24 Months.

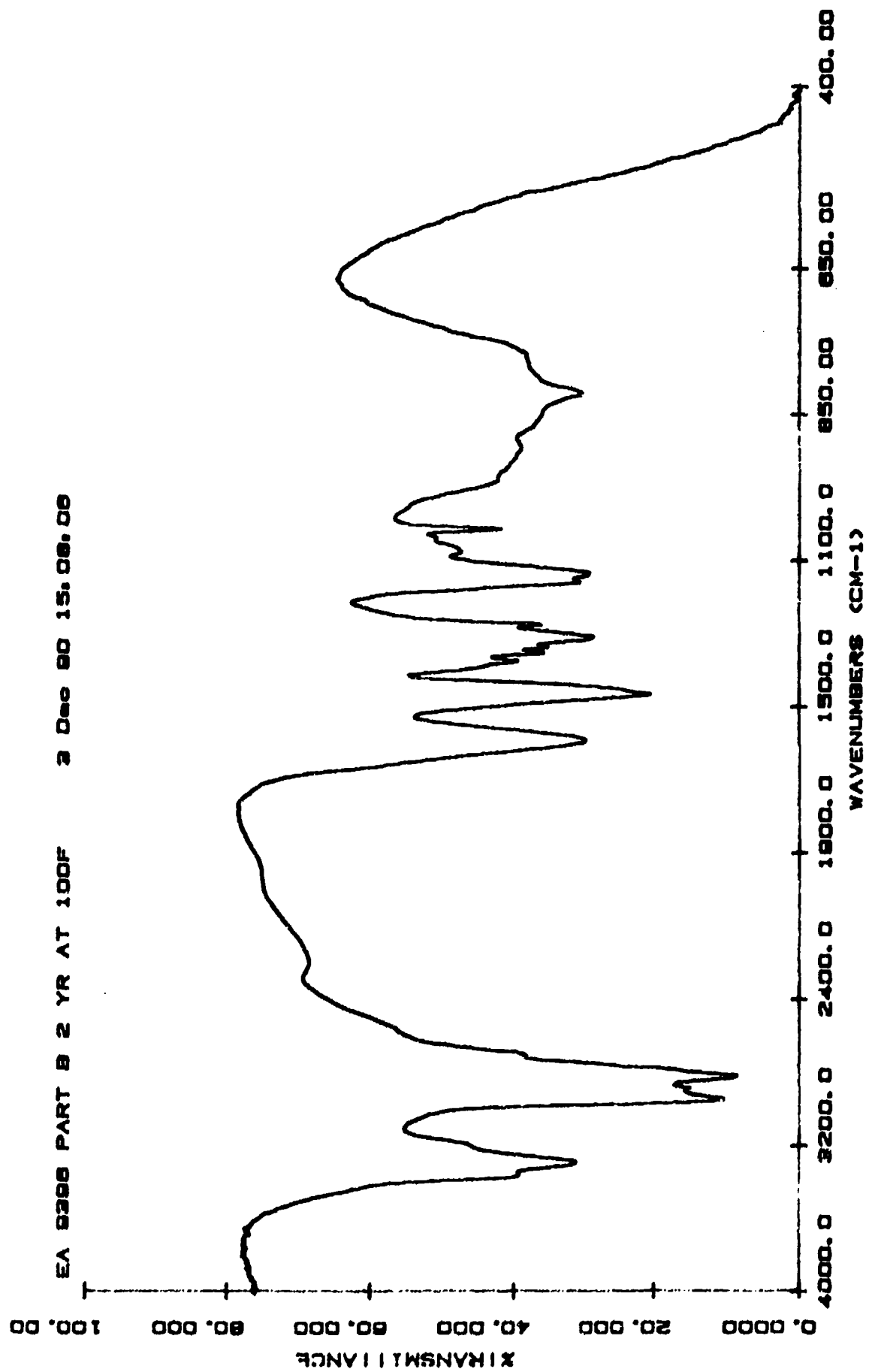


Figure M.53. FTIR Spectra for EA9396, Part B, Stored at 38°C (100°F) for 24 Months.

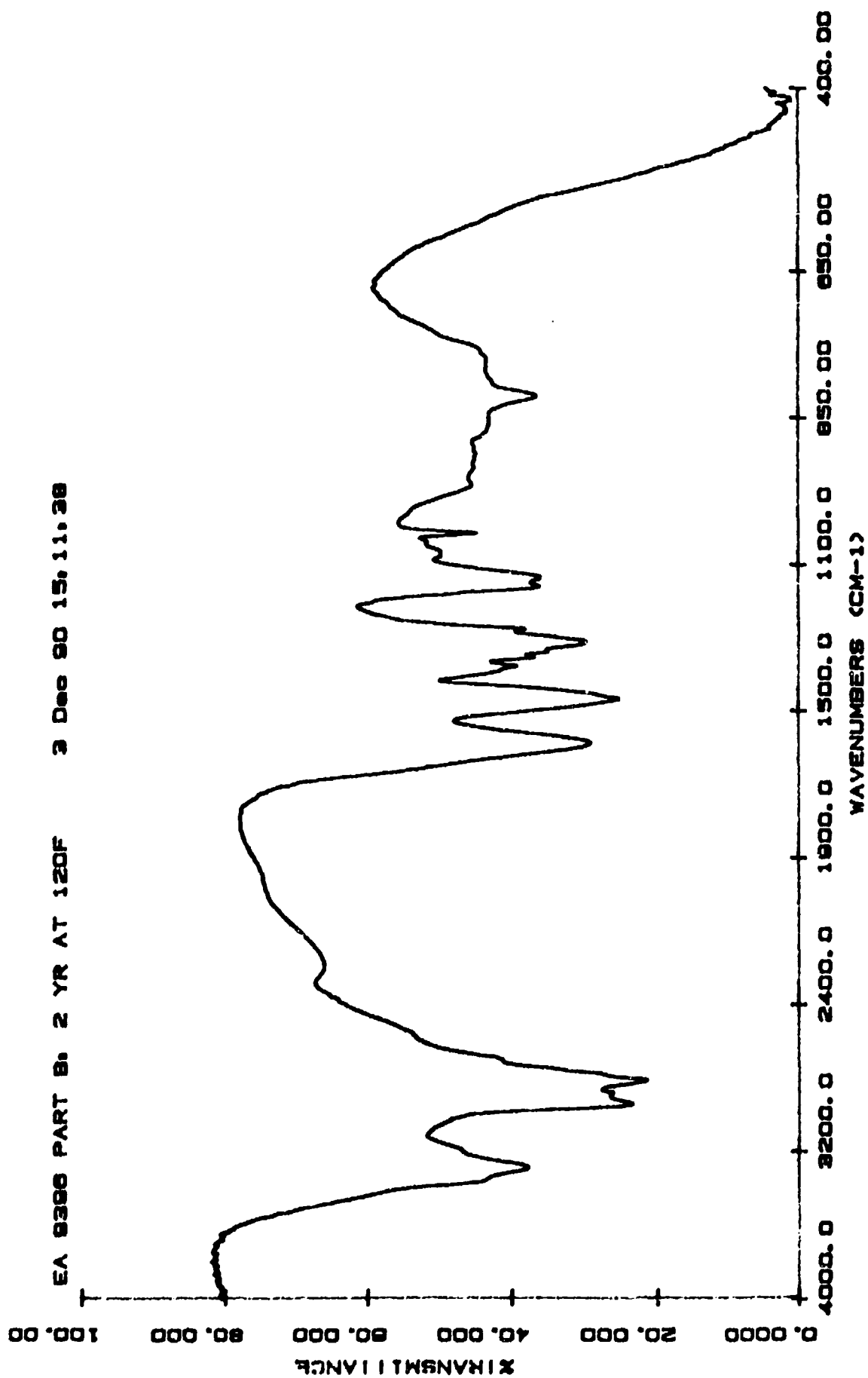


Figure M.54. FTIR Spectra for EA9396, Part B, Stored at 49°C (120°F) for 24 Months.

# Initial testing of EA9396.

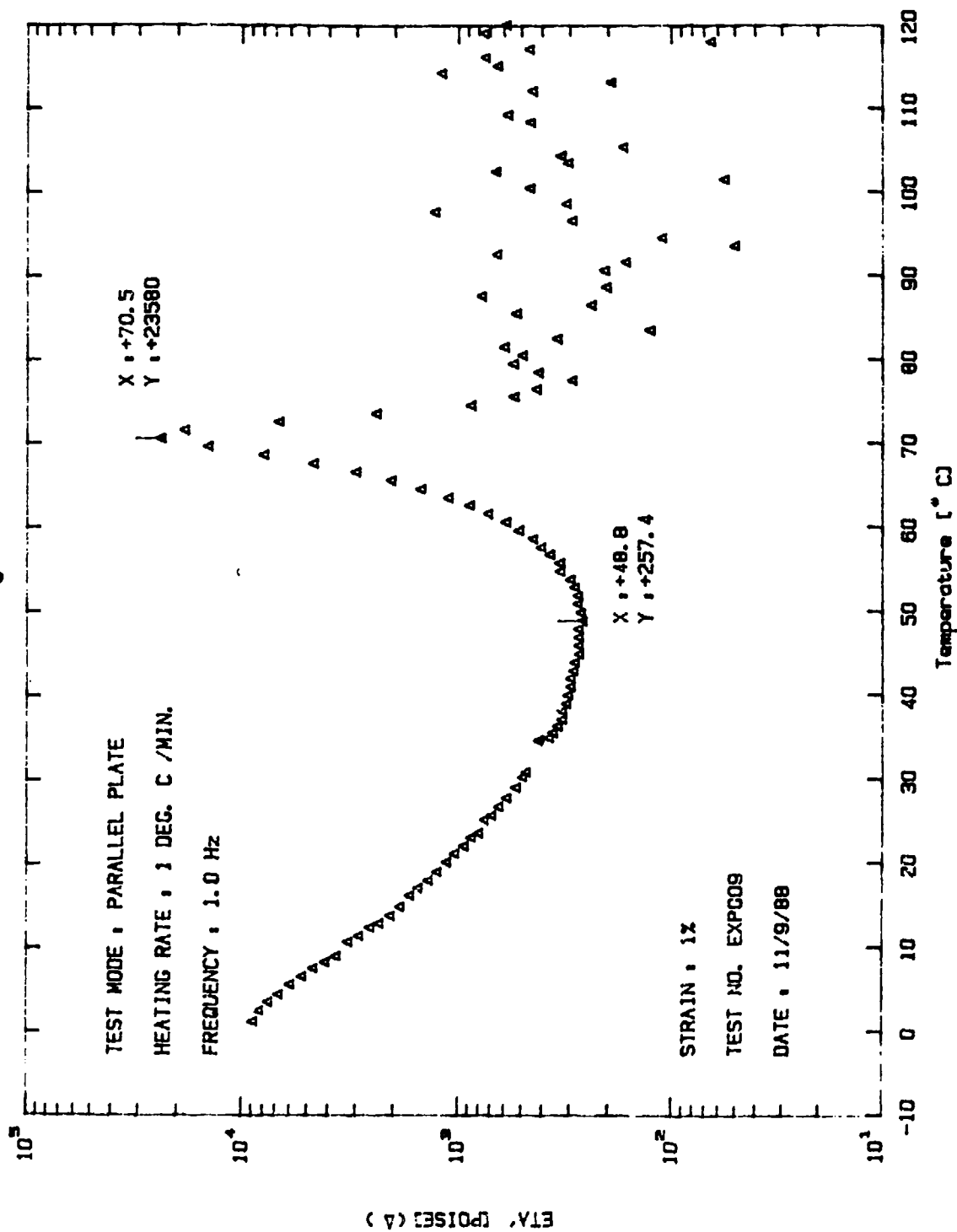


Figure M.55. Viscosity Cure Profile for EA9396, Initial.

EA9396 . Aged 1 month @ 100 deg. F .

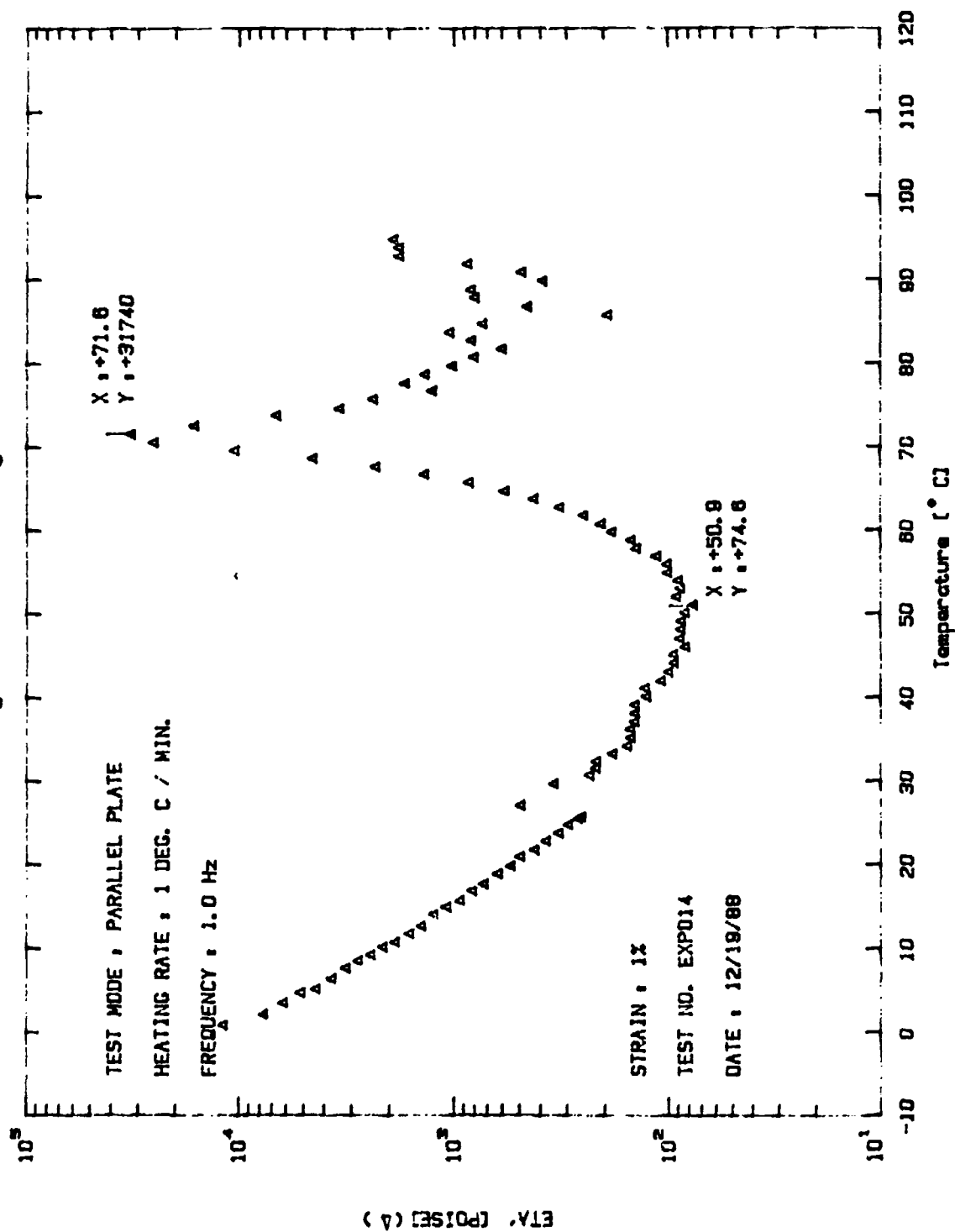


Figure M.56. Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 1 Month.

EA9396 .Aged 1 month @ 120 deg. F .

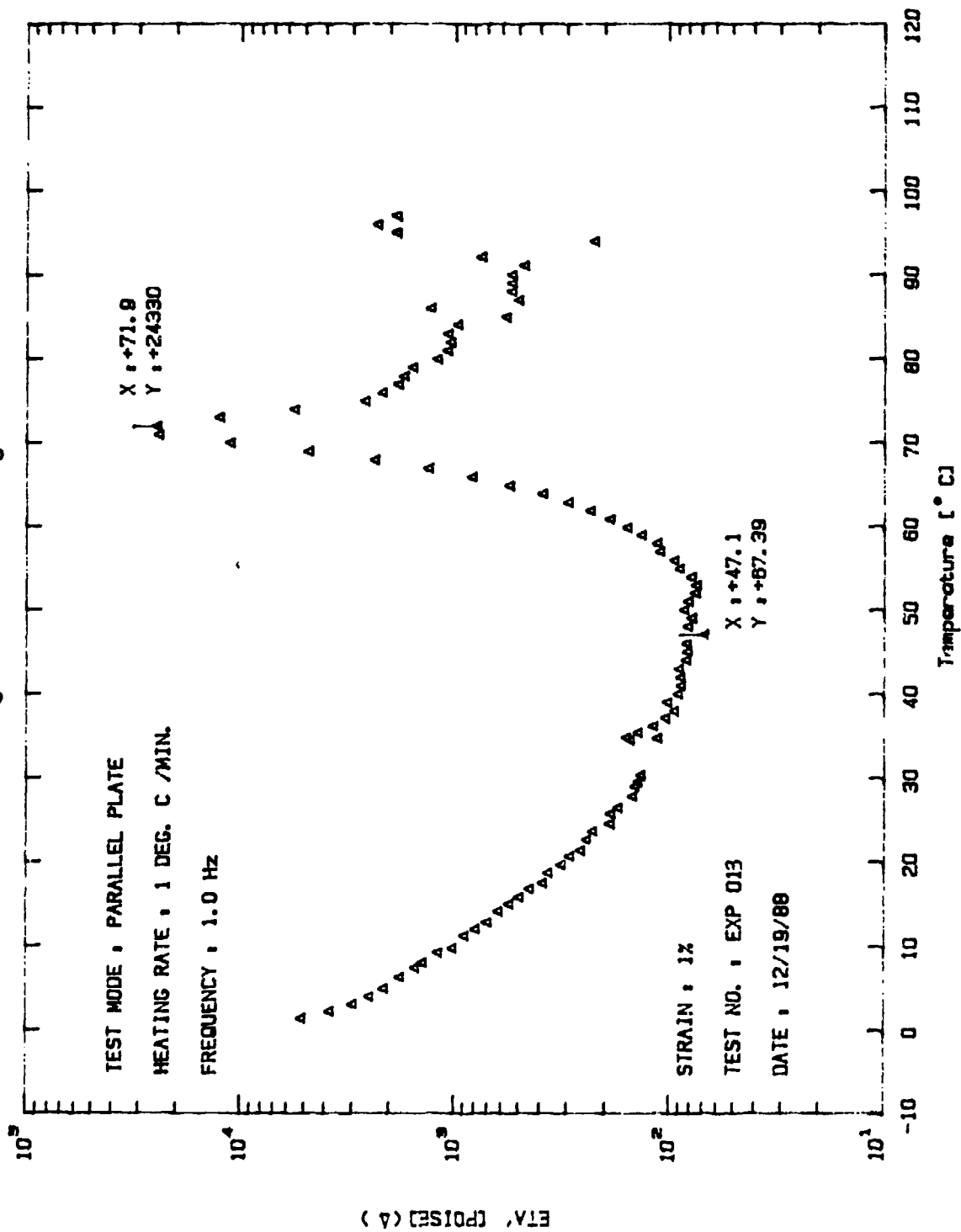


Figure M.57. Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 1 Month.

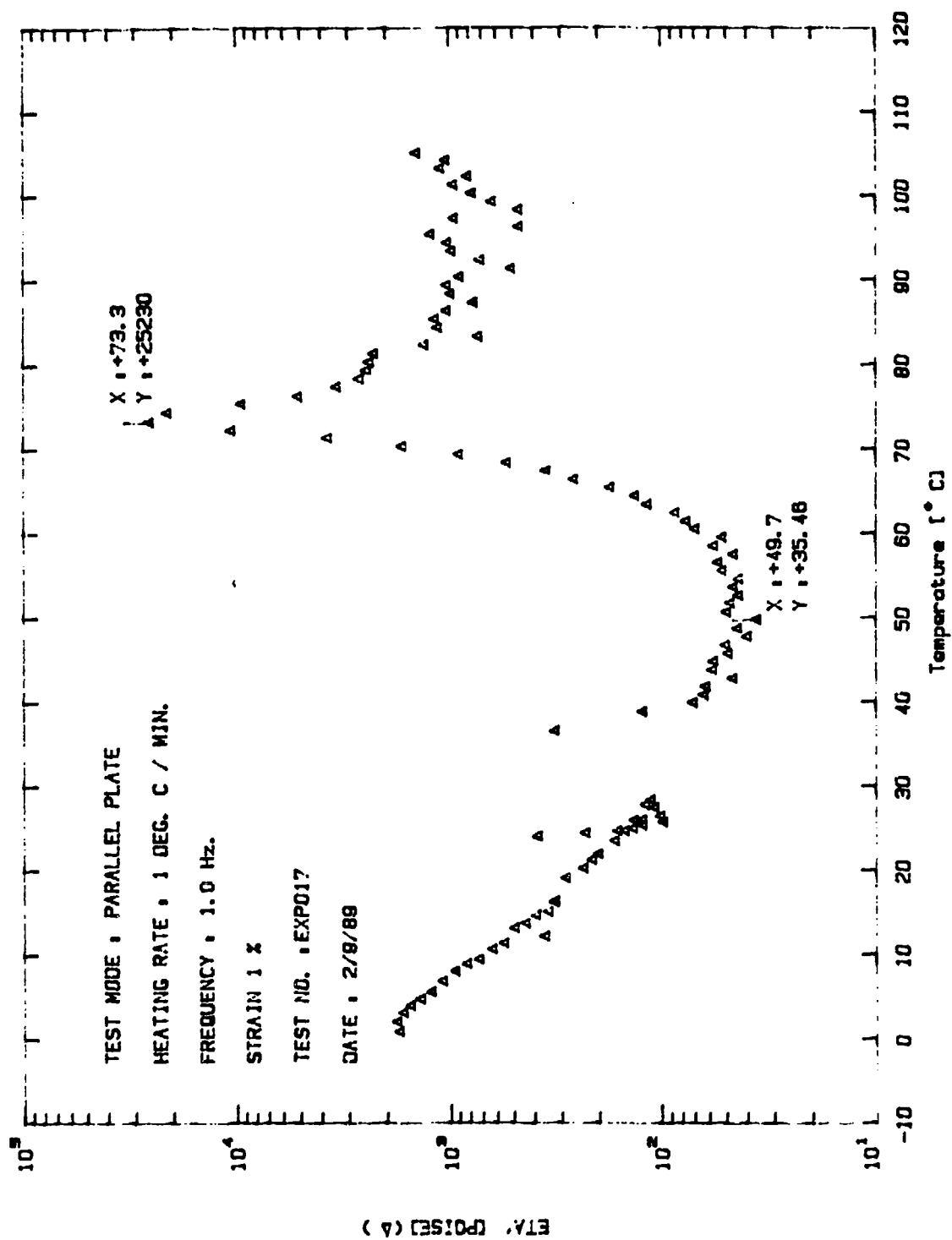


Figure M.58. Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 3 Months.

EA-9396, 6 Months @ RT

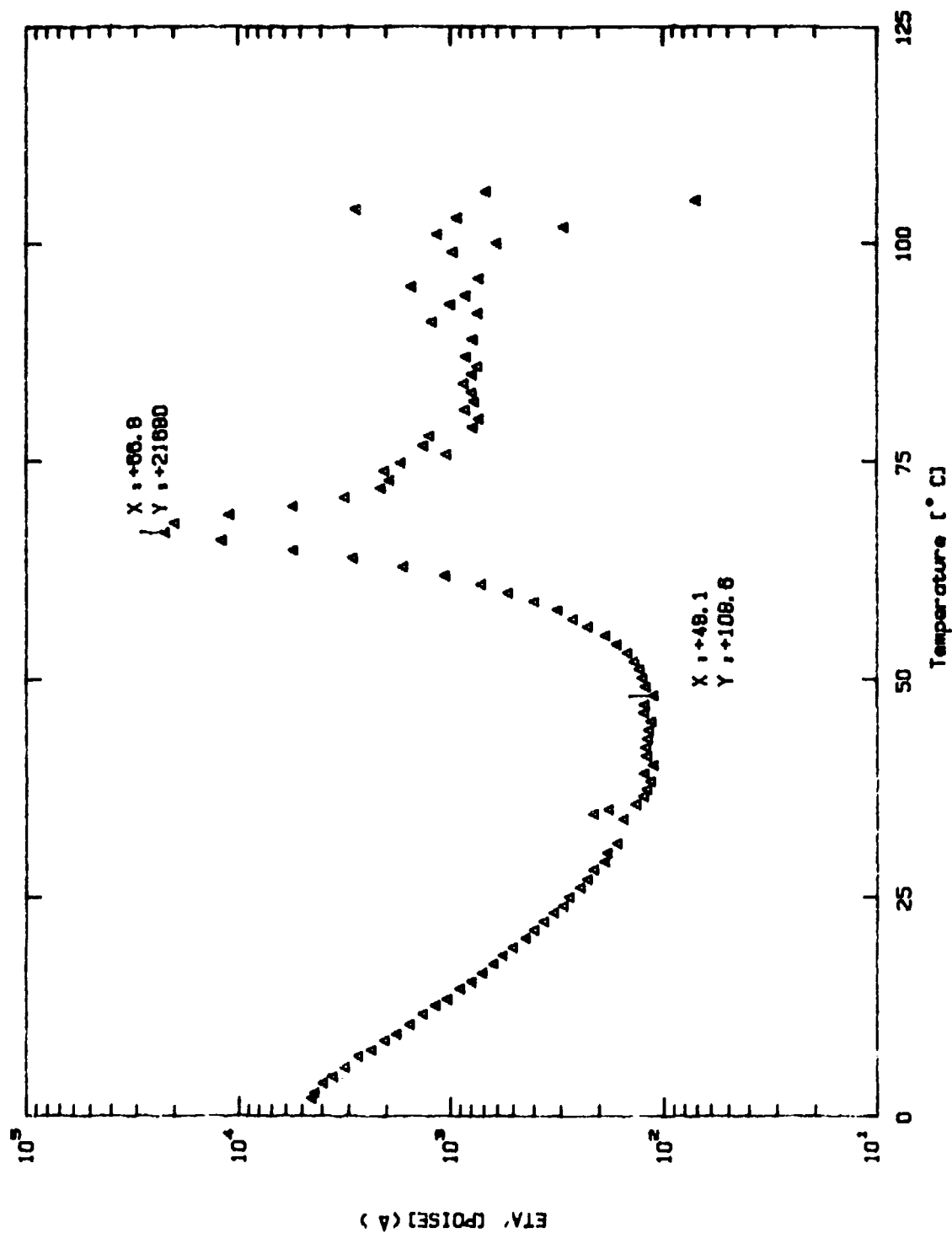


Figure M.59. Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 6 Months.



EA-9396, 6 Months @ 100 deg. F

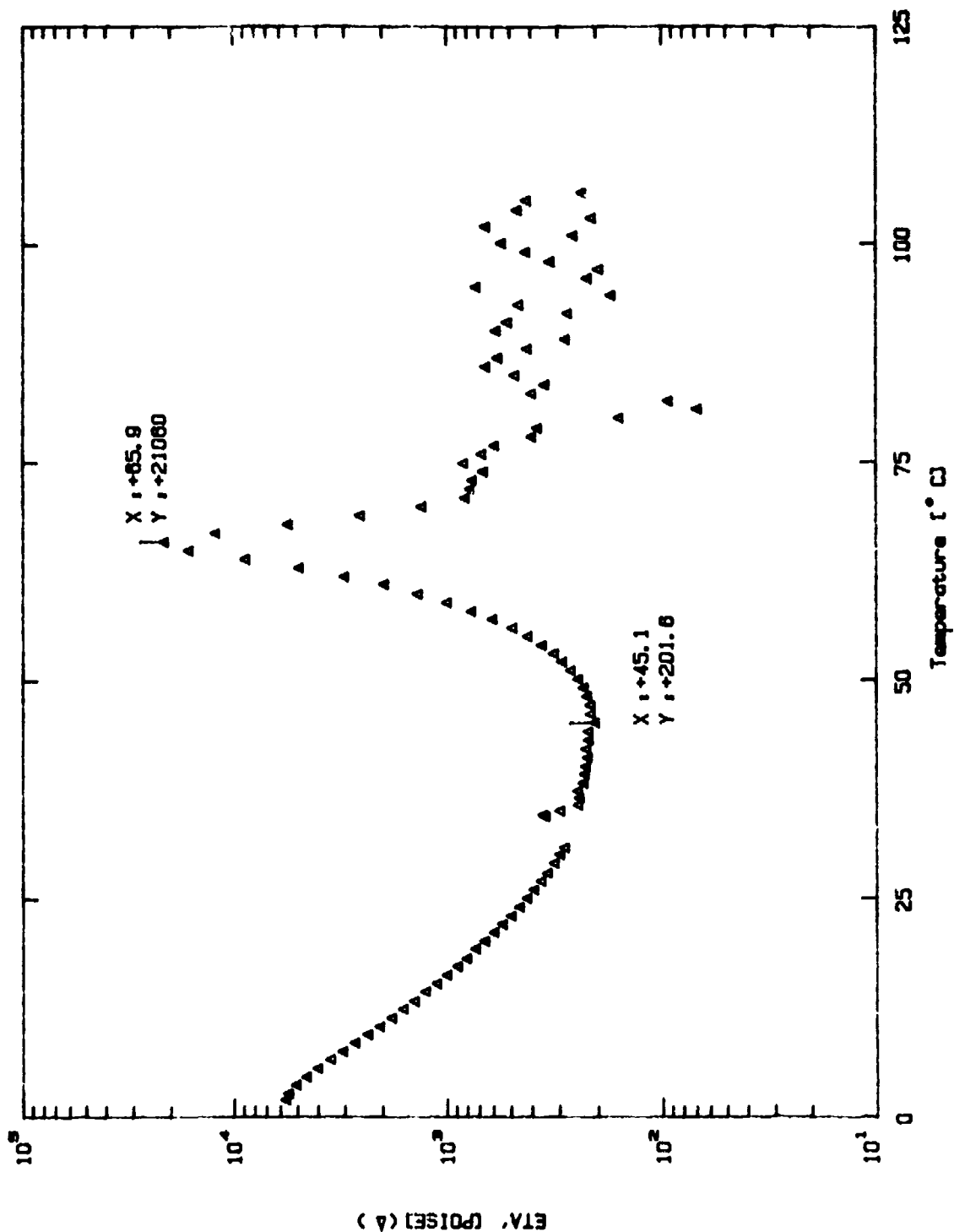


Figure M.60. Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 6 Months.

EA-9396, 6 Months @ 120 deg. F

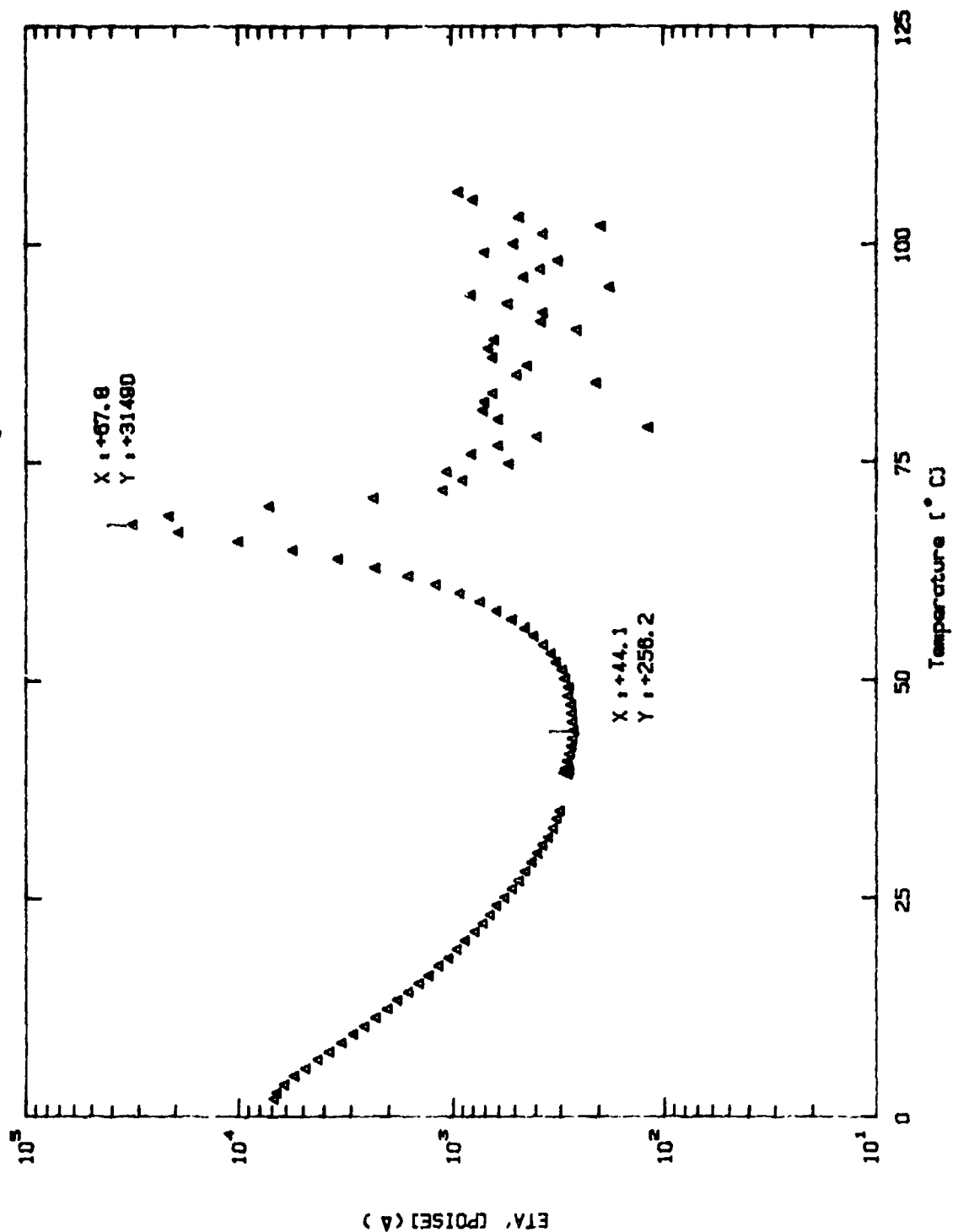


Figure M.61. Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 6 Months.

EA - 9906 RT for 1 year

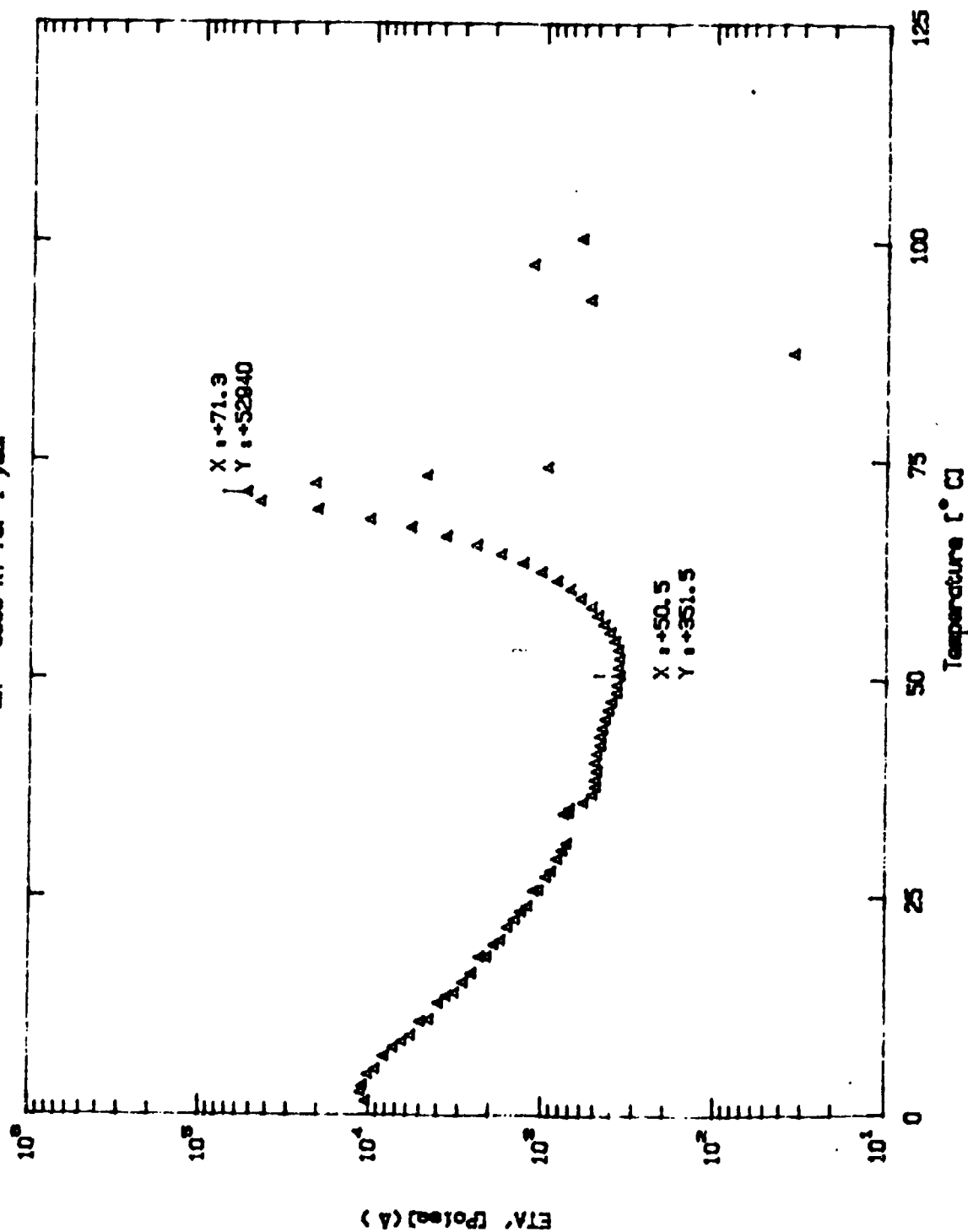


Figure M.62. Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 12 Months.

EA-9396 1 yr. @ 100 deg. F

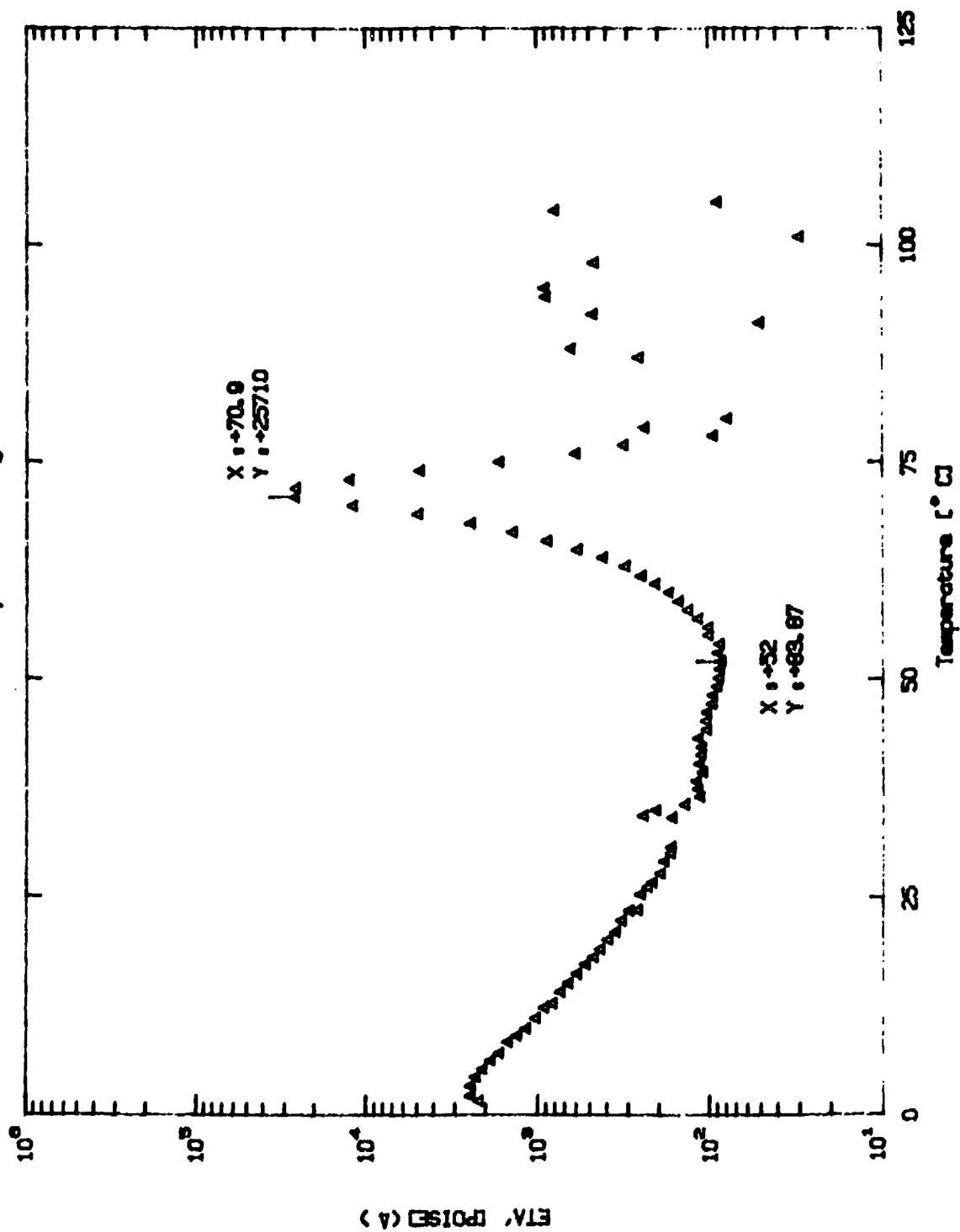


Figure M.63. Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 12 Months.

Ed9396 1 year at 120 deg. F

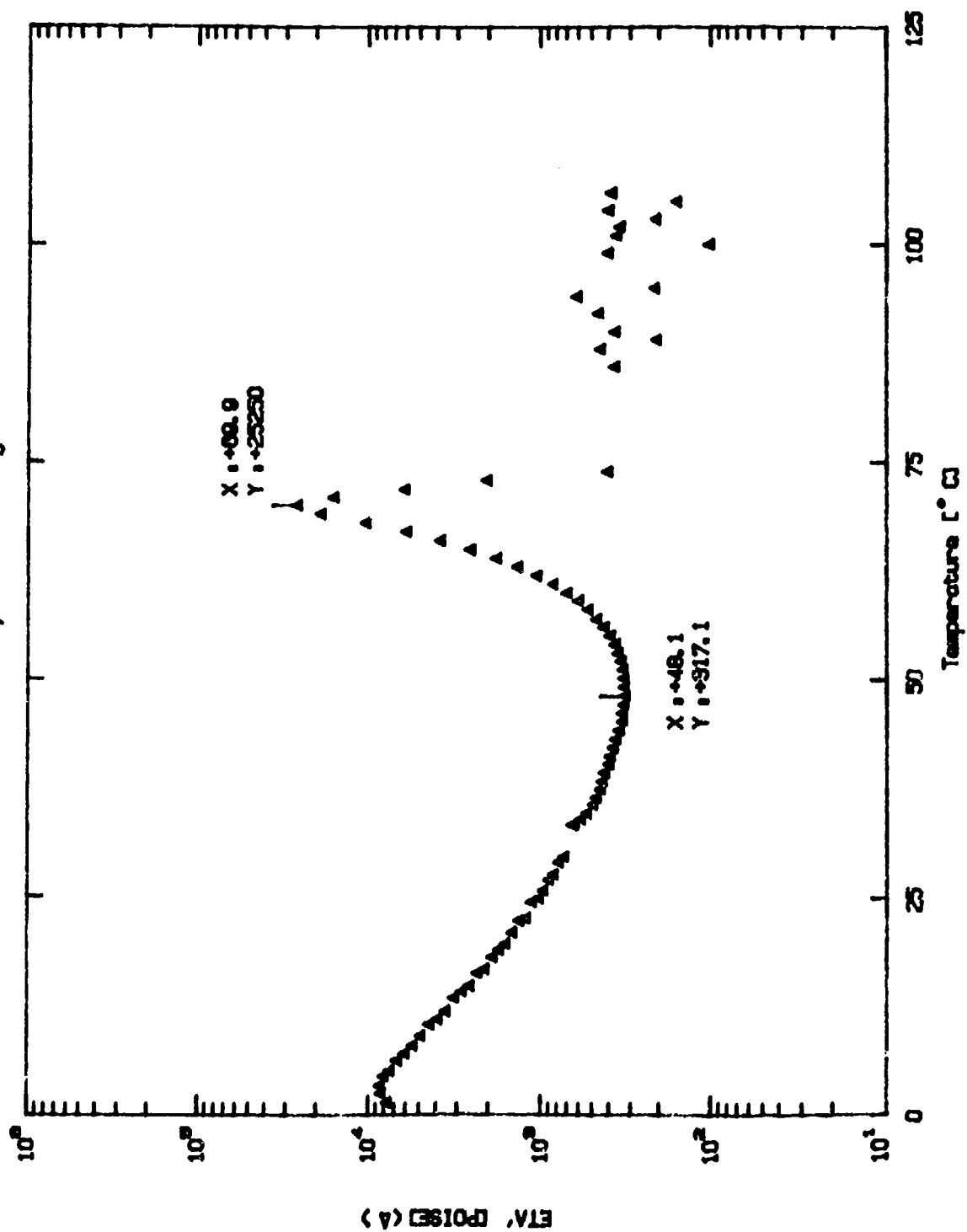


Figure M.64. Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 12 Months.

EA9396 aged 18 months at RT

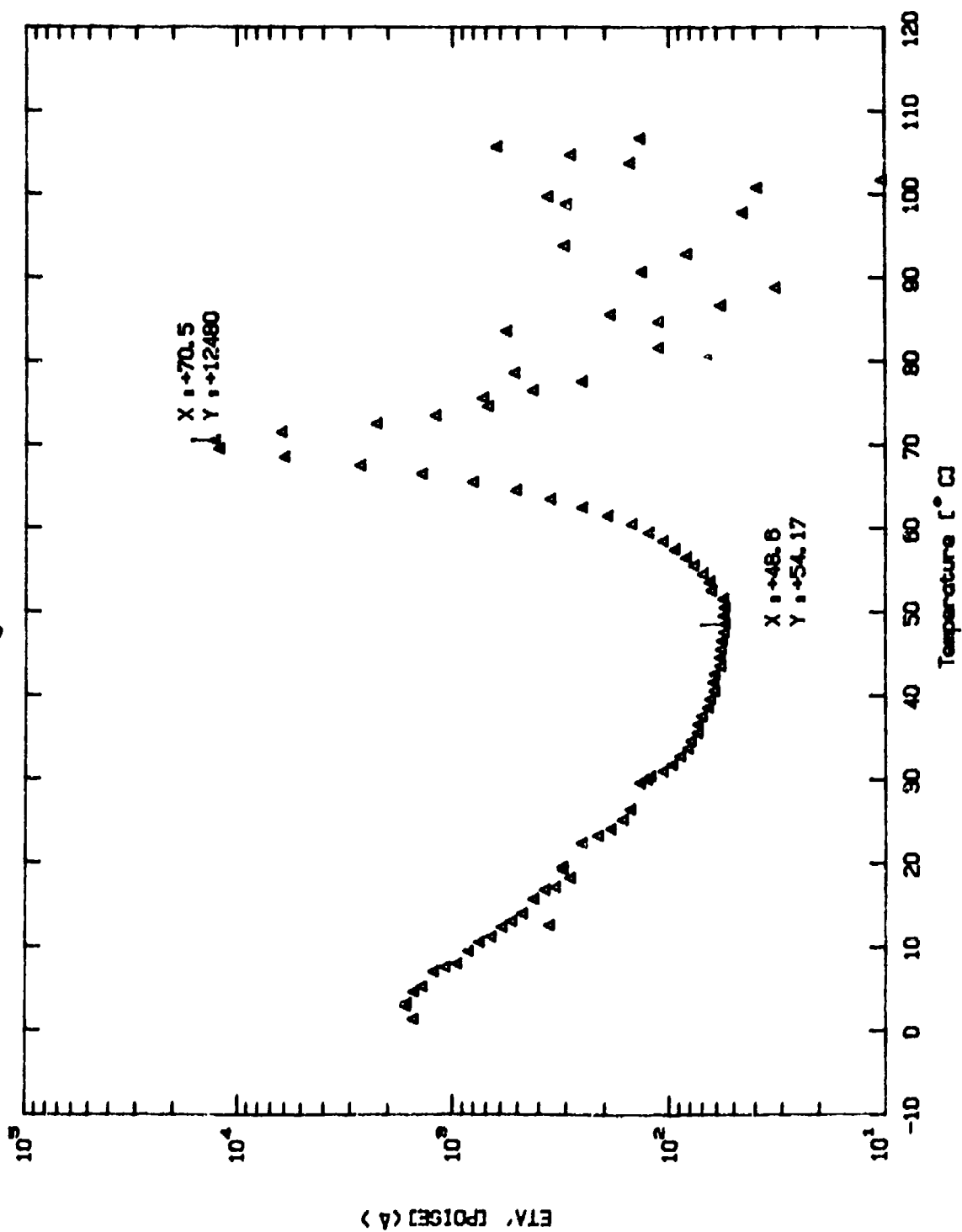


Figure M.65. Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 18 Months.

EA 9396 Aged 18 months at 100 deg. F

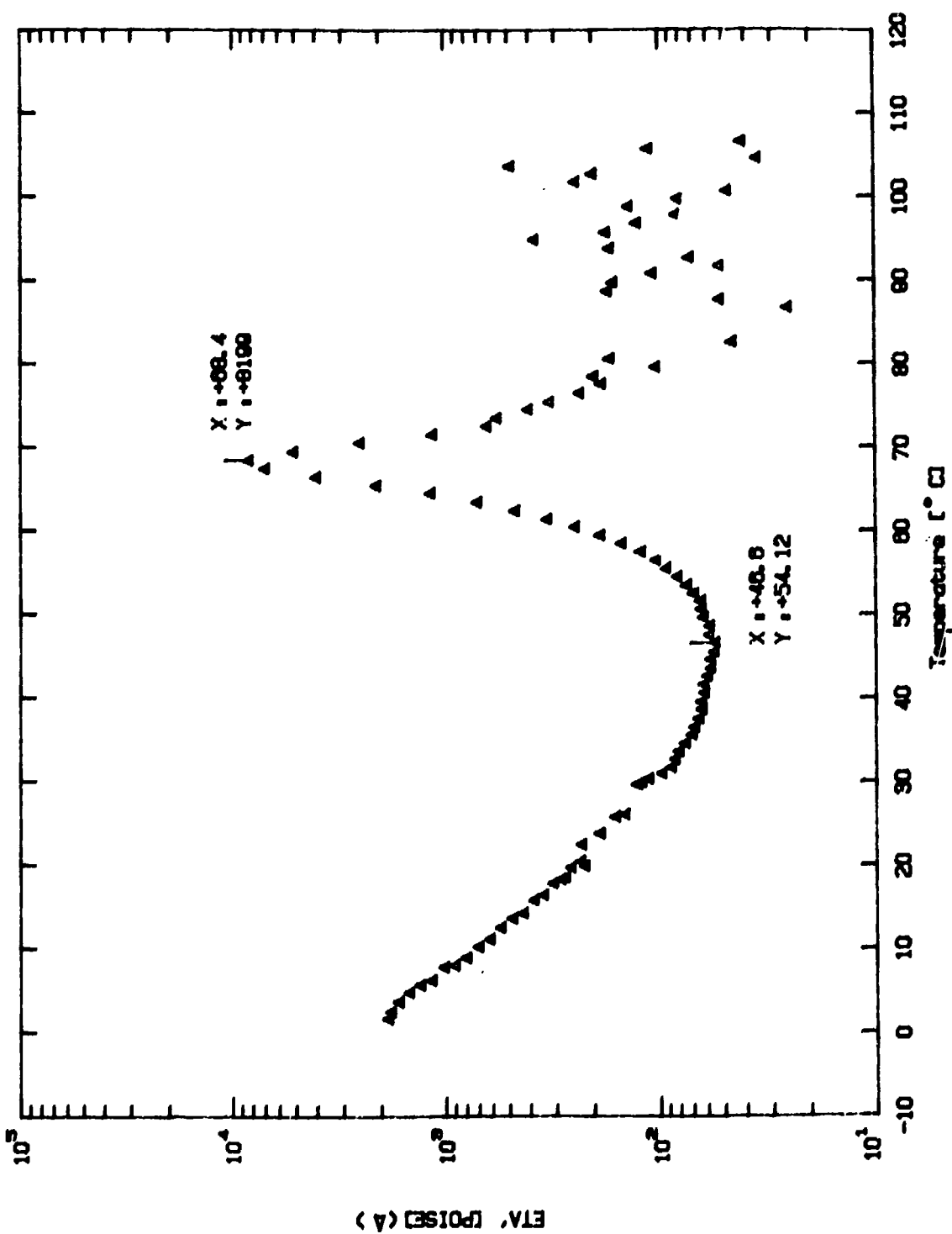


Figure M.66. Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 18 Months.

EA9396 Aged 18 months at 120 deg. F

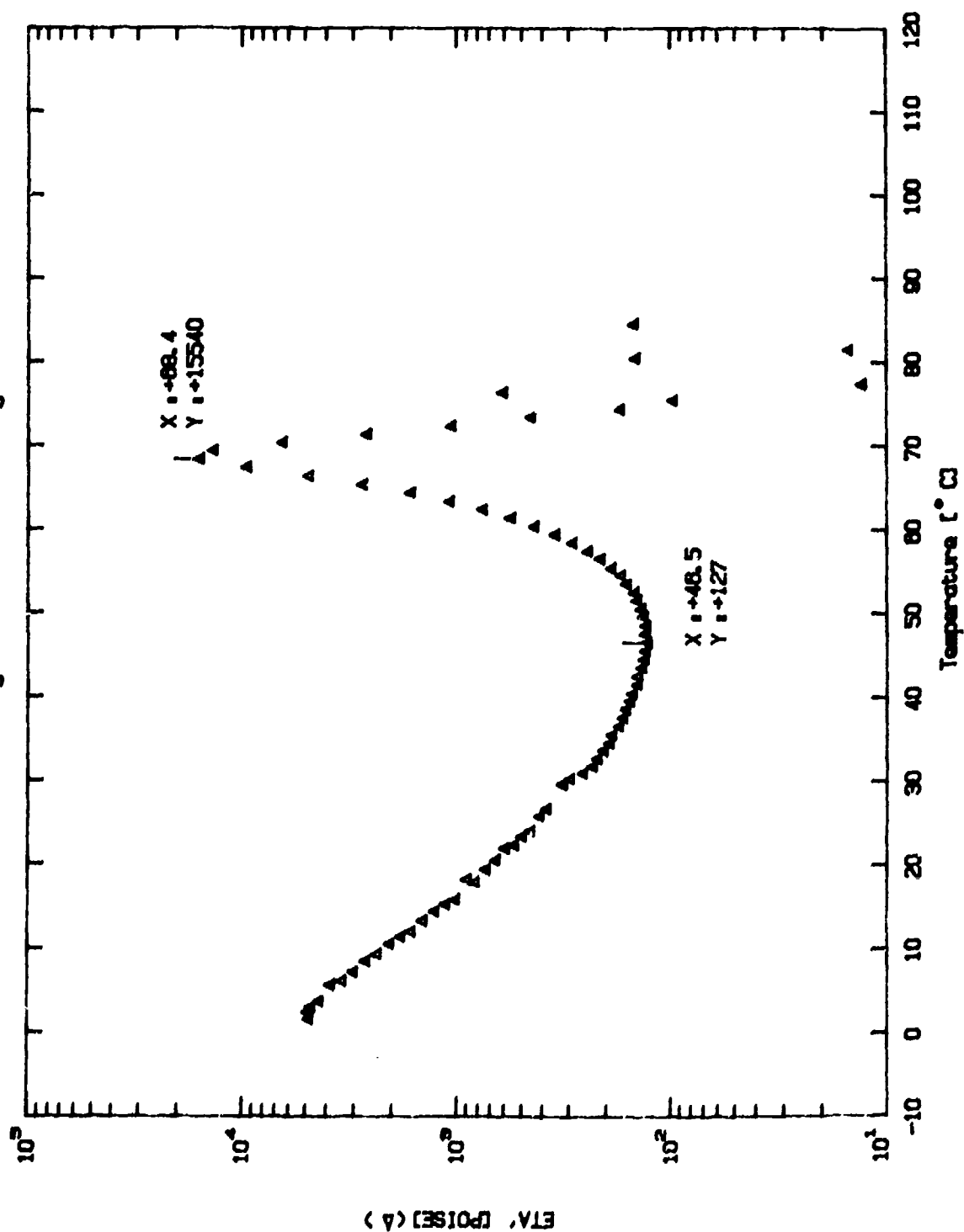


Figure M.67. Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 18 Months.



EA9396 2 Years At RT

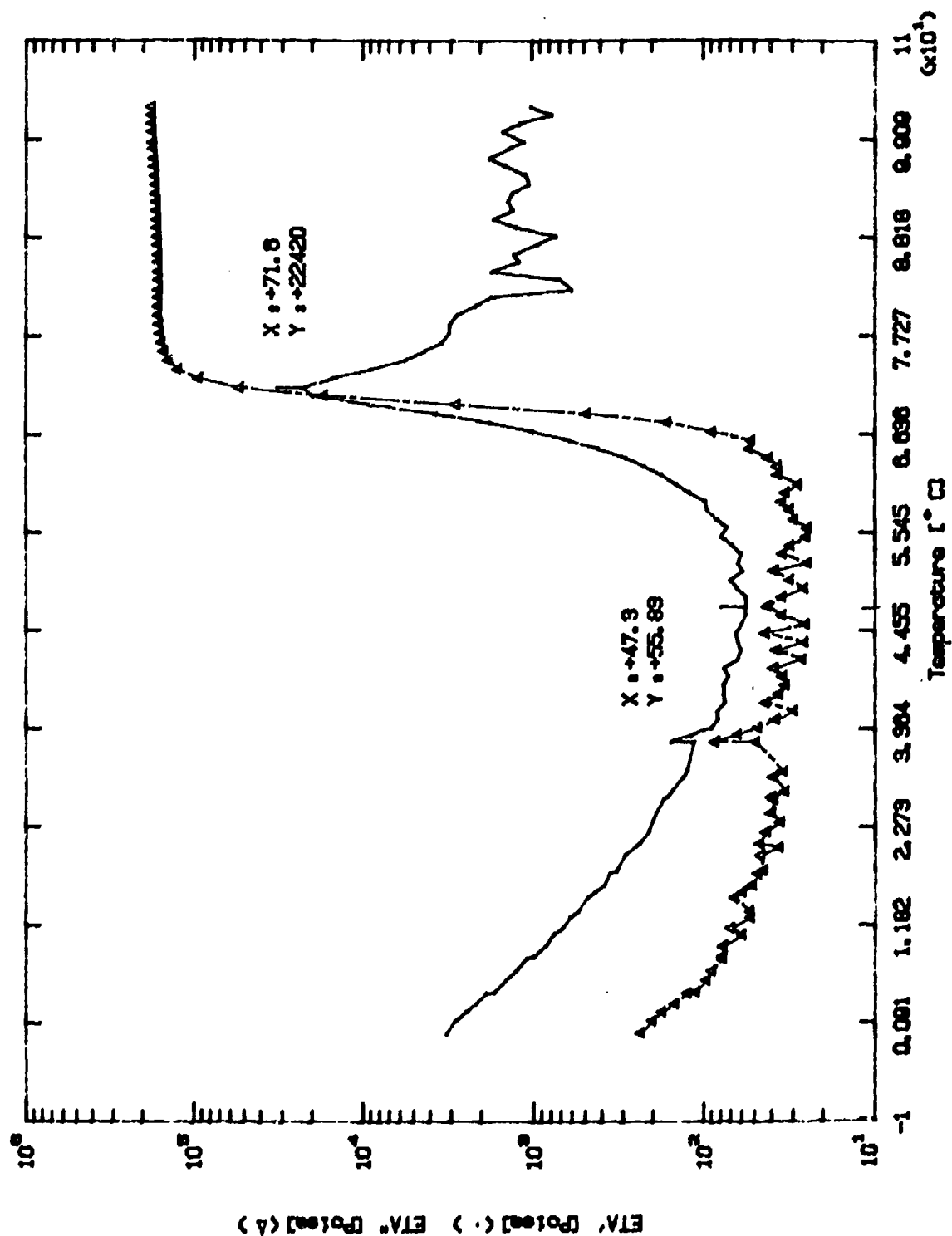


Figure M.68. Viscosity Cure Profile for EA9396, After Storage at 22°C (72°F) for 24 Months.

EA9396 2 yrs. @ 100 F

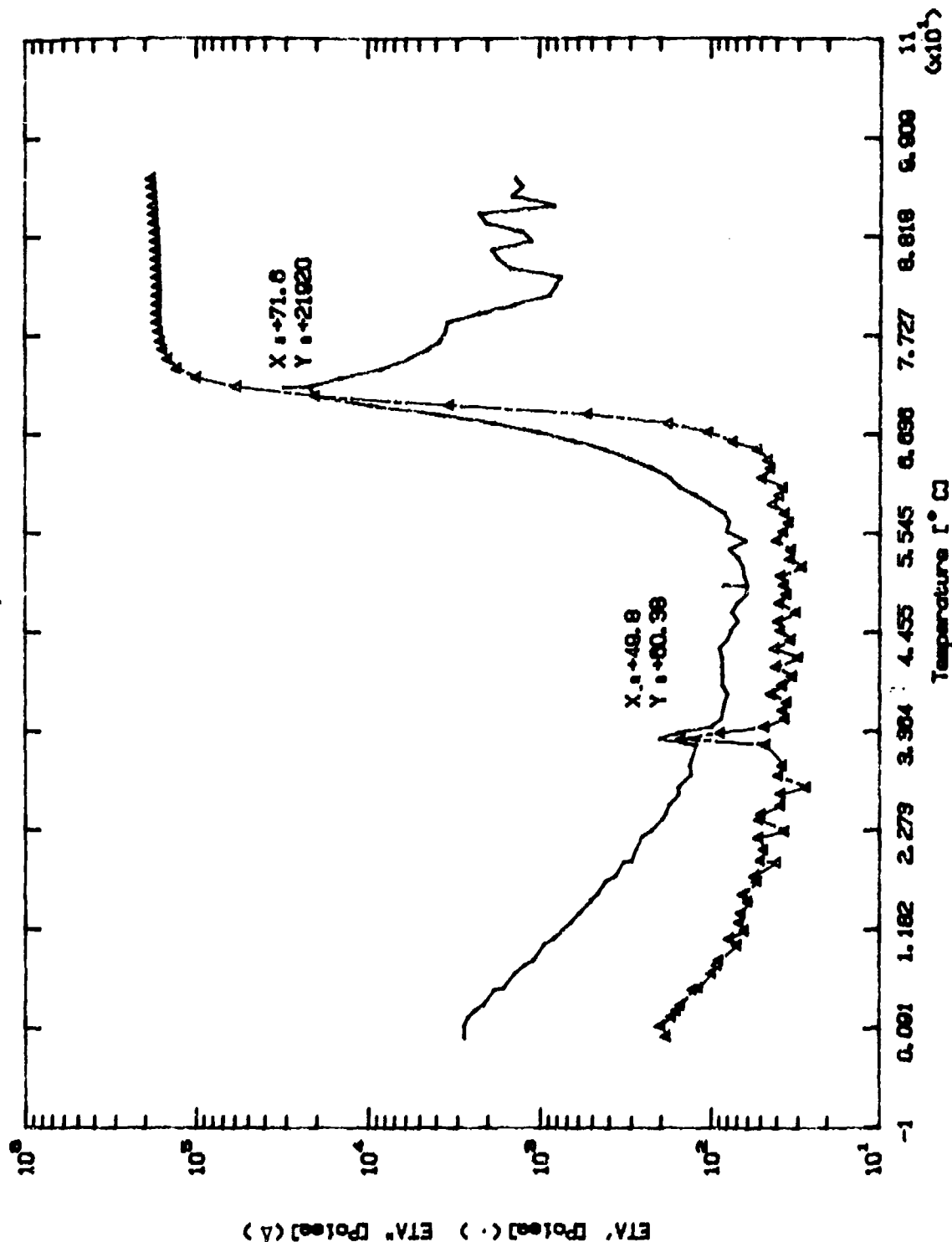


Figure M.69. Viscosity Cure Profile for EA9396, After Storage at 38°C (100°F) for 24 Months.

EA9396 2 Years @ 120 Deg. F

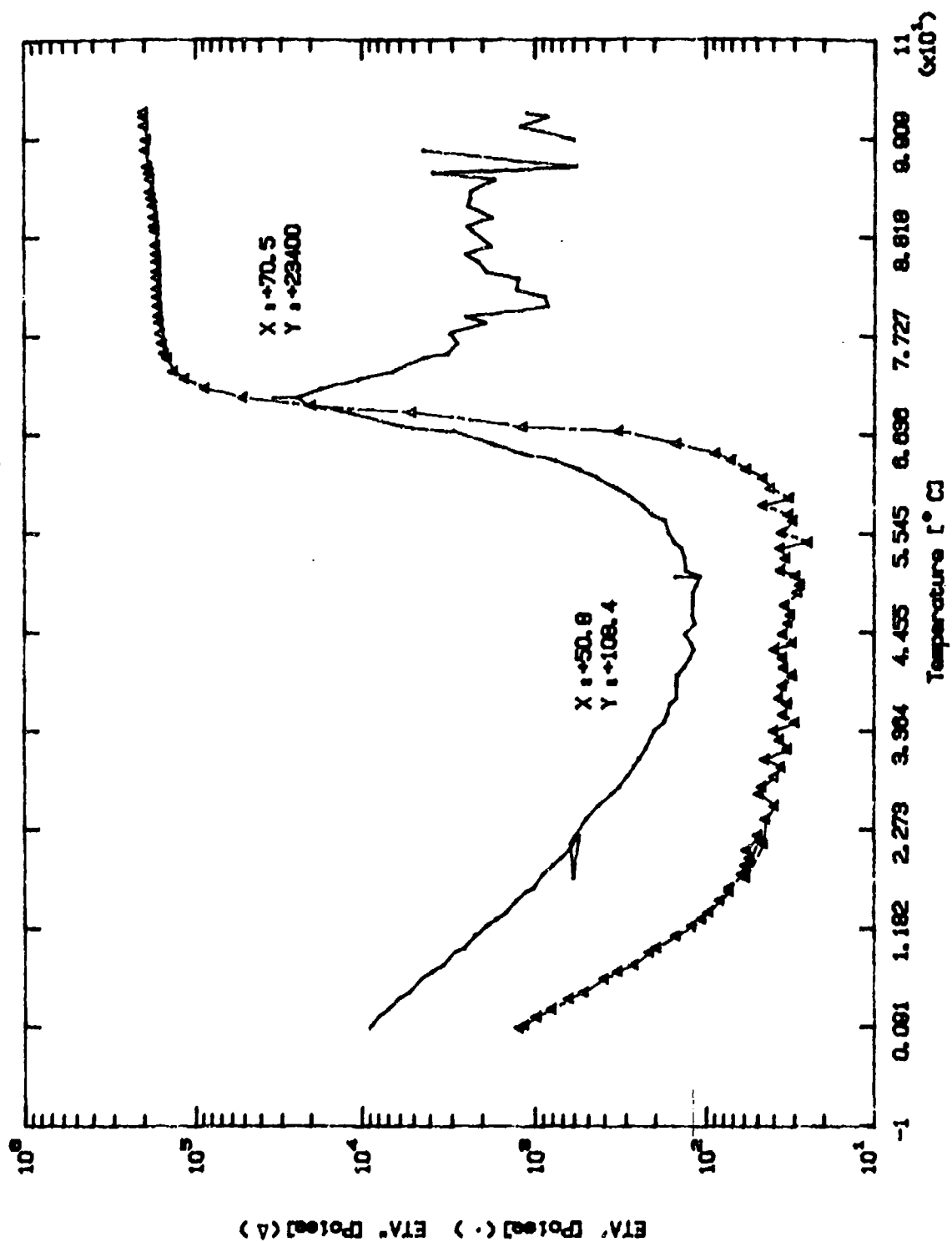


Figure M.70. Viscosity Cure Profile for EA9396, After Storage at 49°C (120°F) for 24 Months.

## APPENDIX N

### INDIVIDUAL SPECIMEN HONEYCOMB FLATWISE TENSILE PROPERTIES, EFFECT OF ADHESIVE FILLET SIZE

When honeycomb sandwich constructions are pulled apart in a flatwise tension mode, the limiting strength is that of the core. Heavier core, with smaller cell size and higher cell wall thickness obviously requires higher loads to tear the core than lighter core. The strength of the core however does not necessarily determine the flatwise tensile strength of a honeycomb construction. Failure may occur at lower loads than that required to fail the core because a variety of other failure modes can occur. Some of these alternative failure modes include debonding of the adhesive from the facing skin, debonding of the adhesive fillets from the core cell walls, cohesive failure within the adhesive itself, or, in the case of composite skins, delamination of the facing skins. Whichever of these various locations is the "weakest-link-in-the-chain" will fail first.

Probably the most common of these alternative failure modes is the failure of the bond between the adhesive fillets and the core cell walls and the leading reason for this is inadequate fillet size. It is intuitively obvious that as the adhesive fillet size increases, and concurrently the area of the fillet-cell wall bond increases, this "link-in-the-chain" will become stronger and failure loads will increase until the strength of the next weakest link in the chain is exceeded.

Since the fillet size is the most easily controlled variable in a honeycomb sandwich bond (one only has to use more adhesive to increase the fillet size), the effect of this variable on flatwise tensile strength was investigated.

Honeycomb sandwich panels were prepared and tested with varying amounts of adhesive (ranging from none to  $0.73 \text{ gm/cm}^2$ ) between the skin and the core. The individual specimen flatwise tensile strengths obtained from these panels are presented in Tables N.1 - N.5. These results were summarized and discussed in Section 3.10.2.

TABLE N.1  
FLATWISE TENSILE STRENGTH OF HONEYCOMB SANDWICH  
WITH NO SUPPLEMENTAL ADHESIVE

| Test :          |                   | Flatwise tension; ASTM C297-88         |         | Task #9                                                         |                           | Tested by: |         |       |         | DRB |             |         |
|-----------------|-------------------|----------------------------------------|---------|-----------------------------------------------------------------|---------------------------|------------|---------|-------|---------|-----|-------------|---------|
| Material:       |                   | Hysol EA-9396 A/B; W133 Graphite Skins |         | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |                           |            |         |       |         |     |             |         |
| Specimen Number | Test Temperature  | Specimen Width                         |         | Maximum Load (lbs.)                                             | Flatwise Tensile Strength |            | A/C (%) |       | A/S (%) |     | Date Tested | Remarks |
|                 |                   | 1 (in.)                                | 2 (in.) |                                                                 | (Psi.)                    | (MPa)      | (%)     | (%)   | (%)     | (%) |             |         |
| BIL-GR-65-1     | 22°C (72°F) (DRY) | 2.000                                  | 2.000   | 725                                                             | 181.3                     | 1.250      | 10      | 80    | 10      | 0   | 3/29/90     | (1,2,3) |
| BIL-GR-65-2     | "                 | 2.000                                  | 2.000   | 625                                                             | 156.3                     | 1.077      | 10      | 80    | 10      | 0   | "           | (1,2,3) |
| BIL-GR-65-3     | "                 | 2.000                                  | 2.000   | 875                                                             | 218.8                     | 1.508      | 10      | 80    | 10      | 0   | "           | (1,2,3) |
| BIL-GR-65-4     | "                 | 2.000                                  | 2.000   | 1,750                                                           | 437.5                     | 3.017      | 10      | 0     | 90      | 0   | "           | (1,2,3) |
|                 |                   |                                        |         | Average                                                         |                           | 248.4      |         | 1.713 |         |     |             |         |
|                 |                   |                                        |         | Std. Dev.                                                       |                           | 128.6      |         | 0.887 |         |     |             |         |

Remarks:

- (1) Failure Mode:
- A/C: Fillet-to-core interface (bare honeycomb)
  - A/S: Adhesive-to-skin interface (bare aluminum or composite skin)
  - A: Cohesive within adhesive (between base of fillet and adhesive layer)
  - C: Core tearing
- (2) Failed on top side of core.
- (3) No adhesive present between core and either skin.

TABLE N.2

FLATWISE TENSILE STRENGTH OF HONEYCOMB SANDWICH  
WITH MODERATE ADHESIVE LAYER ALONG TOP SKIN

| Test :          |                   | Flatwise tension; ASTM C297-88         |         | Task #9                                                         |                           | Tested by: |         |     |         | DRB |             |         |         |
|-----------------|-------------------|----------------------------------------|---------|-----------------------------------------------------------------|---------------------------|------------|---------|-----|---------|-----|-------------|---------|---------|
| Material:       |                   | Hysol EA-9396 A/B; W133 Graphite Skins |         | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |                           |            |         |     |         |     |             |         |         |
| Specimen Number | Test Temperature  | Specimen Width                         |         | Maximum Load (lbs.)                                             | Flatwise Tensile Strength |            | A/C (%) |     | A/S (%) |     | Date Tested | Remarks |         |
|                 |                   | 1 (in.)                                | 2 (in.) |                                                                 | (Psi.)                    | (MPa)      | (%)     | (%) | (%)     | (%) |             |         |         |
| BIL-GR-64-1     | 22°C (72°F) (DRY) | 2.000                                  | 2.000   | 2,550                                                           | 637.5                     | 4.396      | 10      | 0   | 0       | 90  | 0           | 3/29/90 | (1,2,3) |
| BIL-GR-64-2     | "                 | 2.000                                  | 2.000   | 2,875                                                           | 718.8                     | 4.956      | 5       | 0   | 0       | 95  | 0           | "       | (1,2,3) |
| BIL-GR-64-3     | "                 | 2.000                                  | 2.000   | 2,320                                                           | 580.0                     | 3.999      | 5       | 0   | 0       | 95  | 0           | "       | (1,2,3) |
| BIL-GR-64-4     | "                 | 2.000                                  | 2.000   | 1,975                                                           | 493.8                     | 3.404      | 10      | 0   | 0       | 90  | 0           | "       | (1,2,3) |
| Average         |                   |                                        |         | 607.5                                                           |                           | 4.189      |         |     |         |     |             |         |         |
| Std. Dev.       |                   |                                        |         | 94.8                                                            |                           | 0.654      |         |     |         |     |             |         |         |

## Remarks:

(1) Failure Mode:

A/C: Fillet-to-core interface (bare honeycomb)

A/S: Adhesive-to-skin interface (bare aluminum or composite skin)

A: Cohesive within adhesive (between base of fillet and adhesive layer)

C: Core tearing

(2) Failed on bottom side of core.

(3) 0.21 gm/cm<sup>2</sup> adhesive between core and top skin.

TABLE N.3

FLATWISE TENSILE STRENGTH OF HONEYCOMB SANDWICH  
WITH LIGHT ADHESIVE LAYER ALONG BOTH SKINS

| Test :          |                   | Flatwise tension; ASTM C297-88         |         | Task #9b                                                        |                                   | Tested by: |              |    |         |         | DRB   |       |             |         |
|-----------------|-------------------|----------------------------------------|---------|-----------------------------------------------------------------|-----------------------------------|------------|--------------|----|---------|---------|-------|-------|-------------|---------|
| Material:       |                   | Hysol EA-9396 A/B; W133 Graphite Skins |         | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |                                   |            |              |    |         |         |       |       |             |         |
| Specimen Number | Test Temperature  | Specimen Width                         |         | Maximum Load (lbs.)                                             | Flatwise Tensile Strerngth (Psi.) |            | Failure Mode |    | A/C (%) | A/S (%) | A (%) | C (%) | Date Tested | Remarks |
|                 |                   | 1 (in.)                                | 2 (in.) |                                                                 |                                   | (MPa)      |              |    |         |         |       |       |             |         |
| BIL-GR-81-1     | 22°C (72°F) (DRY) | 2.000                                  | 2.000   | 2,889                                                           | 722.3                             | 4.980      | 20           | 65 | 15      | 0       |       |       | 9/10/90     | (1,2)   |
| BIL-GR-81-2     | "                 | 2.000                                  | 2.000   | 3,267                                                           | 816.8                             | 5.631      | 35           | 60 | 5       | 0       |       |       | "           | (1,2)   |
| BIL-GR-81-3     | "                 | 2.000                                  | 2.000   | 2,901                                                           | 725.3                             | 5.001      | 50           | 45 | 5       | 0       |       |       | "           | (1,2)   |
| BIL-GR-81-4     | "                 | 2.000                                  | 2.000   | 2,959                                                           | 739.8                             | 5.101      | 30           | 70 | 0       | 0       |       |       | "           | (1,2)   |
|                 |                   |                                        |         | Average                                                         | 751.0                             | 5.178      |              |    |         |         |       |       |             |         |
|                 |                   |                                        |         | Std. Dev.                                                       | 44.5                              | 0.307      |              |    |         |         |       |       |             |         |

Remarks:

(1) Failure Mode:

A/C: Fillet-to-core interface (bare honeycomb)

A/S: Adhesive-to-skin interface (bare aluminum or composite skin)

A: Cohesive within adhesive (between base of fillet and adhesive layer)

C: Core tearing

(2) 0.08 gm/cm<sup>2</sup> adhesive between core and both skins.

TABLE N.4

FLATWISE TENSILE STRENGTH OF HONEYCOMB SANDWICH  
WITH MODERATE ADHESIVE LAYER ALONG BOTH SKINS

| Test :          |                   | Flatwise tension: ASTM C297-88         |         | Task #9b                                                        |                           | Tested by: |              |         |       | DRB   |               |
|-----------------|-------------------|----------------------------------------|---------|-----------------------------------------------------------------|---------------------------|------------|--------------|---------|-------|-------|---------------|
| Material:       |                   | Hysol EA-9396 A/B; W133 Graphite Skins |         | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |                           |            |              |         |       |       |               |
| Specimen Number | Test Temperature  | Specimen Width                         |         | Maximum Load (lbs.)                                             | Flatwise Tensile Strength |            | Failure Mode |         |       |       | Remarks       |
|                 |                   | 1 (in.)                                | 2 (in.) |                                                                 | (Psi.)                    | (MPa)      | A/C (%)      | A/S (%) | A (%) | C (%) |               |
| BIL-GR-83-1     | 22°C (72°F) (DRY) | 2.000                                  | 2.000   | 3,219                                                           | 804.8                     | 5.549      | 0            | 65      | 35    | 0     | 9/10/90 (1,2) |
| BIL-GR-83-2     | "                 | 2.000                                  | 2.000   | 3,279                                                           | 819.8                     | 5.652      | 10           | 50      | 40    | 0     | " (1,2)       |
| BIL-GR-83-3     | "                 | 2.000                                  | 2.000   | 3,490                                                           | 872.5                     | 6.016      | 20           | 40      | 40    | 0     | " (1,2)       |
| BIL-GR-83-4     | "                 | 2.000                                  | 2.000   | 3,552                                                           | 888.0                     | 6.123      | 10           | 45      | 45    | 0     | " (1,2)       |
| Average         |                   |                                        |         |                                                                 | 846.3                     | 5.835      |              |         |       |       |               |
| Std. Dev.       |                   |                                        |         |                                                                 | 40.2                      | 0.277      |              |         |       |       |               |

## Remarks:

(1) Failure Mode:

A/C: Fillet-to-core interface (bare honeycomb)

A/S: Adhesive-to-skin interface (bare aluminum or composite skin)

A: Cohesive within adhesive (between base of fillet and adhesive layer)

C: Core tearing

(2) 0.21 gm/cm<sup>2</sup> adhesive between core and both skins.



TABLE N.5  
FLATWISE TENSILE STRENGTH OF HONEYCOMB SANDWICH  
WITH HEAVY ADHESIVE LAYER ALONG BOTH SKINS

| Test            | Flatwise tension, ASTM C297-88         |                |         | Task #9b                                                        |                           | Tested by: |              |         |         |             | DRB     |
|-----------------|----------------------------------------|----------------|---------|-----------------------------------------------------------------|---------------------------|------------|--------------|---------|---------|-------------|---------|
| Material:       | Hysol EA-9396 A/B; W133 Graphite Skins |                |         | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |                           |            |              |         |         |             |         |
| Specimen Number | Test Temperature                       | Specimen Width |         | Maximum Load (lbs.)                                             | Flatwise Tensile Strength |            | Failure Mode |         |         | Date Tested | Remarks |
|                 |                                        | 1 (in.)        | 2 (in.) |                                                                 | (Psi.)                    | (MPa)      | A/C (%)      | A/S (%) | A C (%) |             |         |
| BIL-GR-88-1     | 22°C (72°F) (DRY)                      | 2.000          | 2.000   | 3,915                                                           | 978.8                     | 6.748      | 55           | 45      | 0       | 7/23/91     | (1,2,3) |
| BIL-GR-88-2     | "                                      | 2.000          | 2.000   | 3,725                                                           | 931.3                     | 6.421      | 55           | 45      | 0       | "           | (1,2,3) |
| BIL-GR-88-3     | "                                      | 2.000          | 2.000   | 4,120                                                           | 1030.0                    | 7.102      | 0            | 0       | 0       | "           | (1,2,4) |
| Average         |                                        |                |         |                                                                 | 980.0                     | 6.757      |              |         |         |             |         |
| Std. Dev.       |                                        |                |         |                                                                 | 49.4                      | 0.341      |              |         |         |             |         |

Remarks:

(1) Failure Mode:

A/C: Fillet-to-core interface (bare honeycomb)

A/S: Adhesive-to-skin interface (bare aluminum or composite skin)

A: Cohesive within adhesive (between base of fillet and adhesive layer)

C: Core tearing

(2) 0.75 gm/cm<sup>2</sup> adhesive between core and both skins.

(3) Most of the failure within the adhesive layer consisted of debonding of the adhesive from the glass scrim fabric.

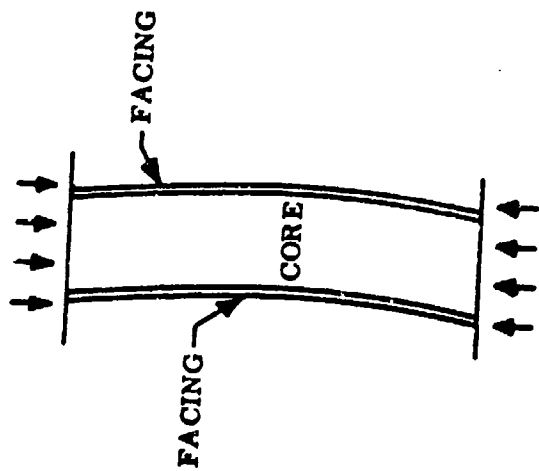
(4) Failure was 75% delamination of facing skin and 25% debonding between facing skin and loading blocks.

**APPENDIX O**  
**INDIVIDUAL SPECIMEN HONEYCOMB SANDWICH**  
**EDGEWISE COMPRESSION PROPERTIES, EFFECT OF**  
**COCURING VS. SECONDARY BONDING**

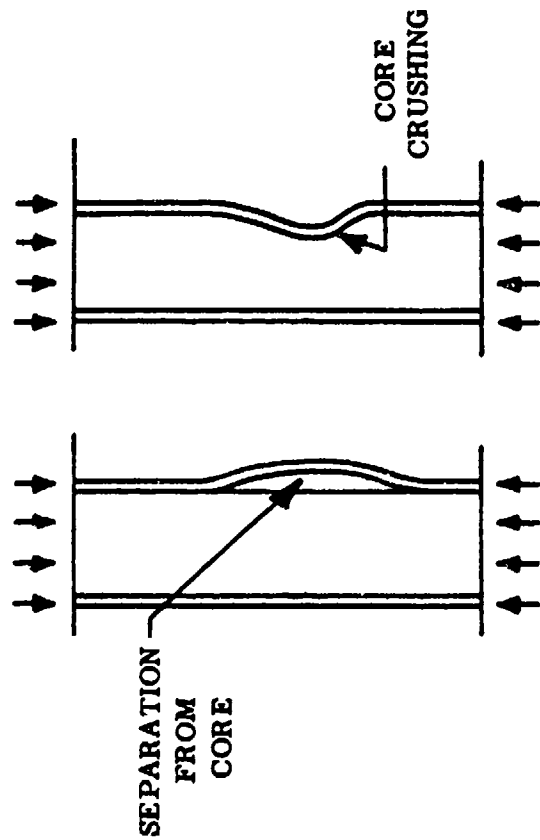
The six tables in this appendix present the detailed edgewise compression strength data for honeycomb sandwich specimens prepared by either cocuring of the skins to the core or secondarily bonding the skins to the core. The specimens consisted of either graphite or glass fabric reinforced skins on two different density aluminum honeycomb cores.

In order to prevent crushing of the ends of the sandwich specimens during loading, approximately 4.5 cm (1.75 in) of the core on each end of the specimen was filled with epoxy resin, leaving a central, unpotted, gage section between the loading fixtures of approximately 14 cm (5.5 in).

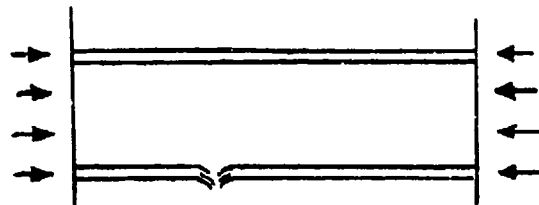
Figure O.1 illustrates the various failure modes observed for these specimens.



A. General Buckling



B. Wrinkling of Facings



C. Skin Compression

Figure 0.1. Types of Failure Modes Observed in Edgewise Compression Tests.

TABLE 0.1

EDGEWISE COMPRESSION STRENGTH OF COCURED HONEYCOMB SANDWICH WITH LIGHT  
CORE AND GRAPHITE REINFORCED SKINS

|                            |                                 |                       |                                                                  |                   |         |
|----------------------------|---------------------------------|-----------------------|------------------------------------------------------------------|-------------------|---------|
| Test :                     | Edgewise Compression; ASTM-C364 |                       | Task #9A                                                         | Tested By: PM     |         |
| Material :                 | EA-9396 A/B; W133 Graphite      | 2-ply skins           | CR III-3/16-5052-.002N-5.7-2.54 cm (1 inch) thick honeycomb core |                   |         |
| Reinforcement Orientation: | Fill                            | Core Orientation: "W" |                                                                  | Bonding Approach: | Cocured |

| Combined Skin   |                   |             |                             |                                        |             |
|-----------------|-------------------|-------------|-----------------------------|----------------------------------------|-------------|
| Specimen Number | Test Conditions   | Width (in.) | Thicknesses (T1 + T2) (in.) |                                        | Date Tested |
|                 |                   |             | Maximum Load (lbs.)         | Maximum Stress in Facings (Ksi.) (MPa) |             |
| 9A-1-1          | 22°C (72°F) (DRY) | 2.980       | 7,388                       | 34.92                                  | 1/22/90     |
| 9A-1-2          | "                 | 2.975       | 10,293                      | 48.73                                  | 1/23/91     |
| 9A-1-3          | "                 | 2.970       | 8,628                       | 40.92                                  | "           |
| Average         |                   |             |                             | 41.52                                  | 286.3       |
| Std. Dev.       |                   |             |                             | 6.93                                   | 47.8        |

## Remarks:

(1) Failure Mode:

- a) General buckling.
- b) Shear crimping (with skin damage).
- c) Dimpling of facings.
- d) Wrinkling of facings:
  - x) Core crushing.
  - y) Separation from core.
- e) Skin compression.

(2) Test speed = 0.02 in/min.

TABLE 0.2

EDGEWISE COMPRESSION STRENGTH OF SECONDARILY BONDED HONEYCOMB SANDWICH  
WITH LIGHT CORE AND GRAPHITE REINFORCED SKINS

|                            |                                 |                       |                             |                     |                                                                  |             |
|----------------------------|---------------------------------|-----------------------|-----------------------------|---------------------|------------------------------------------------------------------|-------------|
| Test :                     | Edgewise Compression; ASTM-C364 |                       |                             | Task #9A            | Tested By: PM                                                    |             |
| Material :                 | EA-9396 A/B; W133 Graphite      |                       |                             | 2-ply skins         | CR III-3/16-5052-.002N-5.7-2.54 cm (1 inch) thick honeycomb core |             |
| Reinforcement Orientation: | Fill                            | Core Orientation: "W" |                             |                     | Bonding Approach: Secondarily Bonded                             |             |
| Combined Skin              |                                 |                       |                             |                     |                                                                  |             |
| Specimen Number            | Test Conditions                 | Width (in.)           | Thicknesses (T1 + T2) (in.) | Maximum Load (lbs.) | Maximum Stress                                                   |             |
|                            |                                 |                       |                             |                     | (Ksi.)                                                           | (MPa)       |
| 9A-2-1                     | 22°C (72°F) (DRY)               | 3.024                 | 0.0670                      | 8,081               | 39.89                                                            | 275.0       |
| 9A-2-2                     | "                               | 3.088                 | 0.0670                      | 6,021               | 29.10                                                            | 200.6       |
| 9A-2-3                     | "                               | 3.020                 | 0.0670                      | 7,495               | 37.04                                                            | 255.4       |
| Average                    |                                 |                       |                             |                     | 35.34                                                            | 243.7       |
| Std. Dev.                  |                                 |                       |                             |                     | 5.59                                                             | 38.5        |
|                            |                                 |                       |                             |                     |                                                                  | Date Tested |
|                            |                                 |                       |                             |                     |                                                                  | 1/23/91     |
|                            |                                 |                       |                             |                     |                                                                  | "           |
|                            |                                 |                       |                             |                     |                                                                  | "           |
|                            |                                 |                       |                             |                     |                                                                  | Remarks     |
|                            |                                 |                       |                             |                     |                                                                  | (1dy,2)     |
|                            |                                 |                       |                             |                     |                                                                  | (1dy,1e,2)  |
|                            |                                 |                       |                             |                     |                                                                  | (1dy,2)     |

## Remarks:

## (1) Failure Mode:

- a) General buckling.
- b) Shear crimping (with skin damage).
- c) Dimpling of facings.
- d) Wrinkling of facings:
  - x) Core crushing.
  - y) Separation from core.
- e) Skin compression.

(2) Test speed = 0.02 in/min.

TABLE 0.3

EDGEWISE COMPRESSION STRENGTH OF COCURED HONEYCOMB SANDWICH WITH HEAVY  
CORE AND GRAPHITE REINFORCED SKINS

|                            |                                        |                       |                             |                                                                 |                           |       |             |            |
|----------------------------|----------------------------------------|-----------------------|-----------------------------|-----------------------------------------------------------------|---------------------------|-------|-------------|------------|
| Test :                     | Edgewise Compression; ASTM-C364        |                       |                             | Task #9A                                                        | Tested By: PM             |       |             |            |
| Material :                 | EA-9396 A/B; W133 Graphite 2-ply skins |                       |                             | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |                           |       |             |            |
| Reinforcement Orientation: | Fill                                   | Core Orientation: "W" |                             |                                                                 | Bonding Approach: Cocured |       |             |            |
| Combined Skin              |                                        |                       |                             |                                                                 |                           |       |             |            |
| Specimen Number            | Test Conditions                        | Width (in.)           | Thicknesses (T1 + T2) (in.) | Maximum Load (lbs.)                                             | Maximum Stress in Facings |       | Date Tested | Remarks    |
|                            |                                        |                       |                             |                                                                 | (Ksi.)                    | (MPa) |             |            |
| 9A-3-1                     | 22°C (72°F) (DRY)                      | 2.983                 | 0.0670                      | 9,536                                                           | 47.71                     | 329.0 | 1/23/91     | (1dx,1e,2) |
| 9A-3-2                     | "                                      | 2.960                 | 0.0670                      | 9,766                                                           | 49.24                     | 339.5 | 1/24/91     | (1dx,1e,2) |
| 9A-3-3                     | "                                      | 2.964                 | 0.0670                      | 8,892                                                           | 44.77                     | 308.7 | "           | (1dx,1e,2) |
|                            |                                        |                       |                             |                                                                 | Average                   |       | 325.7       |            |
|                            |                                        |                       |                             |                                                                 | Std. Dev.                 |       | 15.7        |            |

## Remarks:

- (1) Failure Mode:
- a) General buckling.
  - b) Shear crimping (with skin damage).
  - c) Dimpling of facings.
  - d) Wrinkling of facings:
    - x) Core crushing.
    - y) Separation from core.
  - e) Skin compression.

(2) Test speed = 0.02 in/min.

TABLE 0.4

**EDGEWISE COMPRESSION STRENGTH OF SECONDARILY BONDED HONEYCOMB SANDWICH  
WITH HEAVY CORE AND GRAPHITE REINFORCED SKINS**

|                            |                   |                                 |                             |                     |                                                                 |       |             |            |
|----------------------------|-------------------|---------------------------------|-----------------------------|---------------------|-----------------------------------------------------------------|-------|-------------|------------|
| Test :                     |                   | Edgewise Compression; ASTM-C364 |                             | Task #9A            | Tested By: PM                                                   |       |             |            |
| Material :                 |                   | EA-9396 A/B; W133 Graphite      |                             | 2-ply skins         | CR III-1/4-5052-.004N-7.9-2.54 cm (1 inch) thick honeycomb core |       |             |            |
| Reinforcement Orientation: |                   | Fill                            | Core Orientation: "L"       |                     | Bonding Approach: Secondarily Bonded                            |       |             |            |
| Combined Skin              |                   |                                 |                             |                     |                                                                 |       |             |            |
| Specimen Number            | Test Conditions   | Width (in.)                     | Thicknesses (T1 + T2) (in.) | Maximum Load (lbs.) | Maximum Stress                                                  |       | Date Tested | Remarks    |
|                            |                   |                                 |                             |                     | (Ksi.)                                                          | (MPa) |             |            |
| 9A-4-2                     | 22°C (72°F) (DRY) | 2.975                           | 0.0650                      | 7,647               | 39.54                                                           | 272.6 | 1/24/91     | (1dy,1e,2) |
| 9A-4-3                     | "                 | 2.962                           | 0.0650                      | 7,524               | 39.08                                                           | 269.5 | "           | (1dy,2)    |
| Average                    |                   |                                 |                             |                     | 39.31                                                           | 271.1 |             |            |
| Std. Dev.                  |                   |                                 |                             |                     | 0.33                                                            | 2.2   |             |            |

## Remarks:

(1) Failure Mode:

- a) General buckling.
- b) Shear crimping (with skin damage).
- c) Dimpling of facings.
- d) Wrinkling of facings:
  - x) Core crushing.
  - y) Separation from core.
- e) Skin compression.

(2) Test speed = 0.02 in/min.

TABLE 0.5

EDGEWISE COMPRESSION STRENGTH OF COCURED HONEYCOMB SANDWICH WITH LIGHT  
CORE AND GLASS REINFORCED SKINS

|                            |                                     |                       |                                                                  |                           |                           |       |             |             |
|----------------------------|-------------------------------------|-----------------------|------------------------------------------------------------------|---------------------------|---------------------------|-------|-------------|-------------|
| Test :                     | Edgewise Compression; ASTM-C364     |                       |                                                                  | Task #9A                  | Tested By: PM             |       |             |             |
| Material :                 | EA-9396 A/B; 7781 Glass 4-ply skins |                       | CR III-3/16-5052-.002N-5.7-2.54 cm (1 inch) thick honeycomb core |                           |                           |       |             |             |
| Reinforcement Orientation: | Fill                                | Core Orientation: "W" |                                                                  | Bonding Approach: Cocured |                           |       |             |             |
| Combined Skin              |                                     |                       |                                                                  |                           |                           |       |             |             |
| Specimen Number            | Test Conditions                     | Width (in.)           | Thicknesses (T1 + T2) (in.)                                      | Maximum Load (lbs.)       | Maximum Stress in Facings |       | Date Tested | Remarks     |
|                            |                                     |                       |                                                                  |                           | (Ksi.)                    | (MPa) |             |             |
| 9A-5-1                     | 22°C (72°F) (DRY)                   | 2.955                 | 0.0860                                                           | 11,271                    | 44.35                     | 305.8 | 1/24/91     | (1a,dx,e,2) |
| 9A-5-2                     | "                                   | 2.970                 | 0.0860                                                           | 10,625                    | 41.60                     | 286.8 | "           | (1a,dx,e,2) |
| 9A-5-3                     | "                                   | 2.965                 | 0.0860                                                           | 10,654                    | 41.78                     | 288.1 | "           | (1a,dx,e,2) |
|                            |                                     |                       |                                                                  | Average                   | 42.58                     | 293.6 |             |             |
|                            |                                     |                       |                                                                  | Std. Dev.                 | 1.54                      | 10.6  |             |             |

## Remarks:

## (1) Failure Mode:

- a) General buckling.
- b) Shear crimping (with skin damage).
- c) Dimpling of facings.
- d) Wrinkling of facings:
  - x) Core crushing.
  - y) Separation from core.
- e) Skin compression.

(2) Test speed = 0.02 in/min.



TABLE 0.6

EDGEWISE COMPRESSION STRENGTH OF SECONDARILY BONDED HONEYCOMB SANDWICH  
WITH LIGHT CORE AND GLASS REINFORCED SKINS

|                            |                   |                                     |                             |                                                                  |                                      |       |
|----------------------------|-------------------|-------------------------------------|-----------------------------|------------------------------------------------------------------|--------------------------------------|-------|
| Test :                     |                   | Edgewise Compression; ASTM-C364     |                             | Task #9A                                                         | Tested By: PM                        |       |
| Material :                 |                   | EA-9396 A/B; 7781 Glass 4-ply skins |                             | CR III-3/16-5052-.002N-5.7-2.54 cm (1 inch) thick honeycomb core |                                      |       |
| Reinforcement Orientation: |                   | Fill                                | Core Orientation: "L"       |                                                                  | Bonding Approach: Secondarily Bonded |       |
| Combined Skin              |                   |                                     |                             |                                                                  |                                      |       |
| Specimen Number            | Test Conditions   | Width (in.)                         | Thicknesses (T1 + T2) (in.) | Maximum Load (lbs.)                                              | Maximum Stress                       |       |
|                            |                   |                                     |                             |                                                                  | in Facings (Ksi.)                    | (MPa) |
| 9A-6-1                     | 22°C (72°F) (DRY) | 3.025                               | 0.0800                      | 8,408                                                            | 34.74                                | 239.6 |
| 9A-6-2                     | "                 | 2.915                               | 0.0800                      | 6,660                                                            | 28.56                                | 196.9 |
| 9A-6-3                     | "                 | 3.010                               | 0.0800                      | 11,191                                                           | 46.47                                | 320.4 |
| Average                    |                   |                                     |                             |                                                                  | 36.59                                | 252.3 |
| Std. Dev.                  |                   |                                     |                             |                                                                  | 9.10                                 | 62.7  |
|                            |                   | Date Tested                         |                             | Remarks                                                          |                                      |       |
|                            |                   | 1/24/91                             |                             | (1a,dy,2)                                                        |                                      |       |
|                            |                   | 1/25/91                             |                             | (1a,dx,dy,e,2)                                                   |                                      |       |
|                            |                   | "                                   |                             | (1a,dx,e,2)                                                      |                                      |       |

## Remarks:

(1) Failure Mode:

- a) General buckling.
- b) Shear crimping (with skin damage).
- c) Dimpling of facings.
- d) Wrinkling of facings:
  - x) Core crushing.
  - y) Separation from core.
- e) Skin compression.

(2) Test speed = 0.02 in/min.

**APPENDIX P**  
**INDIVIDUAL SPECIMEN COMPRESSION PROPERTIES,**  
**EFFECT OF THERMAL PULSE**

The 13 tables in this appendix present the detailed compression strength data for specimens exposed to a thermal pulse. A summary of these data was presented and discussed in Section 3.12.2.

ROOM TEMPERATURE DRY COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
NOT SUBJECTED TO A THERMAL PULSE

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)  
(2) Specimen failed outside gage section.

- (3) Test speed = 0.05 in./min.  
(4) Load only recorded.

TABLE P.2  
ROOM TEMPERATURE DRY COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

|                 |                     |                               |             |                 |             |                    |                             |             |         |
|-----------------|---------------------|-------------------------------|-------------|-----------------|-------------|--------------------|-----------------------------|-------------|---------|
| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 |             | Fiber Orientation: |                             | Fill        |         |
| Material :      |                     | EA-9396 A/B; 7781-E Glass     |             |                 |             | Tested By:         |                             | DRB         |         |
|                 |                     | Batch #1                      | Task #15    |                 |             |                    |                             |             |         |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum     |                    | Compressive Strength (Ksi.) | Date Tested | Remarks |
|                 |                     |                               |             |                 | Load (lbs.) | Ultimate           |                             |             |         |
| BIL-GL-25-1     | Thermal             | 22°C (72°F) (DRY)             | 1.040       | 0.1366          | 5,670       | 39.90              | 275.1                       | 10/17/90    | (1,3,4) |
| BIL-GL-25-3     | Pulsed              | "                             | 1.039       | 0.1422          | 5,940       | 40.22              | 277.3                       | "           | (1,3,4) |
| BIL-GL-25-15    | "                   | "                             | 1.042       | 0.1414          | 5,610       | 38.08              | 262.6                       | "           | (1,3,4) |
| BIL-GL-25-12    | "                   | "                             | 1.042       | 0.1413          | 6,160       | 41.85              | 288.6                       | "           | (1,3,4) |
| BIL-GL-25-24    | "                   | "                             | 1.042       | 0.1451          | 6,850       | 45.29              | 312.3                       | "           | (1,3,4) |
|                 |                     |                               |             |                 | Average     | 41.07              | 283.2                       |             |         |
|                 |                     |                               |             |                 | Std. Dev.   | 2.71               | 18.7                        |             |         |

Remarks:

(1) Specimen failed within the 1/2 inch gage section. (Shear fracture)

(2) Specimen failed outside gage section.

(3) Test speed = 0.05 in/min.

(4) Load only recorded.

TABLE P.3  
ELEVATED TEMPERATURE DRY COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 |                     | Fiber Orientation:                   |             |
|-----------------|---------------------|-------------------------------|-------------|-----------------|---------------------|--------------------------------------|-------------|
| Material :      |                     | EA-9396 A/B; 7781-E Glass     |             | Batch #1        | Task #15            | Tested By:                           | PM          |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) | Date Tested |
| BIL-GL-25-2     | Thermal pulsed      | 93°C (200°F) (DRY)            | 1.003       | 0.1409          | 3,540               | 25.06                                | 11/29/90    |
| BIL-GL-25-4     | "                   | "                             | 1.003       | 0.1422          | 3,750               | 26.30                                | "           |
| BIL-GL-25-11    | "                   | "                             | 1.002       | 0.1394          | 3,440               | 24.63                                | "           |
| BIL-GL-25-13    | "                   | "                             | 1.003       | 0.1443          | 4,025               | 27.82                                | "           |
| BIL-GL-25-15    | "                   | "                             | 1.003       | 0.1449          | 3,620               | 24.91                                | "           |
| Average         |                     |                               |             |                 |                     | 25.74                                | 177.5       |
| Std. Dev.       |                     |                               |             |                 |                     | 1.33                                 | 9.1         |
|                 |                     |                               |             |                 |                     | (MPa)                                | Remarks     |
|                 |                     |                               |             |                 |                     |                                      | (1,3,4,5)   |
|                 |                     |                               |             |                 |                     |                                      | (1,3,4,5)   |
|                 |                     |                               |             |                 |                     |                                      | (1,3,4,5)   |
|                 |                     |                               |             |                 |                     |                                      | (1,3,4,5)   |
|                 |                     |                               |             |                 |                     |                                      | (1,3,4,5)   |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)  
(2) Specimen failed outside gage section.

- (3) Test speed = 0.05 in/min.  
(4) Load only recorded.  
(5) 15 min. soak at test temperature.

TABLE P.4

LOW TEMPERATURE WET COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 |             |                             | Fiber Orientation:         |          | Fill          |             |         |
|-----------------|---------------------|-------------------------------|-------------|-----------------|-------------|-----------------------------|----------------------------|----------|---------------|-------------|---------|
| Material :      |                     | EA-9396 A/B; 7781-E Glass     |             |                 |             |                             | Batch #1                   |          | Task #15      | Tested By:  | PM      |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum     |                             |                            | Ultimate |               | Date Tested | Remarks |
|                 |                     |                               |             |                 | Load (lbs.) | Compressive Strength (Ksi.) | Compressive Strength (MPa) |          |               |             |         |
| BIL-GL-25-7     | Wet aged then       | -54°C (-65°F) (WET)           | 0.999       | 0.1467          | 5,640       | 38.49                       | 265.4                      | 11/27/90 | (1,3,4,5,6,7) |             |         |
| BIL-GL-25-9     | thermal pulsed      | "                             | 1.000       | 0.1464          | 6,630       | 45.31                       | 312.4                      | "        | (1,3,4,5,6,7) |             |         |
| BIL-GL-25-17    | "                   | "                             | 1.005       | 0.1463          | 6,120       | 41.64                       | 287.1                      | "        | (1,3,4,5,6,7) |             |         |
| BIL-GL-25-19    | "                   | "                             | 1.004       | 0.1432          | 5,780       | 40.19                       | 277.1                      | "        | (1,3,4,5,6,7) |             |         |
| BIL-GL-25-22    | "                   | "                             | 1.002       | 0.1468          | 5,530       | 37.60                       | 259.2                      | "        | (1,3,4,5,6,7) |             |         |
| Average         |                     |                               |             |                 |             |                             | 40.64                      | 280.2    |               |             |         |
| Std. Dev.       |                     |                               |             |                 |             |                             | 3.04                       | 20.9     |               |             |         |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Load only recorded.

- (5) Specimens aged @ 140°F/95-100% R.H. until saturated and before thermal pulse.
- (6) Average Weight Gain before thermal pulse = 2.52%
- (7) 15 min. soak at test temperature.

TABLE P.5

ROOM TEMPERATURE WET COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
NOT SUBJECTED TO A THERMAL PULSE

| Test            | IITRI Compression: ASTM-D3410 |                   |             |                 | Fiber Orientation:              |                             | Fili  |             |             |
|-----------------|-------------------------------|-------------------|-------------|-----------------|---------------------------------|-----------------------------|-------|-------------|-------------|
| Material        | EA-9396 A/B: 7781-E Glass     |                   |             |                 | Tested By:                      |                             |       | DRB         |             |
| Specimen Number | Exposure Conditions           | Test Conditions   | Width (in.) | Thickness (in.) | Ultimate                        |                             |       | Date Tested | Remarks     |
|                 |                               |                   |             |                 | Maximu <sup>r</sup> Load (lbs.) | Compressive Strength (Ksi.) | (MPa) |             |             |
| BIL-GL-25-26    | Wet aged: no                  | 22°C (72°F) (WET) | 0.988       | 0.1423          | 3,200                           | 22.76                       | 157.0 | 11/20/90    | (1,3,4,5,6) |
| BIL-GL-25-28    | thermal pulse                 | "                 | 0.994       | 0.1470          | 3,560                           | 24.37                       | 168.0 | "           | (1,3,4,5,6) |
| BIL-GL-25-30    | "                             | "                 | 0.981       | 0.1400          | 3,040                           | 22.14                       | 152.7 | "           | (1,3,4,5,6) |
| Average         |                               |                   |             |                 |                                 | 23.09                       | 159.2 |             |             |
| Std. Dev.       |                               |                   |             |                 |                                 | 1.15                        | 7.9   |             |             |

P. 6

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

- (4) Load only recorded.
- (5) Specimens aged @ 140°F/95-100% R.H. until saturated.
- (6) Average Weight Gain = 1.85%

TABLE P.6

ROOM TEMPERATURE WET COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

| Test :             |                        | IITRI Compression; ASTM-D3410 |                |                    | Fiber Orientation: |                                |                            |
|--------------------|------------------------|-------------------------------|----------------|--------------------|--------------------|--------------------------------|----------------------------|
| Material :         |                        | EA-9396 A/B; 7781-E Glass     |                |                    | Tested By:         |                                |                            |
|                    |                        | Batch #1                      |                |                    | Task #15           |                                |                            |
| Specimen<br>Number | Exposure<br>Conditions | Test<br>Conditions            | Width<br>(in.) | Thickness<br>(in.) | Maximum            |                                | Remarks                    |
|                    |                        |                               |                |                    | Load<br>(lbs.)     | Compressive Strength<br>(Ksi.) |                            |
| BIL-GL-25-6        | Wet aged then          | 22°C (72°F) (WET)             | 0.999          | 0.1476             | 3,420              | 23.21                          | 160.0 11/20/90 (1,3,4,5,6) |
| BIL-GL-25-10       | thermal pulsed         | "                             | 0.998          | 0.1446             | 3,550              | 24.60                          | 169.6 " (1,3,4,5,6)        |
| BIL-GL-25-18       | "                      | "                             | 1.004          | 0.1446             | 3,235              | 22.27                          | 153.6 " (1,3,4,5,6)        |
| BIL-GL-25-21       | "                      | "                             | 1.002          | 0.1461             | 2,845              | 19.43                          | 134.0 " (1,3,4,5,6)        |
| BIL-GL-25-24       | "                      | "                             | 1.002          | 0.1454             | 2,470              | 16.95                          | 116.9 " (1,3,4,5,6)        |
|                    |                        |                               |                |                    | Average            | 21.29                          | 146.8                      |
|                    |                        |                               |                |                    | Std. Dev.          | 3.08                           | 21.2                       |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Load only recorded.

- (5) Specimens aged @ 140°F/95-100% R.H. until saturated and before thermal pulse.
- (6) Average Weight Gain before thermal pulse = 2.52%



TABLE P.7  
ELEVATED TEMPERATURE WET COMPRESSION STRENGTH  
OF GLASS REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 |             | Fiber Orientation:         |                                      | Fill        |               |
|-----------------|---------------------|-------------------------------|-------------|-----------------|-------------|----------------------------|--------------------------------------|-------------|---------------|
| Material :      |                     | EA-9396 A/B; 7781-E Glass     |             |                 |             | Tested By:                 |                                      | PM          |               |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum     |                            | Ultimate Compressive Strength (Ksi.) | Date Tested | Remarks       |
|                 |                     |                               |             |                 | Load (lbs.) | Compressive Strength (MPa) |                                      |             |               |
| BIL-GL-25-8     | Wet aged then       | 93°C (200°F) (WET)            | 0.998       | 0.1443          | 1,430       | 9.93                       | 68.5                                 | 11/26/90    | (1,3,4,5,6,7) |
| BIL-GL-25-16    | thermal pulsed      | "                             | 1.004       | 0.1455          | 1,565       | 10.71                      | 73.9                                 | "           | (1,3,4,5,6,7) |
| BIL-GL-25-20    | "                   | "                             | 1.003       | 0.1388          | 1,485       | 10.66                      | 73.5                                 | "           | (1,3,4,5,6,7) |
| BIL-GL-25-23    | "                   | "                             | 1.002       | 0.1438          | 1,420       | 9.86                       | 68.0                                 | "           | (1,3,4,5,6,7) |
| BIL-GL-25-25    | "                   | "                             | 1.001       | 0.1429          | 1,440       | 10.06                      | 69.4                                 | "           | (1,3,4,5,6,7) |
| Average         |                     |                               |             |                 |             |                            | 10.25                                | 70.6        |               |
| Std. Dev.       |                     |                               |             |                 |             |                            | 0.41                                 | 2.8         |               |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear fracture)
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.
- (4) Load only recorded.

- (5) Specimens aged @ 140°F/95-100% R.H. until saturated and before thermal pulse.
- (6) Average Weight Gain before thermal pulse = 2.52%
- (7) 4 min. soak after test oven door closed.

TABLE P.8

ROOM TEMPERATURE DRY COMPRESSION STRENGTH  
OF GRAPHITE REINFORCED SPECIMENS THAT WERE  
NOT SUBJECTED TO A THERMAL PULSE

| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 | Fiber Orientation: |                             | Fill        |                   |
|-----------------|---------------------|-------------------------------|-------------|-----------------|--------------------|-----------------------------|-------------|-------------------|
| Material :      |                     | EA-9396 A/B; W133 Graphite    |             |                 | Tested By:         |                             | DRB         |                   |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum            |                             | Date Tested | Remarks           |
|                 |                     |                               |             |                 | Load (lbs.)        | Compressive Strength (Ksi.) |             |                   |
| BIL-GR-50-27    | None                | 22°C (72°F) (DRY)             | 0.996       | 0.1892          | 11,270             | 59.82                       | 412.5       | 10/17/90 (1a,3,4) |
| BIL-GR-50-29    | "                   | "                             | 1.001       | 0.1942          | 13,630             | 70.14                       | 483.6       | " (1a,3,4)        |
|                 |                     |                               |             |                 |                    | Average                     | 64.98       | 448.0             |
|                 |                     |                               |             |                 |                    | Std. Dev.                   | 7.29        | 50.3              |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.  
 a) Shear crimping  
 b) Shear fracture

- (2) Specimen failed outside gage section.  
 (3) Test speed = 0.05 in/min.  
 (4) Load only recorded.

TABLE P.9

ROOM TEMPERATURE DRY COMPRESSION STRENGTH  
OF GRAPHITE REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

|                 |                               |                   |                 |             |                     |                                      |             |                   |
|-----------------|-------------------------------|-------------------|-----------------|-------------|---------------------|--------------------------------------|-------------|-------------------|
| Test :          | IITRI Compression; ASTM-D3410 |                   |                 |             | Fiber Orientation:  |                                      | Fill        |                   |
| Material :      | EA-9396 A/B; W133 Graphite    |                   |                 |             | Task #15            |                                      | DRB         |                   |
|                 |                               | Batch #1          | Thickness (in.) | Width (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) | Tested By:  |                   |
| Specimen Number | Exposure Conditions           | Test Conditions   |                 |             |                     |                                      | Date Tested | Remarks           |
| BIL-GR-50-1     | Thermal pulsed                | 22°C (72°F) (DRY) | 1.040           | 0.1901      | 12,970              | 65.58                                | 452.2       | 10/17/90 (1a,3,4) |
| BIL-GR-50-3     | "                             | "                 | 1.040           | 0.1905      | 10,300              | 52.00                                | 358.6       | " (1b,3,4)        |
| BIL-GR-50-5     | "                             | "                 | 1.043           | 0.1956      | 12,380              | 60.69                                | 418.5       | " (1a,3,4)        |
| BIL-GR-50-12    | "                             | "                 | 1.043           | 0.1970      | 10,240              | 49.83                                | 343.6       | " (1b,3,4)        |
| BIL-GR-50-14    | "                             | "                 | 1.040           | 0.1897      | 11,550              | 58.56                                | 403.7       | " (1a,3,4)        |
| Average         |                               |                   |                 |             |                     | 57.33                                | 395.3       |                   |
| Std. Dev.       |                               |                   |                 |             |                     | 6.43                                 | 44.4        |                   |

## Remarks:

(1) Specimen failed within the 1/2 inch gage section.

- a) Shear crimping  
b) Shear fracture

- (2) Specimen failed outside gage section.  
(3) Test speed = 0.05 in/min.  
(4) Load only recorded.

TABLE P.10  
ELEVATED TEMPERATURE DRY COMPRESSION STRENGTH  
OF GRAPHITE REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 |                     | Fiber Orientation:                   |             |
|-----------------|---------------------|-------------------------------|-------------|-----------------|---------------------|--------------------------------------|-------------|
| Material :      |                     | EA-9396 A/B; W133 Graphite    |             | Batch #1        | Task #15            | Tested By:                           | PM          |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate Compressive Strength (Ksi.) | Date Tested |
| BIL-GR-50-2     | Thermal pulsed      | 93°C (200°F) (DRY)            | 0.979       | 0.1891          | 8,157               | 44.06                                | 4/17/91     |
| BIL-GR-50-4     | "                   | "                             | 1.001       | 0.1919          | 7,905               | 41.17                                | "           |
| BIL-GR-50-11    | "                   | "                             | 0.988       | 0.1947          | 7,949               | 41.32                                | "           |
| BIL-GR-50-13    | "                   | "                             | 0.988       | 0.1960          | 8,406               | 43.40                                | "           |
| BIL-GR-50-15    | "                   | "                             | 0.985       | 0.1788          | 8,047               | 45.68                                | "           |
| Average         |                     |                               |             |                 |                     | 43.12                                | 297.3       |
| Std. Dev.       |                     |                               |             |                 |                     | 1.91                                 | 13.2        |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section. (Shear crimping)  
(2) Specimen failed outside gage section.

- (3) Test speed = 0.05 in/min.  
(4) 15 min. soak at test temperature.

TABLE P.11  
LOW TEMPERATURE WET COMPRESSION STRENGTH  
OF GRAPHITE REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

|                 |                     |                               |             |                 |             |                             |                |                |
|-----------------|---------------------|-------------------------------|-------------|-----------------|-------------|-----------------------------|----------------|----------------|
| Test :          |                     | IITRI Compression: ASTM-D3410 |             |                 |             | Fiber Orientation:          |                | Fill           |
| Material :      |                     | EA-9396 A/B: W133 Graphite    |             |                 |             | Tested By:                  |                | DRB            |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum     |                             | Date Tested    | Remarks        |
|                 |                     |                               |             |                 | Load (lbs.) | Compressive Strength (Ksi.) |                |                |
| BIL-GR-50-7     | Wet aged then       | -54°C (-65°F) (WET)           | 0.995       | 0.2068          | 13,760      | 66.85                       | 11/28/90       | (1a,3,4,5,6,7) |
| BIL-GR-50-9     | thermal pulsed      | "                             | 0.998       | 0.2050          | 15,660      | 76.54                       | "              | (1a,3,4,5,6,7) |
| BIL-GR-50-17    | "                   | "                             | 1.006       | 0.2061          | 13,800      | 66.55                       | "              | (1a,3,4,5,6,7) |
| BIL-GR-50-19    | "                   | "                             | 1.007       | 0.1913          | 14,340      | 74.43                       | "              | (1a,3,4,5,6,7) |
| BIL-GR-50-22    | "                   | "                             | 1.000       | 0.1975          | 14,800      | 74.94                       | "              | (1a,3,4,5,6,7) |
|                 |                     |                               |             |                 | Average     | 71.86                       | 495.5          |                |
|                 |                     |                               |             |                 | Std. Dev.   | 4.78                        | 32.9           |                |
|                 |                     |                               |             |                 | Ultimate    |                             |                |                |
|                 |                     |                               |             |                 |             | Compressive Strength (MPa)  |                |                |
|                 |                     |                               |             |                 |             |                             | (1a,3,4,5,6,7) |                |
|                 |                     |                               |             |                 |             |                             | (1a,3,4,5,6,7) |                |
|                 |                     |                               |             |                 |             |                             | (1a,3,4,5,6,7) |                |
|                 |                     |                               |             |                 |             |                             | (1a,3,4,5,6,7) |                |
|                 |                     |                               |             |                 |             |                             | (1a,3,4,5,6,7) |                |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
  - a) Shear crimping
  - b) Shear fracture
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

- (4) Load only recorded.
- (5) Specimens aged @ 140°F/95-100% R.H. until saturated and before thermal pulse.
- (6) Average Weight Gain before thermal pulse = 1.90%
- (7) 15 min. soak at test temperature.

TABLE P.12

ROOM TEMPERATURE WET COMPRESSION STRENGTH  
OF GRAPHITE REINFORCED SPECIMENS THAT WERE  
NOT SUBJECTED TO A THERMAL PULSE

| Test :          |                     | IITRI Compression; ASTM-D3410 |             |                 |             | Fiber Orientation:          |                            | Fill        |              |
|-----------------|---------------------|-------------------------------|-------------|-----------------|-------------|-----------------------------|----------------------------|-------------|--------------|
| Material :      |                     | EA-9396 A/B; W133 Graphite    |             |                 |             | Tested By:                  |                            | DRB         |              |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Maximum     |                             | Ultimate                   |             |              |
|                 |                     |                               |             |                 | Load (lbs.) | Compressive Strength (Ksi.) | Compressive Strength (MPa) | Date Tested | Remarks      |
| BIL-GR-50-26    | Wet aged; no        | 22°C (72°F) (WET)             | 0.998       | 0.1983          | 8,900       | 44.97                       | 310.0                      | 11/20/90    | (1a,3,4,5,6) |
| BIL-GR-50-28    | thermal pulse       | "                             | 0.991       | 0.1977          | 9,080       | 46.33                       | 319.5                      | "           | (1b,3,4,5,6) |
| BIL-GR-50-30    | "                   | "                             | 0.995       | 0.1874          | 8,500       | 45.59                       | 314.4                      | "           | (1a,3,4,5,6) |
|                 |                     |                               |             |                 | Average     | 45.63                       | 314.6                      |             |              |
|                 |                     |                               |             |                 | Std. Dev.   | 0.68                        | 4.7                        |             |              |

## Remarks:

- (1) Specimen failed within the 1/2 inch gage section.  
 a) Shear crimping  
 b) Shear fracture
- (2) Specimen failed outside gage section.

(3) Test speed = 0.05 in/min.

(4) Load only recorded.

(5) Specimens aged @ 140°F/95-100% R.H. until saturated.

(6) Average Weight Gain = 2.14%

TABLE P.13  
ROOM TEMPERATURE WET COMPRESSION STRENGTH  
OF GRAPHITE REINFORCED SPECIMENS THAT WERE  
SUBJECTED TO A THERMAL PULSE

|                 |                     |                               |             |                 |                    |                             |                            |             |              |
|-----------------|---------------------|-------------------------------|-------------|-----------------|--------------------|-----------------------------|----------------------------|-------------|--------------|
| Test :          |                     | IITRI Compression: ASTM-D3410 |             |                 | Fiber Orientation: |                             | Fill                       |             |              |
| Material :      |                     | EA-9396 A/B; W133 Graphite    |             |                 | Batch #1           | Task #15                    | Tested By: DRB             |             |              |
| Specimen Number | Exposure Conditions | Test Conditions               | Width (in.) | Thickness (in.) | Load (lbs.)        | Ultimate                    |                            | Date Tested | Remarks      |
|                 |                     |                               |             |                 |                    | Compressive Strength (Ksi.) | Compressive Strength (MPa) |             |              |
| BIL-GR-50-6     | Wet aged then       | 22°C (72°F) (WET)             | 0.996       | 0.2050          | 8,750              | 42.85                       | 295.5                      | 11/20/90    | (1b,3,4,5,6) |
| BIL-GR-50-10    | thermal pulsed      | "                             | 0.998       | 0.2034          | 8,570              | 42.24                       | 291.2                      | "           | (1b,3,4,5,6) |
| BIL-GR-50-18    | "                   | "                             | 1.005       | 0.1969          | 9,510              | 48.04                       | 331.2                      | "           | (1b,3,4,5,6) |
| BIL-GR-50-21    | "                   | "                             | 0.999       | 0.1980          | 9,080              | 45.93                       | 316.7                      | "           | (1a,3,4,5,6) |
| BIL-GR-50-24    | "                   | "                             | 0.999       | 0.1984          | 9,790              | 49.42                       | 340.7                      | "           | (1b,3,4,5,6) |
|                 |                     |                               |             |                 |                    | Average                     |                            | 315.1       |              |
|                 |                     |                               |             |                 |                    | Std. Dev.                   |                            | 21.7        |              |

Remarks:

- (1) Specimen failed within the 1/2 inch gage section.
  - a) Shear crimping
  - b) Shear fracture
- (2) Specimen failed outside gage section.
- (3) Test speed = 0.05 in/min.

- (4) Load only recorded.
- (5) Specimens aged @ 140°F/95-100% R.H. until saturated and before thermal pulse.
- (6) Average Weight Gain before thermal pulse = 1.90%

APPENDIX Q  
INDIVIDUAL SPECIMEN MECHANICAL PROPERTIES,  
EFFECT OF SILANE SIZING ON ENVIRONMENTAL DEGRADATION  
OF GLASS REINFORCED LAMINATES

The nine tables in this appendix present the detailed mechanical property data for specimens prepared with silane-sized glass reinforcement. The properties measured on these laminates included tensile, inplane shear, and interlaminar shear. It will be noted in Tables Q.1 - Q.3 that the tensile specimens failed inside the tab area. Figure Q.1 illustrates the location and nature of these failures. A summary of these data was presented and discussed in Section 3.11.



TABLE Q.1  
ROOM TEMPERATURE DRY TENSILE PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Straight sided tension; ASTM-D3039             |                   |             |                 |                     |                         |                        |                         |                 |             | Fiber Orientation : Warp |  |
|------------------------------------------------|-------------------|-------------|-----------------|---------------------|-------------------------|------------------------|-------------------------|-----------------|-------------|--------------------------|--|
| Material : EA-9396 A/B; 7781 Glass (A1100-538) |                   |             |                 |                     |                         |                        |                         |                 |             | Tested by : DH           |  |
| Specimen Number                                | Test Conditions   | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                         | Poisson's Ratio | Date Tested | Remarks                  |  |
|                                                |                   |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (in/in) |                 |             |                          |  |
| BIL-GL-44-1                                    | 22°C (72°F) (DRY) | 0.998       | 0.0641          | 2,773               | 43.38                   | 3.842                  | 12.627                  | 0.103           | 2/5/90      | (2,3,4)                  |  |
| BIL-GL-44-4                                    | "                 | 0.995       | 0.0731          | 2,916               | 40.11                   | 3.483                  | 12.048                  | "               | "           | (2,3,5)                  |  |
| BIL-GL-44-7                                    | "                 | 0.995       | 0.0722          | 3,152               | 43.87                   | 3.435                  | 10,122                  | "               | "           | (2,3,5)                  |  |
| BIL-GL-44-10                                   | "                 | 0.997       | 0.0738          | 2,557               | 34.75                   | 3.503                  | 11,001                  | "               | "           | (2,3,5)                  |  |
| BIL-GL-44-13                                   | "                 | 0.998       | 0.0729          | 3,032               | 41.67                   | 3.460                  | 13,579                  | 0.106           | "           | (2,3,4)                  |  |
| Average                                        |                   |             |                 | 40.76               | 3.545                   | 11,876                 | 0.104                   |                 |             |                          |  |
| Std. Dev.                                      |                   |             |                 | 3.67                | 0.168                   | 1,354                  | 0.002                   |                 |             |                          |  |

Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.

| SI Conversion          |                       |                                       |  |
|------------------------|-----------------------|---------------------------------------|--|
| Ultimate               |                       |                                       |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 299.1                  | 26.49                 | 12,627                                |  |
| 276.6                  | 24.01                 | 12,048                                |  |
| 302.5                  | 23.69                 | 10,122                                |  |
| 239.6                  | 24.16                 | 11,001                                |  |
| 287.3                  | 23.86                 | 13,579                                |  |
| 281.0                  | 24.44                 | 11,876                                |  |
| 25.3                   | 1.16                  | 1,354                                 |  |

TABLE Q.2

ROOM TEMPERATURE WET TENSILE PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test :          |                   | Straight sided tension; ASTM-D3039  |                 |                     | Fiber Orientation :     |                        |                                |
|-----------------|-------------------|-------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------------|
| Material :      |                   | EA-9396 A/B; 7781 Glass (A1100-538) |                 |                     | Tested by :             |                        |                                |
|                 |                   | Batch #3                            |                 |                     | Task #19                |                        |                                |
|                 |                   | Ultimate                            |                 |                     | Poisson's Ratio         |                        |                                |
| Specimen Number | Test Conditions   | Width (in.)                         | Thickness (in.) | Maximum Load (lbs.) | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain ( $\mu$ in/in) |
| BIL-GL-44-2     | 22°C (72°F) (WET) | 0.994                               | 0.0660          | 2,506               | 38.19                   | 3,244                  | 12,432                         |
| BIL-GL-44-5     | "                 | 0.997                               | 0.0728          | 2,457               | 33.86                   | 3,068                  | 11,758                         |
| BIL-GL-44-8     | "                 | 0.997                               | 0.0747          | 2,675               | 35.91                   | 3,099                  | 12,466                         |
| BIL-GL-44-11    | "                 | 0.997                               | 0.0726          | 2,562               | 35.38                   | 3,093                  | 12,075                         |
| BIL-GL-44-14    | "                 | 0.997                               | 0.0703          | 2,494               | 35.57                   | 3,207                  | 11,904                         |
|                 |                   | Average                             |                 |                     | 35.78                   | 3,142                  | 12,127                         |
|                 |                   | Std. Dev.                           |                 |                     | 1.56                    | 0.078                  | 315                            |
|                 |                   |                                     |                 |                     |                         |                        | 0.079                          |
|                 |                   |                                     |                 |                     |                         |                        | 0.011                          |
|                 |                   |                                     |                 |                     |                         |                        | (2,3,5,6,7)                    |
|                 |                   |                                     |                 |                     |                         |                        | (2,3,4,6,7)                    |
|                 |                   |                                     |                 |                     |                         |                        | (2,3,5,6,7)                    |
|                 |                   |                                     |                 |                     |                         |                        | (2,3,4,6,7)                    |
|                 |                   |                                     |                 |                     |                         |                        | (2,3,5,6,7)                    |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H. for 43 days.
- (7) Average Weight Gain = 3.0870%

## SI Conversion

| Ultimate               |               | Tensile                |               | Ultimate                       |                                |
|------------------------|---------------|------------------------|---------------|--------------------------------|--------------------------------|
| Tensile Strength (MPa) | Modulus (GPa) | Tensile Strength (MPa) | Modulus (GPa) | Ultimate Strain ( $\mu$ cm/cm) | Ultimate Strain ( $\mu$ cm/cm) |
| 263.3                  | 22.37         | 263.3                  | 22.37         | 12,432                         | 12,432                         |
| 233.5                  | 21.16         | 233.5                  | 21.16         | 11,758                         | 11,758                         |
| 247.6                  | 21.37         | 247.6                  | 21.37         | 12,466                         | 12,466                         |
| 244.0                  | 21.33         | 244.0                  | 21.33         | 12,075                         | 12,075                         |
| 245.3                  | 22.11         | 245.3                  | 22.11         | 11,904                         | 11,904                         |
| Average                |               | 246.7                  | 21.67         | 12,127                         | 12,127                         |
| Std. Dev.              |               | 10.7                   | 0.54          | 315                            | 315                            |

TABLE Q.3

ELEVATED TEMPERATURE WET TENSILE PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test :          |                    | Straight sided tension; ASTM-D3039  |                 |                     |                         |                        | Fiber Orientation :      |                 |             |             |
|-----------------|--------------------|-------------------------------------|-----------------|---------------------|-------------------------|------------------------|--------------------------|-----------------|-------------|-------------|
| Material :      |                    | EA-9396 A/B; 7781 Glass (A1100-538) |                 |                     |                         |                        | Tested by : DH           |                 |             |             |
| Specimen Number | Test Conditions    | Width (in.)                         | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        |                          | Poisson's Ratio | Date Tested | Remarks     |
|                 |                    |                                     |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Ultimate Strain (μin/in) |                 |             |             |
| BIL-GL-44-3     | 93°C (200°F) (WET) | 0.997                               | 0.0707          | 1,821               | 25.83                   | 2.797                  | 9.614                    |                 | 3/19/90     | (2,3,5,6,7) |
| BIL-GL-44-6     | "                  | 0.999                               | 0.0738          | 1,887               | 25.59                   | 2.724                  | 9.897                    | 0.102           | "           | (2,3,4,6,7) |
| BIL-GL-44-9     | "                  | 0.996                               | 0.0746          | 1,721               | 23.16                   | 2.691                  | 9.258                    |                 | "           | (2,3,5,6,7) |
| BIL-GL-44-12    | "                  | 1.000                               | 0.0736          | 1,830               | 24.87                   | 2.536                  | 10.034                   | 0.113           | "           | (2,3,4,6,7) |
| BIL-GL-44-15    | "                  | 0.997                               | 0.0686          | 1,666               | 24.37                   | 2.900                  | 8.794                    |                 | "           | (2,3,5,6,7) |
|                 |                    |                                     |                 |                     | Average                 | 24.76                  | 2.730                    | 9.520           | 0.108       |             |
|                 |                    |                                     |                 |                     | Std. Dev.               | 1.07                   | 0.135                    | 503             | 0.008       |             |

## Remarks:

- (1) Specimen failed within the 6.5 inch gage section.
- (2) Specimen failed inside tab area.
- (3) Test speed = 0.1 in/min.
- (4) Specimen had 0° and 90° strain gages attached.
- (5) Specimen had only 0° strain gage attached.
- (6) Specimens aged @ 140°F/95-100% R.H. for 42 days.
- (7) Average Weight Gain = 2.9160%

| SI Conversion          |                       |                                       |  |
|------------------------|-----------------------|---------------------------------------|--|
| Ultimate               |                       |                                       |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Ultimate Strain ( $\mu\text{cm/cm}$ ) |  |
| 178.1                  | 19.28                 | 9.614                                 |  |
| 176.4                  | 18.78                 | 9.897                                 |  |
| 159.7                  | 18.56                 | 9.258                                 |  |
| 171.5                  | 17.48                 | 10.034                                |  |
| 168.0                  | 20.00                 | 8.794                                 |  |
| Average                | 18.82                 | 9.520                                 |  |
| Std. Dev.              | 0.93                  | 503                                   |  |

TABLE Q.4

ROOM TEMPERATURE DRY INPLANE SHEAR PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test : $\pm 45^\circ$ Tension/Inplane Shear: ASTM-D3518 |                   |             |                 |                     |                         |                        |                       |                      |             | Fiber Orientation: $\pm 45^\circ$ |                 |
|---------------------------------------------------------|-------------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-------------|-----------------------------------|-----------------|
| Material : EA-9396 A/B: 7781 Glass (A1100-538)          |                   |             |                 |                     |                         |                        |                       |                      |             | Tested By: DH                     |                 |
| Batch #3 Task #19                                       |                   |             |                 |                     |                         |                        |                       |                      |             |                                   |                 |
| Specimen Number                                         | Test Conditions   | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Date Tested | Remarks                           |                 |
|                                                         |                   |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |             |                                   | Poisson's Ratio |
| BIL-GL-46-1                                             | 22°C (72°F) (DRY) | 0.994       | 0.0679          | 1,386               | 20.52                   | 1,900                  | 10.26                 | 0.622                | 0.527       | 2/6/90                            | (1,2,3,5)       |
| BIL-GL-46-4                                             | "                 | 1.002       | 0.0705          | 1,364               | 19.30                   | 1,784                  | 9.65                  | 0.632                | 0.412       | "                                 | (1,2,3,5)       |
| BIL-GL-46-7                                             | "                 | 1.004       | 0.0713          | 1,165               | 16.28                   | 1,828                  | 8.14                  | 0.621                | 0.472       | "                                 | (1,2,3,5)       |
| BIL-GL-46-10                                            | "                 | 1.004       | 0.0685          | 1,305               | 18.97                   | 2,035                  | 9.49                  | 0.625                | 0.628       | "                                 | (1,2,3,5)       |
| BIL-GL-46-13                                            | "                 | 1.004       | 0.0669          | 1,350               | 20.10                   | 2,125                  | 10.05                 | 0.677                | 0.570       | "                                 | (1,2,3,5)       |
| Average                                                 |                   |             |                 |                     | 19.03                   | 1,934                  | 9.52                  | 0.635                | 0.522       |                                   |                 |
| Std. Dev.                                               |                   |             |                 |                     | 1.66                    | 0.143                  | 0.83                  | 0.023                | 0.084       |                                   |                 |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had  $0^\circ$  and  $90^\circ$  strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.

| SI Conversion          |                       |                      |                     |          |  |
|------------------------|-----------------------|----------------------|---------------------|----------|--|
| Ultimate               |                       | In-Plane             |                     | In-Plane |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |          |  |
| 141.5                  | 13.10                 | 70.8                 | 4.290               |          |  |
| 133.1                  | 12.30                 | 66.5                 | 4.356               |          |  |
| 112.2                  | 12.60                 | 56.1                 | 4.281               |          |  |
| 130.8                  | 14.03                 | 65.4                 | 4.310               |          |  |
| 138.6                  | 14.65                 | 69.3                 | 4.665               |          |  |
| Average                | 13.34                 | 65.6                 | 4.380               |          |  |
| Std. Dev.              | 0.98                  | 5.7                  | 0.161               |          |  |

TABLE Q.5

ROOM TEMPERATURE WET INPLANE SHEAR PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test :          |                   | ±45° Tension/Inplane Shear; ASTM-D3518 |                 |                     |                         | Fiber Orientation:     |                       | ±45°                 |                       |
|-----------------|-------------------|----------------------------------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------------|
| Material :      |                   | EA-9396 A/B: 7781 Glass (A1100-538)    |                 |                     |                         | Tested By:             |                       | PM                   |                       |
| Specimen Number | Test Conditions   | Width (in.)                            | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Date Tested           |
|                 |                   |                                        |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                       |
| BIL-GL-46-2     | 22°C (72°F) (WET) | 1.001                                  | 0.0693          | 928                 | 13.37                   | 1.194                  | 6.69                  | 0.394                | 4/24/90 (1,2,3,5,6,7) |
| BIL-GL-46-5     | "                 | 0.999                                  | 0.0694          | 876                 | 12.65                   | 1.180                  | 6.32                  | 0.404                | 4/23/90 (1,2,3,5,6)   |
| BIL-GL-46-8     | "                 | 1.001                                  | 0.0699          | 861                 | 12.31                   | 1.186                  | 6.16                  | 0.365                | " (1,2,3,5,6)         |
| BIL-GL-46-11    | "                 | 1.002                                  | 0.0685          | 892                 | 12.99                   | 1.323                  | 6.49                  | 0.392                | " (1,2,3,5,6)         |
| BIL-GL-46-14    | "                 | 0.999                                  | 0.0677          | 855                 | 12.64                   | 1.118                  | 6.32                  | 0.335                | " (1,2,3,5,6)         |
| Average         |                   |                                        |                 |                     | 12.79                   | 1.200                  | 6.40                  | 0.378                | 0.591                 |
| Std. Dev.       |                   |                                        |                 |                     | 0.40                    | 0.075                  | 0.20                  | 0.028                | 0.100                 |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. to saturation.
- (7) Weight Gain = 2.37%  
(Only one specimen tracked).

| SI Conversion |          |          |          |
|---------------|----------|----------|----------|
| Ultimate      | In-Plane | In-Plane | In-Plane |
| Tensile       | Shear    | Shear    | Shear    |
| Strength      | Strength | Strength | Strength |
| (MPa)         | (MPa)    | (MPa)    | (MPa)    |
| 92.2          | 46.1     | 46.1     | 2.720    |
| 87.2          | 43.6     | 43.6     | 2.789    |
| 84.9          | 42.4     | 42.4     | 2.518    |
| 89.5          | 44.8     | 44.8     | 2.705    |
| 87.2          | 43.6     | 43.6     | 2.308    |
| Average       | 44.1     | 44.1     | 2.608    |
| Std. Dev.     | 1.4      | 1.4      | 0.195    |

TABLE Q.6

ELEVATED TEMPERATURE WET INPLANE SHEAR PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test : $\pm 45^\circ$ Tension/Inplane Shear; ASTM-D3518 |                    |             |                 |                     |                         |                        |                       |                      |                 | Fiber Orientation: $\pm 45^\circ$ |               |
|---------------------------------------------------------|--------------------|-------------|-----------------|---------------------|-------------------------|------------------------|-----------------------|----------------------|-----------------|-----------------------------------|---------------|
| Material : EA-9396 A/B: 7781 Glass (A1100-538)          |                    |             |                 |                     |                         |                        |                       |                      |                 | Tested By: PM                     |               |
| Batch #3 Task #19                                       |                    |             |                 |                     |                         |                        |                       |                      |                 |                                   |               |
| Specimen Number                                         | Test Conditions    | Width (in.) | Thickness (in.) | Maximum Load (lbs.) | Ultimate                |                        | In-Plane              |                      | Poisson's Ratio | Date Tested                       | Remarks       |
|                                                         |                    |             |                 |                     | Tensile Strength (Ksi.) | Tensile Modulus (Msi.) | Shear Strength (Ksi.) | Shear Modulus (Msi.) |                 |                                   |               |
| BIL-GL-46-3                                             | 93°C (200°F) (WET) | 1.001       | 0.0706          | 533                 | 7.54                    | 0.381                  | 3.77                  | 0.117                | 0.629           | 4/24/90                           | (1,2,3,5,6,7) |
| BIL-GL-46-6                                             | "                  | 0.998       | 0.0693          | 453                 | 6.55                    | 0.470                  | 3.27                  | 0.134                | 0.758           | "                                 | (1,2,3,5,6)   |
| BIL-GL-46-9                                             | "                  | 1.005       | 0.0691          | 531                 | 7.65                    | 0.536                  | 3.83                  | 0.142                | 0.893           | "                                 | (1,2,3,5,6)   |
| BIL-GL-46-12                                            | "                  | 1.003       | 0.0667          | 567                 | 8.48                    | 0.487                  | 4.24                  | 0.124                | 0.961           | "                                 | (1,2,3,5,6)   |
| BIL-GL-46-15                                            | "                  | 1.000       | 0.0639          | 456                 | 7.14                    | 0.487                  | 3.57                  | 0.140                | 0.732           | "                                 | (1,2,3,5,6)   |
| Average                                                 |                    |             |                 |                     | 7.47                    | 0.472                  | 3.74                  | 0.131                | 0.795           |                                   |               |
| Std. Dev.                                               |                    |             |                 |                     | 0.71                    | 0.057                  | 0.35                  | 0.011                | 0.132           |                                   |               |

| SI Conversion          |                       |                      |                     |          |  |
|------------------------|-----------------------|----------------------|---------------------|----------|--|
| Ultimate               |                       | In-Plane             |                     | In-Plane |  |
| Tensile Strength (MPa) | Tensile Modulus (GPa) | Shear Strength (MPa) | Shear Modulus (GPa) |          |  |
| 52.0                   | 2.62                  | 26.0                 | 0.805               |          |  |
| 45.2                   | 3.24                  | 22.6                 | 0.922               |          |  |
| 52.8                   | 3.70                  | 26.4                 | 0.976               |          |  |
| 58.5                   | 3.36                  | 29.2                 | 0.856               |          |  |
| 49.2                   | 3.36                  | 24.6                 | 0.969               |          |  |
| Average                | 3.25                  | 25.8                 | 0.906               |          |  |
| Std. Dev.              | 0.39                  | 2.4                  | 0.074               |          |  |

## Remarks:

- (1) The in-plane shear modulus is calculated using the equation  $[G=E/2(1+\nu)]$ .
- (2) Specimen had 0° and 90° strain gages attached.
- (3) Test speed = 0.1 in/min.
- (4) Specimen failed inside the "tab area".
- (5) Specimen failed within the 6.5 inch gage section.
- (6) Specimens aged @ 140°F/95-100% R.H. to saturation.
- (7) Weight Gain = 2.43%  
(Only one specimen tracked).

TABLE Q.7

ROOM TEMPERATURE DRY INTERLAMINAR SHEAR PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test            | Apparent interlaminar shear         |             |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |                                    | Specimen Orientation: Warp        |             |         |
|-----------------|-------------------------------------|-------------|-----------------|------------|-------------------------------------|------------------------------------|-----------------------------------|-------------|---------|
| Material :      | EA-9396 A/B; 7781 Glass (A1100-538) |             |                 |            | Batch #3 Task #19                   |                                    | Tested By: DH                     |             |         |
| Specimen Number | Test Conditions                     | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Date Tested | Remarks |
| BIL-GL-45-1     | 22°C (72°F) (DRY)                   | 1.000       | 0.1405          | 1.141      | 1,142                               | 6.095                              | 42.02                             | 1/11/90     |         |
| BIL-GL-45-4     | "                                   | 0.999       | 0.1436          | 1.141      | 1,235                               | 6.454                              | 44.50                             | "           |         |
| BIL-GL-45-7     | "                                   | 1.001       | 0.1426          | 1.141      | 1,150                               | 6.044                              | 41.67                             | "           |         |
| BIL-GL-45-10    | "                                   | 1.001       | 0.1425          | 1.141      | 1,171                               | 6.158                              | 42.46                             | "           |         |
| BIL-GL-45-13    | "                                   | 1.001       | 0.1437          | 1.141      | 1,145                               | 5.973                              | 41.18                             | "           |         |
| Average         |                                     |             |                 |            |                                     | 6.145                              | 42.37                             |             |         |
| Std. Dev.       |                                     |             |                 |            |                                     | 0.186                              | 1.28                              |             |         |

TABLE Q.8

ROOM TEMPERATURE WET INTERLAMINAR SHEAR PROPERTIES OF EA9396 LAMINATES  
REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test :          | Apparent interlaminar shear         |             |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |                                    |                                   |                 | Specimen Orientation: |         |
|-----------------|-------------------------------------|-------------|-----------------|------------|-------------------------------------|------------------------------------|-----------------------------------|-----------------|-----------------------|---------|
| Material :      | EA-9396 A/B; 7781 Glass (A1100-538) |             |                 |            | Batch #3 Task #19                   |                                    |                                   |                 | Tested By: DH         |         |
| Specimen Number | Test Conditions                     | Width (in.) | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Weight Gain (%) | Date Tested           | Remarks |
| BIL-GL-45-2     | 22°C (72°F) (WET)                   | 0.998       | 0.1407          | 1.142      | 794                                 | 4.241                              | 29.24                             | 2.69            | 3/20/90               | (1,2)   |
| BIL-GL-45-5     | "                                   | 1.001       | 0.1451          | 1.142      | 859                                 | 4.436                              | 30.58                             | 2.71            | "                     | (1,2)   |
| BIL-GL-45-8     | "                                   | 1.000       | 0.1404          | 1.142      | 747                                 | 3.990                              | 27.51                             | 2.62            | "                     | (1,2)   |
| BIL-GL-45-11    | "                                   | 1.001       | 0.1434          | 1.142      | 846                                 | 4.420                              | 30.48                             | 2.70            | "                     | (1,2)   |
| BIL-GL-45-14    | "                                   | 1.000       | 0.1433          | 1.142      | 805                                 | 4.213                              | 29.05                             | 2.73            | "                     | (1,2)   |
| Average         |                                     |             |                 |            |                                     |                                    |                                   | 29.37           | 2.69                  |         |
| Std. Dev.       |                                     |             |                 |            |                                     |                                    |                                   | 1.25            | 0.04                  |         |

## Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. for 68 days.
- (2) Average Weight Gain = 2.69%



TABLE Q.9  
ELEVATED TEMPERATURE WET INTERLAMINAR SHEAR PROPERTIES OF  
EA9396 LAMINATES REINFORCED WITH SILANE SIZED GLASS REINFORCEMENT

| Test :          |                    | Apparent interlaminar shear         |                 |            | (4pt loading at 1/4 pts. L/D = 8/1) |                                    |                                   | Specimen Orientation: Warp |             |         |
|-----------------|--------------------|-------------------------------------|-----------------|------------|-------------------------------------|------------------------------------|-----------------------------------|----------------------------|-------------|---------|
| Material :      |                    | EA-9396 A/B; 7781 Glass (A1100-538) |                 |            | Batch #3 Task #19                   |                                    |                                   | Tested By: DH              |             |         |
| Specimen Number | Test Conditions    | Width (in.)                         | Thickness (in.) | Span (in.) | Maximum Load (lbs.)                 | Interlaminar Shear Strength (Ksi.) | Interlaminar Shear Strength (MPa) | Weight Gain (%)            | Date Tested | Remarks |
| BIL-GL-45-3     | 93°C (200°F) (WET) | 1.001                               | 0.1425          | 1.142      | 343                                 | 1.803                              | 12.43                             | 2.72                       | 3/21/90     | (1,2)   |
| BIL-GL-45-6     | "                  | 1.001                               | 0.1452          | 1.142      | 346                                 | 1.785                              | 12.31                             | 2.67                       | "           | (1,2)   |
| BIL-GL-45-9     | "                  | 1.000                               | 0.1398          | 1.142      | 350                                 | 1.878                              | 12.95                             | 2.63                       | "           | (1,2)   |
| BIL-GL-45-12    | "                  | 1.000                               | 0.1439          | 1.142      | 355                                 | 1.850                              | 12.76                             | 2.70                       | "           | (1,2)   |
| BIL-GL-45-15    | "                  | 0.998                               | 0.1437          | 1.142      | 356                                 | 1.862                              | 12.84                             | 2.67                       | "           | (1,2)   |
|                 |                    |                                     |                 |            |                                     | Average                            |                                   | 12.66                      |             | 2.68    |
|                 |                    |                                     |                 |            |                                     | Std. Dev.                          |                                   | 0.039                      |             | 0.03    |

Remarks:

- (1) Specimens aged @ 140°F/95-100% R.H. for 68 days.
- (2) Average Weight Gain = 2.68%

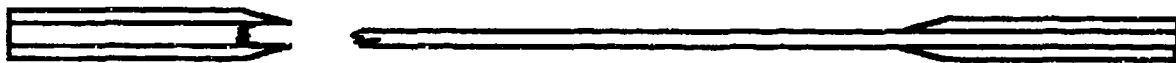


Figure Q.1. Failure Location of Tensile Specimens  
That Failed Inside Tab Area.

## APPENDIX R

### DETERMINATION OF BLEEDER ABSORPTIVITY

The bleeder materials used in this program may not be available when performing a repair. If an alternative bleeder material is used, its absorptivity can be determined by the procedure outlined below. It is suggested that absorptivity be determined by this procedure for several bleeder/laminate ply ratios that bracket the layup actually used so that a reliable average value can be determined. The primary reason that bleeder absorptivity is of interest is to provide guidance in selecting a bleeder/laminate ply ratio that will produce the desired final resin content. It must be recognized, however, that not all resin is removed by the bleeder. Some will be lost around the edges of the layup. Additionally, the amount absorbed by the bleeder will probably vary if the amount of excess resin used in the laminate layup or the bleeder/laminate ply ratio varies significantly from those used in the absorptivity determination.

1. Select Bleeder/Laminate ply ratio.
2. Bleeder plies are to be same size as laminate plies, and should be both weighed and measured (length x width) prior to layup.
3. Compute area density (gm/m<sup>2</sup>) of dry bleeder material

$$\frac{\text{wt. of DBPS}}{\text{area of DBPS} \times \text{no. of plies in DBPS}} = \text{area density of DBP (gm / m}^2\text{)}$$

where DBPS = dry bleeder ply stack.

4. Layup and impregnate laminate plies in accordance with standard procedure described in Appendix A (except for bleeder ply differences if using other than Mochburg CW 1850).
5. Bag and cure in accordance with the standard procedure described in Appendix A.
6. After cure, dismantle the bagged layup and separate the impregnated stack of bleeder plies from the nonporous teflon/glass and the porous teflon/glass sheets.
7. Weigh and remeasure the impregnated bleeder stack.
8. Compute amount of resin absorbed in each unit area of bleeder

$$\frac{\text{wt. of IBS}}{\text{area of IBS} \times \text{no. of plies in IBS}} = \text{area density of IBS (gm / m}^2\text{)}$$

where IBS = impregnated bleeder stack.

$$\frac{\text{area density of IBS} - \text{area density of DBPS}}{\text{no. of plies in IBS}} = \text{area density of resin in bleeder, or absorptivity (gm / m}^2\text{)}$$

9. Compute amount of resin absorbed in each unit weight of bleeder

$$\frac{\text{wt. of IBS} - \text{wt. of DBPS}}{\text{wt. of DBPS}} = \text{absorptivity (gm resin / gm bleeder)}$$