

construction
engineering
research
laboratory



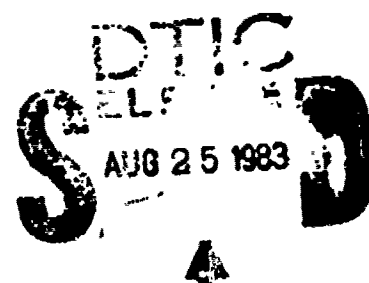
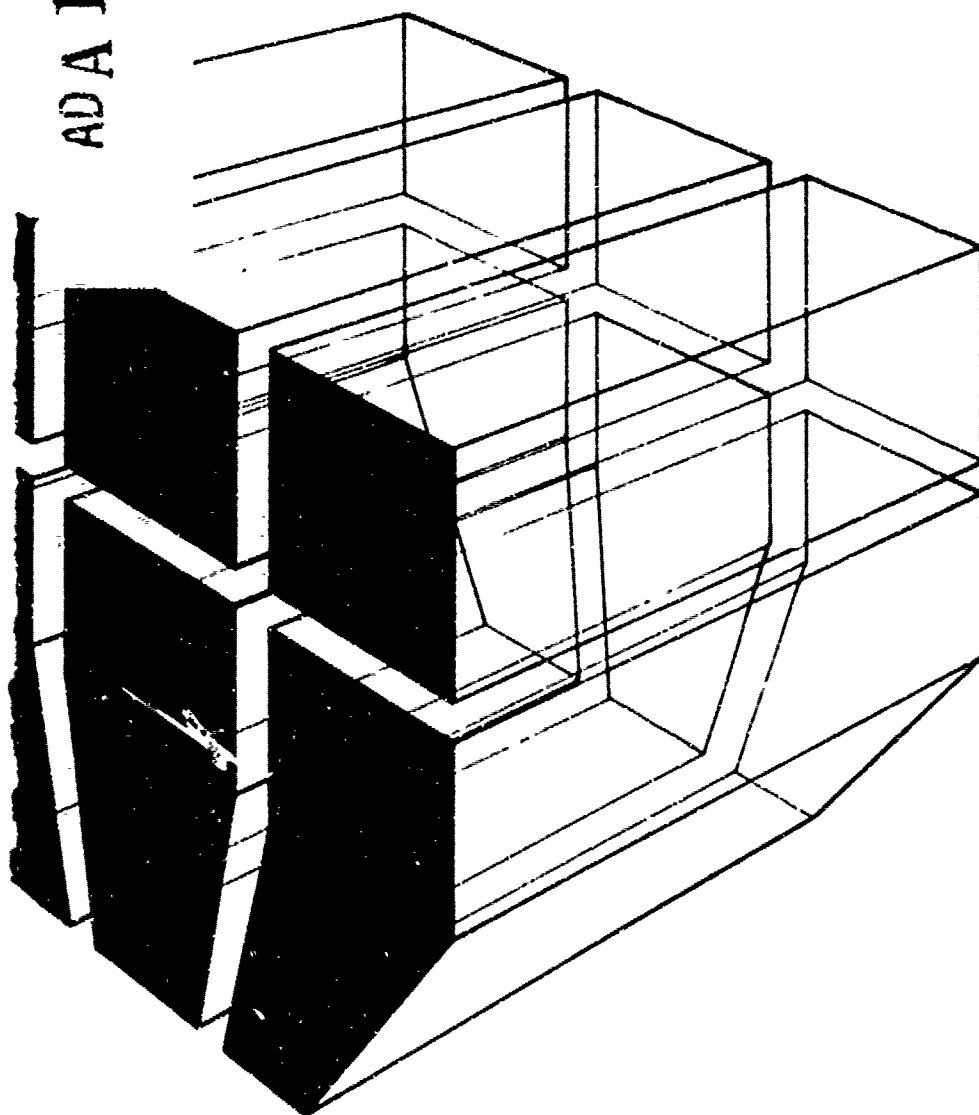
United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

Technical Report M-329
June 1983

ADA 131829

PROTECTIVE COATINGS FOR ALUMINUM TORPEDOES

by
S. A. Johnston

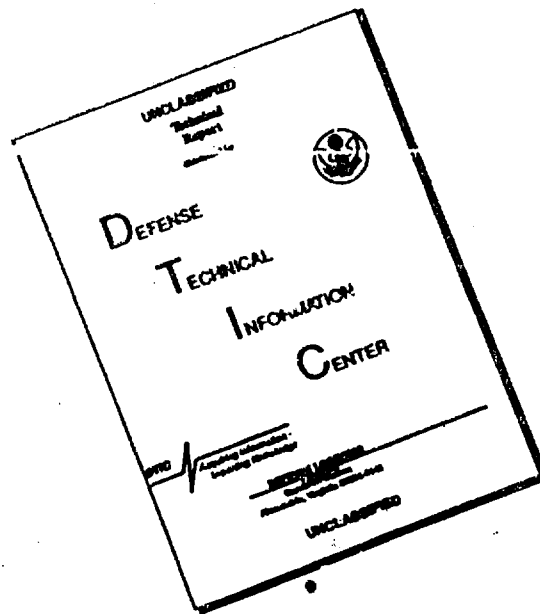


DTIC FILE COPY

Approved for public release; distribution unlimited.

83 08 25 081

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official indorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

**DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED
DO NOT RETURN IT TO THE ORIGINATOR**

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CERL-TR-M-329	2. GOVT ACCESSION NO. AD-A131 825	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PROTECTIVE COATINGS FOR ALUMINUM TORPEDOES		5. TYPE OF REPORT & PERIOD COVERED FINAL
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Susan A. Johnston		8. CONTRACT OR GRANT NUMBER(s) MIPR No. N600481 MP10005
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. BOX 4005, CHAMPAIGN, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Underwater Systems Center Newport, RI 02840		12. REPORT DATE June 1983
		13. NUMBER OF PAGES 130
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		16. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service Springfield, VA 22161		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) torpedoes protective coatings aluminum		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The U.S. Navy is now using a proprietary polyurethane coating on its aluminum torpedoes. Although this coating has good resistance to rough handling and corrosive environments, there are two drawbacks: 1. Some people are highly allergic to the isocyanate materials in urethane coatings; there is concern that the Occupational Safety and Health Administration (OSHA) may restrict the use and availability of these coatings. (Continued on next page)		

BLOCK 20 (Continued)

2. The polyurethane now used is a proprietary material. If it became unavailable for any reason, it would be difficult to select an alternative coating system because there is little experience with other systems in this environment.

To address these problems, the Navy asked the U.S. Army Construction Engineering Research Laboratory to evaluate alternative coatings for aluminum.

The objectives of this study were to select and evaluate aluminum coatings and coating systems for their resistance to mechanical handling, and for their capability to protect aluminum from corrosion in seawater and Otto fuel, the torpedo propellant.

Of the 10 coating systems tested for this study, two were found to be suitable for use on torpedo exteriors:

1. The epoxy-polyamide coating MIL-P-24441 has excellent corrosion resistant properties. Formula 158 and Formula 152 are the primer and topcoat within the specification which are best suited for use on aluminum substrates. The MIL-P-24441 system has excellent adhesion. The impact resistance of this coating is best if the topcoat is applied at no more than 5 mils dry film thickness. The MIL-P-24441 system had the best overall performance of the 10 candidate coatings for torpedo exteriors.

2. The Ameron vinyl system (Amercoat 86 primer and Amercoat 99HS topcoat) provides a high degree of corrosion protection, has good impact resistance and adhesion, and (because it is a solution vinyl) should be easily repaired when the original coating is damaged. A 15-mil thick coat of this vinyl provides much greater protection against damage by impact than does a 10- or 5-mil coat. Adequate drying time must be allowed before putting this coating system into immersion, or premature loss of adhesion may result. The flexibility, repairability, and good performance of this coating make it a good second choice of the 10 candidate coatings for torpedo exteriors.

To coat the lining of a torpedo's internal fuel tank, the MIL-C-4556 system had the best overall performance when applied over the dichromate sealed, hardcoat anodized 7075 series aluminum. When undamaged, this coating is highly resistant to deterioration in Otto fuel, seawater, or a mixture of the two. When the coating is physically damaged, it does not break away from the damaged area, but remains intact even if corrosion has undercut the coating.

FOREWORD

This study was done by the Engineering and Materials Division (EMD), U.S. Army Construction Engineering Research Laboratory (CERL) for the Naval Underwater Systems Center under MIPR No. N660481 MP10005. The Navy technical monitor was Mr. H. Pearl, Code 36622. The Navy funding was provided by Work Unit Number (WUN) 106, whose Principal Investigators are Mr. K. J. Haydon, NAVSEA-PMS-402 F12, and Mr. J. R. Quartarone, NUSC 36112.

The assistance of Mr. R. G. Lampo in the preliminary work on this project is acknowledged.

Dr. R. Quattrone is Chief of EM. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

[illegible]

CONTENTS

	<u>Page</u>
DD FORM 1473	2
FOREWORD	3
LIST OF TABLES AND FIGURES	5
 1 INTRODUCTION.....	 9
Background	
Objectives	
Approach	
 2 MATERIAL SELECTION AND PREPARATION OF TEST SPECIMENS.....	 11
Selection of the Coatings	
Aluminum Test Specimens	
Application of the Coatings: Techniques and Observations	
Preparation of the Panels for Immersion	
 3 TEST METHODS.....	 24
Physical Test Procedures	
Characterization of the Coatings	
Test Methods	
 4 TEST RESULTS.....	 31
Physical Tests	
Immersion Tests	
 5 CONCLUSIONS.....	 58
Task I: Torpedo Exterior Coatings	
Task II: Torpedo Interior Fuel Tank Coatings	
 6 RECOMMENDATIONS.....	 60
REFERENCES	61
METRIC CONVERSIONS	61
APPENDIX A: Gas Chromatographic and Infrared Spectrum Analyses	62
APPENDIX B: Additional Vendor Information	109
DISTRIBUTION	

TABLES

<u>Number</u>		<u>Page</u>
1	Application of the Coatings	15
2	Mean Coating Thicknesses	19
3	Characterization Test Results	29
4	Physical Test Results	32
5	Corrosion Resistance of Specimens During 90-Day Immersion	44

FIGURES

1	Solderless Terminal	20
2	Assembly of Galvanically Coupled Specimen	21
3	Scribe Lines	21
4	Location of Pre-immersion Points	22
5	Specimen Corroded at 40 in.-lb Impact Point	23
6	Specimen Uncorroded After 90-Day Immersion	23
7	Elcometer Adhesion Tester	26
8	Scrape Adhesion Tester	26
9	Gardner Impact Tester	27
10	Elcometer Adhesion	36
11	Scrape Adhesion	36
12	Impact, 23°C	36
13	Impact, 40°C	36
14	Elcometer Adhesion Test Results of Task I Urethane Coatings	39
15	Scrape Adhesion Test Results of Task I Urethane Coatings	39
16	Elcometer Adhesion Test Results of Task II Coatings in Four Immersion Tests	41
17	Scrape Adhesion Test Results of Task II Coatings	41

FIGURES (Cont'd)

<u>Number</u>		<u>Page</u>
18	Impact at 4°C Test Results of Task II Coatings	42
19	Specimens After 90-Day Immersion	46
20	Bare Aluminum After 90-Day Immersion in Seawater	49
21	Hardcoat Anodized Dichromate Sealed Aluminum After 90-Day Immersion in Seawater	49
22	Hardcoat Anodized Unsealed Aluminum After 90-Day Immersion in Seawater	50
23	Chromate Conversion Coated Aluminum After 90-Day Immersion in Seawater	50
24	Bare Aluminum After 90-Day Immersion in 50 Percent Seawater/ 50 Percent Otto Fuel	54
25	Hardcoat Anodized Dichromate Sealed Aluminum After 90-Day Immersion in 50 Percent Seawater/50 Percent Otto Fuel	54
26	Hardcoat Anodized Unsealed Aluminum After 90-Day Immersion in 50 Percent Seawater/50 Percent Otto Fuel	55
27	Chromate Conversion Coated Aluminum After 90-Day Immersion in 50 Percent Seawater/50 Percent Otto Fuel	55
A1	Gas Chromatogram: MIL-P-24441 Formula 158 Primer	62
A2	Gas Chromatogram: MIL-P-24441 Formula 152 Topcoat	63
A3	Gas Chromatogram: MIL-C-4556 Primer	64
A4	Gas Chromatogram: MIL-C-4556 Topcoat	65
A5	Gas Chromatogram: Deft MIL-P-23377	66
A6	Gas Chromatogram: MIL-C-22750	67
A7	Gas Chromatogram: Steelcote 100 Percent Solids Epoxy	68
A8	Gas Chromatogram: Amercoat 86 Primer	69
A9	Gas Chromatogram: Amercoat 6 Thinner	70
A10	Gas Chromatogram: Amercoat 99HS Topcoat	71
A11	Gas Chromatogram: Amercoat 9 Thinner	72
A12	Gas Chromatogram: Hughson XS 3236-26 Wash Primer	73

FIGURES (Cont'd)

<u>Number</u>		<u>Page</u>
A13	Gas Chromatogram: Hughson TS 3236-23 Topcoat	74
A14	Gas Chromatogram: MIL-C-83286	75
A15	Gas Chromatogram: Irathane 155	76
A16	Gas Chromatogram: BMS-10-11K	77
A17	Gas Chromatogram: MIL-T-81772/AS Thinner	78
A18	Gas Chromatogram: Solvent Used for Preparing Samples -- Pentane	79
A19	Infrared Analysis: MIL-P-24441 Primer, Component A	80
A20	Infrared Analysis: MIL-P-24441 Primer, Component B	81
A21	Infrared Analysis: MIL-P-24441 Topcoat, Component A	82
A22	Infrared Analysis: MIL-P-24441 Topcoat, Component B	83
A23	Infrared Analysis: MIL-C-4556 Primer, Component A	84
A24	Infrared Analysis: MIL-C-4556 Primer, Component B	85
A25	Infrared Analysis: MIL-C-4556 Topcoat, Component A	86
A26	Infrared Analysis: MIL-C-4556 Topcoat, Component B	87
A27	Infrared Analysis: MIL-P-23377, Component A	88
A28	Infrared Analysis: MIL-P-23377, Component B	89
A29	Infrared Analysis: MIL-C-22750, Component A	90
A30	Infrared Analysis: MIL-C-22750, Component B	91
A31	Infrared Analysis: Steelcote 100 Percent Solids Epoxy, Component A	92
A32	Infrared Analysis: Steelcote 100 Percent Solids Epoxy, Component B	93
A33	Infrared Analysis: Amercoat 86, Liquid, Pigment Removed	94
A34	Infrared Analysis: Amercoat 6 Thinner	95
A35	Infrared Analysis: Amercoat 99HS, Liquid, Pigment Removed	96
A36	Infrared Analysis: Amercoat 9 thinner	97
A37	Infrared Analysis: Hughson TS 3236-26 Wash Primer, Component A	98

FIGURES (Cont'd)

<u>Number</u>		<u>Page</u>
A38	Infrared Analysis: Hughson TS 3236-26 Wash Primer, Component B	99
A39	Infrared Analysis: Hughson TS 3236-23 Topcoat, Component A	100
A40	Infrared Analysis: Hughson TS 3236-23 Topcoat, Component B	101
A41	Infrared Analysis: MIL-C-83286, Component I	102
A42	Infrared Analysis: MIL-C-83286, Component II	103
A43	Infrared Analysis: Irathane 155, Component A	104
A44	Infrared Analysis: Irathane 155, Component B	105
A45	Infrared Analysis: BMS-10-11K, Component A	106
A46	Infrared Analysis: BMS-10-11K, Component B	107
A47	Infrared Analysis: MIL-T-81772/AS Thinner	108
B1	Vendor Information: MIL-P-24441	109
B2	Vendor Information: Ameron System	116
B3	Vendor Information: MIL-C-4556	121

PROTECTIVE COATINGS FOR ALUMINUM TORPEDOES

1 INTRODUCTION

Background

When aluminum alloys are selected, their strength is often considered first, while the environment to which they will be exposed is a secondary consideration. In seawater, for example, the 6000 series alloys have good corrosion resistance while the 7000 series alloys do not; however, the 7000 series is often used because it is stronger.

Since the Navy's MK48 torpedoes are typically manufactured with 7000 series aluminum, the exteriors must be coated to protect against corrosion caused by seawater. The internal surface of the aluminum fuel tank must also be coated. This coating must be resistant to the corrosive properties of Otto fuel (the torpedo propellant) and of any mixture of Otto fuel and seawater. Although gouging and abrasion are not a problem inside the fuel tank, the coating must be highly adherent and nonflaking because any loose particles could enter the propulsion mechanism and cause a malfunction.

The Navy is now using a proprietary elastomeric polyurethane coating on its aluminum torpedoes. Although this coating has good resistance to rough handling and corrosive environments, there are two drawbacks:

1. Some people are highly allergic to the isocyanate materials in urethane coatings; there is concern that the Occupational Safety and Health Administration (OSHA) may restrict the use and availability of these coatings.

2. The polyurethane now used is a proprietary material. If it became unavailable for any reason, it would be difficult to select an alternative coating system because there is little experience with other systems in this environment.

To address these problems, the Navy asked the U.S. Army Construction Engineering Research Laboratory (CERL) to evaluate alternative coatings for aluminum.

Objectives

The objectives of this study were to select and evaluate a very limited number of coatings and coating systems for aluminum that are resistant to mechanical handling and seawater corrosion (Task I), and to protect aluminum from corrosion in seawater and Otto fuel (Task II). Emphasis was placed on nonpolyurethane coatings. The candidate coatings were to be selected based on major differences in polymer composition and physical properties. The results are to be used for direction in developing more effective organic coatings.

Approach

Task I: Nine potentially suitable candidate coating systems for torpedo exteriors were selected for this study. These coatings were tested, evaluated, and ranked in order of effectiveness. Some proprietary coatings were evaluated, but priority in selection was given to applicable Federal or military specification materials. No specific repairability tests were included, but priority was given to organic coatings that might be easily repaired after they were damaged. To help ensure that the same paint is obtained in the future, physical and chemical tests were performed to characterize and identify the major constituents and their concentrations. Additional characterization of constituents was obtained from pertinent vendor data and material safety sheets. The testing and evaluation of the performance of the coatings examined mechanical strength; impact, adhesion, and corrosion resistance; as well as electrical measurements of the impedance, resistance, and capacitance of the paint systems on anodized or chromate conversion pretreated 7075-T6 aluminum panels before, during, and after a 90-day immersion in aerated synthetic seawater. The effect of coating thickness and/or the nature of the substrate pretreatments was determined. The presently used elastomeric polyurethane coatings and other types of polyurethanes were tested to compare their performance. The corrosion performance of unpainted specimens was also observed.

Task II: The candidate coatings for the torpedo fuel tanks were selected, tested, and evaluated. These coatings were ranked for adherence, nonflaking, and corrosion protection for anodized or chromate conversion pretreated 7075-T6 aluminum alloy specimens in seawater, Otto fuel, or a mixture of 50 percent seawater and 50 percent Otto fuel. Tests conducted include impact, adhesion, immersion, and electrical evaluations similar to those for Task I. The corrosion performance of unpainted specimens immersed in the pertinent liquids was determined.

2 MATERIAL SELECTION AND PREPARATION OF TEST SPECIMENS

Selection of the Coatings

To select the coatings to be evaluated, CERL searched the Federal and military paint specifications to find those appropriate for the given exposures. Epoxy primer, military specification MIL-P-23377, was used for all tested coatings (both specification and proprietary), unless a different primer was needed for a given system. Based on this search, CERL found that it would be worthwhile to evaluate the following coatings for Task I:

1. Nonurethane:

- Epoxy-polyamide
- Epoxy-polyamine
- "Flexible" epoxy
- 100 percent solids epoxy
- Vinyl.

2. Urethane:

- Currently used elastomeric system
- Currently used elastomeric topcoat over MIL-P-23377 primer
- Nonelastomeric urethane system
- High-build urethane system.

For Task II, it was decided to select coatings designed for fuel tank linings. All coatings chosen were epoxy materials.

The coatings selected for evaluation are discussed below. The basis for selection and the source of sample materials are given.

Task I

Nonurethane Coatings. Six different coatings were selected for this part of the study.

1. Epoxy-polyamide meeting MIL-P-24441. It was known that this specification material has excellent seawater and chemical resistance. However, CERL had to find out whether this coating has the necessary flexibility, gouge, and impact resistance. This specification is subdivided into various formulas for different topcoats and primers. Formula 158 primer was selected since it is specifically formulated to be used over aluminum and with the MIL-P-24441 topcoats.

Samples of the Formula 158 primer (yellow) were obtained from:

Matcote Company
P.O. Box 10762
Houston, TX 77018

Samples of the Formula 152 topcoat (white) were obtained from:

Mobil Chemical Company
901 North Greenwood
Kankakee, IL 60901

2. Epoxy coating system meeting MIL-C-4556. This coating specification is really a coating system. That is, the specification covers both an epoxy-polyamide primer and an epoxy-polyamide topcoat. This system is meant for fuel tanks, and therefore has excellent chemical resistance and adhesion. Several paint manufacturers recommend this specification for both the exterior of torpedoes and the interior of the fuel tanks. This coating was evaluated for both Task I and Task II. If the performance were acceptable in both exposures, only one coating system would need to be specified for the torpedoes.

The sample for this evaluation was obtained from:

Plas Chem Coatings
6300 Bartmer Industrial Drive
St. Louis, MO 63130

The primer tested was orange in color, and the topcoat was white.

3. "Flexible" epoxy meeting MIL-C-22750. As with most epoxy-polyamide coatings, this was expected to have good seawater and chemical resistance. The advantage of this material is that it can be made more flexible than MIL-P-24441 epoxy. Chemrex Specialty Coatings Company, El Paso, TX, prepared a sample in its laboratory. The sample was formulated to provide good flexibility and to meet Federal Standard 595 color #14062 (dark green).

4. A 100 percent solids epoxy coating. Steelcote Manufacturing Company, Saint Louis, MO, claims to have an epoxy coating that has: (1) the needed resistance to seawater corrosion, (2) an inherent flexibility and toughness, and (3) no volatile solvents. CERL tested a sample made in Steelcote's laboratory and pigmented to meet color #14062.

5. The MIL-P-23377 epoxy primer. This was tested at a thickness of 5 mils and without a topcoat. The coating was obtained from:

Deft, Inc.
17451 Von Karman Avenue
Irvine, CA 92714

This primer is yellow.

6. Vinyl coating system. Solution vinyl coatings are typically tough and flexible, and have reasonably good chemical resistance. One advantage is that they can be applied over an old vinyl coating with no intercoat adhesion problems providing the old surface is clean.

A vinyl coating system manufactured by Ameron, 201 North Berry Street, Brea, CA 92621, was selected for this study. The system includes a synthetic resin inhibitive primer, Amercoat 86, and a topcoat, Amercoat 99HS. These materials are standard off-the-shelf products. The topcoat is Ameron's color, medium green, which is lighter than the #14062 color. The primer color is red oxide.

Urethane Coatings. Four different coating systems were evaluated.

1. Currently used urethane system. This consists of a vinyl butyral phosphoric acid wash-primer first coat (Lord, Hughson identification #TS 3236-26, yellow) and an elastomeric topcoat made from an aliphatic polyisocyanate and a butyl ketoxime blocked aromatic polyamine (Lord, Hughson #TS 3236-23A/B, revision #1, color #14062) manufactured by Lord Corporation, Chemical Products Group, Erie, Pennsylvania 16514.

2. Currently used urethane system topcoat manufactured by Lord Corp. over MIL-P-23377 primer obtained from Deft, Inc.

3. Nonelastomeric aliphatic urethane coating meeting military specification MIL-P-83286. This coating is a topcoat material only; it was applied over MIL-P-23377 primer. A single, small sample of this coating in color #14062 could not be obtained in an acceptable time at a reasonable cost. However, the manufacturer, Deft, Inc., maintained that making the correct color should not be hard, and that the pigmentation difference should not be a great factor in its performance properties. A sample of a white coating pigmented with titanium dioxide, conforming to MIL-P-83286, was received from Deft, Inc.

4. High-build elastomeric polyurethane. A yellow topcoat, Irathane 155, was applied over the MIL-P-23377 yellow primer. The topcoat was obtained from Irathane Systems, Inc., Hibbing, MN.

Task II

Three coatings were selected for this portion of the study.

1. Flexible epoxy-polyamide meeting MIL-C-22750. In the technical manual on Otto Fuel II, an epoxy coating meeting MIL-P-22808 is listed as an acceptable tank lining.¹ However, MIL-P-22808 has been cancelled and replaced by MIL-C-22750. MIL-C-22750 was also evaluated as a coating for the torpedo exteriors. Chemrex supplied a sample for testing. The topcoat meets color #14062.

2. Epoxy coating meeting military specification MIL-C-4556. This coating might be expected to have slightly better chemical resistance than the

¹ Otto Fuel II: Safety, Storage, and Handling, NAVSEA OP 3368 Fifth Revision (Naval Sea Systems Command, 15 January 1973, Change 1, 15 May 1975).

MIL-C-22750 coating. MIL-C-4556 is a primer and a topcoat system. This coating also was evaluated for torpedo exteriors. Plas Chem supplied samples of the orange primer and a white topcoat formulation.

3. Amine-cured epoxy coating meeting Boeing Aircraft specification #BMS-10-11K. It was thought worthwhile to include in this study an industry specification material used for lining tanks which may contain material similar to the Otto fuel. The Boeing specification material is a readily available, conventionally pigmented coating. It is self-priming and need not be topcoated as long as the material is not exposed to sunlight. This coating was obtained as an off-the-shelf product from Deft, Inc. The coating is light green in color.

Aluminum Test Specimens

All aluminum test specimens were 3 in. by 6 in. by 0.125 in. aluminum alloy 7075-T6. The panels were divided among three groups. Throughout this report, these three pretreatments will be called substrates a, b, and c:

substrate a — 7075-T6 with a 2 ($\pm$ 0.5)-mil-thick Type III, class 1, dichromate sealed, hardcoat anodizing in accordance with MIL-A-8625C, 15 January 1968 and amendment 1, 13 March 1969.

substrate b — 7075-T6 with a 2 ($\pm$ 0.5)-mil-thick Type III, class 1, unsealed, hardcoat anodizing in accordance with MIL-A-8625C, 15 January 1968 and amendment 1, 13 March 1969.

substrate c — 7075-T6 with a chromate conversion coating, class 1A, in accordance with MIL-C-5541, 30 June 1970 and amendment 2, 30 November 1972.

The test panels were made from the same batch of stock material. All edges were deburred and rounded. A single 1/4-in. hole was drilled in each specimen centered on the 3-in. side and 1/4 in. from the edge. The panels were degreased, cleaned, and blasted on all sides and edges with silica sand to a white metal finish and a mean surface profile of approximately 1 mil before treatment. The specimens were supplied by:

The Metaspec Company
P.O. Box 27707
San Antonio, TX 78227

Application of the Coatings: Techniques and Observations

All coatings in this study were applied by conventional suction-cup air spray equipment, except as noted in Table 1.

To evaluate the effect of film thickness on coating performance, almost all the nonpolyurethane coatings for Task I were applied at topcoat dry film thicknesses of 5, 10, and 15 mils. The urethane coatings were applied at a topcoat dry film thickness of 5 mils — except for the high-build urethane system, which was applied at 15 mils. The urethanes were applied over substrates a, b, and c. Successful preliminary results on the MIL-P-24441 epoxy

Table 1
Application of the Coatings

<u>Coating</u>	<u>Thinner</u>	<u>Equipment</u>	<u>Pot Life</u>	<u>Problems</u>
MIL-P-24441 topcoat and primer	None	Conventional	5 hours	None
MIL-C-4556 topcoat and primer	None	Conventional	6 hours	None
MIL-P-23377 primer	None	Conventional	8 hours	Does not dry to a smooth finish over anodizing
MIL-C-22750	MIL-T-81772	Conventional	6 hours	Air bubbles if more than a very thin coat is applied
100% solids epoxy	None	Conventional airspray fitted with a pressure pot	1-1/2 to 2 hours	Sagging, dripping
Amercoat 86 primer	Amercoat 6	Conventional air- spray fitted with a pressure pot and a fine tip	Unlimited	Cobwebs
Amercoat 99HS topcoat	Amercoat 9	Conventional air- spray fitted with a pressure pot	Unlimited	Pinholes if not thinned sufficiently
Hughson wash primer	None	Conventional	8 hours	None
Hughson polyurethane topcoat	None	Conventional	2 hours	None
MIL-C-83286	None	Conventional	6 hours	Air bubbles if more than a thin coat is applied
Iratane 155	None	Conventional	3 hours	None
BMS-10-11K	None	Conventional	8 hours	Must be applied in multiple thin coats to avoid surface ten- sion problems

system and the Ameron vinyl system suggested that these coatings be evaluated over all three substrates.* Other coatings in Task I were evaluated on substrate a only.

Task II coatings were applied at the thickness suggested by the manufacturer or by the military specification. These coatings were applied to all three substrates.

The techniques used to apply each coating are discussed below. This information is summarized in Table I.

MIL-P-24441: Both the primer and the topcoat were easily mixed and applied without thinning. Each coat was allowed to dry overnight before recoating. Each coat dried to a thickness of about 3 mils.

MIL-C-4556: Both the primer and the finish coat sprayed easily with conventional suction-cup spray. Thinning was not necessary. The primer was applied at approximately 2 mils dry film thickness. Each coat of the topcoat was about 5 mils dry film thickness. Each coat was allowed to dry overnight before recoating. The system became very hard and brittle as it cured.

MIL-P-23377: This primer was used with several different topcoats. It was applied at a thickness of 1 mil with no thinning. Some difficulty was encountered in applying the primer to the anodized aluminum panels, both with and without the dichromate sealing. These surfaces are somewhat porous, and the solvents in the primer were absorbed into the surface as the coating was applied. The primer dried with a sandy, rough surface when applied at a 1-mil thickness over anodizing. Applying a somewhat heavier coat prevented much roughness, but the coating still did not have the smooth surface that normally would be expected. There was no problem in applying this primer over the nonanodized chromate conversion coated panels.

MIL-C-22750: This coating was very difficult to spray. When more than a mist coat was applied, air bubbles up to 1/8 in. in diameter appeared on the surface about a minute after spraying. This happened whether the coating was thinned or unthinned, or was applied on smooth metal, sandblasted metal, or over the MIL-P-23377 primer. Acceptable results were obtained only with very careful work. The coating was thinned to 18 seconds on a #4 Ford cup with the MIL-T-81772 thinner recommended in MIL-C-22750. The first coat was applied as a very thin mist and allowed to dry for 1 hour before recoating. This coating was chosen for testing in Tasks I and II. Task I required coating thicknesses of 5, 10, and 15 mils. Since the coating could only be applied in coats of less than 1 mil, it was difficult and time consuming to obtain the necessary film build. The Task II specimens were coated according to MIL-C-22750 directions with a mist coat and one more coat. The total thickness of the topcoat was 0.9 to 1.2 mils.

The 100 percent solids epoxy coating: This coating was applied using conventional spray equipment fitted with a pressure pot. A pressure of about 15 psi was applied to the pot. To apply a 5-mil coat, the coating was sprayed to give a "spattered" coat which did not cover the entire surface. Within a

* Both coatings were rated highly on physical tests performed before immersion.

few seconds this coat flowed together smoothly and uniformly. The coating has some tendency to sag and drip, even at 5 mils. It was not possible to spray the panels at a thickness of less than 5 mils. Each coat was allowed to cure overnight before recoating.

Ameron 86 and Ameron 99HS: The primer, Amercoat 86, was thinned to 25 seconds on the #2 Zahn cup with Amercoat 6 thinner. It was difficult to get good atomization of this paint with conventional spray equipment. The best results were obtained using the pressure pot and a fine atomizing tip on the spray gun. Two fast passes of the spray gun gave an even coat about 1.5 mils thick. The first pass was allowed to dry a few minutes before the second coat was sprayed on. The primer was messy to apply; during spraying, semidry paint particles and cobwebs filled the air. The topcoat was thinned to 90 seconds on the #2 Zahn cup; about one part paint was mixed with one part thinner. Without this much thinning, the coating had many pinholes. Each coat dried to a thickness of about 1 mil. The topcoat dried rather quickly, so several coats could be applied with only a few minutes' drying time between coats. The topcoat dried to a very dull finish.

Hughson TS 3236-26 and TS 3236-23: Both the wash primer and the topcoat were easy to apply; mixing and spraying presented no particular problems. The wash primer was applied in one thin coat and dried quickly. The topcoat was easily applied over both the wash primer and the MIL-P-23377 epoxy primer. A film build of 5 mils was achieved by applying six coats with a few minutes' drying time between each coat.

MIL-C-83286: No thinning was necessary when applying this polyurethane coating. The first coat had to be a very thin mist coat, otherwise, bubbles formed in the coating. The mist coat was allowed to dry for about 1 hour before recoating. A third coat was applied after overnight drying to give a 5-mil dry film thickness. Many of the panels had pinholes, but these flaws did not appear to go through all coats. There were no pinholes in the MIL-P-23377 primer.

Irathane 155: There were no particular problems with either mixing or spraying. No thinning was required. A dry film thickness of 4 to 5 mils was applied for each coat.

BMS-10-11K: This coating was easy to apply with no thinning; as recommended, no primer was used. Two thin coats were applied to give a dry film thickness of about 1 mil. When one heavier coat was applied, surface tension gave the coating an alligator-skin appearance.

Preparation of the Panels for Immersion

Thickness Measurements

The thickness of the coating on each panel was determined by measuring the total thickness of the coated panel, then subtracting the thickness of the uncoated panel, and dividing by two to get the coating thickness on each side. The measurements were made using a gauge calibrated in mils. The gauge was bolted to a stationary support. The movable dial was rotated to read zero thickness for an uncoated panel. The dial was recalibrated for each substrate

(anodized sealed, unsealed, and chromate conversion coated). This method of measuring total coating thickness assumes that each uncoated panel is the same thickness, and that the film on one side of the panel is the same thickness as that on the other side. The thicknesses of several uncoated panels were measured; the differences between them were minimal. Three measurements were recorded for each panel, about 1 in. from the long edge at the top, middle, and bottom of the panel. The number of panels per test and the coating thickness measurement values are included in Table 2. It was difficult to apply the coatings at the exact film thicknesses desired. The variations in coating thicknesses were normally less than 1.5 to 2.0 mils. Table 2 also includes the number of test specimens for each coating system, thickness, and substrate.

Preparation of Panels for Electrical Measurements

To attach electrical leads to a specimen, part of the coating and anodizing was removed at the top of each panel. A steel template with a 1/2-in.-diameter hole at the top was placed over the panel, and the coating was removed by sandblasting. This technique removed the coating from a small area without damaging the rest of the panel. A 1/8-in. hole was drilled in the center of the clean area, and a solderless terminal was riveted in place (Figure 1). Before it was attached, the terminal was dipped in a conductive silver paint. The bare metal areas were then covered with silicone sealant to protect the connection from the corrosive seawater and Otto fuel.

Galvanically Coupled Panels

Each of the coated specimens in this phase of the testing was galvanically coupled to two brass panels of the same size as the specimen. Leads were soldered to the brass panels; a longer lead coupled one brass panel to the coated panel. Each coated panel was sandwiched between the two brass panels and bolted together using nylon nuts, bolts, and washers (Figure 2). Four washers were inserted between each panel to provide 1/8-in. spacing. The leads from the brass and coated panel were cut to 6 in.; the ends were stripped, twisted together, and soldered. The assembled panels were suspended in the tanks with the coupled ends of the wires well above the surface of the immersion liquid. These panels did not require electrical measurements and did not have to be disassembled until the testing was completed. The length of the wires allowed the panels to be twisted apart enough to observe the condition and appearance of the coating during immersion.

Scored Specimens

Some of the coated specimens were scored with a diamond-tipped cutting tool. Two parallel 3-1/2-in.-long scribe lines were cut 1 in. apart on each face of the panel (Figure 3). The top of each scribe line was 1 in. from the top edge of the panel. On each panel, the left-hand scribe line was cut through to bare metal; the right-hand scribe line was cut through all layers of the coating to the anodizing.

Table 2
Mean Coating Thicknesses

<u>Coating</u>	<u>Substrate</u>	<u>Intended Thickness (mils)</u>	<u># of Panels</u>	<u>Mean Thickness (mils)</u>	<u>Standard Deviation</u>
Task 1: Nonurethanes					
MIL-P-24441	a	6	16	6.4	0.75
over	a	11	16	10.9	1.01
MIL-P-24441	a	16	16	14.0	1.29
	b	6	16	5.7	0.88
	b	11	16	10.4	1.18
	b	16	16	14.5	1.25
	c	6	16	5.0	0.56
	c	11	16	9.5	0.83
	c	16	16	13.1	2.04
MIL-C-4556	a	6	16	6.0	0.70
over	a	11	16	10.5	1.07
MIL-C-4556	a	16	16	10.6	1.19
MIL-C-22750	a	6	16	4.2	0.57
over	a	11	16	8.4	0.74
MIL-P-23377	a	16	16	12.4	0.90
100% Solids	a	6	16	5.7	0.93
over	a	11	16	5.5	0.65
MIL-P-23377	a	16	16	16.3	1.64
MIL-P-23377	a	6	16	6.6	0.59
	b	6	16	5.4	0.60
	c	6	16	5.1	0.65
Amercoat 9985	a	6	16	5.4	0.82
over	a	11	16	9.7	0.69
Amercoat 86	a	16	16	15.4	1.13
	b	6	16	7.4	0.96
	b	11	16	12.5	0.95
	b	16	16	18.0	1.07
	c	6	16	8.3	0.60
	c	11	16	12.7	0.81
	c	16	16	21.9	1.75
Task 1: Urethanes					
Hughson	a	6	16	7.3	0.54
TS 3236-23	b	6	16	8.2	0.64
over	c	6	16	8.0	0.51
TS 3236-26					
Hughson	a	6	16	4.1	0.41
TS 2236-23	b	6	16	4.9	0.45
over	c	6	16	4.5	0.55
MIL-P-23377					
Irathane 155	a	16	16	13.7	2.58
over	b	16	16	18.4	2.17
MIL-P-23377	c	16	16	18.4	1.43

Table 2 (Cont'd)

<u>Coating</u>	<u>Substrate</u>	<u>Intended Thickness (mils)</u>	<u># of Panels</u>	<u>Mean Thickness (mils)</u>	<u>Standard Deviation</u>
Task II					
MIL-C-22750	a	2	26	2.2	0.58
over	b	2	26	3.4	0.51
MIL-F-23377	c	2	26	2.8	0.56
MIL-C-4556	a	9	26	8.6	1.36
over	b	9	26	8.6	1.54
MIL-C-4556	c	9	26	7.1	0.98
BMS-10-11K	a	1	26	1.2	0.50
	b	1	26	2.2	0.46
	c	1	26	2.0	0.61



Figure 1. Solderless terminal.



Figure 2. Assembly of galvanically coupled specimen.



Figure 3. Scribe lines.

Some of the coated specimens were impacted before immersion. This was done with a Gardner Heavy-Duty Variable Impact Tester. Four points in predetermined locations on each panel were impacted with forces of 5, 10, 20, and 40 in.-lb as shown in Figure 4. Since most coatings fail in the range of 5 to 40 in.-lb, each panel had at least one actual coating failure among the four points of impact. Figure 5 shows a specimen which corroded only at the point which was impacted with a force of 40 in.-lb. The specimen was galvanically coupled and immersed in seawater for 90 days.

Undamaged Specimens

Some of the specimens were not damaged prior to immersion. Figure 6 shows a specimen coated with MIL-P-24441 which did not visibly corrode during 90-day immersion in seawater. The specimen was galvanically coupled.

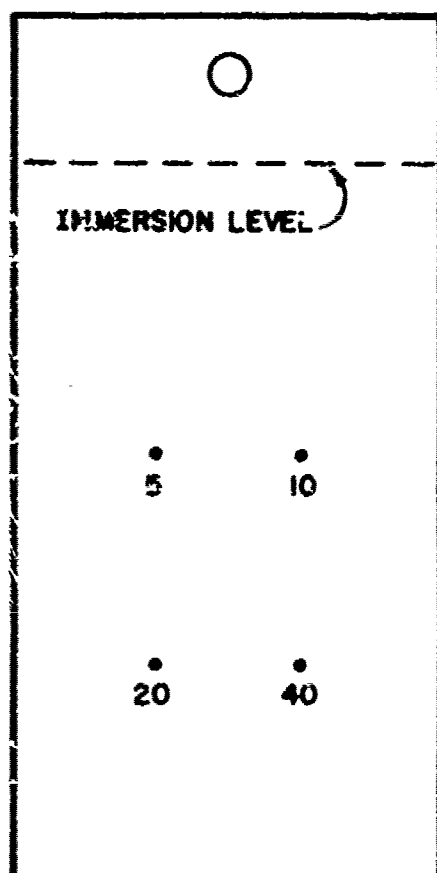


Figure 4. Location of pre-immersion points.

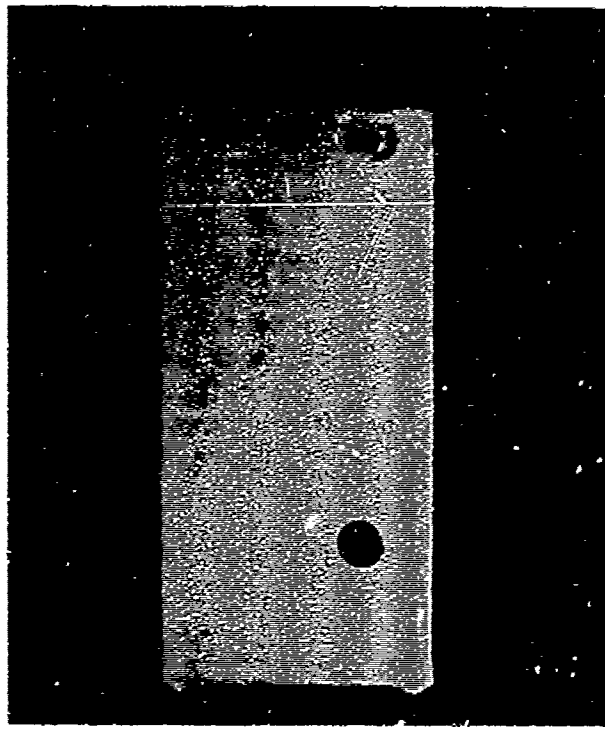


Figure 5. Specimen corroded at 40 in.-lb impact point.

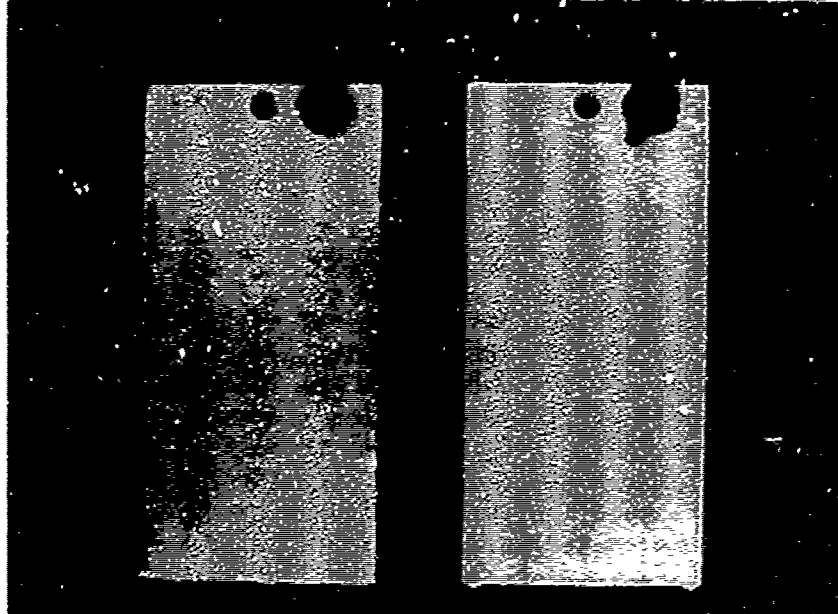


Figure 6. Specimen uncorroded after 90-day immersion.

3 TEST METHODS

More than 900 aluminum panels were coated and tested. Most of the specimens were immersed for 90 days in seawater, Otto fuel, or a mixture of the two. Some specimens were damaged before immersion by impact or by score lines cut into the coating surface. Some of the damaged and undamaged test specimens were galvanically coupled to 60/40 bronze during the immersion period to accelerate the corrosion processes. Electrical measurements of resistance, capacitance, and loss factor at 1 kHz were made on 250 panels weekly during the 90-day immersion period. After the immersion period, each panel was examined to evaluate its condition. The results of the electrical measurements were tabulated, and the resistance and capacitance were plotted versus time of immersion. These plots were not found to give valuable information about the deterioration of the coatings within the 90-day immersion period. The results were not used because the data indicated the immersion time was too short to provide useful information.

Four destructive physical tests were performed on the specimens after immersion and on those specimens that were not immersed:

1. Elcometer adhesion test
2. Scrape adhesion test
3. Impact at room temperature (23°C)
4. Impact at 40°C.

Characterization tests were performed on each coating to provide a basis for comparing any batches of that coating procured by the Navy or CERL in the future with the samples already evaluated by CERL. The pigment content, total solids, and nonvolatile vehicle content of each coating were measured, and infrared and gas chromatographic analyses were performed.

Physical Test Procedures

Elcometer Adhesion Test

Originally, the adhesion of the coatings was to be tested using a tape adhesion method. For this test, two parallel cuts, 1/8 in. apart, and a third line perpendicular to the other two are cut into the coating. A piece of masking tape is firmly placed over the score lines and then peeled back to remove the coating. However, this test was shown to be ineffective because it would not remove many coatings. Therefore, CERL substituted the Elcometer Adhesion Tester. The test method involved using an epoxy glue to cement circular aluminum dollies to the coated surface. The dollies were lightly sand-blasted on the contact surface to ensure good adhesion of the glue. The paint surface was also slightly roughened with sandpaper. Weights were placed on the dollies while the glue was curing. All specimens were allowed to cure overnight. A 1-in. hole saw attached to an electric hand drill was used to cut through the coating around the dolly. The dolly could then be pulled from the specimen with the adhesion tester, and the force at which the dolly was

pulled from the specimen was read in units of pounds per square inch. On most specimens, the dolly pulled all or part of the paint system from the panel. However, on some of the strongest coatings, the epoxy glue broke before the paint system, and the paint was left intact. The adhesion tester had a range of 0 to 1000 psi; the glue typically broke at 700 to 900 psi. Thus, this test did not distinguish between the highly adherent coatings, but it did indicate coatings with poor adhesion. One drawback of this test method is that the solvents in the glue might affect the characteristics of the coating system. For most coatings in this study, solvents would not be expected to have much effect because two-component cured coatings usually are solvent-resistant; however, the solution vinyl coating by Ameron is not. Thus, the Elcometer adhesion test may give false low readings for this coating in particular. Figure 7 is a photo of the test equipment after a test was performed.

Scrape Adhesion Test

A scrape adhesion test was performed with a balanced-beam scrape adhesion tester in accordance with American Society for Testing and Materials (ASTM) D 2197-68, Method A.²

ASTM D 2197-68A does not clearly state when the test should end; successively larger loads are to be used until the coating is removed or until the maximum load of 10 kg has been added. It is unclear whether the endpoint is the removal of the entire coating system from the substrate, or the removal of a portion of the topcoat from the surface. For the purposes of this testing, removal of any part of the coating constituted failure. (If the endpoint were removal of the entire coating system, many of the coatings would have exceeded the 10-kg limit of the apparatus.) The load was determined only to the nearest 0.5 kg because tests at smaller weight increments were not reproducible. The equipment at the conclusion of a test is shown in Figure 8.

Impact Test

An impact test was performed in accordance with ASTM D 2794-69.³ The test was performed at a room temperature of $25 \pm 1^\circ\text{C}$, and again on specimens cooled to $4 \pm 3^\circ\text{C}$ for 1 hour. The test was done on a Gardner Heavy-Duty Variable Impact Tester. A specimen was set over a 0.640-in.-diameter hole in a die mounted on the base of the apparatus. A spherical tipped punch of 0.625-in. diameter was placed on the specimen. A 2-lb weight was raised to a desired height (up to 40 in.) in a graduated tube; this weight delivered a maximum force of 80 in.-lb. The equipment is shown in Figure 9.

According to the test method, cracking of the coating constitutes impact failure. However, since some of the coatings in this study are so elastic that they will not crack, the endpoint was chosen as any of the following types of failure: cracking on the impacted side, cracking on the reverse side, puncture of the topcoat, and debonding ("blistering") of the impact area.

² "Standard Test Methods for Adhesion of Organic Coatings," D 2197 (American Society for Testing and Materials [ASTM], 1968).

³ "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)," D 2794 (ASTM, 1969).

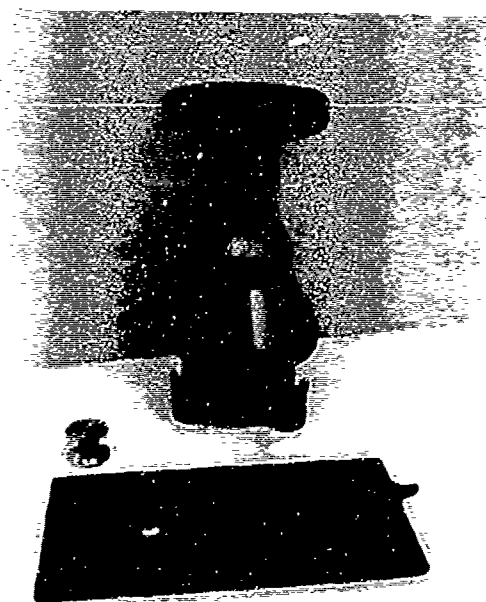


Figure 7. Elcometer adhesion tester.

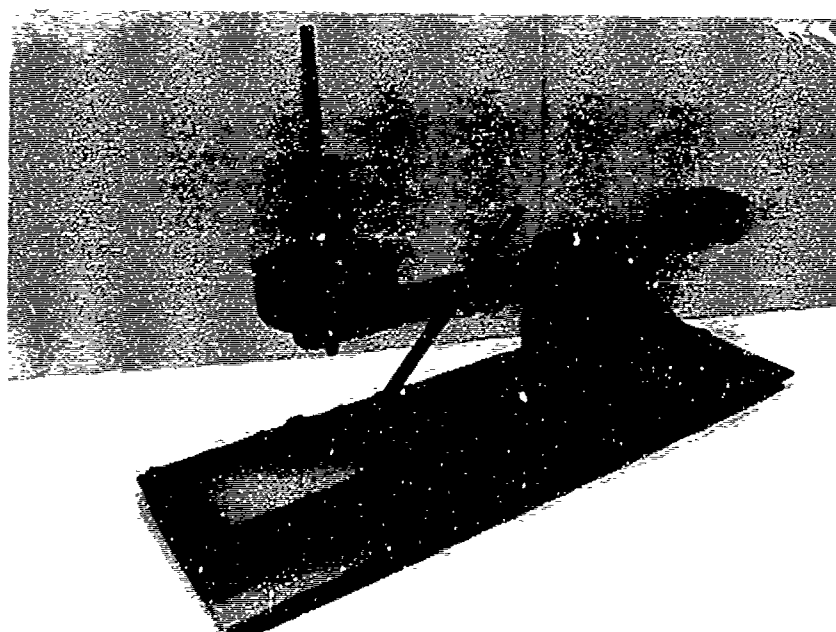


Figure 8. Scrape adhesion tester.

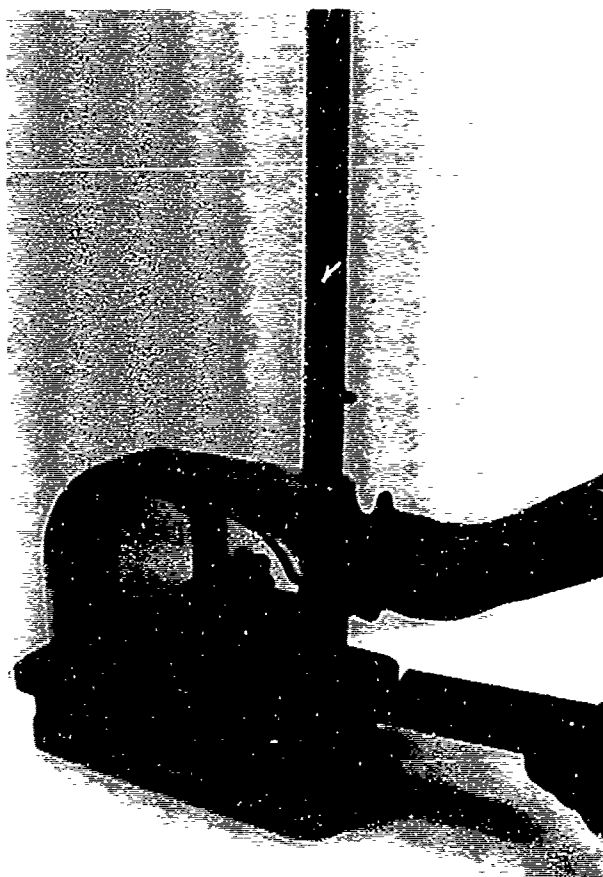


Figure 9. Gardner impact tester.

Electrical Measurements

It was originally thought that studying the resistance and capacitance properties of the coated aluminum specimens during immersion in seawater would yield valuable information about the deterioration of such specimens. The test method was based on previous studies of the electrical properties of polybutadiene coatings on steel. However, the test method did not give useful results for the coatings tested. A piece of stainless steel the same size and shape as the test specimen was used as a reference electrode. The distance between the reference electrode and the test specimen being measured was kept constant with three nylon screws set into the face of the reference electrode. Capacitance and impedance measurements were made with a General Radio Type 1600-A Impedance Bridge at a frequency of 1000 Hz. To prevent any errors caused by changes in the level of the immersion fluid, both the sample and the reference electrode were completely immersed. Measurements were made on each panel daily for the first 3 days, and then weekly for the rest of the 90-day testing period. It was expected that after a time the measured resistance between the specimen and electrode would drop sharply as the coating on the specimen deteriorated. The capacitance between the two would begin to rise at the same time. The data for this series of experiments did not show the

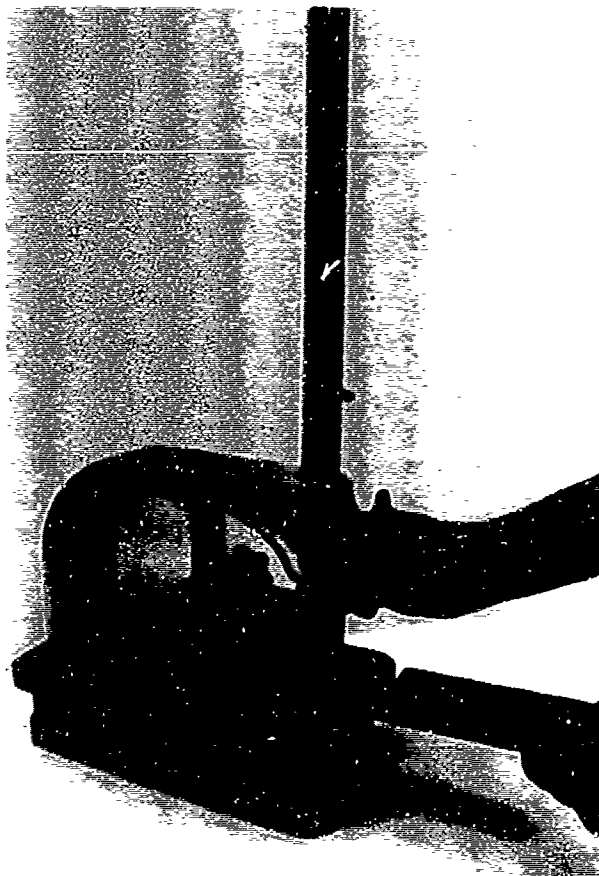


Figure 9. Gardner impact tester.

Electrical Measurements

It was originally thought that studying the resistance and capacitance properties of the coated aluminum specimens during immersion in seawater would yield valuable information about the deterioration of such specimens. The test method was based on previous studies of the electrical properties of polybutadiene coatings on steel. However, the test method did not give useful results for the coatings tested. A piece of stainless steel the same size and shape as the test specimen was used as a reference electrode. The distance between the reference electrode and the test specimen being measured was kept constant with three nylon screws set into the face of the reference electrode. Capacitance and impedance measurements were made with a General Radio Type 1600-A Impedance Bridge at a frequency of 1000 Hz. To prevent any errors caused by changes in the level of the immersion fluid, both the sample and the reference electrode were completely immersed. Measurements were made on each panel daily for the first 3 days, and then weekly for the rest of the 90-day testing period. It was expected that after a time the measured resistance between the specimen and electrode would drop sharply as the coating on the specimen deteriorated. The capacitance between the two would begin to rise at the same time. The data for this series of experiments did not show the

expected trends. There were no significant increases or decreases in the values recorded during the 90-day testing period, even when there were visible areas of corrosion or coating deterioration on the specimens. Initial measurements of capacitance ranged from 0.2 to 5 microfarads. Initial measurements of resistance ranged from 10 to 250 ohms. The highest initial resistance values were for the MIL-P-4556 epoxy system. However, there did not appear to be a strong correlation between coating performance and electrical measurements. A 90-day immersion probably is not long enough to show significant changes in the electrical properties of the coated aluminum.

Characterization of the Coatings

To characterize each sample of paint tested for this study, the pigment content, total solids, and nonvolatile vehicle content of each coating component were measured (Table 3). An infrared spectrum (IR) and a gas chromatographic (GC) analysis of each coating were done to "fingerprint" the samples evaluated in the laboratory. The results of the IR and GC work are shown in Appendix A. The laboratory procedures used are described below. Additional vendor information and safety sheets for the MIL-P-24441, Ameron, and MIL-P-4556 systems are included in Appendix B.

Test Methods

1. Pigment content (Federal Test Method Std. No. 141B, Method 4021, 1 February 1979).

Apparatus: IEC International Centrifuge, Size 2, Model K, 8-unit head. Sartorius Analytical Balance.

Extraction mixture: 50 percent toluene, 50 percent acetone.

Procedure: In a weighed centrifuge tube, approximately 15 g of the sample (coating or coating component) were weighed to the nearest 0.0001 g. Twenty-five milliliters of the extraction mixture were added and mixed thoroughly with a glass rod. The rod was washed with more of the mixture from a wash bottle. The material was centrifuged 30 minutes at 2000 rpm, and the clear supernatant liquid was decanted. These steps were done twice more with 35 ml of the extraction mixture. After the liquid was drawn off for the last time, the tube was set in a steam bath for 10 minutes, put in a 105°C oven overnight, cooled in a dessicator, and weighed. The percentage of pigment was calculated.

2. Total solids

Apparatus: Sartorius Analytical Balance, Aluminum Evaporation Dishes.

Procedure: Into a weighed evaporating dish, approximately 0.5 g of the sample was added and quickly weighed to the nearest 0.0001 g; the dish was put in a 105°C oven for 1-1/2 hours, cooled, and weighed. The percentage of total solids, by weight, was calculated.

Table 3
Characterization Test Results

<u>Coating</u>	<u>Component</u>	<u>Total Solids, Percent</u>	<u>Pigment, Percent</u>	<u>Nonvolatile Vehicle, Percent</u>
MIL-P-24441	A	73.3	50.6	46.0
Formula 158	B	76.7	29.3	67.0
MIL-P-24441	A	68.6	50.9	36.5
Formula 152	B	70.8	27.7	59.6
MIL-P-23377	A	63.7	40.3	39.2
	B	20.5	0.0*	20.5
MIL-C-22750	A	70.8	5.8	69.0
	B	47.2	9.3	41.8
MIL-C-4556	A	68.1	48.4	38.2
Primer	B	82.5	0.0	82.5
MIL-C-4556	A	59.4	33.9	38.6
Topcoat	B	62.5	0.0	62.5
Steelcote	A	96.4	0.0	96.4
100% Solids	B	97.1	23.7	96.2
Ameron 86	*	33.3	17.8	18.9
Ameron 99HS	*	67.4	36.4	48.7
TS3236-26	A	32.9	15.7	20.4
Wash Primer	B	1.7	0.0	1.7
TS3236-23	A	64.6	4.4	63.0
Topcoat	B	16.1	0.0	16.1
MIL-C-83286	A	65.7	32.7	49.0
	B	34.1	0.0	34.1
Irathane 155	A	74.0	4.8	72.7
	B	17.6	0.0	17.6
BMS-10-11K	A	63.5	45.1	33.5
	B	1.7	0.0	1.7

*Not applicable.

3. Nonvolatile vehicle content (Federal Test Method Std. No. 141B, Method No. 4053, 1 February 1980). This method was used to calculate the non-volatile vehicle (NVV) content from the sum of volatile matter and the pigment solids content:

$$\% \text{ NVV} = \frac{\% \text{ total solids} - \% \text{ pigment}}{100 - \% \text{ pigment}} \times 100$$

4. Gas chromatographic analysis. A gas chromatogram of each mixed coating (as a liquid before curing) and of each thinner was prepared using the following apparatus and conditions:

Instrument:	Hewlett-Packard model 5880A
Detector:	Thermal conductivity detector
Column:	Carbowax 1500, 10 ft
Carrier gas:	Helium
Oven temperature profile:	Initial value = 80°C Initial time = 3.00 minutes Temperature increase rate = 20°/minute Final value = 249°C Final time = 7.50 min.
Detector temperature:	225°C
Injector temperature:	225°C
Sample size:	2.5 µl

Sample preparation: Approximately 0.5 ml of the mixed sample was thoroughly mixed with 3 ml of clean pentane in a test tube. The sample was centrifuged at high speed for 10 minutes to remove the resins, pigments, and other nonvolatiles from the solution. A sample of the top layer of the solution was drawn with a syringe and injected into the chromatograph. The gas chromatographic analyses are shown in Appendix A.

5. Infrared analysis. For future reference, infrared spectra were taken of (1) the uncured coating vehicles and (2) the thinners used for their application. The spectra were recorded from 4000 to 200 cm^{-1} on a Perkin Elmer 283B infrared spectrophotometer equipped with an accessory infrared data station.

The clear liquid vehicles and thinners were analyzed in a demountable liquid cell with potassium bromide windows and a 0.010-mm Teflon spacer. Pigmented materials were centrifuged for 5 minutes in a Sharples Super Centrifuge Model #T-41-24 to obtain a vehicle suitable for infrared transmission analysis. Except for removal of the pigments, the vehicles were not altered. The instrumental settings were as follows:

Scan time — 12 minutes
Slit program — normal
Response — 1
Ordinate expansion — 1
Abscissa expansion — 1
Suppression — on.

The infrared analyses are shown in Appendix A.

4 TEST RESULTS

This chapter presents and discusses the physical performance of unpainted and painted specimens before and after immersion in selected liquids, as well as corrosion resistance of each coating during the testing. It includes tabular summaries, general comments, observations, and statistical analyses. Care must be taken when comparing coatings of different types because there were different modes of failure. For example, in the Elcometer adhesion test, some coating systems broke cleanly from the substrate, while other coatings broke between the primer and the topcoat. In the impact tests, some flexible coatings, such as Irathane 155, failed when the topcoat was punctured. Brittle coatings, such as MIL-C-4556, usually failed when the coating cracked at the impact point. It seems acceptable to compare similar coatings when they are applied over the same coating, or over different substrates.

Physical Tests

Tabular Summary - Tasks I and II

Table 4 summarizes the results of the four different tests done on each specimen tested in Tasks I and II.

General Comments

The results of duplicate tests have been averaged. For the Elcometer adhesion test, the units are given in hundreds of pounds per square inch. A (+) in Table 4 indicates a case in which the glue broke before the paint failed. The glue used for this experiment generally broke at 700 to 900 psi. For the scrape adhesion test, the maximum of the testing apparatus was 10 kg. Specimens which did not fail at 10 kg are marked 10+. Results of the impact tests are given for room temperature (23°C) and 4°C; units are in inch-pounds. The maximum range of the test was 80 in.-lb.

Some of the physical test data were analyzed for significant differences by using analysis of variance techniques. Pertinent averages of test results for the various coatings, various thicknesses, and various substrates were compared; the effect of immersion was also evaluated. Interactions among these factors were examined. Tests of significance were conducted at the 0.05 level (i.e., it is 95 percent certain that the differences observed were significant). To simplify the task, only the two best of the five epoxy coatings in Task I were evaluated by this method. The Ameron vinyl system, all of the urethane systems, and all of the Task II candidate coatings were also evaluated.

Performance - Task I: Nonpolyurethane-Coated Specimens - Observations and Statistical Analyses

1. MIL-P-24441 and MIL-C-4556 Systems. A statistical analysis was performed on the physical test data of these two epoxy-polyamide coating systems. The MIL-P-24441 primer and topcoat system was compared with the MIL-C-4556 system for 5-, 10-, and 15-mil thicknesses, and immersed versus not immersed for substrate a. Of the five epoxy systems tested in Task I, these two were

Table 4
Physical Test Results

System	Thickness (mils)	Sub- strate*	Immersion (Yes, No)	Elcometer Adhesion Test**	Scrape Adhesion Test***	Impact Test (23°C)	Impact Test (4°C)	Impact Failure Type
Task I: Monurethanes								
MIL-P-24441	5	a	N	+	NA	10+	20	Crack (all specimens)
over	5	a	Y	8.3	Primer	10+	32	
MIL-P-24441	10	a	N	+	NA	10+	24	
	10	a	f	+	NA	10+	33	
	15	a	N	+	NA	10+	22	
	15	a	Y	+	NA	10+	26	
	5	b	N	+	NA	10+	28	
	5	b	Y	7.7	Primer	10+	30	
	10	b	N	+	NA	10+	34	
	10	b	Y	8.5	Primer	10+	29	
	15	b	N	+	NA	10+	26	
	15	b	Y	+	NA	10+	31	
	5	c	N	+	NA	10+	24	
	5	c	Y	+	NA	10+	21	
	10	c	N	+	NA	10+	22	
	10	c	Y	+	NA	10+	25	
	15	c	N	+	NA	10+	26	
	15	c	Y	+	NA	10+	27	
MIL-C-4556	5	a	N	5.5	Topcoat	10+	24	Crack (all specimens)
over	5	a	Y	6.8	-	10+	21	
MIL-C-4556	10	a	N	6.4	-	10+	24	
	10	a	Y	7.2	-	10+	27	
	15	a	N	4.1	-	10+	34	
	15	a	Y	5.5	-	10+	11	
MIL-G-22750	5	a	N	2.5	Primer	7.3	6	Debond between primer and topcoat
over	5	a	Y	1.7	-	7.6	16	
MIL-P-23377	10	a	N	1.5	-	-	20	
	10	a	Y	1.4	-	7.6	7	
	15	a	N	0.3	-	10+	18	
	15	a	Y	0.5	-	7.5	9	
100% solids	5	a	N	+	NA	5.0	10	Debond between primer and topcoat
over	5	a	Y	7.3	Primer	7.0	5	
MIL-P-23377	10	a	N	+	NA	9.0	4	
	10	a	Y	9.0	Primer	8.1	4	
	15	a	N	5.5	-	6.1	20	
	15	a	Y	6.9	-	3.3	8	Debond between primer and topcoat (all specimens)
MIL-P-23377	5	a	N	1.0	Primer	10+	10	
	5	a	Y	2.9	-	10+	10	
	5	b	N	5.3	-	10+	6	
	5	b	Y	8.2	-	10+	10	
	5	c	N	+	NA	10+	26	Debond between primer and topcoat (all specimens)
	5	c	Y	+	NA	10+	18	
Amercoat 99HS	5	a	N	2.6	Primer	10+	12	
over	5	a	Y	2.3	Topcoat	10+	14	
Amercoat 86	10	a	N	2.2	Primer	10+	14	Puncture (all specimens)
	10	a	Y	1.8	Topcoat	10+	15	
	15	a	N	2.4	Primer	10+	32	
	15	a	Y	2.3	Primer	10+	29	
	5	b	N	2.2	Primer	10+	12	
	5	b	Y	2.2	Primer	10+	10	
	10	b	N	2.5	Primer	10+	16	
	10	b	Y	2.0	Topcoat	10+	19	
	15	b	N	2.4	Primer	8.0	34	
	15	b	Y	4.9	Primer	8.0	32	
	5	c	N	3.1	Topcoat	10+	12	
	5	c	Y	2.3	Topcoat	10+	13	
	10	c	N	3.0	Topcoat	10+	20	
	10	c	Y	1.8	Topcoat	10+	20	
	15	c	N	1.6	Primer	8.5	38	
	15	c	Y	2.0	Primer	6.0	41	

Table 4 (Cont'd)

System	Thickness (mils)	Sub- strate ^a	Immersion (Yes, No)	Elcometer Adhesion Test ^{aa}	Scrape Adhesion Test ^{aaa}	Impact Test (23°C)	Impact Test (4°C)	Impact Failure Type	
Task I: Urethanes									
Hughson polyurethane over	5	a	N	4.3	Primer	10+	20	Puncture (all specimens)	
	5	a	Y	5.4	-	10+	50		
	5	b	N	2.6	-	10+	49		
	5	b	Y	7.6	-	10+	56		
Hughson wash primer	5	c	N	+	NA	10+	80	Puncture (all specimens)	
	5	c	Y	9.4	Primer	10+	60		
	5	a	N	--	--	10+	22		
	5	a	Y	3.6	Primer	10+	50		
Hughson polyurethane over	5	b	N	1.1	-	10+	16	Puncture (all specimens)	
	5	b	Y	4.1	-	10+	49		
	5	c	N	+	NA	10+	18		
	5	c	Y	+	NA	10+	76		
MIL-P-23377									
MIL-P-82286 over	5	a	X	2.6	Primer	7.5	6	Debond between primer and topcoat (all specimens)	
	5	a	Y	2.6	-	4.0	5		
	5	b	N	2.9	-	8.5	6		
	5	b	Y	5.4	-	5.8	3		
MIL-P-23377									
	5	c	N	+	NA	10+	24	Puncture (all specimens)	
	5	c	Y	+	NA	9.6	8		
	5	a	N	+	NA	10	40		
	15	a	Y	9.6	Topcoat	8.1	21		
MIL-P-23377									
	15	b	N	+	NA	5.0	12	Puncture (all specimens)	
	15	b	Y	8.8	Primer	5.1	18		
	15	c	N	+	NA	5.0	14		
	15	c	Y	+	NA	5.2	15		
	15	c	Y	+	NA	5.2	15		
Task II									
MIL-G-22750 over	2	a	None	0.1	Primer	10+	6	Debond at primer and topcoat (all specimens)	
	2	a	Seawater	0.7	-	7.0	4		
MIL-P-23377									
	2	a	Fuel	0.8	-	6.0	3		
	2	a	50/50	0.3	-	6.0	4		
	2	b	None	0.3	-	3.5	2		
	2	b	Seawater	2.4	-	7.7	6		
	2	b	Fuel	0.9	-	5.9	2		
	2	b	50/50	0.9	-	5.1	4		
	2	c	None	+	NA	10+	28		
	2	c	Seawater	+	NA	10+	38		
	2	c	Fuel	+	NA	10+	25		
	2	c	50/50	+	NA	10+	12		
MIL-G-4556 over	8	a	None	+	NA	10+	12	Crack (all specimens)	
	8	a	Seawater	8.1	Primer	10+	7		
MIL-G-4556									
	8	a	Fuel	7.8	-	10+	7		
	8	a	50/50	9.0	-	10+	7		
	8	b	None	+	NA	10+	10		
	8	b	Seawater	2.8	Primer	10+	6		
	8	b	Fuel	7.7	-	10+	5		
	8	b	50/50	8.9	-	10+	6		
	8	c	None	+	NA	10+	8		
	8	c	Seawater	2.6	Primer	10+	9		
	8	c	Fuel	7.8	-	10+	5		
	8	c	50/50	8.9	-	10+	8		

Table 4 (Cont'd)

System	Thickness (mils)	Sub- strate*	Immersion (Yes, No)	Elcometer Adhesion Test**	Scraper Adhesion Test***	Impact Test (23°C)	Impact Test (-4°C)	Impact Failure Type	
BMS-10-11K	1	a	None	1.7	Topcoat	5.0	44	40	Debond
	1	a	Seawater	1.6	-	5.6	40	47	within
	1	a	Fuel	1.0	-	5.3	3	9	topcoat
	1	a	50/50	0.8	-	5.8	5	10	layers
	1	b	None	1.2	-	6.5	14	16	(all specimens)
	1	b	Seawater	1.4	-	4.8	4	9	
	1	b	Fuel	0.7	-	5.7	3	2	
	1	b	50/50	1.0	-	5.2	2	3	
	1	c	None	+	-	9.0	12	20	
	1	c	Seawater	4.9	-	7.8	26	39	
	1	c	Fuel	6.9	-	7.5	17	24	
	1	c	50/50	5.7	-	8.8	33	38	

* a = hardcoat anodized dichromate sealed; b = hardcoat anodized unsealed; c = chromate conversion coated.

** a "+" signifies that the glue broke before paint failed.

*** 10+ signifies that the adhesion of the coating exceeded the range of measurement of the testing apparatus.

NA -- not applicable; data not obtained.

obviously the best. Figures 10 through 13 show the data for these two coating systems.

a. Elcometer adhesion test: no analysis performed because MIL-P-24441 was obviously better.

b. Scrape adhesion test: no analysis performed because the two coatings are equivalent within the measuring range of this test.

c. Impact test, 23°C: differences were not statistically significant.

d. Impact test, 40°C: differences were not statistically significant. Averages are shown below (in.-lbs):

	Impact, 23°C	Impact, 40°C
MIL-P-24441	26.2	25.0
MIL-C-4556	23.2	34.5
Thickness: 5 mils	24.2	34.8
10 mils	26.5	28.5
15 mils	23.2	26.0
Immersed: Yes	25.0	28.2
No	24.3	31.3

2. MIL-P-24441. Because the MIL-P-24441 system performed better than the MIL-C-4556 system in one of the physical tests and was equal to the MIL-C-4556 system in the other tests, the MIL-P-24441 data were analyzed again as a separate group. The data were statistically tested to see if thickness, substrate, or 90-day immersion in seawater affected the performance of the system in the physical tests. No statistically significant differences were found. Thus, for MIL-P-24441, the thickness and substrate do not matter, and immersion of the specimen in seawater for 90 days has no effect. Averages for the four physical tests are given below:

	<u>Thickness (mils)</u>				<u>Substrate</u>			<u>Immersed</u>	
	<u>5</u>	<u>10</u>	<u>15</u>	<u>a</u>	<u>b</u>	<u>c</u>	<u>Yes</u>	<u>No</u>	
Adhesion (psi x 100)	+	+	+	+	+	+	+	+	
Scrape adhesion (kg)	10	10	10	10	10	10	10	10	
Impact, 23°C (in.-lb)	25.8	27.8	26.3	26.2	29.7	24.2	28.2	25.1	
Impact, 40°C (in.-lb)	25.5	25.2	21.3	25.0	24.7	22.3	23.6	24.4	

+ means strength of coating exceeded range of adhesion tester.

		MIL-P- 2444I		MIL-C- 4556	
		IMMERSED		IMMERSED	
		YES	NO	YES	NO
Thickness (mils)	5	+	+	6.8	5.5
	10	+	+	7.2	6.4
	15	+	+	5.5	4.1

Figure 10. Elcometer adhesion.

		MIL-P- 2444I		MIL-C- 4556	
		IMMERSED		IMMERSED	
		YES	NO	YES	NO
Thickness (mils)	5	10	10	10	10
	10	10	10	10	10
	15	10	10	10	10

Figure 11. Scrape adhesion.

		MIL-P- 2444I		MIL-C- 4556	
		IMMERSED		IMMERSED	
		YES	NO	YES	NO
Thickness (mils)	5	32	20	21	24
	10	33	24	27	22
	15	26	24	11	34

Figure 12. Impact 23°C.

		MIL-P- 2444I		MIL-P- 4556	
		IMMERSED		IMMERSED	
		YES	NO	YES	NO
Thickness (mils)	5	28	26	27	58
	10	23	28	39	24
	15	23	22	29	30

Figure 13. Impact 40°C.

3. Ameron Vinyl System. The data for the vinyl system, Amercoat 99HS over Amercoat 86, were also analyzed to see if thickness, substrate, or immersion had any significant effect.

a. Elcometer adhesion test: no statistically significant differences were found for this test. The results of this test are rather low, but as previously stated, the glue used to bond the circular dolly to the coating surface may have more of an effect on this coating than on other types. Averages (psi x 100) are:

<u>Thickness (mils)</u>			<u>Substrate</u>			<u>Immersed</u>	
<u>5</u>	<u>10</u>	<u>15</u>	<u>a</u>	<u>b</u>	<u>c</u>	<u>Yes</u>	<u>No</u>
2.4	2.2	2.6	2.3	2.7	2.3	2.4	2.4

b. Scrape adhesion test: since 14 of the 18 data points were 10 or greater, no comparisons were made. Averages (kg) are:

<u>Thickness (mils)</u>			<u>Substrate</u>			<u>Immersed</u>	
<u>5</u>	<u>10</u>	<u>15</u>	<u>a</u>	<u>b</u>	<u>c</u>	<u>Yes</u>	<u>No</u>
10	10	8.6	10	9.5	9.1	9.4	9.6

c. Impact test 23°C: statistically significant differences were found among substrates and among thicknesses. The 15-mil thickness and substrate c proved to be the best. Immersion in seawater had no effect on the impact resistance at room temperature. The average test values (in.-lbs) are:

<u>Thickness (mils)</u>			<u>Substrate</u>			<u>Immersed</u>	
<u>5</u>	<u>10</u>	<u>15</u>	<u>a</u>	<u>b</u>	<u>c</u>	<u>Yes</u>	<u>No</u>
12.2	17.3	34.3	19.3	20.5	24.0	21.4	21.1

d. Impact test, 4°C: statistically significant differences were found for both substrates and thicknesses. As in the impact test at 23°C, 15 mils and substrate c were the best. Averages (in.-lbs) are:

<u>Thickness (mils)</u>			<u>Substrate</u>			<u>Immersed</u>	
<u>5</u>	<u>10</u>	<u>15</u>	<u>a</u>	<u>b</u>	<u>c</u>	<u>Yes</u>	<u>No</u>
20.8	26.2	46.0	21.2	30.8	41.0	32.2	29.3

The physical test data for the other three nonurethane Task I coatings were not analyzed statistically. However, general comments about the test results follow.

4. MIL-C-22750 Topcoat Over MIL-P-23377 Primer. This epoxy system has very poor adhesion and impact resistance when applied on anodized aluminum (substrate a and b). In the Elcometer adhesion test, the entire coating system was removed, leaving the substrate exposed. During the impact tests, the

coating debonded within the primer layer in an area around the point of impact.

5. Steelcote 100 Percent Solid Topcoat Over MIL-P-23377 Primer. The major drawback of this coating is its poor resistance to damage by impact. The adhesion of this coating is fair, but not as good as many of the other coating systems.

6. MIL-P-23377 Primer — No Topcoat. The Elcometer adhesion test results of this coating are good when the coating is applied over chromate conversion coated aluminum. Scrape adhesion test results were good over all substrates. Impact tests over chromate conversion coated aluminum were slightly better than over anodizing.

Performance - Task I: Polyurethane Coated Specimens - Observations and Statistical Analyses

Test data for the four urethanes were compared to see if differences existed among them or among the three substrates. The effect of immersion was also examined.

1. Elcometer adhesion test: the Irathane 155 coating system was best; substrate c gave significantly better results. The results are shown in Figure 14.

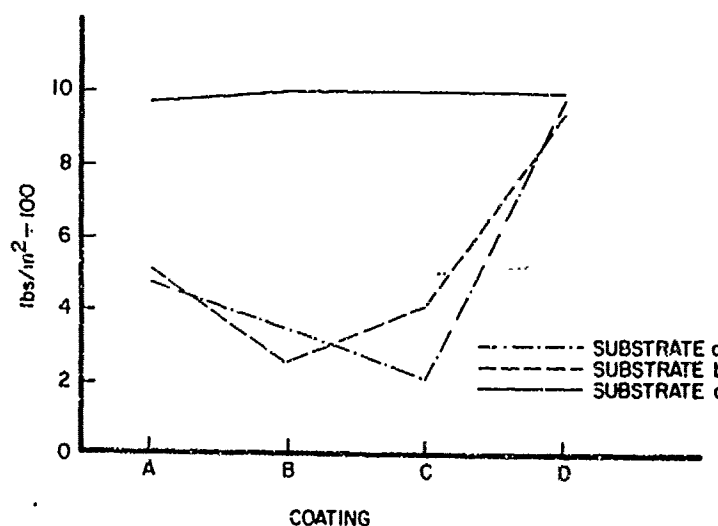
2. Scrape adhesion test: coatings were significantly different and the coating/substrate interaction was significant. The Hughson topcoat over the Hughson wash primer and the Hughson topcoat over the MIL-P-23377 primer with substrate c gave the best results. The results are shown in Figure 15.

3. Impact, 23°C: the only statistical significance was found for the following coatings whose averages were:

Hughson over Hughson	52.5 in.-lb
Hughson over 23377	38.5 in.-lb
MIL-C-83286	8.7 in.-lb
Irathane 155	20.0 in.-lb

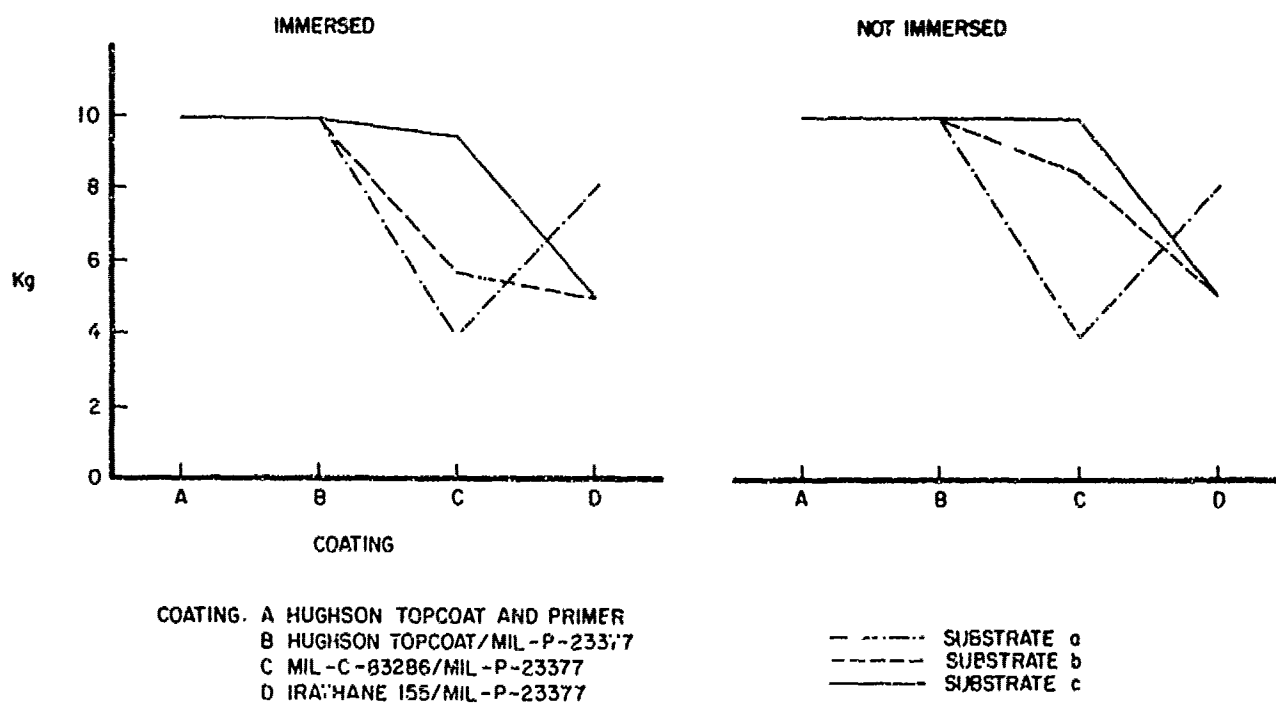
4. Impact, 40°C: no statistically significant differences were found; the four coatings gave similar results, the three substrates gave similar results, and immersion had no effect.

The overall results indicate that all of the polyurethane coatings performed best in the physical tests when applied over chemical conversion coated aluminum (substrate c). The currently used Hughson system performed well in the scrape adhesion and impact tests. The Hughson topcoat over the MIL-P-23377 primer also did well in these tests. The Irathane 155 system was best in the Elcometer adhesion test. The Irathane system is designed to be a high-build polyurethane and was applied at a thickness of 15 mils. Although the test results for the scrape adhesion of the Irathane 155 were somewhat low, the additional thickness of this coating offers protection when the surface has been damaged.



COATING. A HUGHSON TOPCOAT AND PRIMER
 B HUGHSON TOPCOAT/MIL-P-23377
 C MIL-C-83286/MIL-P-23377
 D IRATHANE 155/MIL-P-23377

Figure 14. Elcometer adhesion test results of Task I urethane coatings.



COATING. A HUGHSON TOPCOAT AND PRIMER
 B HUGHSON TOPCOAT/MIL-P-23377
 C MIL-C-83286/MIL-P-23377
 D IRATHANE 155/MIL-P-23377

Figure 15. Scrape adhesion test results of Task I urethane coatings.

The MIL-P-83286 topcoat applied over MIL-P-23377 primer performed fairly well when applied over substrate c. However, the impact resistance of the coating noticeably decreased during the 90-day immersion period in seawater.

Performance - Task II: Nonpolyurethane-Coated Specimens - Observations and Statistical Analyses

The physical test results for the MIL-C-4556 system, the MIL-C-22750 topcoat over MIL-P-23377 primer, and the BMS-10-11K coatings were compared for the three substrates and for the following four immersion levels:

Immersion Level 1: not immersed
 Immersion Level 2: seawater
 Immersion Level 3: Otto fuel
 Immersion Level 4: 50 percent seawater, 50 percent Otto fuel

a. Elcometer adhesion test: statistically significant differences were found among coatings, among substrates, and among immersion levels. The coating/substrate and coating/immersion level interactions were significant (see Figure 16). Overall averages (psi x 100) are:

<u>Coating</u>	<u>Average</u>	<u>Substrate</u>	<u>Average</u>	<u>Immersion Level</u>	<u>Average</u>
MIL-C-22750	3.9	a	3.5	1	5.9
MIL-C-4556	7.8	b	3.2	2	3.8
BMS-10-11K	3.1	c	8.1	3	4.8
				4	5.1

Overall, the MIL-C-4556 system and substrate c are best. Immersion in seawater contributes most to poor adhesion.

2. Scrape adhesion test: statistically significant differences were found among coatings and among substrates. The MIL-C-4556 system had the best scrape adhesion properties, and all of the coatings adhered best to substrate c, chemical conversion coated aluminum. Figure 17 shows the relationship between coatings, substrates, and scrape adhesion. The average test results (kg) are:

<u>Coating</u>	<u>Average</u>
MIL-C-22750	7.6
MIL-C-4556	10+
BMS-10-11K	6.4

<u>Substrate</u>	<u>Average</u>
a	7.6
b	7.0
c	9.4

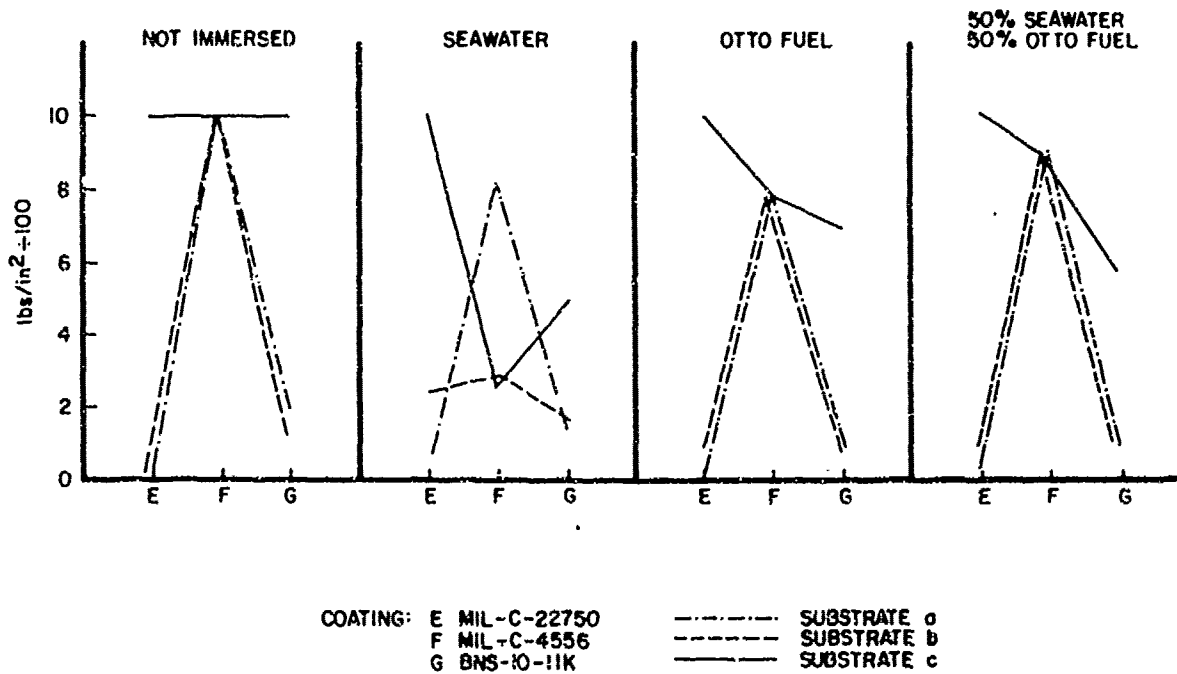


Figure 16. Elcometer adhesion test results of Task II coatings in four immersion tests.

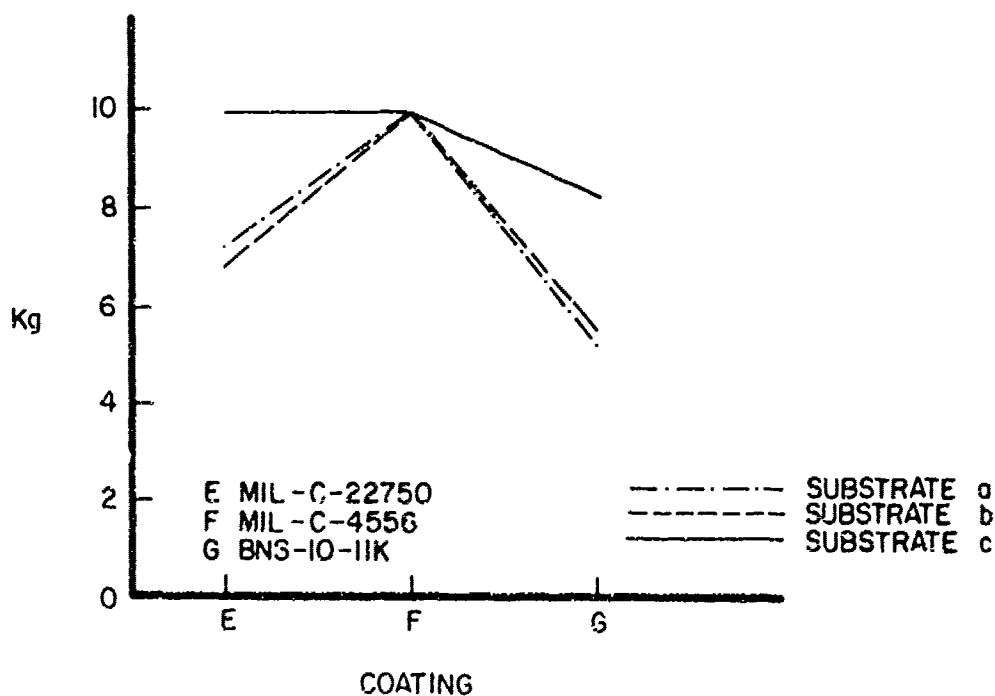


Figure 17. Scrape adhesion test results of Task II coatings.

3. Impact test, 23°C: Impact resistance is not as important for Task II coatings as it is for Task I. The coatings for Task II are tested for application on the interior of torpedo fuel tanks, where the coated surfaces would not be subjected to impact forces. However, for the sake of completeness, these tests were conducted and the results analyzed. There were no significant differences found among coatings. However, substrate c gave significantly better results than substrates a or b. Averages (in.-lbs) for the different substrates are:

<u>Substrate</u>	<u>Average</u>
a	11.8
b	5.3
c	18.4

4. Impact test, 40°C: significant differences were found among coatings and among substrates. The interactions between Task II coatings, substrates, and impact test results are shown in Figure 18. The best impact resistance was seen for the MIL-C-22750 system over substrate c. Average test values (in.-lbs) for the coatings and substrates are:

<u>Coating</u>	<u>Average</u>
MIL-C-22750	22.1
MIL-C-4556	9.8
BMS-10-11K	22.1

<u>Substrate</u>	<u>Average</u>
a	14.5
b	6.7
c	32.8

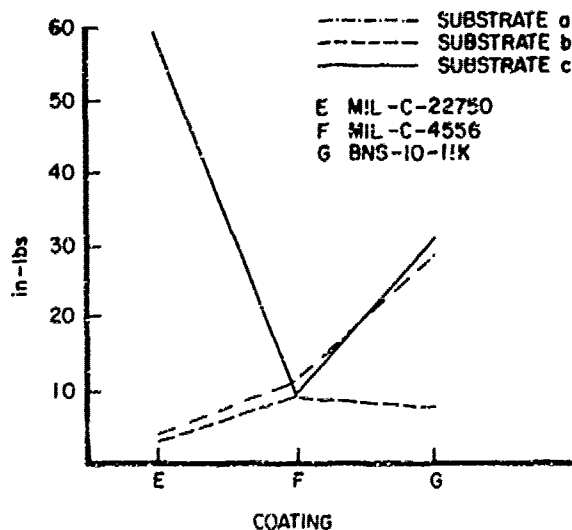


Figure 18. Impact at 40°C test results of Task II coatings.

Immersion Tests

Tabular Summary - Tasks I and II

Table 5 summarizes the results of the immersion tests. Test specimens were immersed for 90 days. Task I specimens were immersed in aerated synthetic seawater. Task II specimens were immersed in seawater, Otto fuel, or a mixture of 50 percent Otto fuel and 50 percent seawater.

Basis for Rating

After 90 days of immersion in seawater, Otto fuel, or a 50/50 mixture of the two, the conditions of each panel were rated according to the following criteria:*

Excellent -- No visible damage to the aluminum substrate. Impact points are not corroded or pitted, although the paint surface may be damaged. The score lines may have some oxides, but there is no pitting or widening of the lines.

Good -- Less than 5 percent of the surface area is corroded. The 20 or 40 in.-lb impact points show some corrosion extending not more than 1/8 in. from the center of the impact point. Score lines widen to no more than 1/8 in. across.

Fair -- 5 to 8 percent of the surface area of the specimen is corroded. The 20 and 40 in.-lb impact points show corrosion 1/8 to 1/4 in. from the center of the impact and usually show a penetration through the panel. Five and 10 in.-lb impact points show a smaller area of corrosion. Score lines widen up to 1/4 in. across and may contain some areas of penetration through the panel.

Poor -- More than 8 percent of the surface area of the specimen is corroded. Forty and 20 in.-lb impact points are corroded more than 1/4 in. from the center of the impact point and penetrate through the panel. Five and 10 in.-lb impact points also may penetrate through the panel. Score lines widen to more than 1/4 in. across and penetrate through the panel along much of their length.

These criteria were used for all specimens including damaged and undamaged specimens, specimens that were galvanically coupled, and specimens that were not galvanically coupled. Examples of specimens illustrating the above criteria are given in Figure 19. The examples shown are panels which have been damaged prior to immersion. The panel on the left was impacted, and the panel on the right was scored prior to immersion. In Figure 19 the reverse side of the impacted panel is shown on the left. At the point of 40 in.-lb impact the coating has broken away from the panel. However, the anodizing is completely intact and no damage has occurred to the aluminum substrate. Each

* ASTM D 1654-79 describes a standard method for evaluating coated specimens exposed to corrosive environments. The standard was not used because it is more appropriate for evaluating specimens less severely corroded than the galvanically coupled specimens in this study.

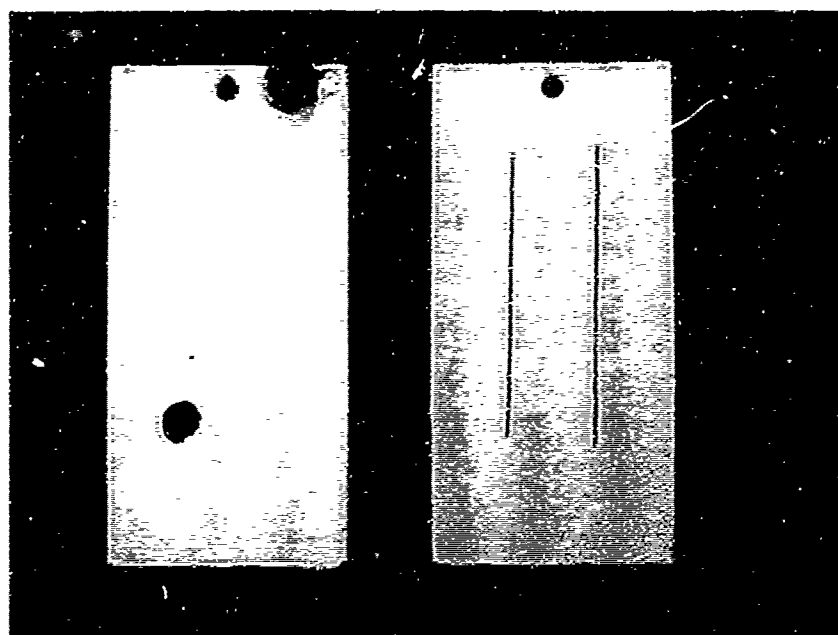
Table 5

Corrosion Resistance of Specimens during 90-Day Immersion

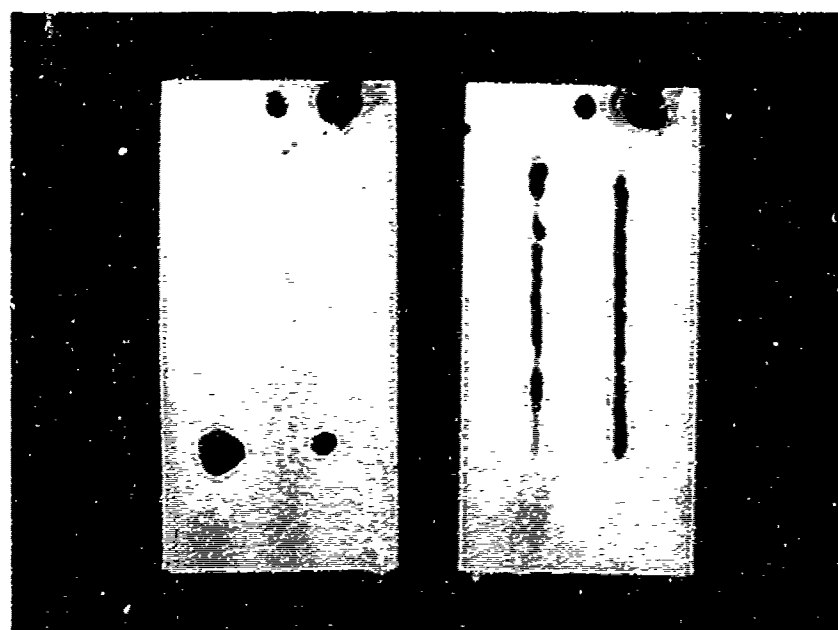
System	Topcoat	Sub- strate	Uncoupled			Coupled		
	Thickness		Undamaged	Scored	Impacted	Undamaged	Scored	Impacted
	(mils)							
Task I: Nonurethanes								
MIL-P-24441	5	a	Excellent	Excellent	Excellent	Excellent	Good	Fair
over	10	a	Excellent	Excellent	Excellent	Excellent	Good	Fair
MIL-P-24441	15	a	Excellent	Excellent	Excellent	Excellent	Good	Fair
	5	b	Excellent	Excellent	Excellent	Excellent	Good	Fair
	10	b	Excellent	Excellent	Excellent	Good	Good	Good
	15	b	Excellent	Excellent	Excellent	Excellent	Poor	Fair
	5	c	Good	Excellent	Excellent	Excellent	Good	Fair
	10	c	Excellent	Excellent	Excellent	Excellent	Fair	Poor
	15	c	Excellent	Excellent	Excellent	Excellent	Good	Poor
MIL-C-4556	5	a	Excellent	Excellent	Good	Excellent	Fair	Good
over	10	a	Excellent	Excellent	Good	Good	Fair	Good
MIL-C-4556	15	a	Excellent	Excellent	Good	Excellent	Fair	Good
MIL-C-22750	5	a	Excellent	Excellent	Good	Excellent	Fair	Fair
over	10	a	Good	Excellent	Good	Excellent	Poor	Poor
MIL-P-23377	15	a	Good	Excellent	Good	Excellent	Poor	Fair
100% Solids	5	a	Excellent	Excellent	Good	Good	Fair	Fair
over	10	a	Excellent	Excellent	Good	Excellent	Fair	Good
MIL-P-23377	15	a	Excellent	Excellent	Good	Fair	Fair	Fair
MIL-P-23377	5	a	Fair	Excellent	Good	Excellent	Good	Good
	5	b	Fair	Excellent	Fair	Excellent	Good	Good
	5	c	Good	Excellent	Good	Excellent	Good	Good
Amercoat 99HS	5	a	Excellent	Excellent	Good	Good	Fair	Fair
over	10	a	Excellent	Excellent	Good	Good	Fair	Fair
Amercoat 86	15	a	Excellent	Excellent	Good	Good	Fair	Good
	5	b	Excellent	Excellent	Excellent	Fair	Good	Poor
	10	b	Excellent	Excellent	Excellent	Good	Good	Fair
	15	b	Excellent	Excellent	Excellent	Excellent	Good	Good
	5	c	Excellent	Excellent	Excellent	Fair	Good	Poor
	10	c	Excellent	Excellent	Excellent	Good	Good	Poor
	15	c	Excellent	Excellent	Excellent	Excellent	Good	Good
Hughson polyurethane	5	a	Good	Fair	Excellent	Fair	Fair	Good
over	5	b	Excellent	Fair	Excellent	Fair	Poor	Poor
Hughson wash primer	5	c	Excellent	Excellent	Excellent	Fair	Fair	Good
Hughson polyurethane	5	a	Excellent	Excellent	Excellent	Good	Fair	Good
over	5	b	Good	Excellent	Excellent	Good	Good	Poor
MIL-P-23377	5	c	Excellent	Excellent	Excellent	Excellent	Fair	Good
MIL-P-83286	5	a	Good	Good	Good	Fair	Fair	Good
over	5	b	Excellent	Good	Good	Poor	Fair	Fair
MIL-P-23377	5	c	Excellent	Excellent	Excellent	Fair	Fair	Good
Irathane 155	15	a	Excellent	Excellent	Excellent	Excellent	Fair	Good
over	15	b	Excellent	Excellent	Excellent	Excellent	Fair	Good
MIL-P-23377	15	c	Excellent	Excellent	Excellent	Excellent	Good	Excellent

Table 5 (Cont'd)

System	Topcoat Thickness	Substrate	Uncoupled			Coupled		
	(mils)		Undamaged	Scored	Impacted	Undamaged	Scored	Impacted
Task II								
MIL-C-22750 over	Seawater	a	Excellent	Excellent	Poor	Poor		
	Otto fuel	a	Excellent	Excellent	Excellent	Excellent		
	50/50	a	Good	Excellent	Poor	Poor		
	Seawater	b	Good	Excellent	Poor	Poor		
	Otto fuel	b	Excellent	Excellent	Excellent	Excellent		
	50/50	b	Good	Excellent	Fair	Poor		
	Seawater	c	Excellent	Excellent	Poor	Fair		
	Otto fuel	c	Excellent	Excellent	Excellent	Excellent		
	50/50	c	Good	Excellent	Poor	Poor		
MIL-C-4556 over	Seawater	a	Excellent	Excellent	Fair	Fair		
	Otto fuel	a	Excellent	Excellent	Excellent	Excellent		
	50/50	a	Good	Good	Excellent	Poor		
MIL-C-4556	Seawater	b	Excellent	Good	Good	Fair		
	Otto fuel	b	Excellent	Excellent	Excellent	Excellent		
	50/50	b	Excellent	Good	Good	Poor		
	Seawater	c	Excellent	Good	Fair	Good		
	Otto fuel	c	Excellent	Excellent	Excellent	Excellent		
	50/50	c	Good	Good	Fair	Poor		
BMS-10-11K	Seawater	a	Excellent	Excellent	Fair	Fair		
	Otto fuel	a	Good	Excellent	Excellent	Excellent		
	50/50	a	Excellent	Excellent	Poor	Poor		
	Seawater	b	Excellent	Excellent	Poor	Good		
	Otto fuel	b	Excellent	Excellent	Excellent	Excellent		
	50/50	b	Excellent	Excellent	Poor	Poor		
	Seawater	c	Excellent	Excellent	Poor	Poor		
	Otto fuel	c	Excellent	Excellent	Excellent	Excellent		
	50/50	c	Excellent	Excellent	Poor	Poor		

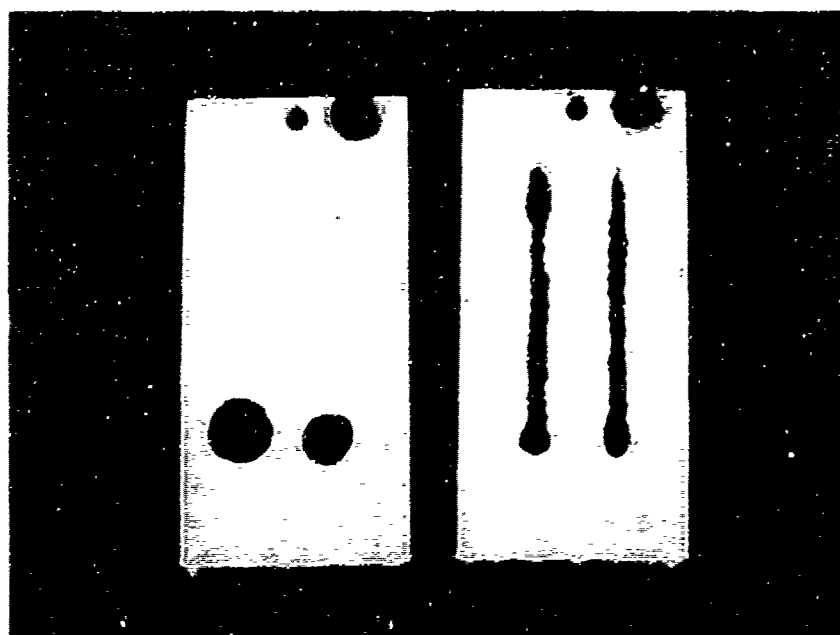


a. Excellent

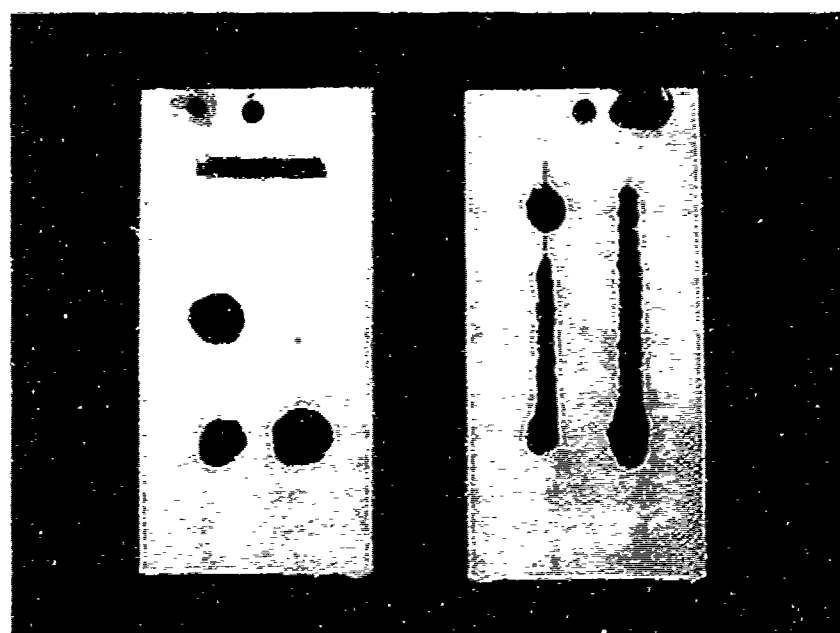


b. Good

Figure 19. Specimens after 90-day immersion.



c. Fair



d. Poor

Figure 19. (Cont'd).

of the scored panels in Figure 19 was scored twice on each side. The score line on the right side of the specimen was cut down to bare aluminum. The score line on the left of each specimen was intended to be cut down to, but not through, the anodizing or conversion coating. However, it was difficult to control the depth of the cut and the bare aluminum substrate was often exposed. Some of the score lines cut to bare aluminum did not corrode significantly during immersion. When the bare aluminum is exposed to seawater some oxides form on the surface of the metal. A scored panel could still meet the criteria for excellent immersion resistance if the corrosion has not extended beyond the original score line in width or in depth. Most of the nongalvanically coupled scored specimens were able to meet this criteria as did many of the coupled specimens. This may have been due to the corrosion inhibitive properties of the coatings and the aluminum pretreatments.

Performance - Task I: Uncoated Specimens - Undamaged

Uncoupled: Bare aluminum panels corroded in seawater over their entire surface, but there was no pitting. Harcoat anodized sealed panels and unsealed panels performed very well with only a few minor areas of corrosion at the edges. Chromate conversion coated panels had a few areas of minor corrosion on their surface and near the edges.

Coupled: Bare aluminum panels that were immersed in seawater for 90 days corroded and pitted over their entire surface (Figure 20). Harcoat anodized sealed panels corroded only on their edges (Figure 21). Harcoat anodized unsealed panels corroded on their edges and at a few surface spots where the anodizing might have been flawed or damaged (Figure 22). The chromate conversion coated panels had light corrosion on their surface. None of these spots were large, but there were many of them (Figure 23).

Performance - Task I: Nonpolyurethane-Coated Specimens - Observations

The corrosion performance of the nonpolyurethane-coated paint specimens in Task I is described for each coating, coupled and uncoupled, damaged and undamaged.

1. MIL-P-24441.

Uncoupled: Layers of topcoat were lost at impact points on all panels. The damage caused by impact was more severe on the panels with a 10- and 15-mil topcoat thickness than on the 5-mil-thick coated panels. However, corrosion of the aluminum substrate was minimal. The primer that remained intact protected the substrate from corrosion in the seawater. Neither the scored nor the undamaged panels exhibited corrosion or loss of adhesion. Nearly all specimens in this test were rated excellent.

Coupled: The chemical conversion coated panels corroded more at impact points than did the anodized sealed and anodized unsealed panels. Thickness had less effect. Areas of penetration through the panel at impact points were quite large, up to 1/3 in. from the impact point. Panels coated with 5 mils

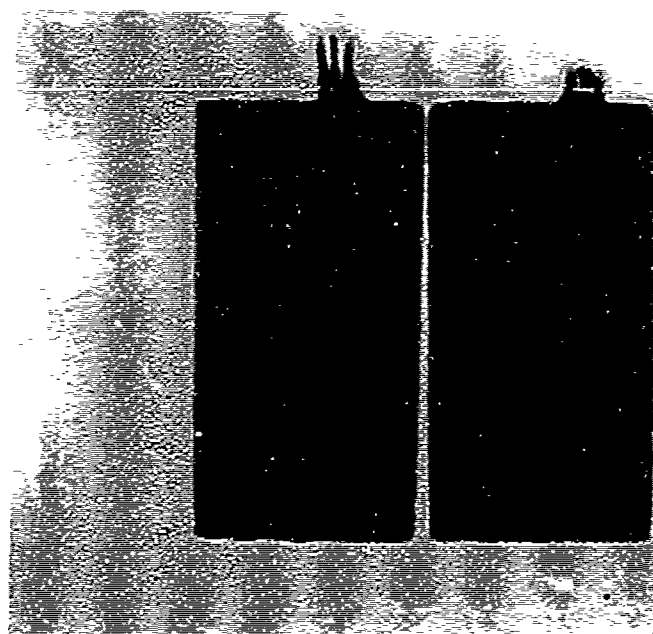


Figure 20. Bare aluminum after 90-day immersion in seawater.

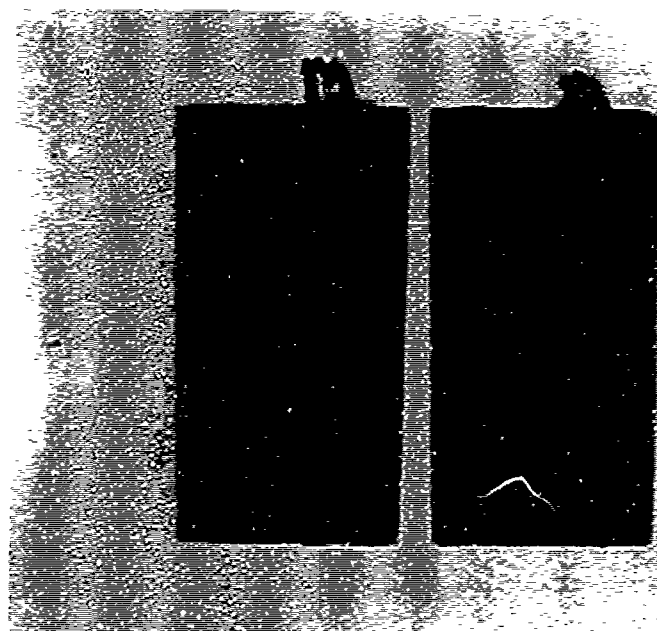


Figure 21. Hardcoat anodized dichromate sealed aluminum after 90-day immersion in seawater.

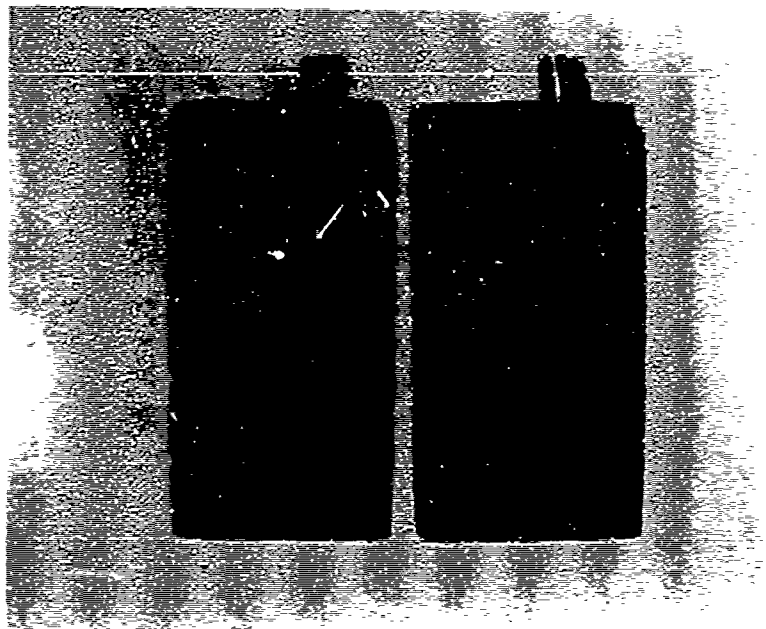


Figure 22. Hardcoat anodized unsealed aluminum after 90-day immersion in seawater.

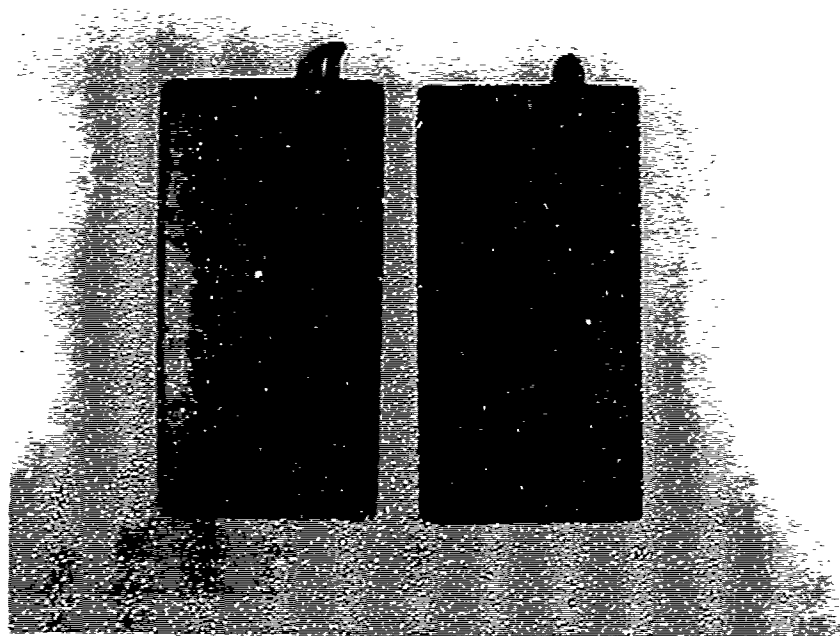


Figure 23. Chromate conversion coated aluminum after 90-day immersion in seawater.

of topcoat showed better corrosion resistance at score lines than did the 10- and 15-mil coated panels. Undamaged panels showed only occasional small areas of corrosion at corners, and most were rated excellent.

2. MIL-C-4556

Uncoupled: There was no corrosion or loss of adhesion around the score lines. Impacted panels showed the removal of the topcoat at 20 and 40 in.-lb impact points, but only the 40 in.-lb area corroded during immersion. The 10-mil-thick coated panels seemed to have better resistance to impact damage than either the 5- or 15-mil-thick coatings, but all three were rated good.

Coupled: Coating thickness had no effect on the corrosion at score lines or impact points. Impact points corroded more on the reverse of the point of impact than on the front. Undamaged panels were rated good to excellent.

3. MIL-C-22750.

Uncoupled: This coating adhered very poorly. Scratching with a fingernail could remove large sections of the coating along a score line. The primer readily debonded from the substrate (anodized chromate sealed aluminum). Blisters up to 3/4 in. in diameter formed around impact points and at edges. The aluminum beneath the blisters was significantly pitted and corroded. Coating thickness did not appear to affect the deterioration of the specimen.

Coupled: Blisters formed around score lines and impact points. Pitting at impact points was severe. Thickness had no apparent effect on the coating's rate of deterioration.

4. The 100 Percent Solids Epoxy Coating

Uncoupled: Panels showed no blistering or corrosion except at impact points. The 10-mil-thick coated panels showed greater resistance to corrosion at impact points than did either the 5- or 15-mil-thick coatings, but the differences were small. The thinner coating did not cover adequately, and the thicker coating was more likely to crack.

Coupled: Impact points corroded to the extent that the aluminum was penetrated except on the 15-mil-thick coating. Scored panels corroded equally for all thicknesses and were rated fair.

5. MIL-P-23377.

Uncoupled: Undamaged and impacted panels were fair to good, but scored panels were rated excellent. The color was somewhat faded because the chromates leached into the seawater. Impact points corroded on the reverse side of the panel. Some pitting of the aluminum was observed at these points.

Coupled: Chromate conversion coated panels showed greater resistance to corrosion at points of impact than did either of the anodized substrates. However, the differences observed were quite small. Score lines showed excellent resistance to corrosion over all three substrates.

6. Ameron Vinyl System

Uncoupled: Overall, this coating had good resistance to corrosion in seawater. There was no loss of adhesion around score lines, except when thicker coatings (10 or 15 mils) were applied over the chemical conversion treated aluminum. Impact points exhibited some corrosion over anodizing. Resistance of the impact points to corrosion depended on coating thickness. Fifteen mils of topcoat provided the best protection from impact damage.

Coupled: Coating thickness had little effect on the corrosion caused by score lines. All were rated fair to good. However, thicker coatings did provide greater corrosion protection at impact points. The Ameron coating was applied to one group of panels very early in the panel preparation period, and to the rest of the panels several weeks later. Thus, some of the panels were allowed a much longer drying time before immersion. Those with the shorter drying period tended to blister, and those with the longer drying period did not. Although there were few blisters, it would be advisable to allow the longest possible drying time before putting Ameron-coated torpedoes in seawater.

Performance - Task I: Polyurethane-Coated Specimens - Observations

1. Hughson Polyurethane Topcoat

The Hughson polyurethane topcoat TS 3236-23 A/E Revision was applied over both the Hughson wash primer TS 3236-26 and the Deft MIL-P-23377.

Uncoupled: Test panels primed with the wash primer had more of a tendency to form small blisters between the primer and the substrate. Also, hardcoat anodized panels had more blisters than did the chromate conversion coated panels. In all other ways the panels seemed to perform equally in a 90-day seawater immersion.

Coupled: All panels had a tendency to blister along the edges, corners, and impact points. However, the panels primed with the Hughson wash primer formed more randomly located blisters on the surface of the panels. The best system for resistance to corrosion at score lines was the MIL-C-23377 primer over the anodized unsealed aluminum, but this system had the least resistance to corrosion around impact points. Overall, the MIL-C-23377 primer performed better than the wash primer, and both systems performed better when applied over chromate conversion coated aluminum.

2. MIL-C-83286.

Uncoupled: The panels pretreated with hardcoat anodizing (sealed or unsealed) exhibited loss of adhesion around score lines, but were still rated good to excellent. The chromate conversion coated panels had no such loss of adhesion. The chemical conversion coated panels also showed no corrosion at impact points (rated excellent), while the other panels showed some pitting (rated good). Undamaged panels performed well over all three substrates.

Coupled: All types of panels showed corrosion at edges and corners; thus, none was rated excellent. The chromate conversion coated panels had the greatest corrosion resistance at impact points. Scored panels showed equal performance over all three substrates and were rated fair.

3. Jtrathane 155.

Uncoupled: The coating looked dirty after immersion and did not come clean when the panels were rinsed. Overall, the corrosion resistance of the coating was excellent. There was no blistering or corrosion anywhere. All uncoupled panels were rated excellent. There was no loss of adhesion of the coating near the score lines. All three substrates showed equally excellent performance. Impact areas had a break in the topcoat, but the primer was intact, and no corrosion was evident.

Coupled: Impact points had high resistance to corrosion and were rated good to excellent. Scored lines had fair to good corrosion resistance. Chromate conversion coated panels were rated higher than anodized sealed and anodized unsealed panels.

Performance - Task II: Uncoated Specimens - Observations

Seawater: For a discussion of the performance of uncoated specimens in seawater, see Performance - Task I: Uncoated Specimens.

Otto Fuel: None of the specimens, uncoupled or coupled, corroded in Otto fuel.

Fifty percent seawater/50 percent Otto fuel: Uncoupled bare aluminum panels corroded over the entire surface exposed to the seawater layer and in a few areas exposed to the Otto fuel layer. There was no deep pitting. Uncoupled hardcoat anodized sealed and unsealed panels did not visibly corrode. Uncoupled chromate conversion coated panels corroded in a few areas in both the seawater and the Otto fuel layer. Coupled bare aluminum corroded heavily in the seawater layer and more lightly in the portion immersed in the Otto fuel layer (Figure 24). The coupled anodized sealed aluminum test panels corroded on the edges at the water/fuel interface and slightly in the seawater layer (Figure 25). The coupled anodized unsealed panels corroded more than the sealed panels, and they corroded mostly on the edges (Figure 26). The coupled chromate conversion coated panels were corroded over much of the surface exposed to the seawater, with more concentrated areas of corrosion at the seawater/fuel interface (Figure 27).

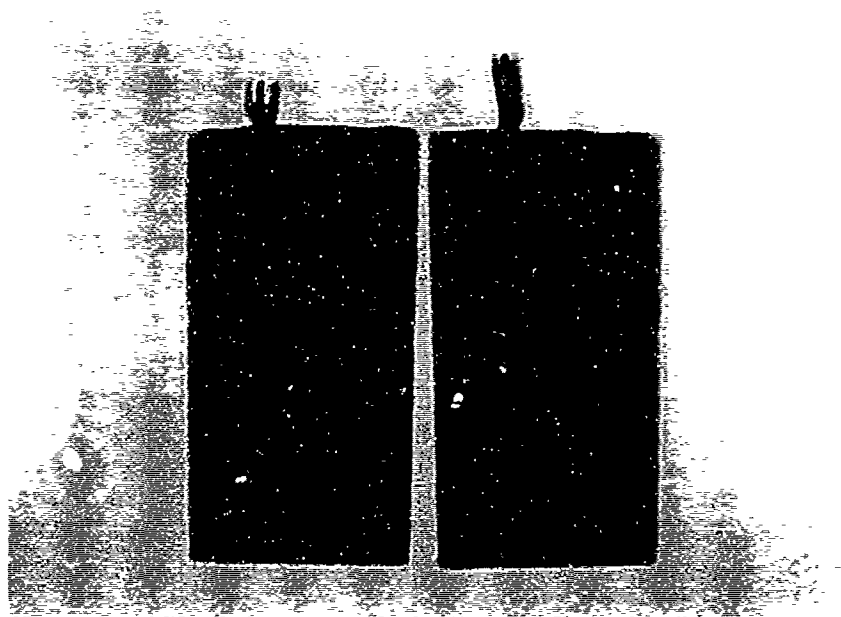


Figure 24. Bare aluminum after 90-day immersion in 50 percent seawater/50 percent Otto fuel.

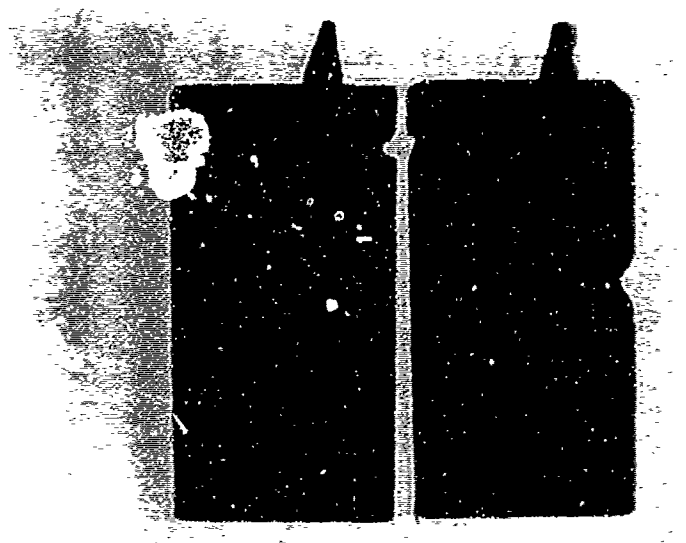


Figure 25. Hardcoat anodized dichromate sealed aluminum after 90-day immersion in 50 percent seawater/50 percent Otto fuel.

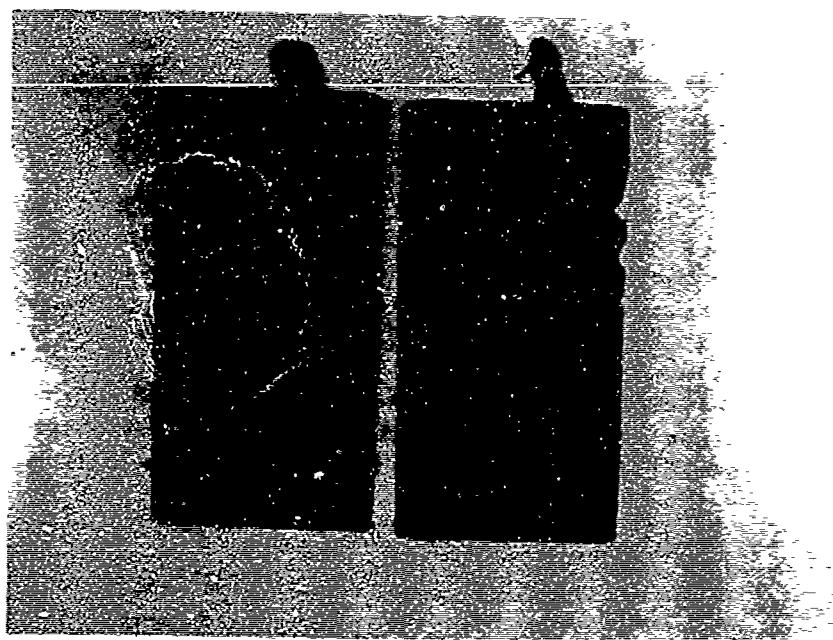


Figure 26. Hardcoat anodized unsealed aluminum after 90-day immersion in 50 percent seawater/50 percent Otto fuel.

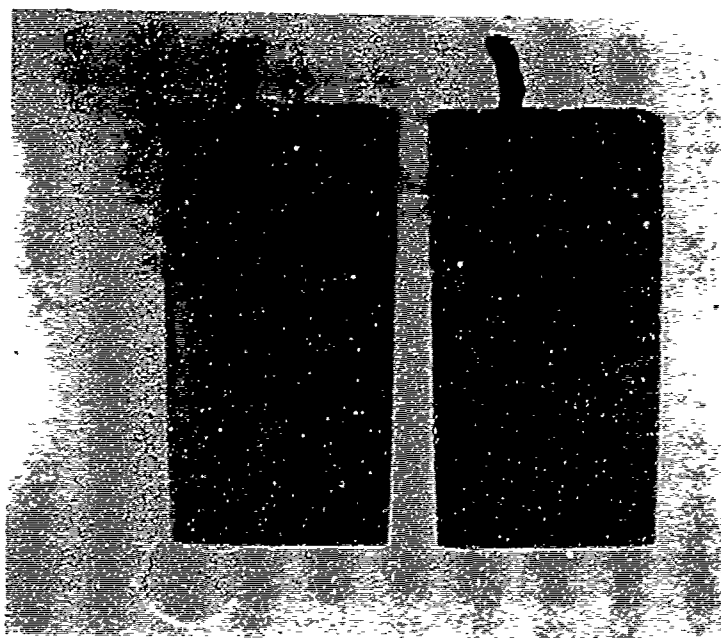


Figure 27. Chromate conversion coated aluminum after 90-day immersion in 50 percent seawater/50 percent Otto fuel.

Performance - Task II: Nonpolyurethane-Coated Specimens - Observations

The coatings discussed below were tested for use on the interior of the torpedo fuel tanks. These coatings were immersed in artificial seawater, Otto fuel, and a mixture of 50 percent Otto fuel and 50 percent seawater. The seawater tanks were aerated; for the seawater and Otto fuel mixture, the seawater layer (the upper layer) was continuously aerated.

1. MIL-C-22750.

Seawater: Uncoupled panels had excellent resistance to corrosion. However, this coating system adhered very poorly. One's fingernail could be used to easily peel paint from the anodized sealed and unsealed panels. The chromate conversion coated panels had good adhesion between the primer and substrate. Coupled panels performed very poorly. There was much loss of metal, and many panels had holes penetrating through the aluminum to the other side. With anodized aluminum, blisters spread out from impact points and score lines. The blisters did not seem to greatly accelerate the corrosion of the area -- the anodizing was still intact on the surface of the aluminum.

Otto fuel: This coating is compatible with Otto fuel. No corrosion or softening of the film was evident.

Fifty percent seawater/50 percent Otto fuel: Anodized sealed and unsealed panels suffered more corrosion at edges and corners than did chemical conversion coated panels. However, the chromate conversion coated panels corroded more at the Otto fuel/seawater interface than did the anodized panels. Uncoupled panels were rated good to excellent. Coupled panels were rated fair to poor.

2. MIL-C-4556.

Seawater: There was some loss of adhesion near score lines on uncoupled panels. This problem was more severe on chromate conversion coated panels than on hardcoat anodized panels. Undamaged panels showed no corrosion. Coupled panels corroded only at score lines, and the extent of corrosion was equal for all three substrates. Uncoupled panels were rated good to excellent. Coupled panels were rated fair to good.

Otto fuel: Uncoupled and coupled panels showed no corrosion, loss of adhesion, or deterioration of the coating.

Fifty percent seawater/50 percent Otto fuel: Uncoupled scored panels showed some small blistered areas along the fuel/seawater interface. Undamaged panels had no blisters. Coupled panels showed the greatest corrosion on the chemical conversion coated panels; the damage on these panels was quite severe -- nearly 70 percent of the coating was removed and much of the aluminum had corroded away. On the anodized unsealed panels about 20 percent of the coating was removed, and on the anodized sealed panels about 5 percent was removed. Uncoupled panels were rated good to excellent. Coupled panels were rated fair to excellent if undamaged, and poor if scored before immersion.

3. BMS-10-11K.

Seawater: Uncoupled panels showed no corrosion and no loss of adhesion around score lines. Undamaged panels also were rated excellent. Coupled panels were rated poor to fair. Pits up to 1/4 in. in diameter were spread over the entire surface of the panels. This coating was applied as a one-coat system without a primer; any small pinholes or other defects in the film were not covered by additional coats. Coupled panels with score lines had fewer pits, but much corrosion of the scored area. The anodized panels performed somewhat better than the chromate conversion coated panels; there were still corroded areas, but there were fewer corrosion pits.

Otto fuel: Both coupled and uncoupled panels showed excellent resistance to Otto fuel. There was no evidence of coating deterioration or substrate corrosion.

Fifty percent seawater/50 percent Otto fuel: Uncoupled panels showed only some minor areas of corrosion on the edges and at corners, and were rated good to excellent. Coupled panels were all very corroded and received a rating of poor. Anodized sealed panels performed slightly better than anodized unsealed panels; chromate conversion coated panels had the poorest performance. The worst areas were at the fuel/seawater interface and the air/seawater interface.

5 CONCLUSIONS

Task 1: Torpedo Exterior Coatings

1. The epoxy systems, MIL-P-24441 and MIL-C-4556, were obviously the best of the five epoxy coatings that were tested in Task I. Both of these epoxies and the epoxy primer MIL-P-23377 had excellent scrape adhesion. MIL-P-24441 was superior to all coatings in the Elcometer adhesion test. The impact strength of MIL-P-24441 and MIL-C-4556 were approximately the same before immersion in seawater. MIL-C-4556 was not quite as resistant after immersion. The impact resistance of MIL-P-23377 was much inferior to either of the other two epoxies. There was no advantage gained in performance when MIL-P-24441 was applied in thicknesses greater than 5 mils. Actually, the surface of the coating chipped more easily at the greater thicknesses. The MIL-P-24441 also had the best corrosion resistance. Based on the test results, the MIL-P-24441 system has the best overall performance of all of the ten candidate coating systems tested for Task I.

2. The Ameron vinyl system (Amercoat 86 primer and Amercoat 99HS top-coat) provides a high degree of corrosion protection, has good impact resistance and adhesion, and (because it is a solution vinyl) should be easily repaired when the original coating is damaged. A 15-mil-thick coating of this vinyl provides much greater protection against damage by impact than does a 10- or 5-mil coat. However, the 15-mil-thick coat has a much longer drying time; adequate time must be allowed before immersing this system. Although the MIL-C-4556 system may have had a slightly better overall performance than the Ameron system, the latter is preferred. The MIL-C-4556 system has corrosion resistance, impact resistance, and adhesion which are only slightly inferior to the MIL-P-24441 system. The Ameron system has properties of flexibility and repairability which are not seen in the two epoxy systems. These properties make the Ameron system a good second choice of the ten systems tested for Task I.

3. Of the four polyurethane systems tested for Task I, Irathane 155 had the best adhesion according to the Elcometer adhesion test. Irathane 155 applied over MIL-P-23377 primer showed superior corrosion resistance during the 90-day seawater immersion tests. The Irathane coating is a high-build polyurethane topcoat and was applied at a dry film thickness of 15 mils. The Irathane polyurethane system would be ranked third among the candidate coatings for Task I.

4. The MIL-P-23377 primer does not adhere well to anodized surfaces. If it is to be used, it should be applied only to chromate conversion coated aluminum. When this primer was applied to anodized surfaces, there were more blisters and much poorer adhesion and impact resistance than when it was applied to the chromate conversion coated aluminum.

5. The effect of coating thickness or type of substrate on performance depends on the specific coating system that is used. There is no one thickness or aluminum pretreatment that is best in all cases.

Task II: Torpedo Interior Fuel Tank Coatings

Of the three candidate coating systems for Task II, the MIL-C-4556 system had the best overall performance when applied over the dichromate sealed, hardcoat anodized 7075 series aluminum. When undamaged, this coating is highly resistant to deterioration in Otto fuel, seawater, or a mixture of the two. When the coating is physically damaged, it does not break away from the damaged area, but remains intact even if corrosion has undercut the coating.

6 RECOMMENDATIONS

This study was very limited in the number of coating systems evaluated. The coatings tested represent different types of coatings and different physical properties. The results of the tests on these coatings may be used to select additional coatings for testing to find the coating system which will best protect torpedo exteriors and the interior fuel tank. Consideration should be given to the following types of coatings:

1. Vinyl-modified epoxies. Coatings of this type are rather new, but have potential. Epoxy coatings have a high degree of chemical resistance, but they tend to be somewhat brittle and inflexible. Incorporating vinyl polymers into epoxy coatings could increase the flexibility and impact resistance of epoxy coatings, while retaining seawater immersion resistance.

2. Vinyl coating systems. The high solids vinyl system manufactured by Ameron performed well, but was somewhat difficult to apply and required a lot of thinning. Alternate vinyl systems should be evaluated, including some low-solids vinyl topcoats.

3. Alternative primers. The MIL-P-23377 epoxy primer manufactured by Deft does not adhere well to anodized surfaces. It is recommended that other primers be evaluated to find a suitable substitute that will have satisfactory adhesion to anodized aluminum. Possible primers include the Boeing specification BMS-10-11K, MIL-P-24441 Formula 158, or possibly a wash primer such as DOD-P-15328.

4. Alternative application methods. The initial study was limited to coatings applied by conventional spraying methods. Possible alternative coatings may include electrostatically applied epoxy coatings, plasma-sprayed coatings, or low-level heat cured coatings.

In addition to materials, there are several recommendations regarding test procedures. These include both modifications to test procedures previously used and the development of new test procedures. The following changes are recommended:

1. The number of test specimens per coating should be increased from 16 to 18. Six panels each should be allowed for nonimmersion, galvanically coupled immersion, and uncoupled immersion tests. Previously only four panels were allowed for nonimmersion tests. Statistical comparisons are more useful when equal numbers of specimens are used for each test.

2. The characterization of the candidate coatings by standard gas chromatographic analysis is only able to determine the number and relative amounts of volatile materials in each coating. An alternative procedure called pyrolysis gas chromatography is now possible on equipment recently acquired by CERL. In this technique, a solid sample of coating film is pyrolyzed under controlled conditions, and the volatile pyrolysis products are analyzed by gas chromatography. The resulting chromatogram is characteristic of the particular coating formulation. This characterization method should be used in conjunction with the infrared analysis techniques used in this study.

3. The major limitation of the Elcometer adhesion test is the adhesive used to bond the aluminum dolly to the surface of the coating. Although the best available adhesives were used, it was found that their strength was often less than the bond strength of the test coatings to the substrate. This test does, however, differentiate between coatings with very low adhesion and those with good adhesive strength. This test therefore continues to be an acceptable method for measuring the adhesive strengths of coatings.

REFERENCES

- Otto Fuel II: Safety, Storage and Handling, NAVSEA OP 3368 Fifth Revision (Naval Sea Systems Command, 15 January 1973; Change 1, 15 May 1975).
- Standard Test Methods for Adhesion of Organic Coatings, D 2197 (American Society for Testing and Materials [ASTM], 1968).
- Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact), D 2794 (ASTM, 1969).

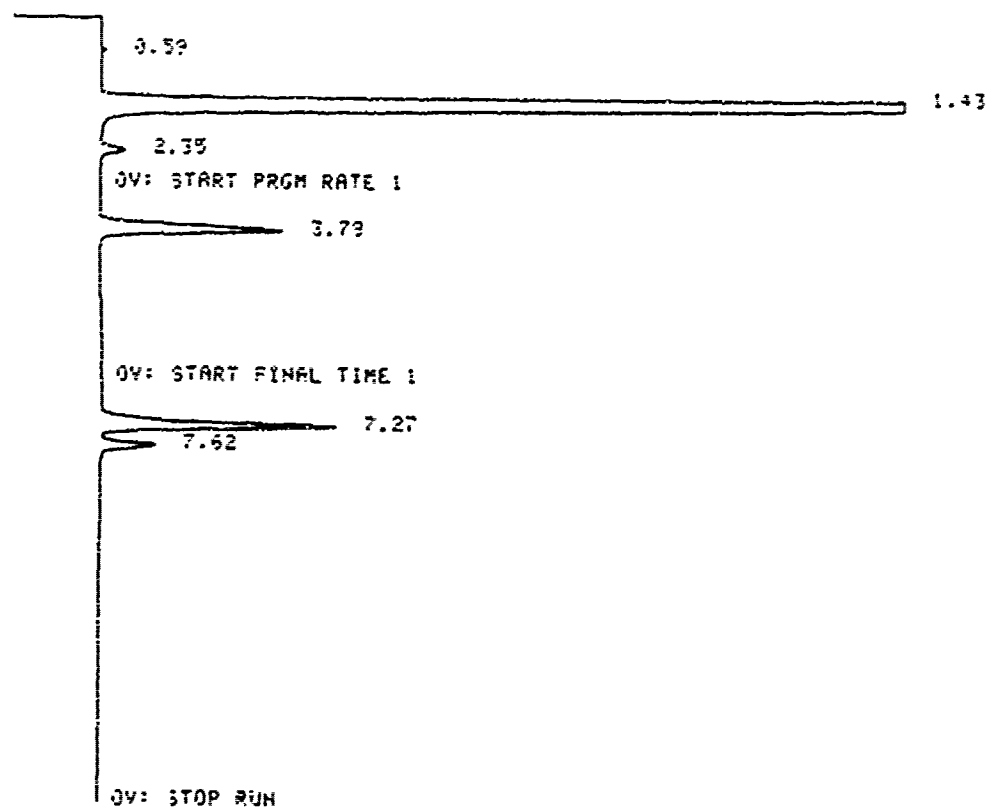
METRIC CONVERSIONS

1 in.	= 25.4 mm
1 in.-lb	= 1.1298×10^6 dyne centimeters
1 mil	= 2.54×10^{-5} m
1 psi	= 6.9 kPa

APPENDIX A:

GAS CHROMATOGRAPHIC AND INFRARED SPECTROM ANALYSES

MIL-P-24441 FORMULA 158



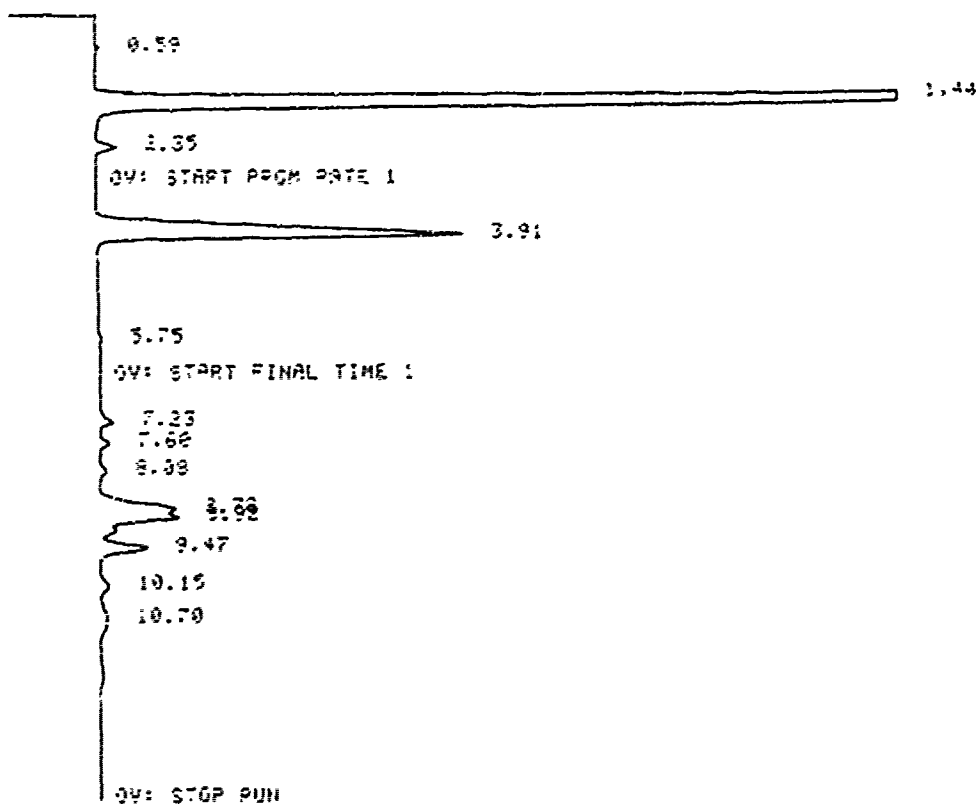
END 5920A MANUAL INJECTION @ 97:55 JUN 21, 1982
AREA %

RT	AREA	TYPE	AREA %
3.73	511555.00	PS	43.093
7.27	562443.00	SV	47.371
7.62	113218.00	VB	9.536

TOTAL AREA = 1187320.00
MULTIPLIER = 1

Figure A1. Gas chromatogram: MIL-P-24441 Formula 158 primer.

MIL-P-24441 FORMULA 152



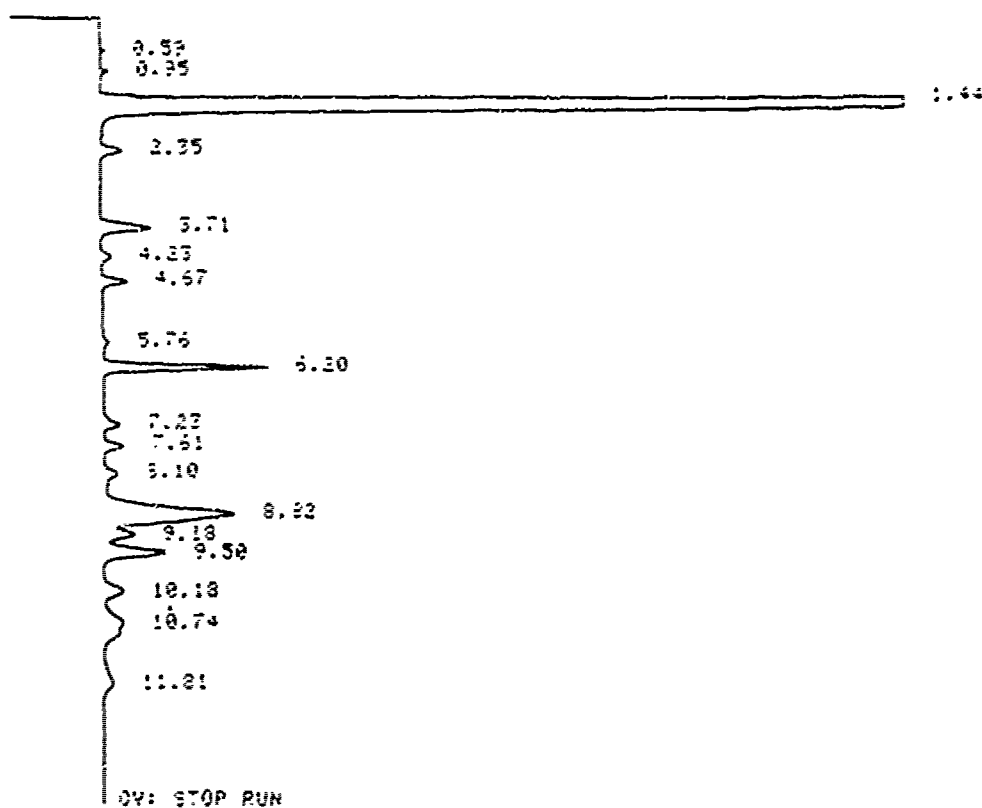
END 5880P MANUAL INJECTION @ 09:40 JUN 21, 1982
AREA %

RT	AREA	TYPE	AREA %
3.91	1328060.00	PB	63.970
5.75	5287.27	BV	0.245
7.23	33165.70	OV	1.537
7.62	21439.90	VP	0.994
8.09	16186.30	PP	0.750
8.76	255332.00	PV	11.845
9.02	223119.00	VV	10.342
9.47	142119.00	VP	6.508
10.15	26794.60	BV	1.234
10.70	51653.40	VP	2.394

TOTAL AREA = 2157359.00
MULTIPLIER = 1

Figure A2. Gas chromatogram: MIL-P-24441 Formula 152 topcoat.

MIL-C-4556 primer



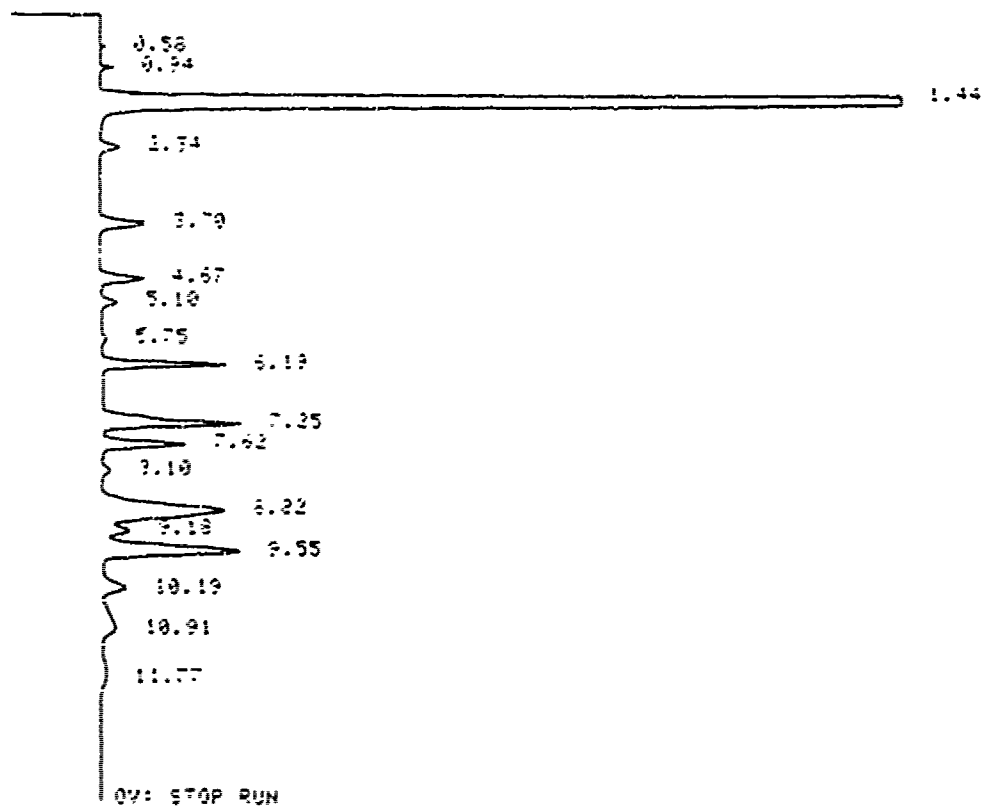
END 5682A MANUAL INJECTION @ 07:29 JUN 23, 1982
AREA %

RT	AREA	TYPE	AREA %
3.71	120000.00	PP	6.883
4.23	23703.30	PP	1.274
4.67	55637.30	PV	2.992
5.76	12086.80	BP	0.658
6.20	301260.00	PB	16.198
7.23	41022.20	VP	2.206
7.61	42438.00	PV	2.282
8.10	54579.20	VV	2.935
8.32	640754.00	VV	34.452
9.18	87240.60	VV	4.691
9.50	193639.00	VV	10.412
10.18	72798.90	VV	3.914
10.74	145917.00	VV	7.846
11.01	60765.20	VP	3.267

TOTAL AREA = 1859949.00
MULTIPLIER = 1

Figure A3. Gas chromatogram: MIL-C-4556 primer.

MIL-C-4556 TOPCOAT



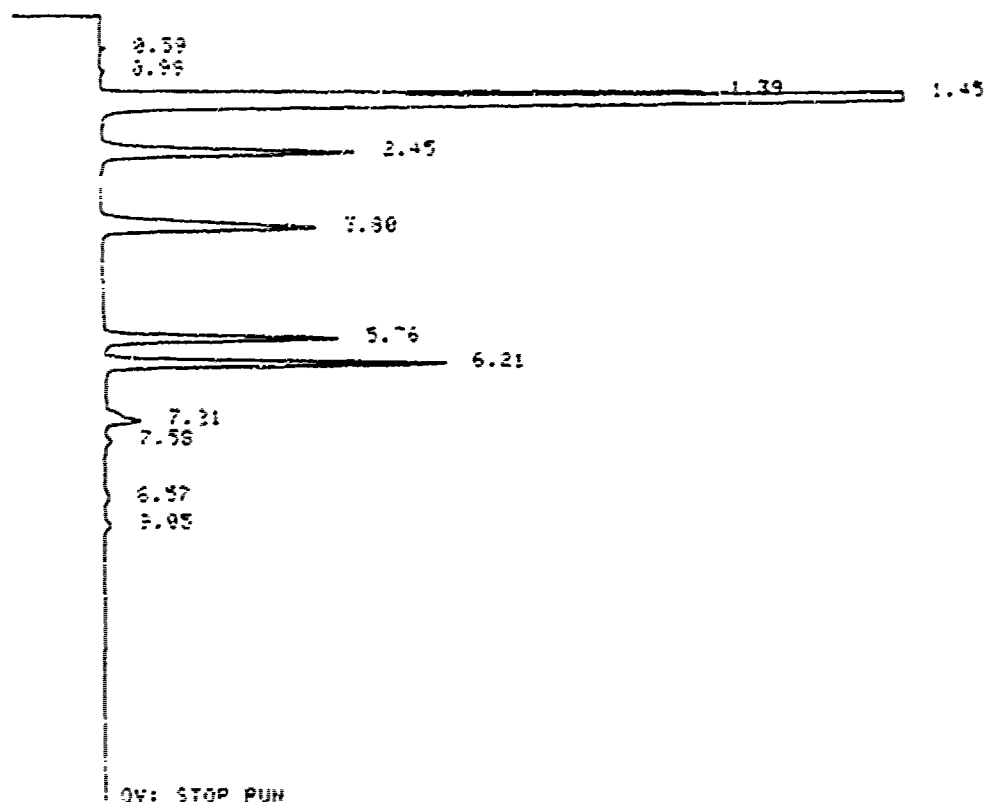
INP 3000A MANUAL INJECTION @ 07:06 JUN 23, 1982
AREA :

RT	AREA	TYPE	AREA %
3.79	117375.00	BP	4.802
4.67	26821.00	BP	3.961
5.10	34827.00	VV	1.425
5.75	3155.05	BP	0.375
6.19	222776.00	PS	9.114
7.25	360814.00	BP	14.760
7.62	120169.00	VP	7.379
8.10	19149.50	PP	0.793
8.92	605395.00	PV	24.766
9.13	92276.20	VV	3.366
9.55	455521.00	VV	19.635
10.19	100257.00	VV	4.101
10.91	110644.00	VV	4.526
11.77	49279.50	VP	2.016

TOTAL AREA = 2444460.00
MULTIPLIER = 1

Figure A4. Gas chromatogram: MIL-C-4556 topcoat.

DEFT MIL-P-23377



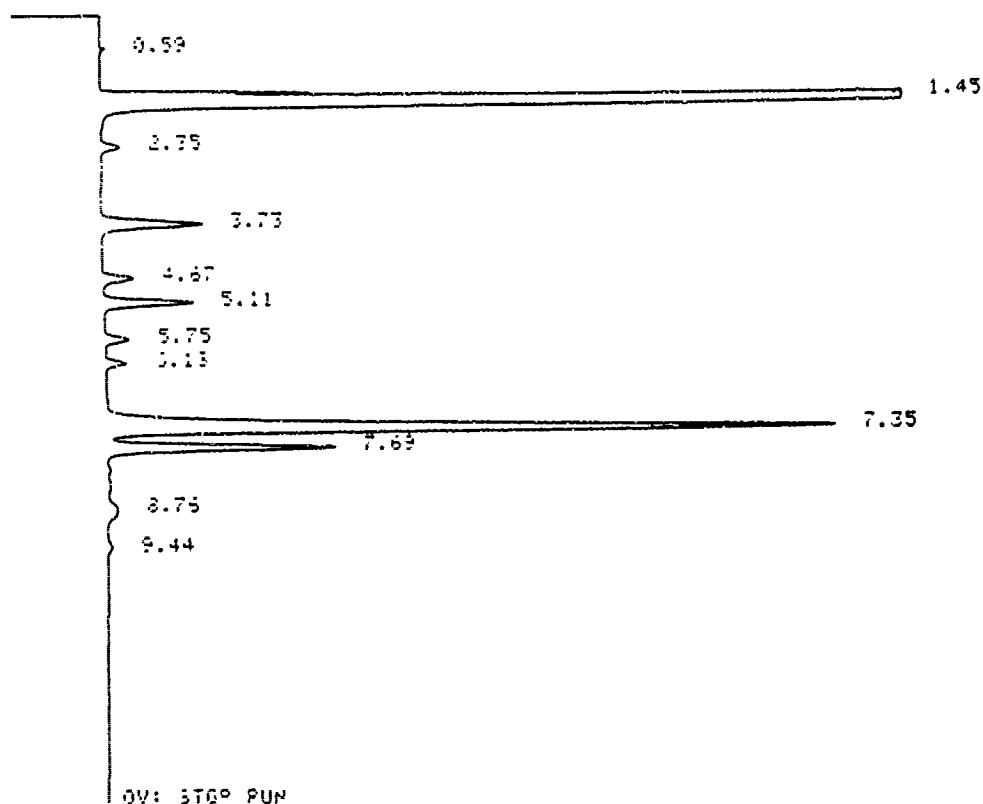
EXP 5360A MANUAL INJECTION @ 12:22 JUN 21, 1982
AREA :

RT	AREA	TYPE	AREA %
3.30	621120.00	PS	32.970
5.76	474452.00	BY	25.184
6.21	651345.00	VB	34.574
7.21	91803.40	VV	4.877
7.53	12663.20	VB	0.672
8.57	16357.60	BY	0.868
9.05	16095.40	VB	0.854

TOTAL AREA = 1883910.00
MULTIPLIER = 1

Figure A5. Gas chromatogram: Deft MIL-P-23377.

MIL-C-22750



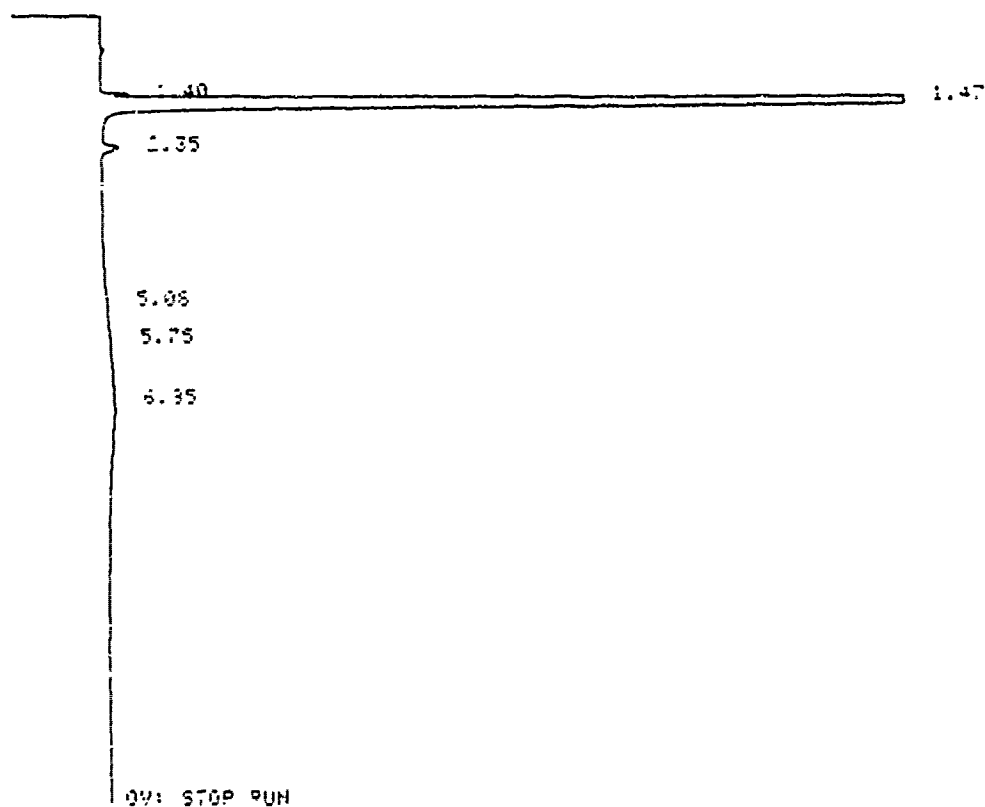
EXP 58809 MANUAL INJECTION @ 12:39 JUN 21, 1982
AREA %

RT	AREA	TYPE	AREA %
3.73	263260.00	PH	7.619
4.67	72161.00	SH	2.089
5.11	207441.00	HH	5.865
5.75	62957.20	HH	1.813
6.13	53967.00	HL	1.544
7.35	2121139.00	HH	61.372
7.69	535431.00	HH	15.497
8.75	33441.70	HH	0.989
9.44	43495.10	HH	1.233

TOTAL AREA = 3455090.00
MULTIPLIER = 1

Figure A6. Gas chromatogram: MIL-C-22750.

STEELCOTE 100% SOLIDS



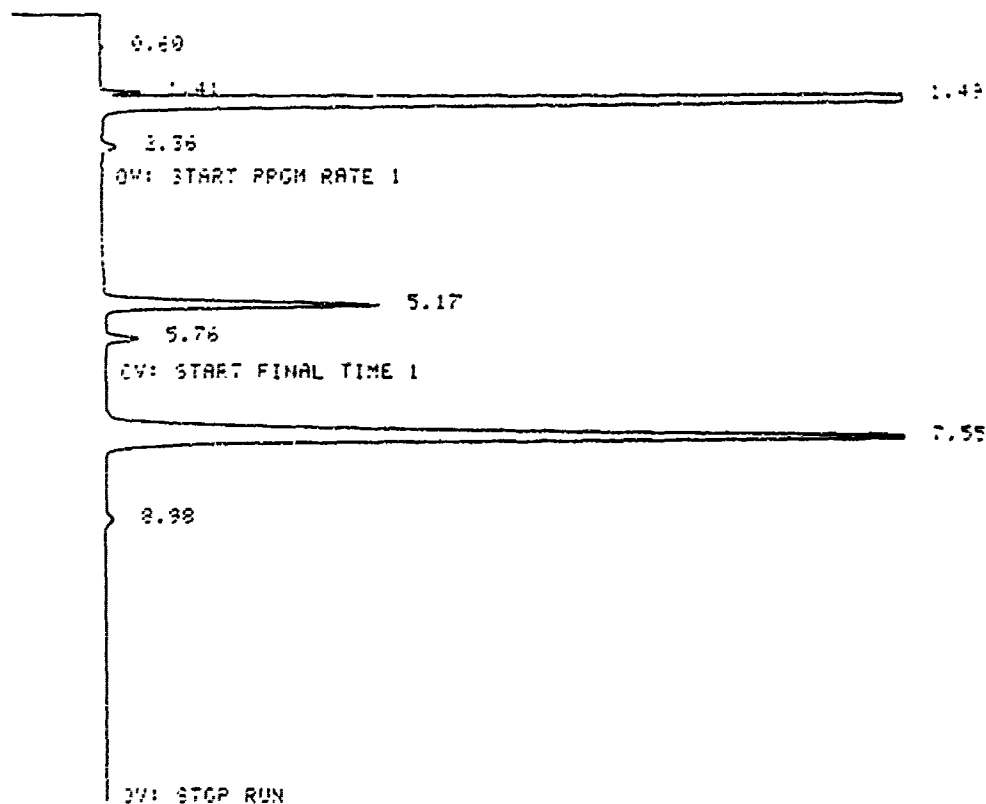
END 5320A MANUAL INJECTION C 06:43 JUN 23, 1982
AREA %

RT	AREA	TYPE	AREA %
5.08	26012.40	HH	5.258
5.75	56357.40	HH	11.391
6.35	412373.00	HH	83.351

TOTAL AREA = 494743.00
MULTIPLIER = 1

Figure A7. Gas chromatogram: Steelcote 100 percent solids epoxy.

AMERCOAT 86



MANUAL INJECTION @ 08:37 JUN 21, 1982
 AREA %

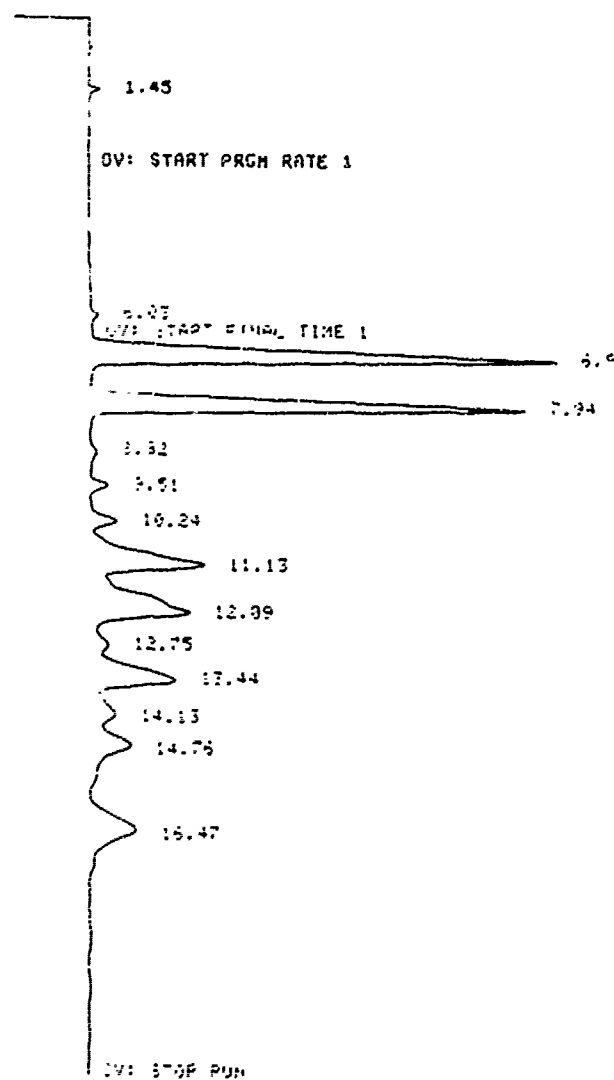
RT	AREA	TYPE	AREA %
5.17	652147.00	PV	16.492
5.76	68699.00	V6	1.737
7.35	3212600.00	P8	81.242
7.55	20895.10	P8	0.528

TOTAL AREA = 3954340.00
 MULTIPLIER = 1

Figure A8. Gas chromatogram: Amercoat 86 primer.

OVEN TEMP FINAL TIME 15

AMERCOAT 6 THINNER



1003 53204 MANUAL INJECTION 9 10:01 JUN 21, 1992

AREA %

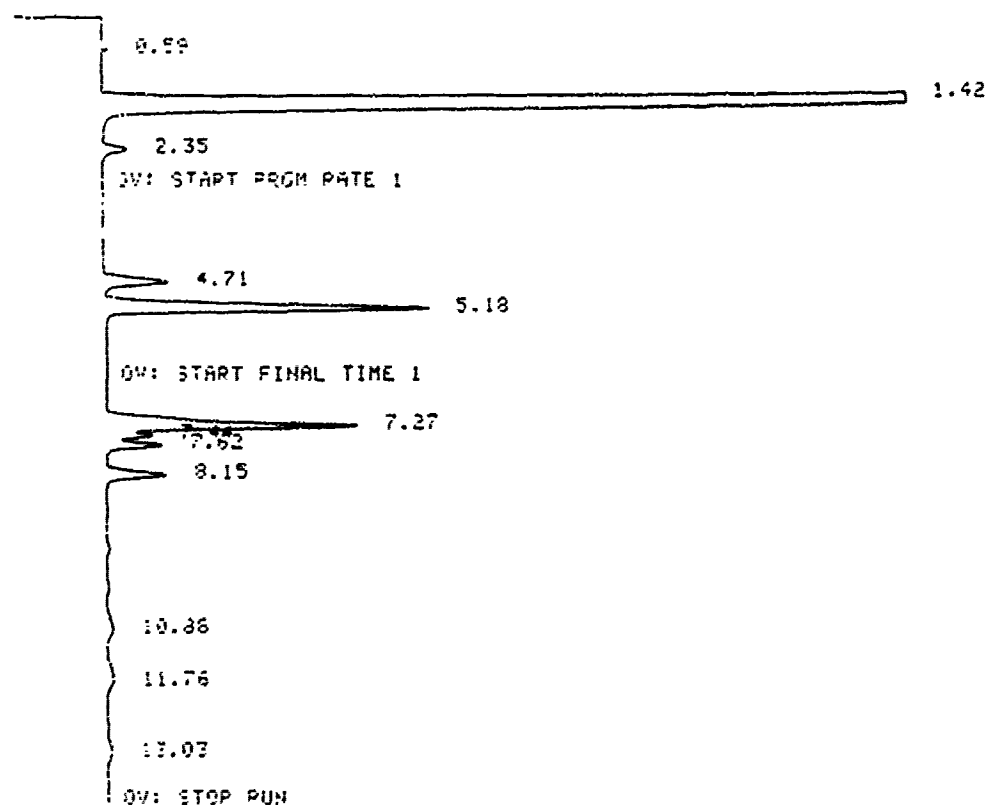
RT	AREA	TYPE	AREA %
6.03	44177.60	HM	0.479
6.96	2418440.00	HM	26.222
7.94	2183030.00	HM	22.802
8.82	56467.50	HM	0.612
9.51	84794.32	HM	0.910
10.24	154110.00	HM	1.679
11.13	952623.00	HM	10.329
12.09	1091270.00	HM	11.832
12.75	155446.00	HM	1.683
13.44	765326.00	HM	8.299
14.13	298071.00	HM	3.245
14.76	510150.00	HM	5.531
15.47	596370.00	HM	6.456

TOTAL AREA = 9223100.00

MULTIPLIER = 1

Figure A9. Gas chromatogram: Amercoat 6 thinner.

AMERON AMERCOAT 99HS



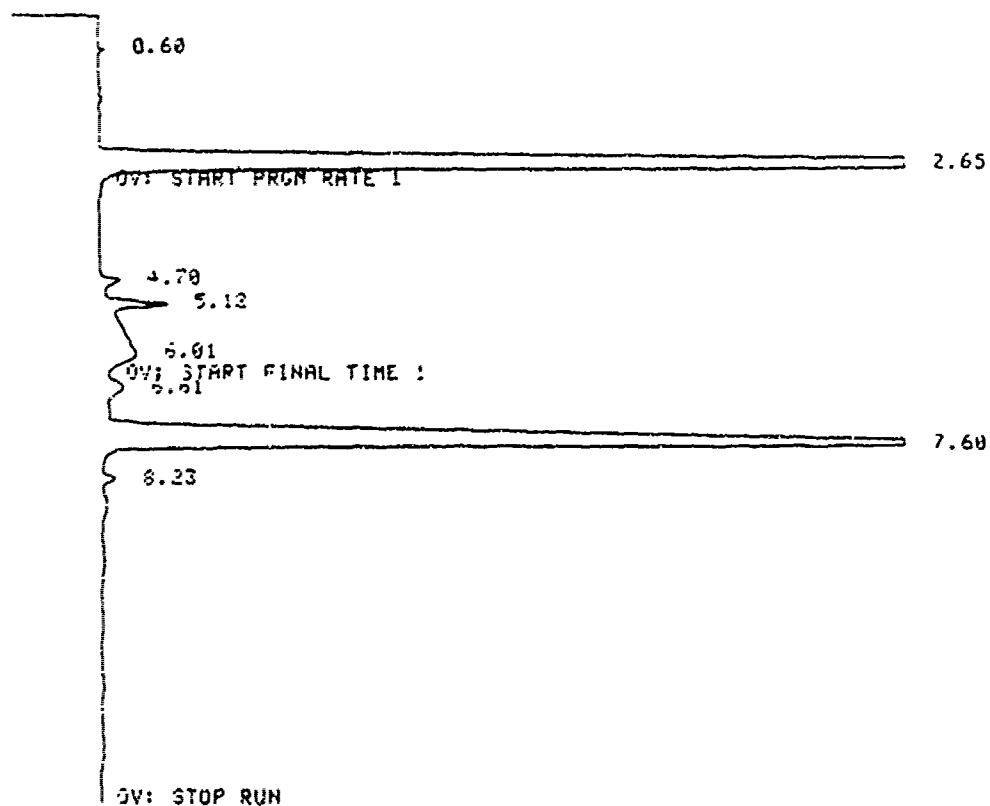
DATA 58804 MANUAL INJECTION @ 08:17 JUN 21, 1982
AREA %

RT	AREA	TYPE	AREA %
4.71	160277.00	PV	7.769
5.18	783571.00	VB	37.982
7.27	569786.00	BY	32.466
7.44	83596.70	VV	4.052
7.63	115664.00	VP	5.607
8.15	142907.00	FB	6.927
10.83	35510.00	PV	1.721
11.76	47035.30	VV	2.290
13.07	24678.70	VP	1.196

TOTAL AREA = 2063030.00
MULTIPLIER = 1

Figure A10. Gas chromatogram: Amercoat 99HS topcoat.

AMERCOAT 9 THINNER



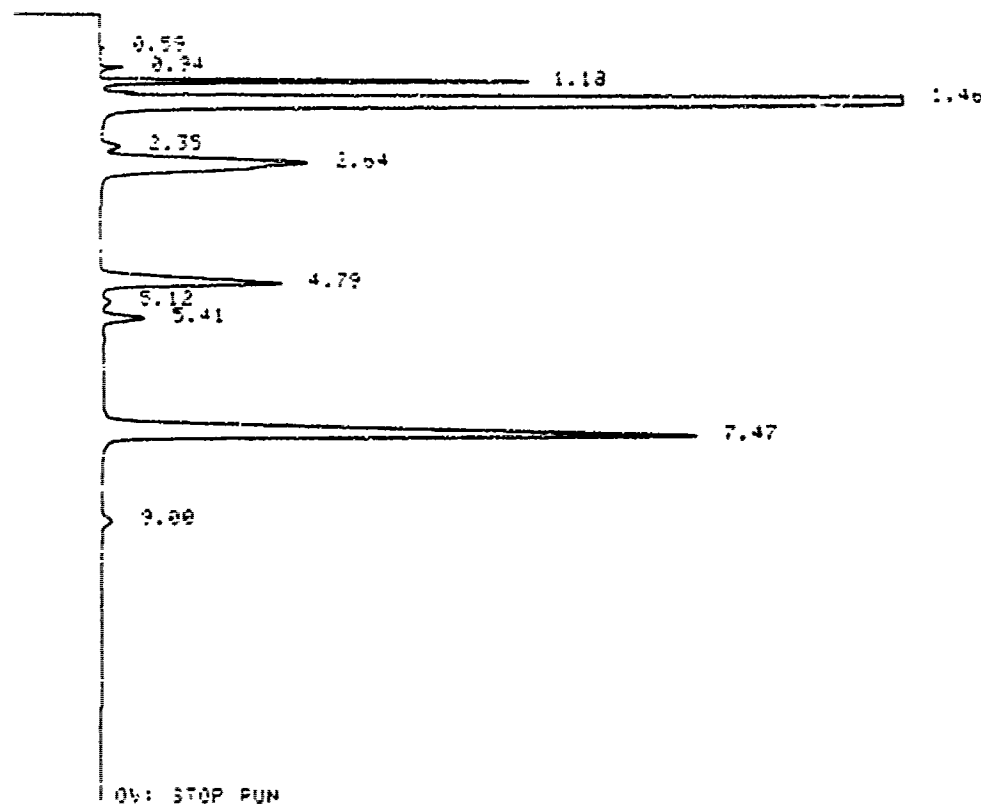
INP: 5880A MANUAL INJECTION @ 09:21 JUN 21, 1992
AREA %

RT	AREA	TYPE	AREA %
2.65	5534398.00	VB	52.284
4.70	46626.10	HH	0.440
5.12	171998.00	HH	1.625
6.01	433704.00	HH	4.097
6.61	113197.00	HH	1.117
7.60	4244630.00	HH	40.899
8.23	35796.00	HH	0.338

TOTAL AREA = 10585300.00
MULTIPLIER = 1

Figure All. Gas chromatogram: Amercoat 9 thinner.

TS3236-26 WASH PRIMER



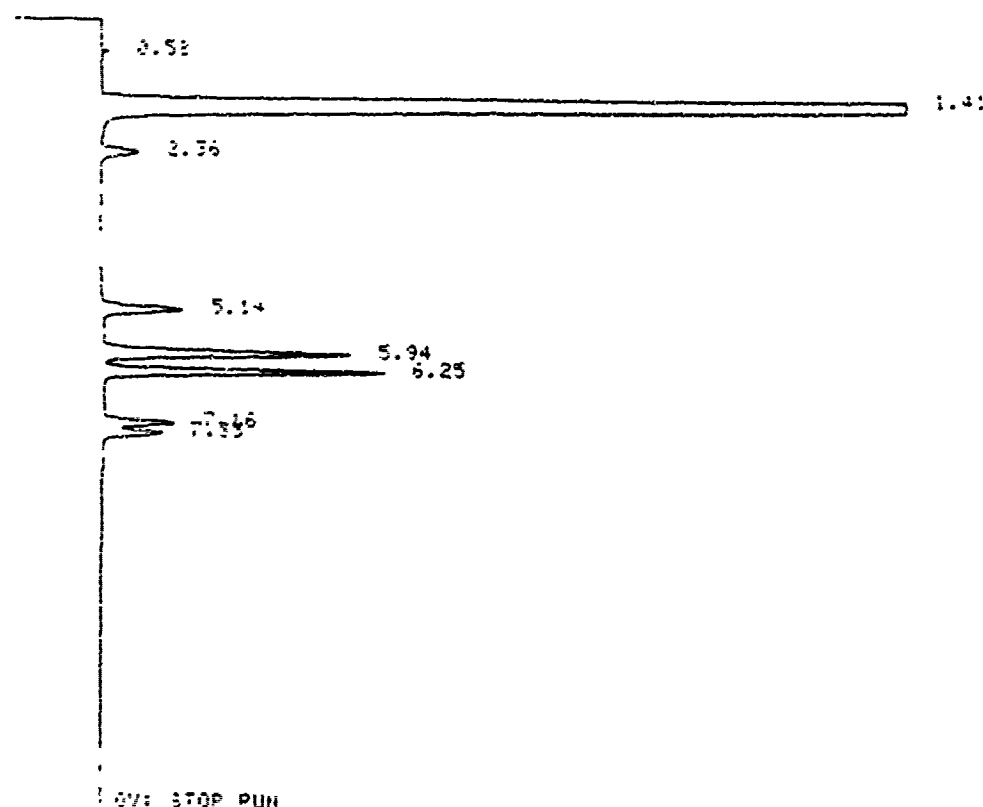
END 5880R MANUAL INJECTION @ 09:07 JUN 23, 1982
AREA %

RT	AREA	TYPE	AREA %
1.13	428829.00	VV	11.475
2.64	834794.00	VB	22.339
4.79	498960.00	SV	13.133
5.12	22791.00	VV	0.610
5.41	91133.40	VV	2.439
7.47	1839450.00	VB	49.223
9.00	29025.00	PH	0.777

TOTAL AREA = 3736920.00
MULTIPLIER = 1

Figure A12. Gas chromatogram: Hughson TS 3236-26 wash primer.

HUGHSON POLYURETHANE TOPCOAT



OV: STOP RUN

1:1 3890A MANUAL INJECTION @ 15:30 OCT 25, 1982

AREA %

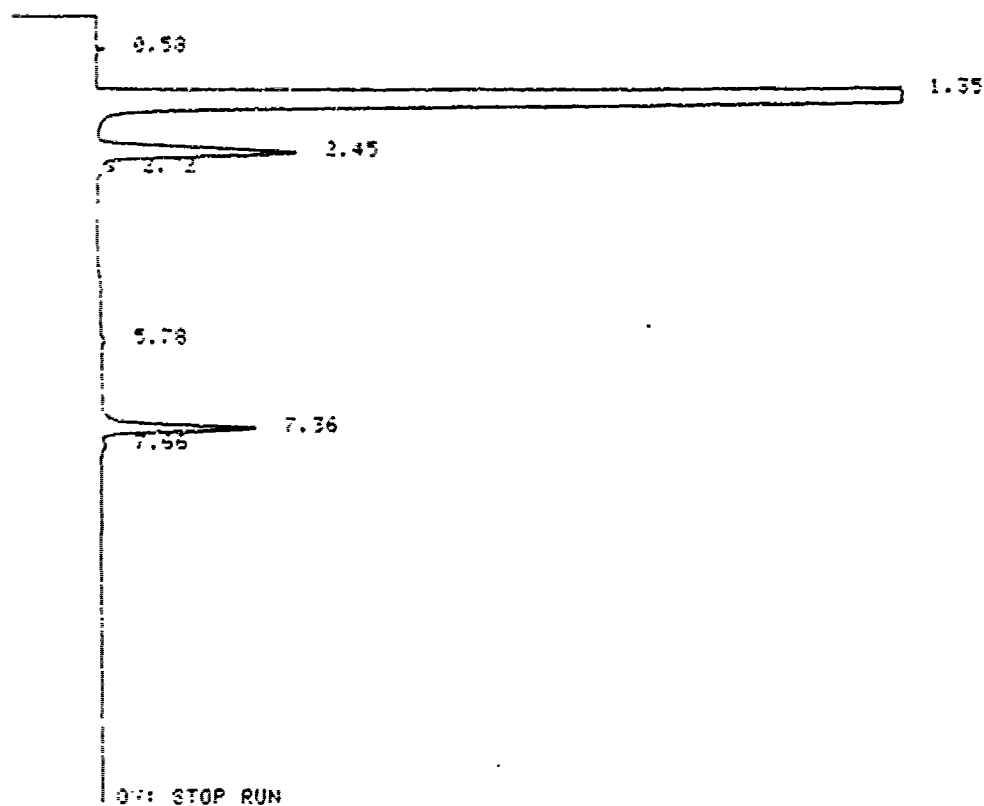
RT	AREA	TYPE	AREA %
5.14	179521.00	BV	12.067
5.94	539357.00	BV	36.221
6.25	520301.00	VB	34.974
7.16	137866.00	VV	9.267
7.33	111138.00	VP	7.471

TOTAL AREA = 1487680.00

MULTIPLIER = 1

Figure A13. Gas chromatogram: Hughson TS 3236-23 topcoat.

MIL-C-83286



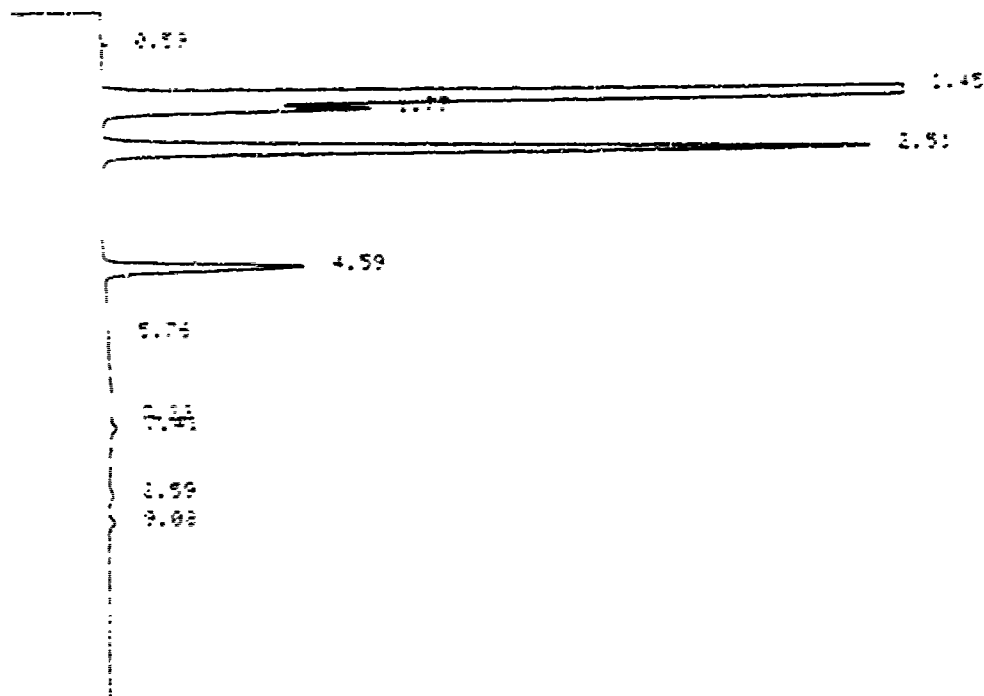
INP: 5800A MANUAL INJECTION @ 16:03 OCT 25, 1982
 OPER: J.

RT	AREA	TYPE	AREA %
1.35	41124.10	VP	9.558
2.45	13095.50	PV	3.044
7.36	366190.00	8V	85.197
7.56	2050.53	V8	2.291

TOTAL AREA = 430268.00
 MULTIPLIER = 1

Figure A14. Gas chromatogram: MIL-C-83286.

IRATHANE C-155



NO. 1 STOP RUN

END 5 STOP MANUAL INJECTION @ 13:34 JUL 12, 1982
AREA %

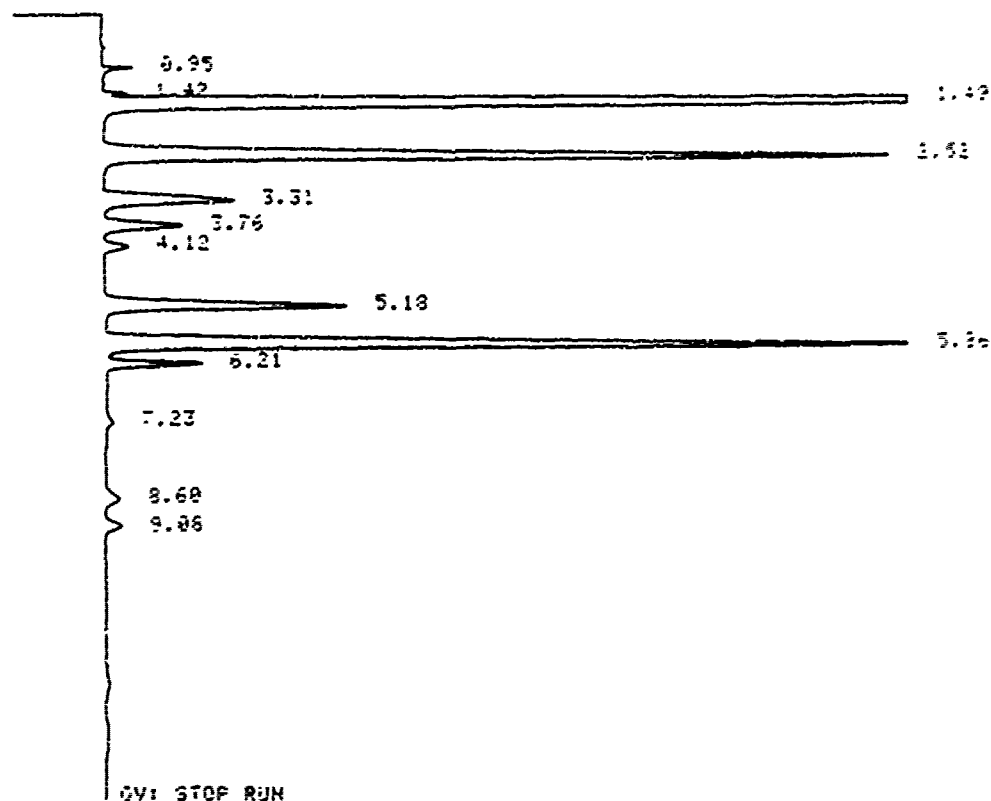
RT	AREA	TYPE	AREA %
0.59	1964130.00	V2	74.609
4.59	466762.00	SV	17.730
5.76	27155.90	VV	1.032
7.11	97410.00	VV	3.700
7.41	43510.90	VV	1.643
8.59	12494.10	BP	0.475
9.08	16109.90	PB	0.612

TOTAL AREA = 2632570.00

MULTIPLIER = 1

Figure A15. Gas chromatogram: Irathane 155.

BMS-10-11K



QV: STOP RUN

EXP 5260A MANUAL INJECTION @ 13:16 JUN 21, 1982

AREA %

RT	AREA	TYPE	AREA %
1.42	1966420.00	VB	35.484
3.31	364154.00	OV	6.571
3.76	192575.00	VV	3.475
4.12	56727.70	VP	1.024
5.13	612168.00	PV	11.047
5.26	2965090.00	VV	37.265
5.21	168062.00	VB	3.033
7.23	28029.50	VV	0.351
8.60	49762.10	PV	0.897
9.06	46713.00	VB	0.843

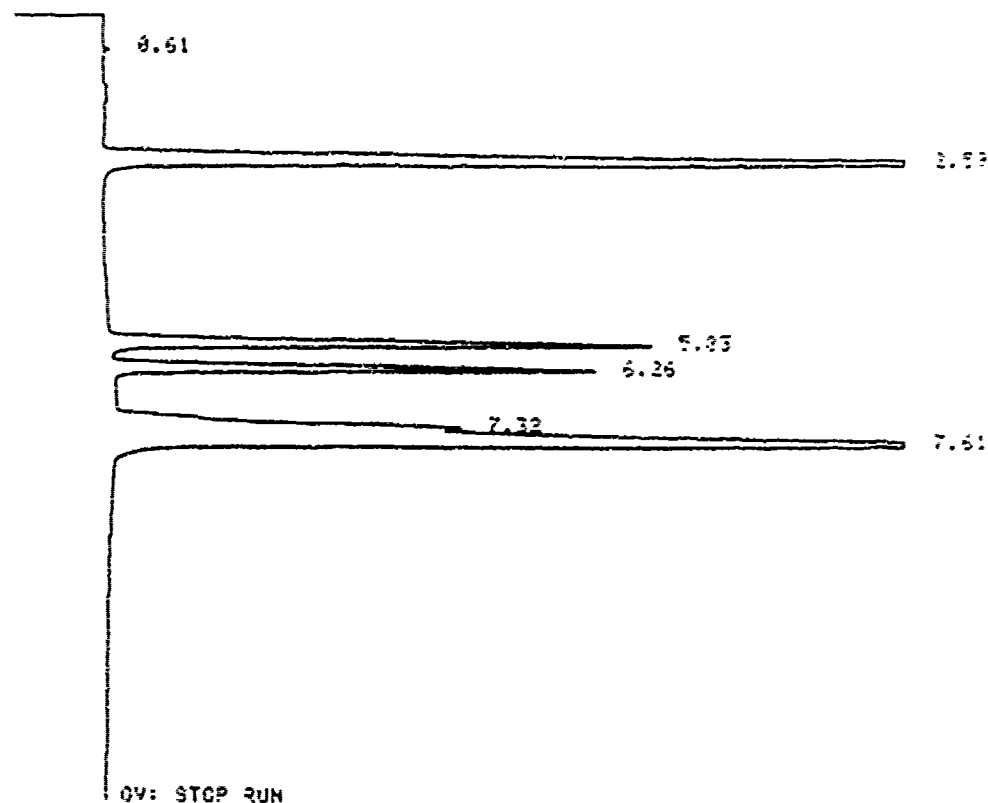
TOTAL AREA = 5541640.00

MULTIPLIER = 1

PAGE

Figure A16. Gas chromatogram: BMS-10-11K.

DEFT CHEMICAL COATINGS IS-143
MIL-T-81772/AS



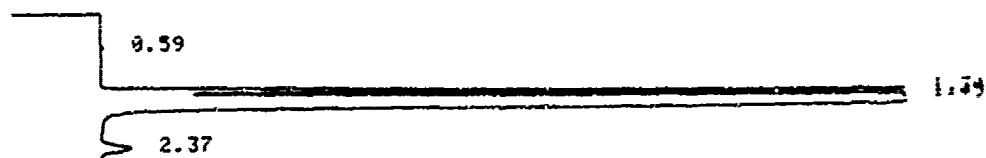
INJ 5680A MANUAL INJECTION @ 13:46 JUL 22, 1982
AREA %

RT	AREA	TYPE	AREA %
0.61	2397110.00	VB	28.140
2.59	1338190.00	HH	12.993
5.33	1063070.00	HH	10.374
6.26	1057630.00	HH	10.273
7.32	3954490.00	HH	38.215

TOTAL AREA = 10295400.00
MULTIPLIER = 1

Figure A17. Gas chromatogram: MIL-T-81772/AS thinner.

PENTANE



INSTR 5880A MANUAL INJECTION 9 15:59 OCT 25, 1982
AREA %

PT	AREA	TYPE	AREA %
----	------	------	--------

TOTAL AREA = 0.00
MULTIPLIER = 1

PAGE

Figure A18. Gas chromatogram: solvent used for preparing samples -- pentane.

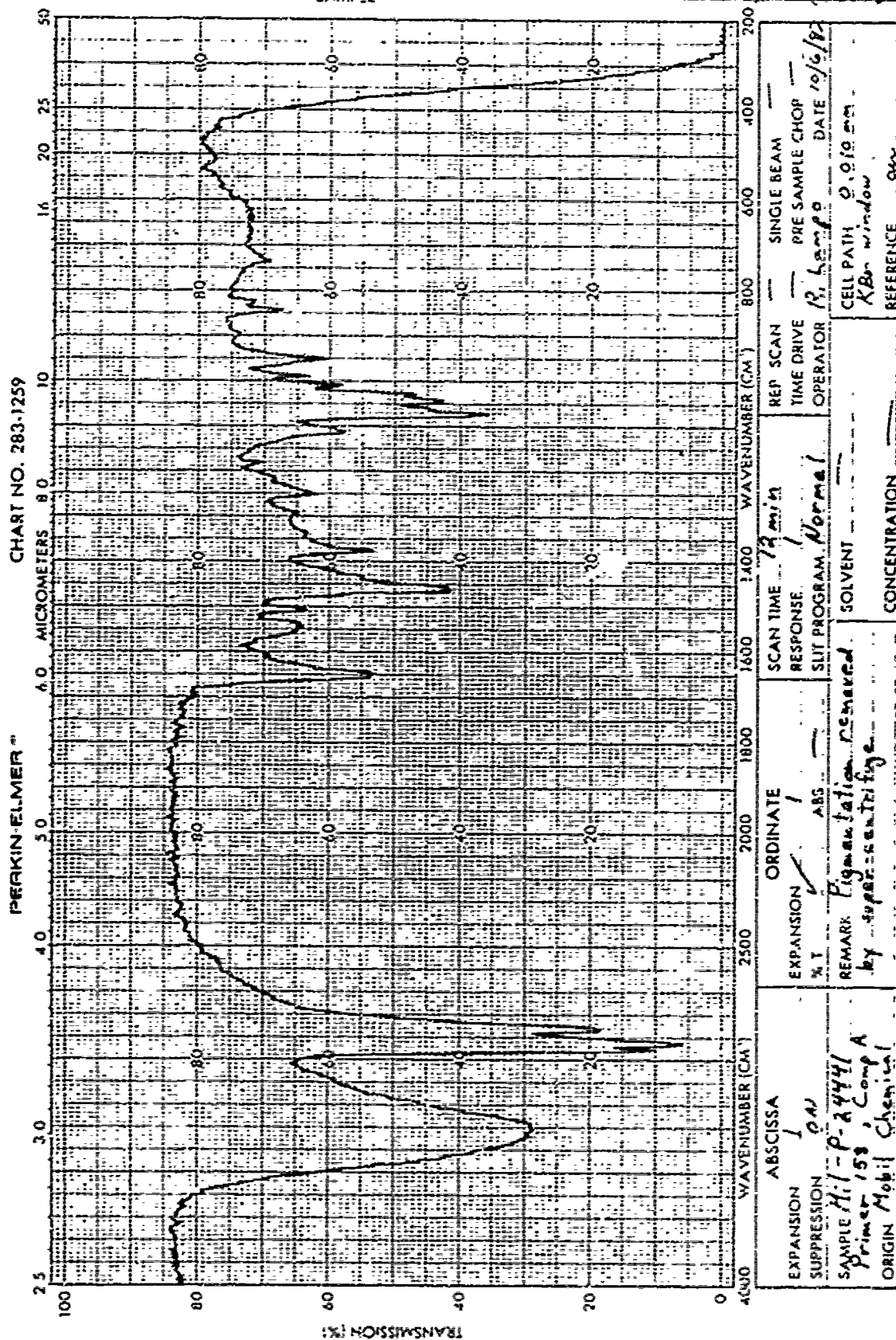
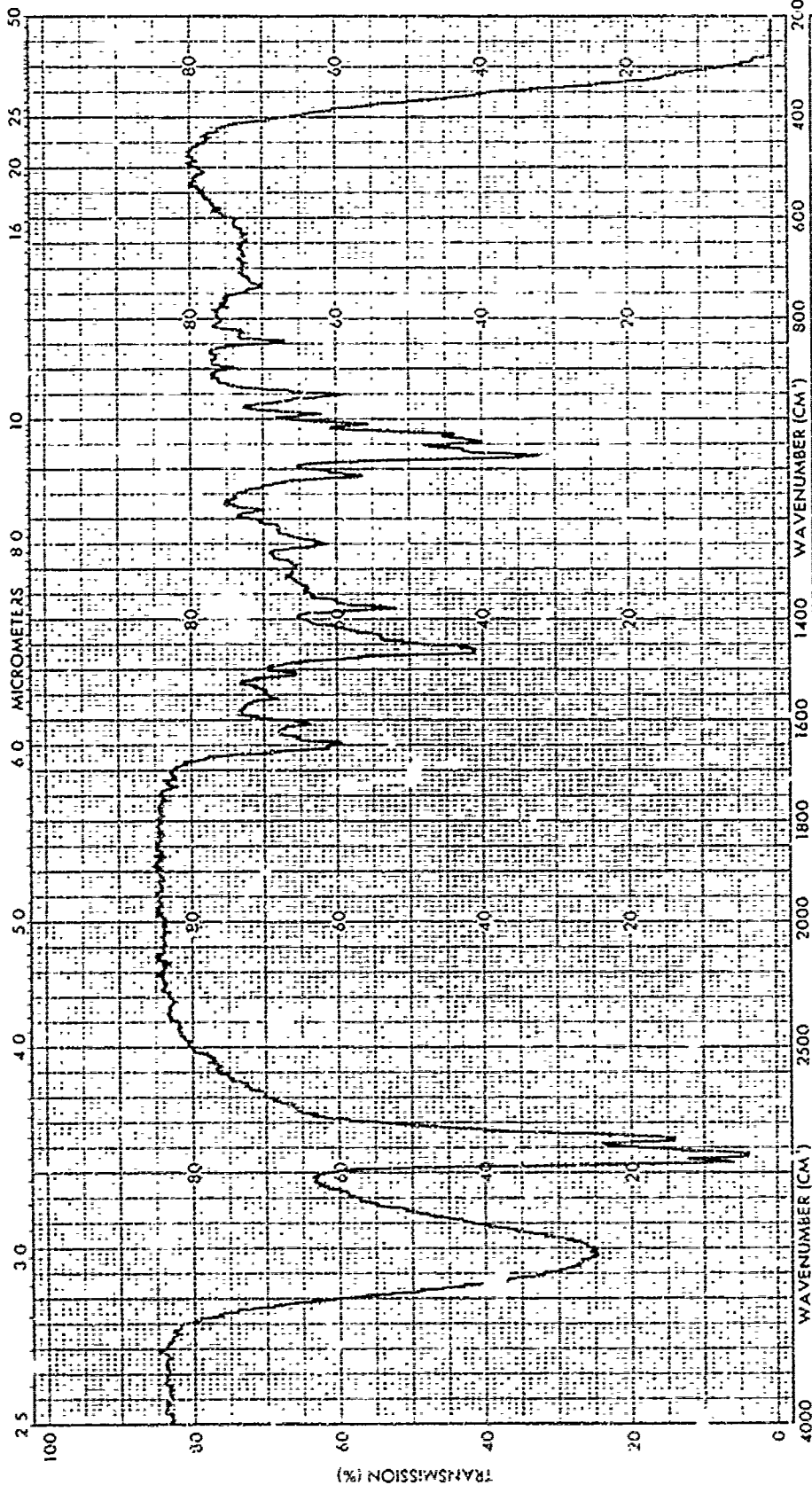


Figure A19. Infrared analysis: ML-P-24441 primer, component A.

CHART NO 283-1259

PERKIN ELMER



SAMPLE

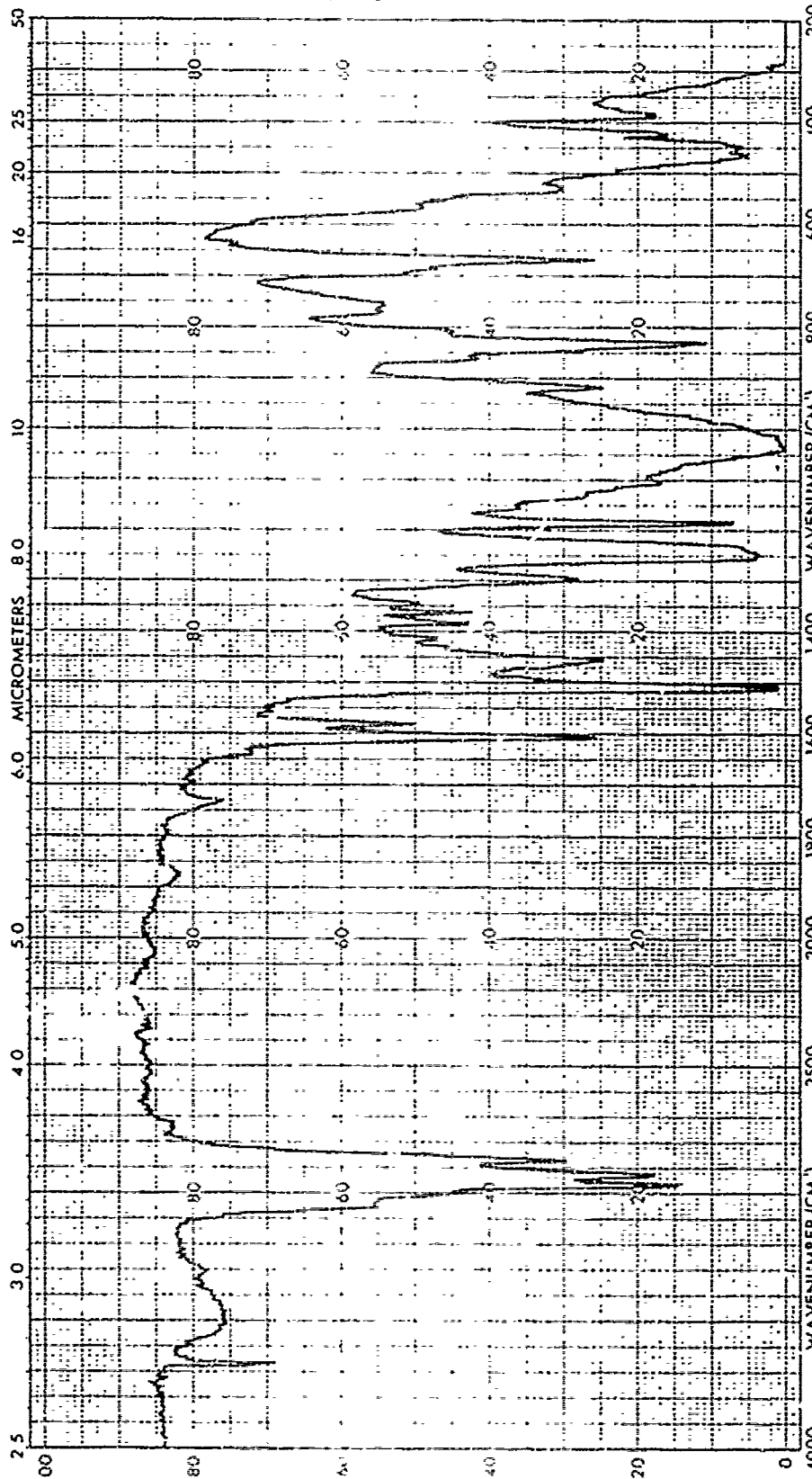
REF. NO NAVY II (E1521)

EXPANSION SUPPRESSION	ABSCISSA ON	EXPANSION % T	ORDINATE ABS	SCAN TIME 12 min	RESPONSE SUIT PROGRAM	REP. SCAN TIME DRIVE	SINGLE BEAM PRE SAMPLE CHOP
SAMPLE <u>MIL-P-24441</u> <u>Top coat 1:2, Comp A</u>		REMARKS <u>Pigmentation removed</u> <u>by supercentrifuge</u>		SOLVENT		OPERATOR <u>R. Lamps</u>	DATE <u>10/6/82</u>
ORIGIN <u>Mobil Chemical</u>		CONCENTRATION		CELL PATH <u>0.012 mm</u> <u>KBr window</u>		REFERENCE	

Figure A21. Infrared analysis: MIL-P-24441 topcoat, component A.

PERKIN ELMER #

CHART NO 283-1259



SAMPLE

REF NO NAVY II (E1522)

EXPANSION SUPPRESSION	ABSCISSA 1	ORDINATE EXPANSION % T	SCAN TIME 12 min	REP. SCAN TIME DRIVE	SINGLE BEAM PRE SAMPLE CHOP
SAMPLE MIL-P-24441 Topcoat 152, Comp B	REMARKS Sample compressed between salt plates	SOLVENT spacer used	SLIT PROGRAM Normal	OPERATOR R. L. Hays	DATE 10/7/82
ORIGIN Mobil Chemical		CONCENTRATION		CELL PATH KBr Window	REFERENCE an

Figure A22. Infrared analysis: MIL-P-24441 topcoat, component B.

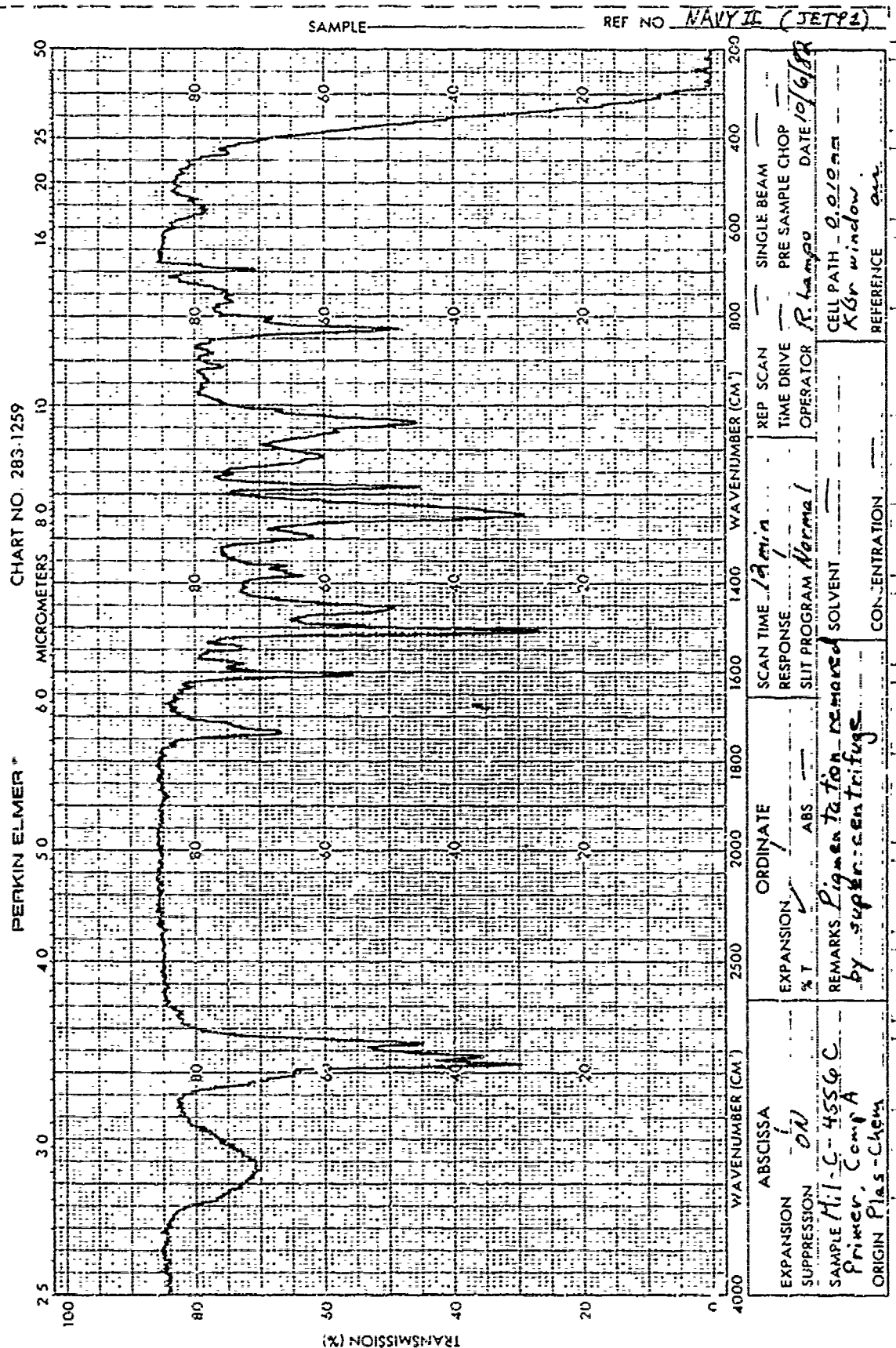


Figure A23. Infrared analysis: MIL-C-4556 primer, component A.

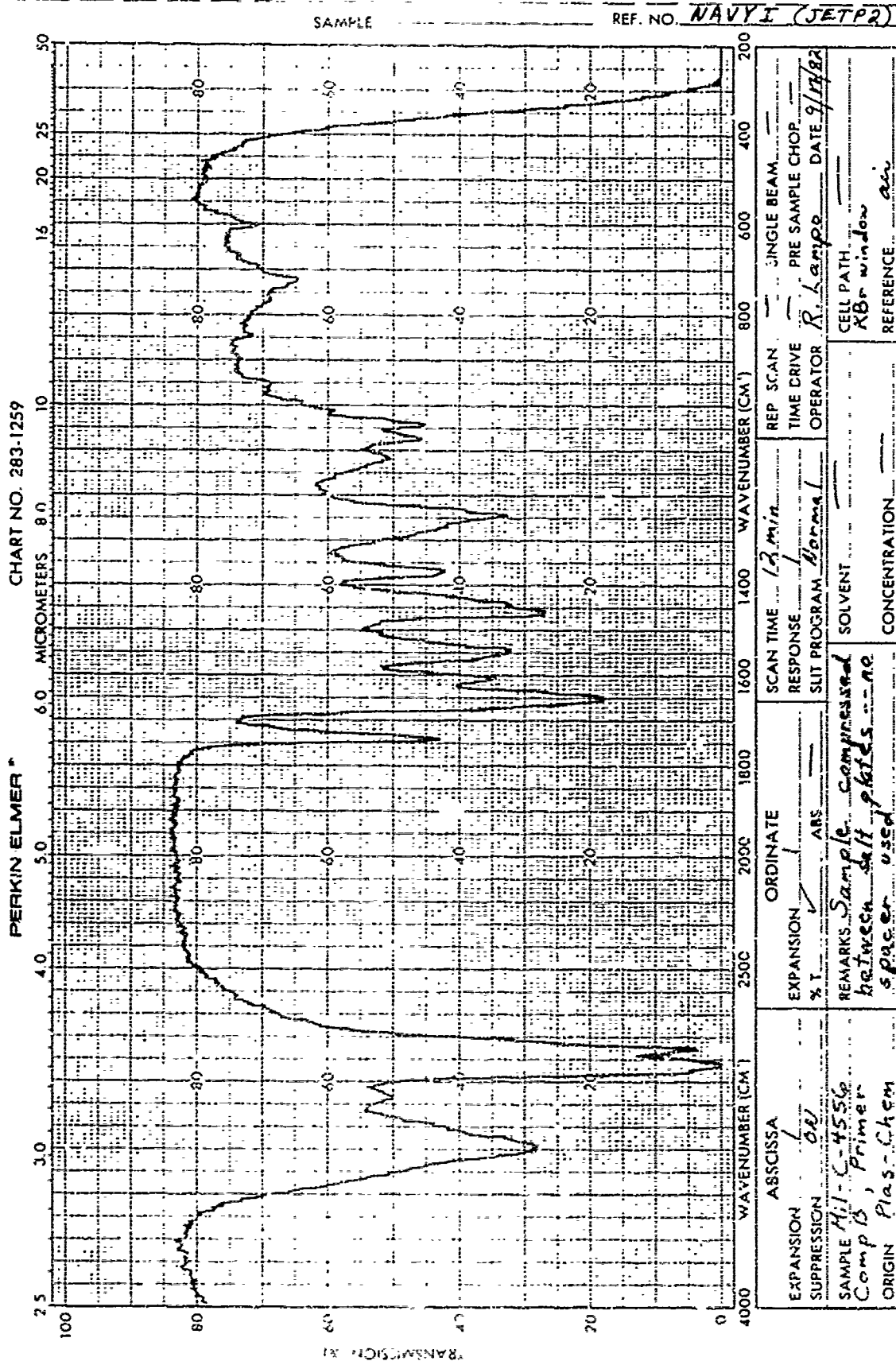


Figure A24. Infrared analysis: MIL-C-4556 primer, component B.

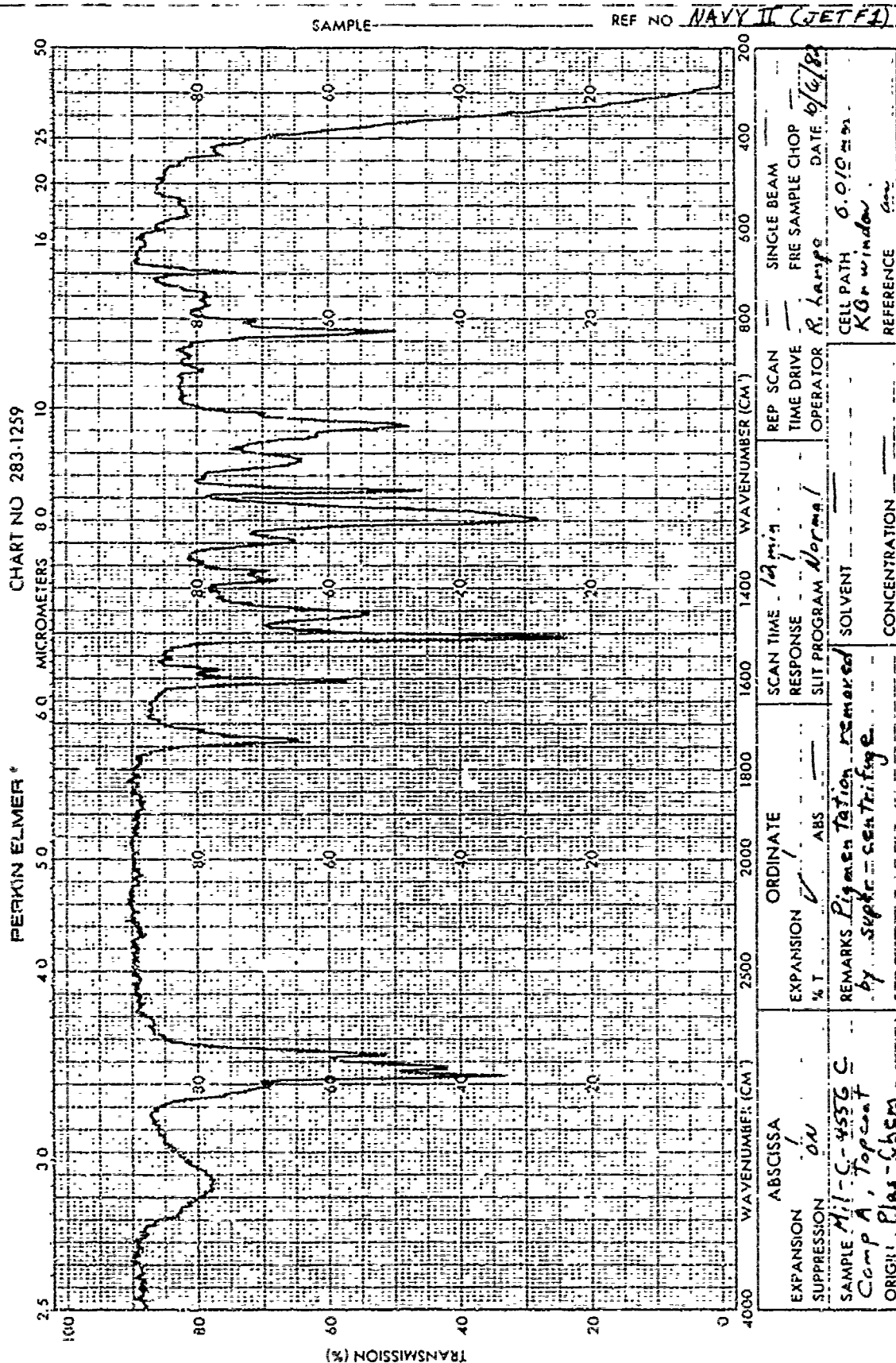
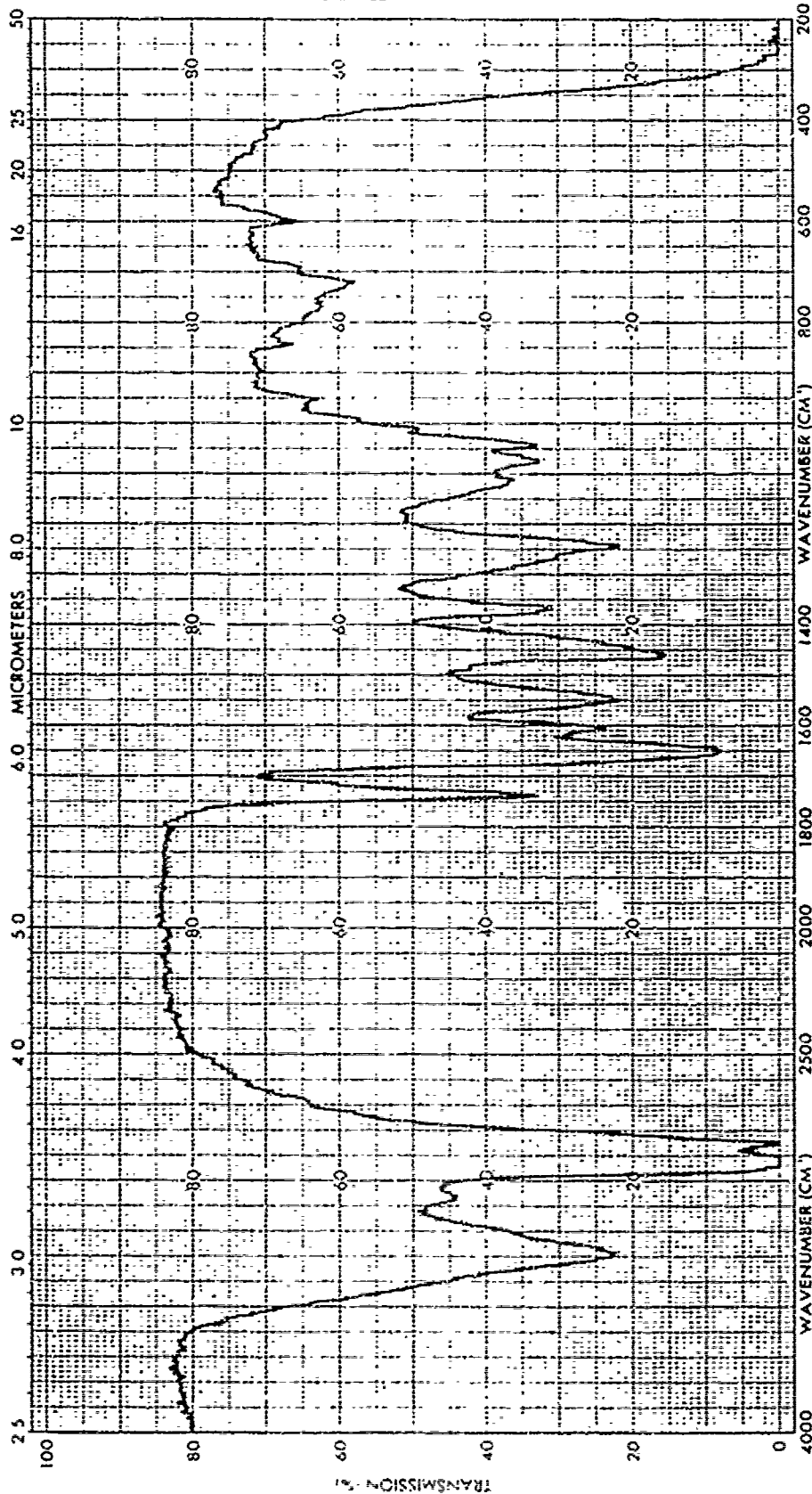


Figure A25. Infrared analysis: MIL-C-4556 topcoat, component A.

CHART NO. 283-1259

PERKIN ELMER "



SAMPLE

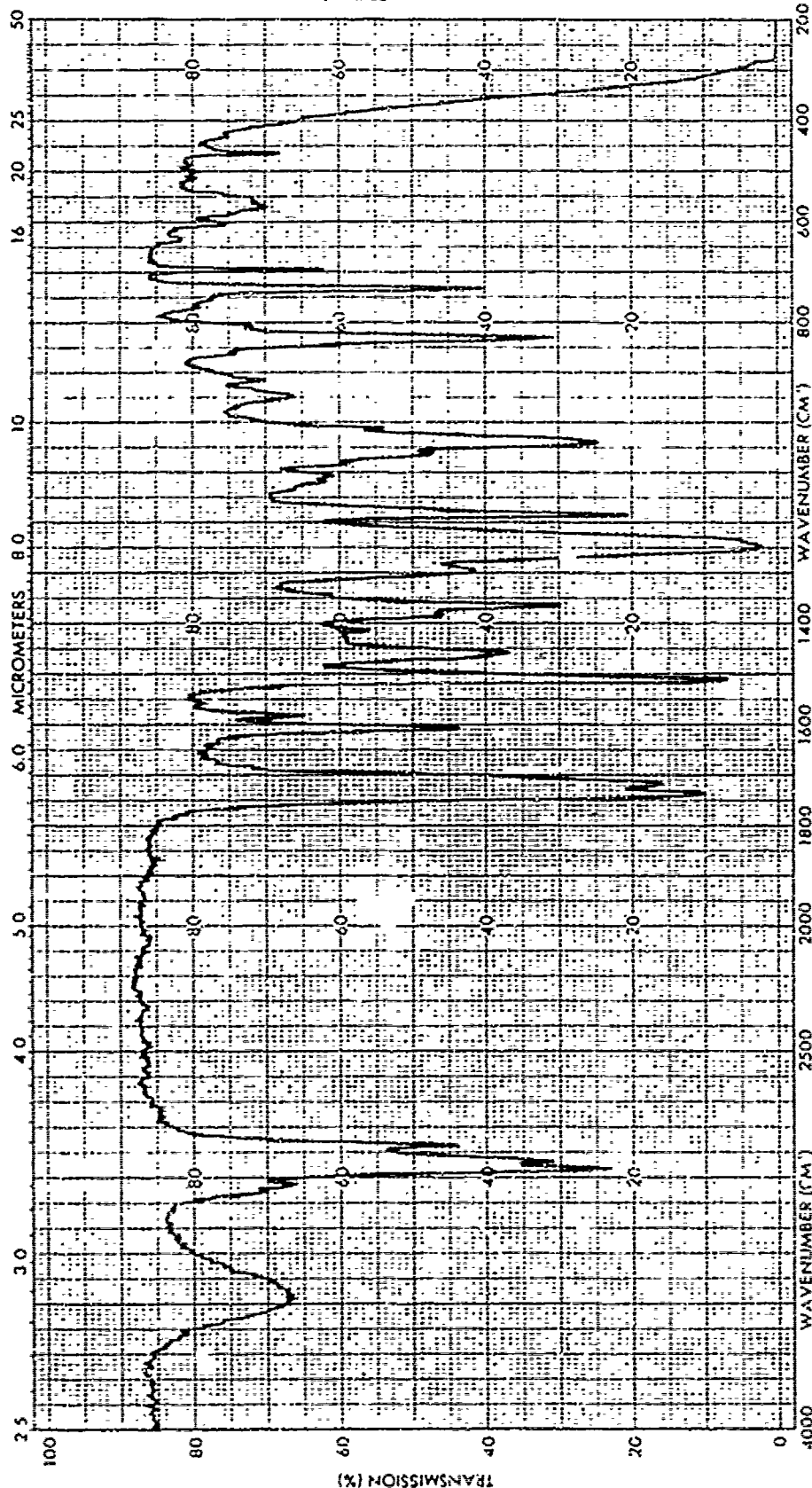
REF. NO. NAVY I (JETP2)

EXPANSION	ORDINATE	SCAN TIME	REP SCAN	SINGLE BEAM
SUPPRESSION <u>ON</u>	EXPANSION <u>1</u>	RESPONSE <u>1</u>	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE <u>MIL-C-4556</u>	% T <u>✓</u>	SPLIT PROGRAM <u>Normal</u>	OPERATOR <u>R. Lange</u>	DATE <u>9/15/82</u>
Compb, Topcoat	REMARKS <u>Sample compressed</u>	SOLVENT	CELL PATH	
ORIGIN <u>Plas-Chem</u>	<u>between salt plates</u>	CONCENTRATION	<u>KBr window</u>	
	<u>spacers used</u>		REFERENCE	<u>25%</u>

Figure A26. Infrared analysis: MIL-C-4556 topcoat, component B.

CHART NO 283-1259

PERKIN-ELMER



SAMPLE

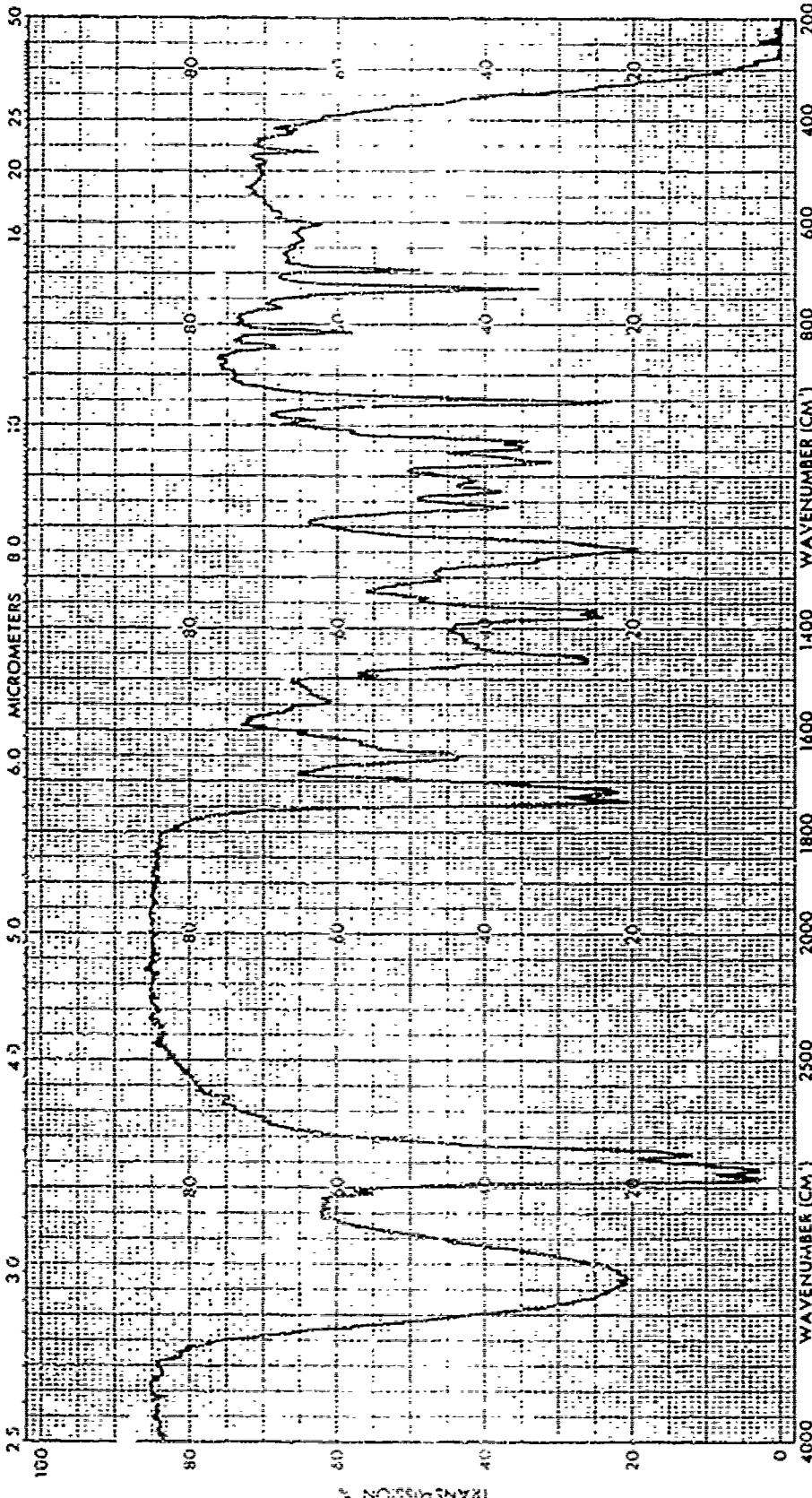
REF NO NAVY I (PRIM)

EXPANSION	ABSCISSA	ORDINATE	SCAN TIME	REP SCAN	SINGLE BEAM
SUPPRESSION	ON	ADS	12 min	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE	MIL-P-23377D	REMARKS	SUIT PROGRAM	OPERATOR	DATE
COMP	A, Type I	Pigmentation removed by super-centrifuge	Normal		9/1/62
ORIGIN	DEF COATINGS	SOLVENT	CONCENTRATION	CELL PATH	REFERENCE
				0.010 mm	KBr window
					air

Figure A27. Infrared analysis: MIL-P-23377, component A.

CHART NO. 283-1259

PERKIN ELMER



SAMPLE

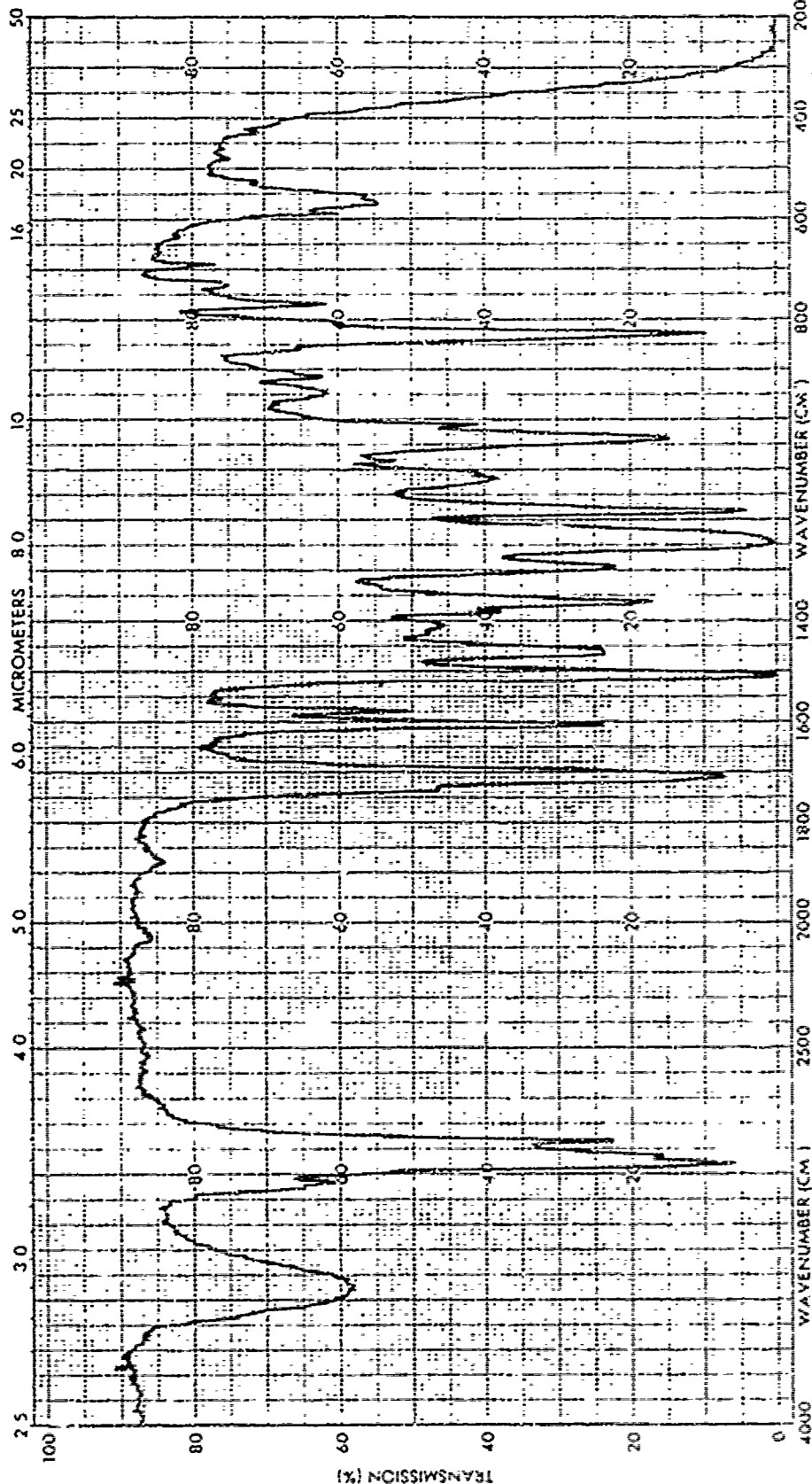
REF NO. NAVY I (PRIMA)

EXPANSION <u>1</u>	ORDINATE <u>1</u>	SCAN TIME <u>12 min</u>	REP SCAN <u>—</u>	SINGLE BEAM <u>—</u>
SUPPRESSION <u>ON</u>	% T <u>✓</u> — ABS <u>—</u>	RESPONSE <u>1</u>	TIME DRIVE <u>—</u>	PRE SAMPLE CHOP <u>—</u>
SAMPLE <u>MIL-P-23377D</u>	REMARKS <u>—</u>	SPLIT PROGRAM <u>Normal</u>	OPERATOR <u>R. L. Camp</u>	DATE <u>9/15/80</u>
ORIGIN <u>DEFT COATINGS</u>		SOLVENT <u>—</u>	CELL PATH <u>0.010 mm</u>	KBr window <u>—</u>
		CONCENTRATION <u>—</u>	REFERENCE <u>—</u>	

Figure A28. Infrared analysis: MIL-P-23377, component B.

CHART NO 283-1259

PERKIN-ELMER *



SAMPLE

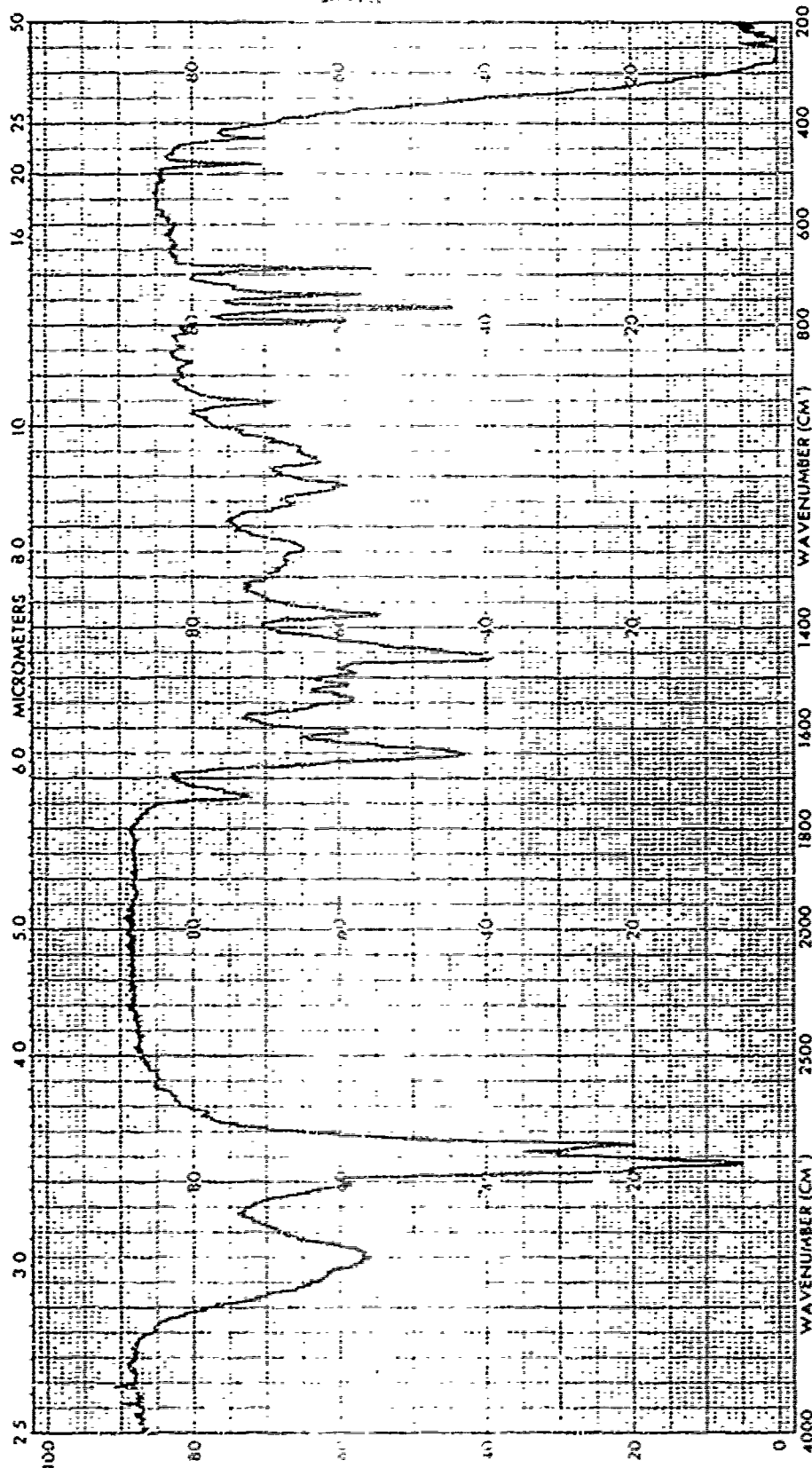
REF NO NAVY II (EPOXI)

EXPANSION SUPPRESSION <u>ON</u>	ABSCISSA <u>1</u>	ORDINATE <u>1</u>	EXPANSION % T <u>✓</u>	ABSORBANCE <u>ABS</u>	SCAN TIME RESPONSE <u>12 min</u>	REP SCAN TIME DRIVE	SINGLE BEAM
SAMPLE <u>M.I.-C-22750</u>	COMP A	REMARKS <u>Polymerization initiated by super-centrifuge</u>	SLIT PROGRAM <u>Normal</u>	SOLVENT	OPERATOR <u>R. Lang</u>	PRE SAMPLE CHOP	DATE <u>9/28/82</u>
ORIGIN <u>Chemrex Coatings</u>			CONCENTRATION		CELL PATH <u>2.010 mm</u>	REFERENCE	

Figure A29. Infrared analysis: MII-C-22750, component A.

CHART NO. 283.1259

PERKIN ELMER®



SAMPLE

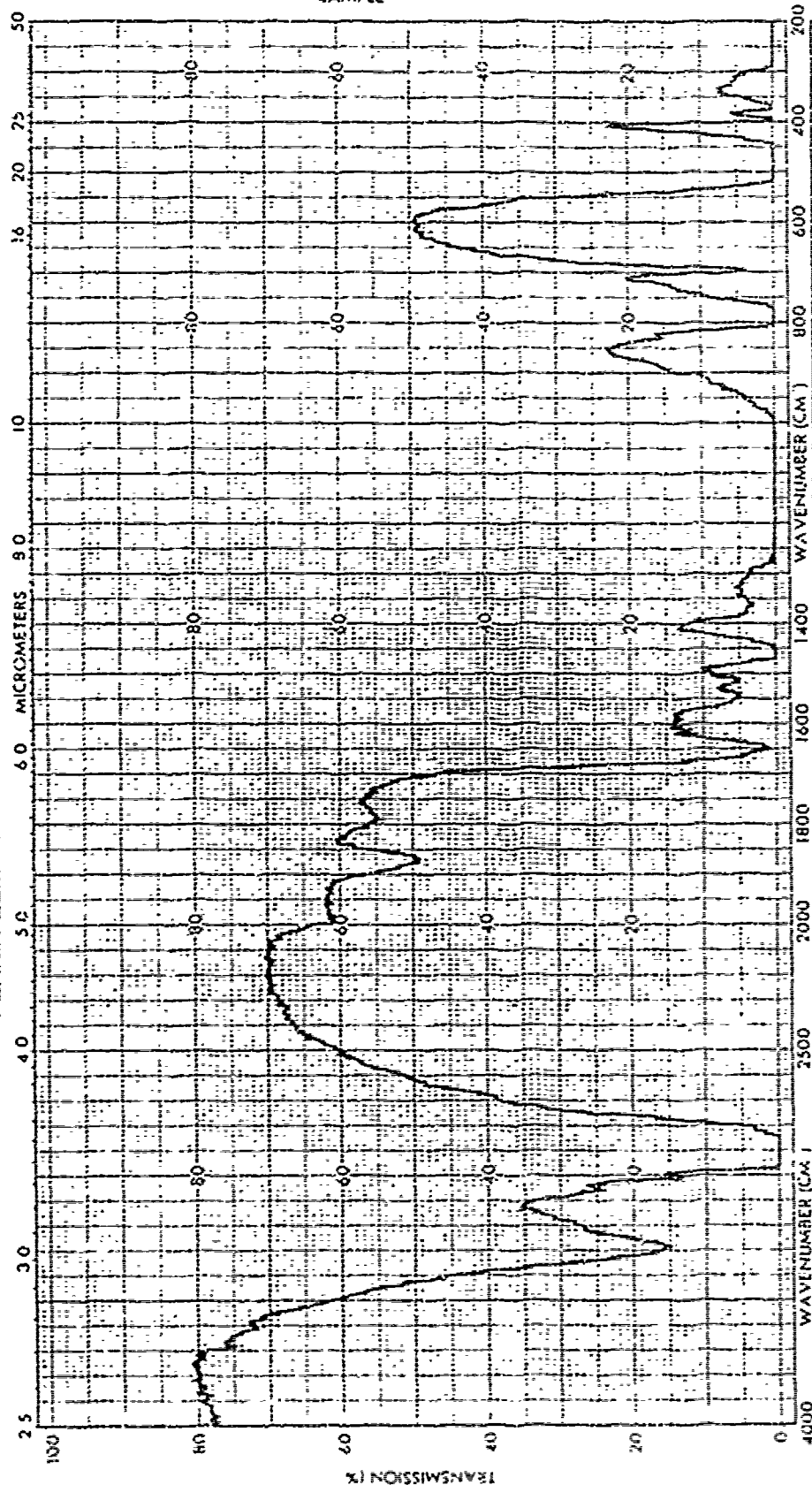
REF NO. NAVY II (EPOX2)

EXPANSION	ABSCISSA	ORDINATE	SCAN TIME / μ min	REP SCAN	SINGLE BEAM
SUPPRESSION <u>ON</u>		EXPANSION <u>1</u>	RESPONSE <u>1</u>	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE <u>MIL-C-22250</u>		% T <u>✓</u>	SPLIT PROGRAM <u>Normal</u>	OPERATOR <u>R. Kamps</u>	DATE <u>10/6/52</u>
ORIGIN <u>Chemres Coatings</u>		REMARKS <u>Pigmentation removed by super-centrifuge</u>	SOLVENT	CELL PATH <u>0.010 cm</u>	REFERENCE <u>KBr window</u>
			CONCENTRATION		

Figure A30. Infrared analysis: MIL-C-22250, component B.

CHART NO. 283-1259

PERKIN ELMER *



SAMPLE

REF NO. NAVY III (STLC1)

EXPANSION SUPPRESSION	ABSCISSA ON	ORDINATE /	SCAN TIME RESPONSE	REP SCAN TIME DRIVE	SINGLE BEAM PRE SAMPLE CHOP
SAMPLE 100% Solids Epoxy Comp Steelcote	REMARKS	EXPANSION % T	SLIT PROGRAM Normal	OPERATOR R. Lange	DATE
			SOLVENT	CELL PATH 0.010mm	REFERENCE
			CONCENTRATION		

Figure A31. Infrared analysis: Steelcote 100 percent solids epoxy, component A.

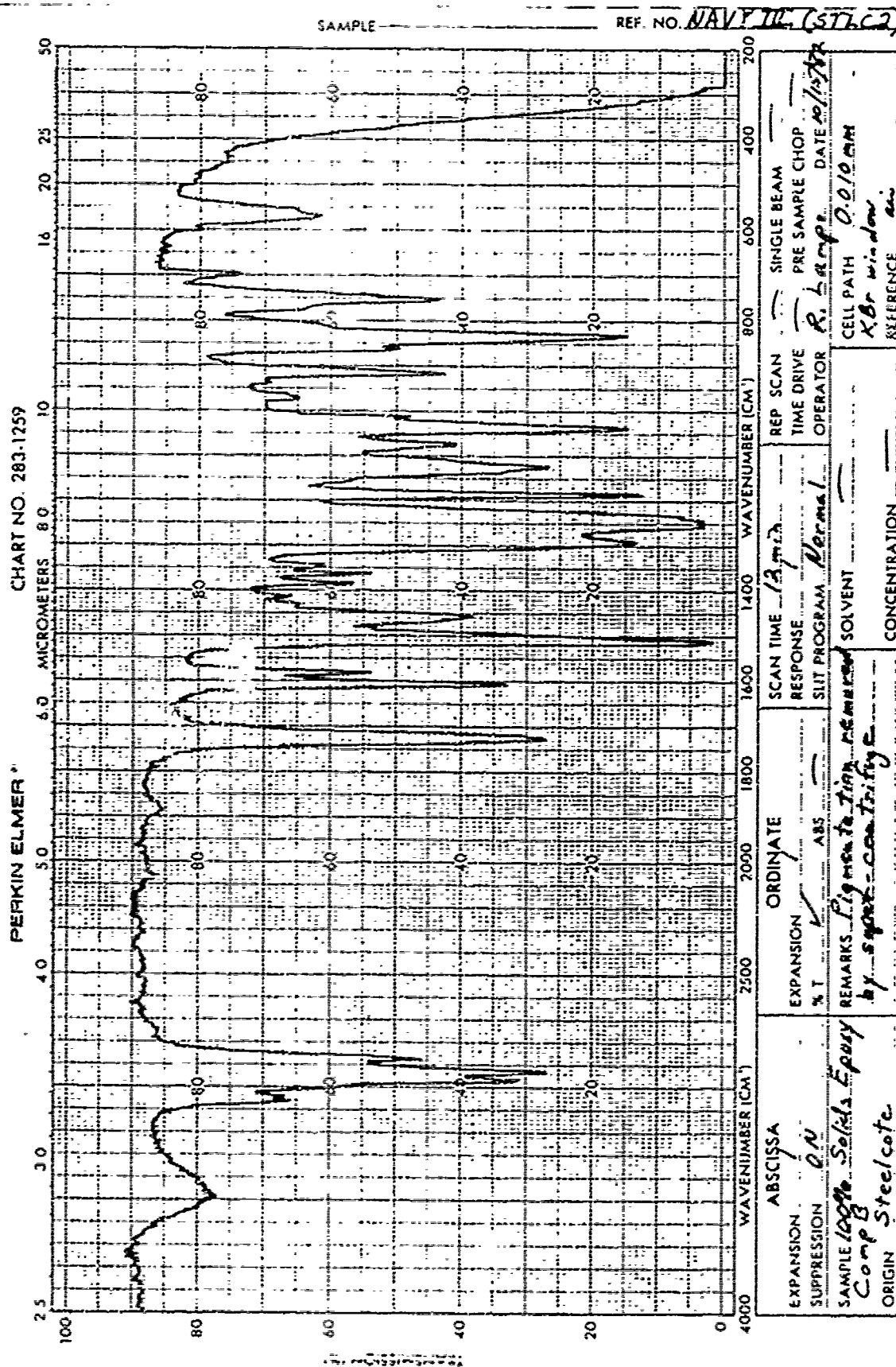
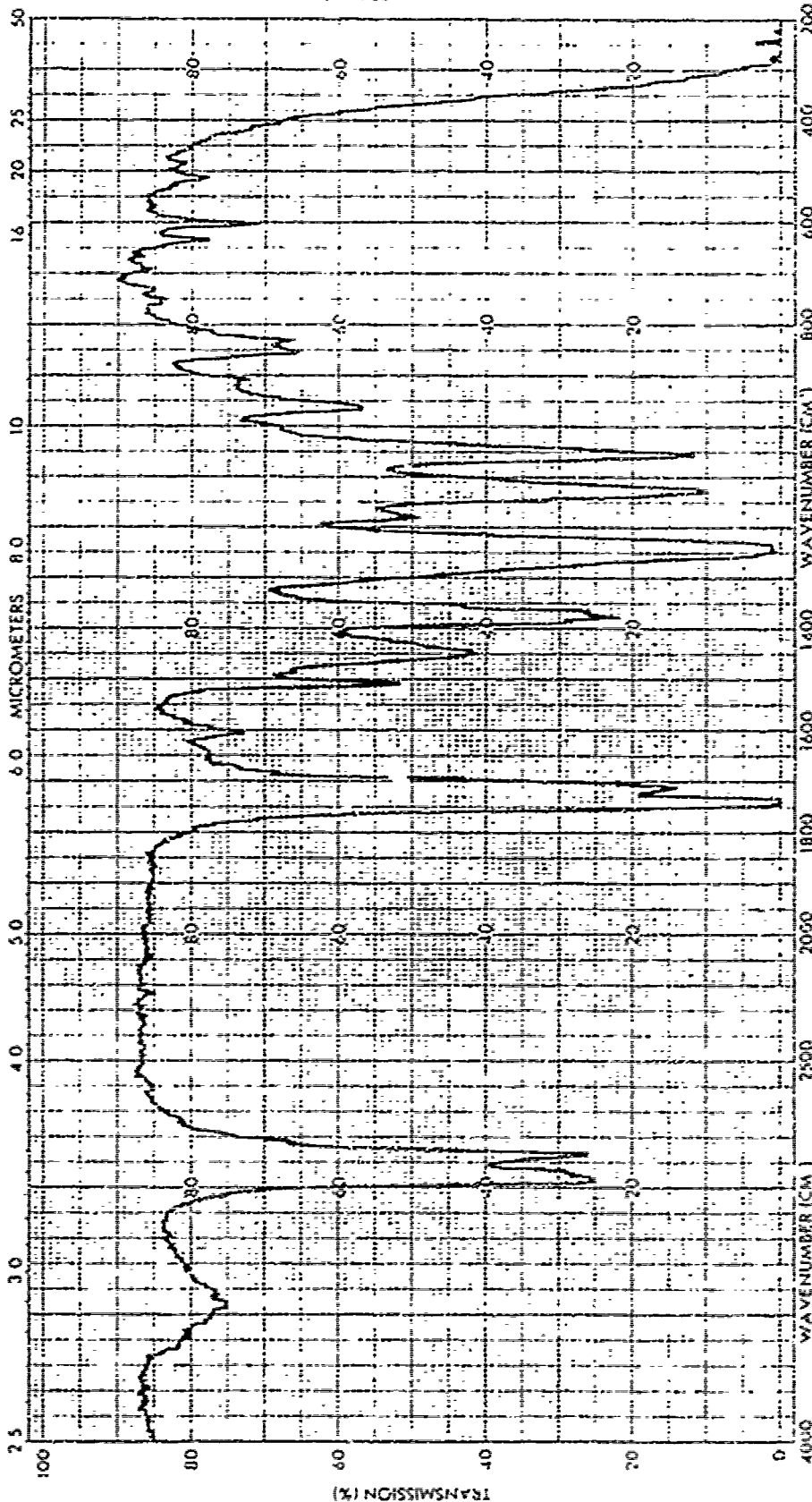


Figure A12. Infrared analysis: Steelcote 100 percent solids epoxy, component B.

CHART NO. 283-1259

PERKIN ELMER *



SAMPLE

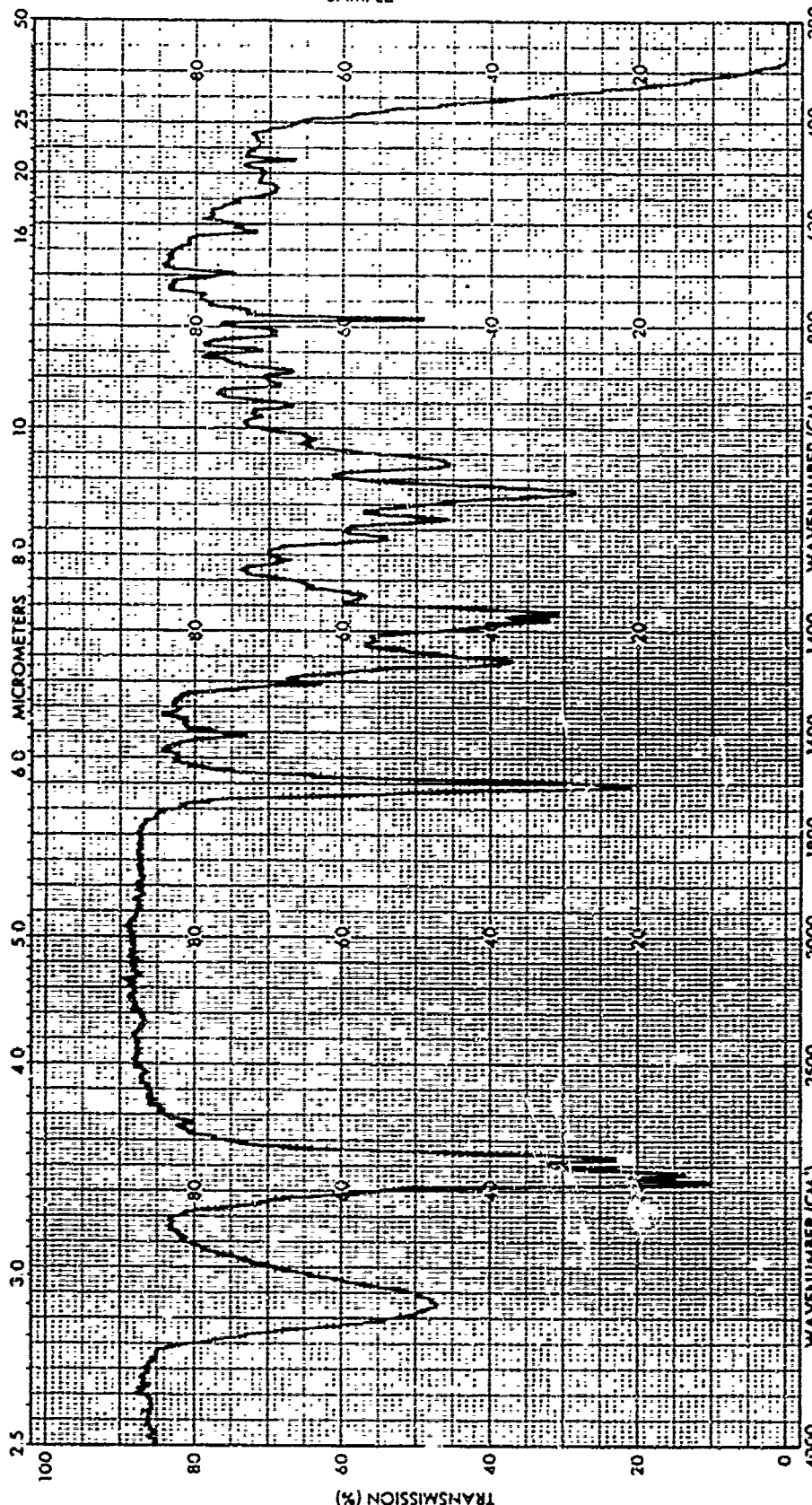
REF NO *NAVY I (AMR86)*

EXPANSION SUPPRESSION		ABSCISSA ON		EXPANSION % T		ORDINATE ABS		SCAN TIME RESPONSE		REP SCAN		SINGLE BEAM	
SAMPLE Ameron 86, Primer		Remarks Pigmentation removed by super-centrifuge.		CONCENTRATION		SLIT PROGRAM Normal		TIME DRIVE		OPERATOR R. Lamp		DATE 9/29/82	
ORIGIN Ameron Coatings												CELL PATH 0.010 mm	
												XBr window	
												REFERENCE	

Figure A33. Infrared analysis: Amercoat 86, liquid, pigment removed.

CHART NO. 283-1259

PERKIN-ELMER *



SAMPLE

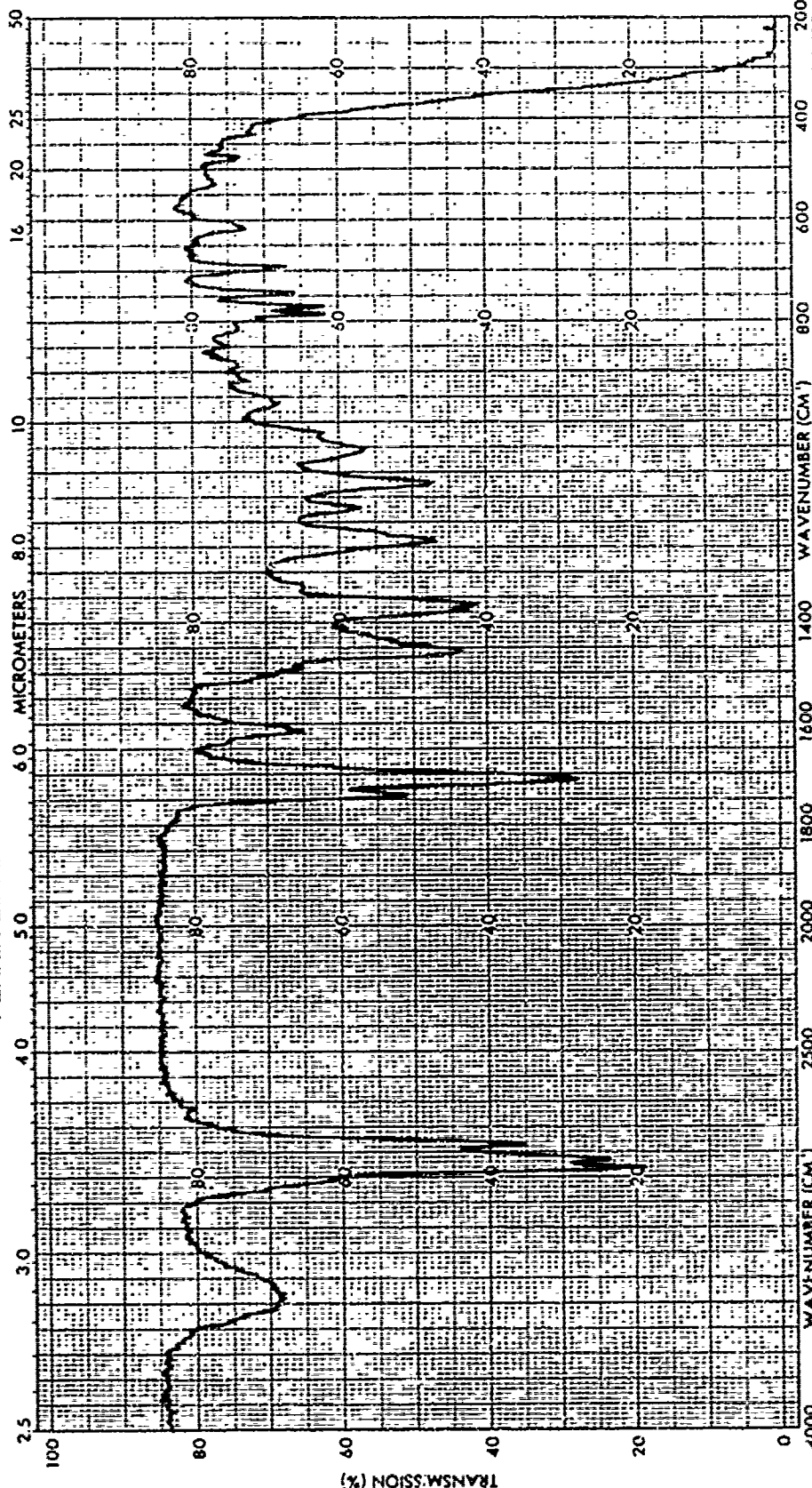
REF. NO. NAVY (THING)

EXPANSION		ORDINATE		SCAN TIME <u>12 min</u>		REP. SCAN		SINGLE BEAM	
SUPPRESSION <u>ON</u>		EXPANSION <u>1</u>		RESPONSE <u>Normal</u>		TIME DRIVE		PRE SAMPLE CHOP	
SAMPLE <u>Amercoat #6 thinner</u>		REMARKS		SLIT PROGRAM <u>Normal</u>		OPERATOR <u>R. Longo</u>		DATE <u>10/13/68</u>	
ORIGIN <u>Amercoat Coatings</u>				SOLVENT		CELL PATH <u>0.010 mm</u>		KBr window	
				CONCENTRATION		REFERENCE		gas	

Figure A34. Infrared analysis: Amercoat 6 thinner.

CHART NO 283.1259

PERKIN ELMER



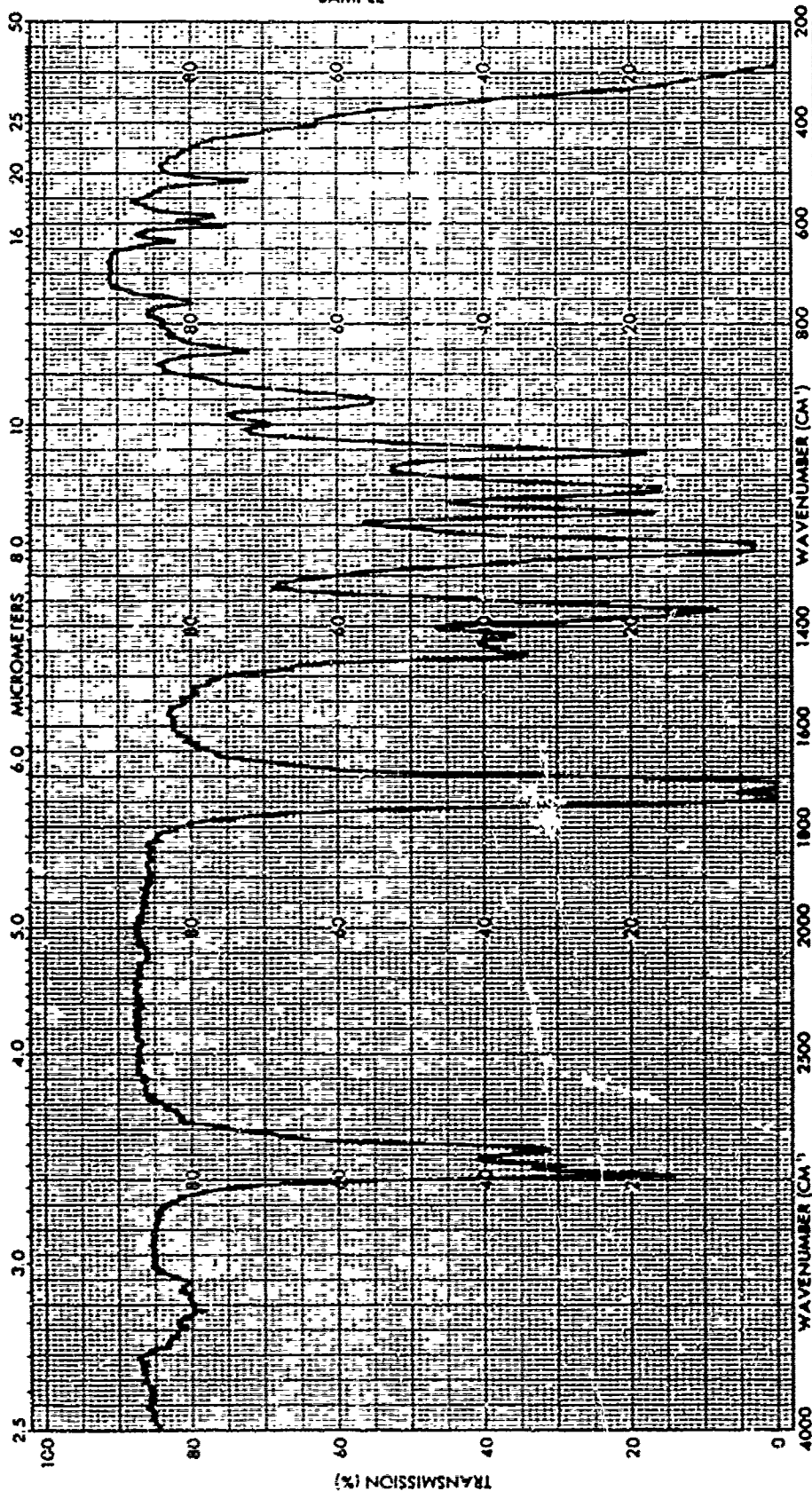
SAMPLE _____ REF NO NAVY I (AME 99)

EXPANSION SUPPRESSION	ABSCISSA 1 cm	ORDINATE 1 %	EXPANSION % T	SCAN TIME 12 min	RESPONSE 1	REP. SCAN 1	SINGLE BEAM 1
SAMPLE <u>Ameron 99 HS</u>						TIME DRIVE 1	PRE SAMPLE CHOP 1
ORIGIN <u>Ameron Coatings</u>						OPERATOR <u>R. Lamp</u>	DATE <u>7/29/82</u>
						SOLVENT	CELL PATH <u>0.010 mm</u>
						REMARKS <u>Pigmentation removed by super-centrifuge</u>	REFERENCE <u>KBr window</u>
						CONCENTRATION	

Figure A35. Infrared analysis: Amercoat 99HS, liquid, pigment removed.

CHART NO. 283-1259

PERKIN-ELMER *



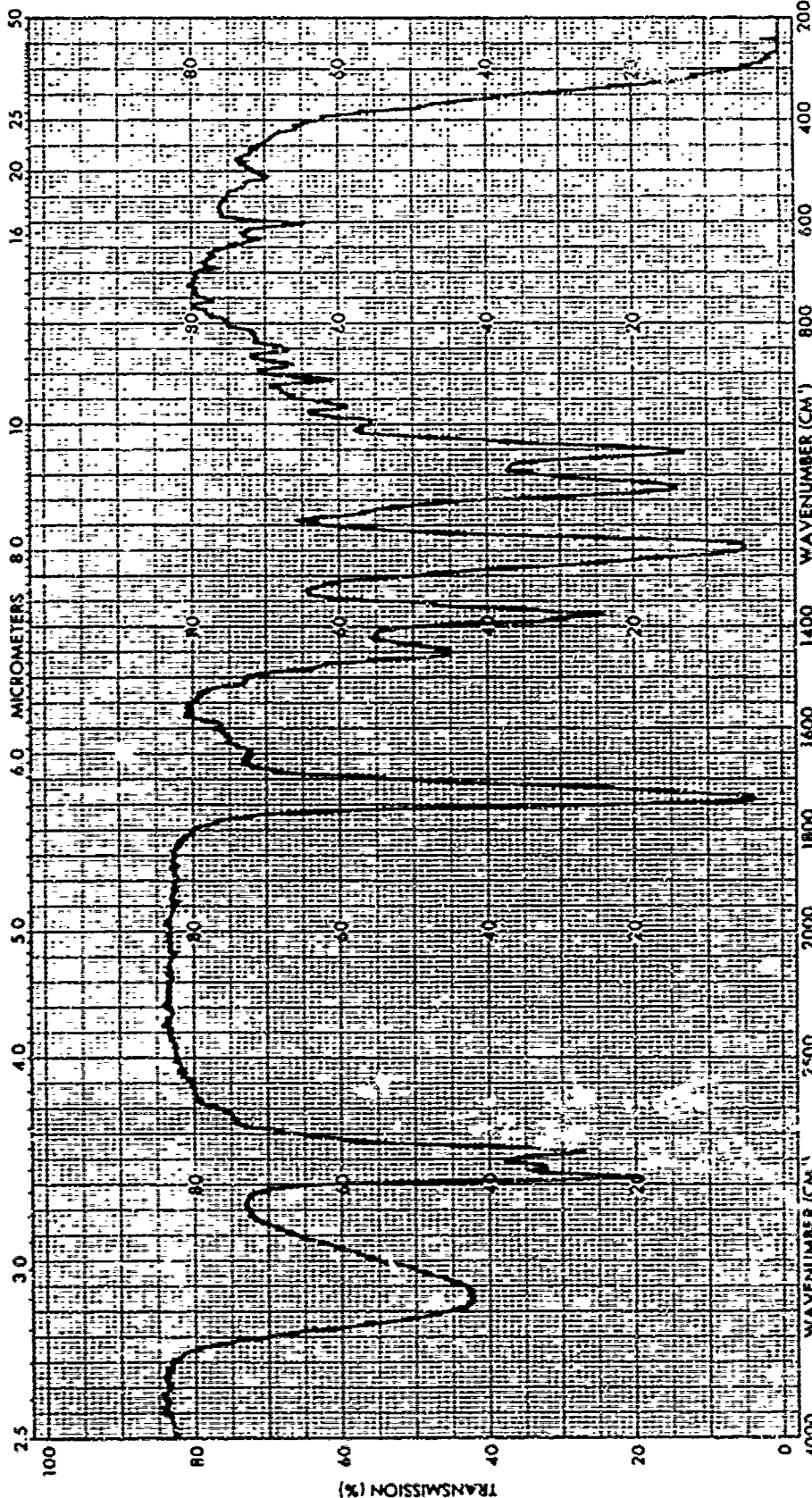
SAMPLE _____ REF. NO. NAVY IV (THIN 9)

EXPANSION _____		ORDINATE _____		SCAN TIME <u>16 min</u>		REP. SCAN _____	
SUPPRESSION <u>ON</u>		EXPANSION <u>ABS</u>		RESPONSE <u>Normal</u>		TIME DRIVE _____	
SAMPLE <u>Amercoat #9</u>		REMARKS _____		SOLVENT _____		OPERATOR <u>R. Lamp</u>	
ORIGIN <u>American Coatings</u>		CONCENTRATION _____		CELL PATH <u>0.010 mm</u>		DATE <u>10/13/68</u>	
				REFERENCE <u>13 Br window</u>			

Figure A36. Infrared analysis: Amercoat 9 thinner.

CHART NO 283-1259

PERKIN ELMER



SAMPLE

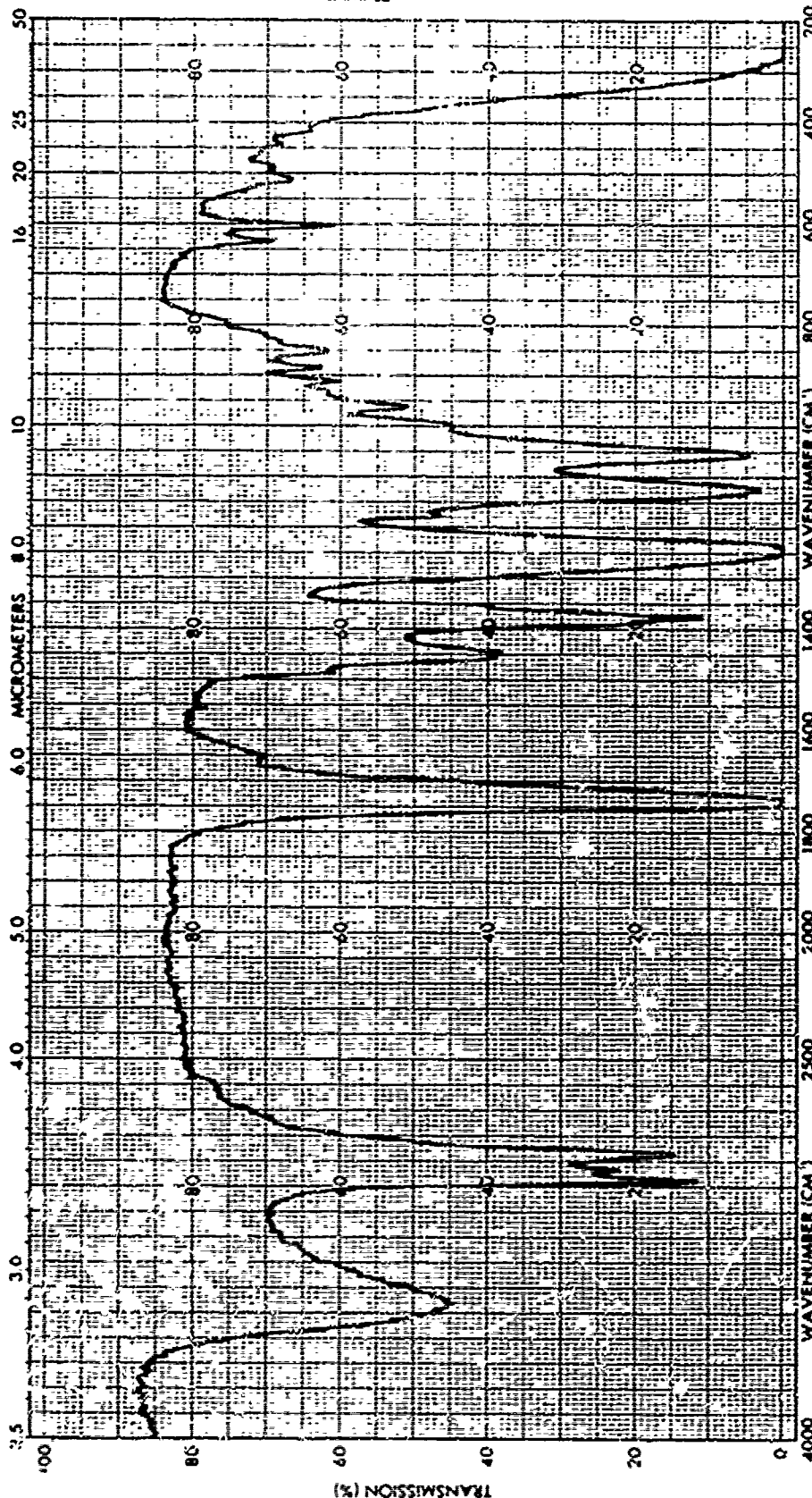
REF. NO. NAVY II (WPRI)

EXPANSION	ABSCISSA	ORDINATE	SCAN TIME	REP. SCAN	SINGLE BEAM
SUPPRESSION	EXPANSION	RESPONSE	TIME DRIVE	PRE SAMPLE CHOP	
	% T	ABS.	SPLIT PROGRAM	OPERATOR	DATE
SAMPLE	REMARKS		SOLVENT	CELL PATH	
TS 3236-26A	Wash Primer			KBr window	
ORIGIN	CONCENTRATION		REFERENCE		
Hughson	Chemical				

Figure A37. Infrared analysis: Hughson TS 3236-26 wash primer, component A.

CHART NO. 283-1259

PERKIN-ELMER *



SAMPLE

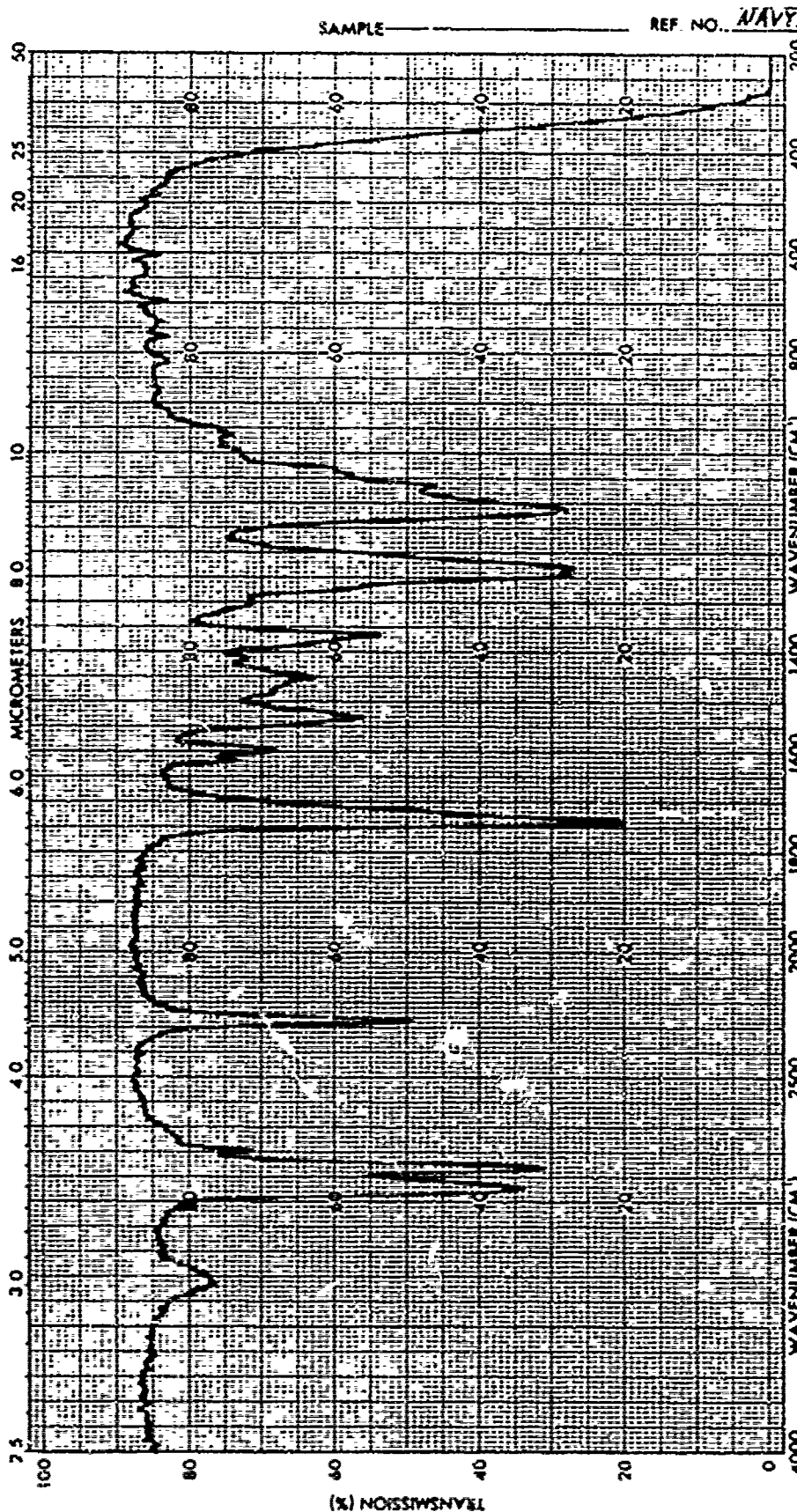
REF. NO. NAVY III (WPRI2)

EXPANSION	ORDINATE	REF. SCAN	SINGLE BEAM
SUPPRESSION	EXPANSION	TIME DRIVE	PRE SAMPLE CHOP
	% T	OPERATOR	DATE
SAMPLE <u>Line thone Wash Primer</u>	REMARKS	SOLVENT	CELL PATH <u>0.010 mm</u>
TS 3236-26, Comp B		CONCENTRATION	REFERENCE
ORIGIN <u>Hughson Chemical</u>			

Figure A38. Infrared analysis: Hughson TS 3236-26 wash primer, component B.

CHART NO 283-1259

PERKIN-ELMER



SAMPLE

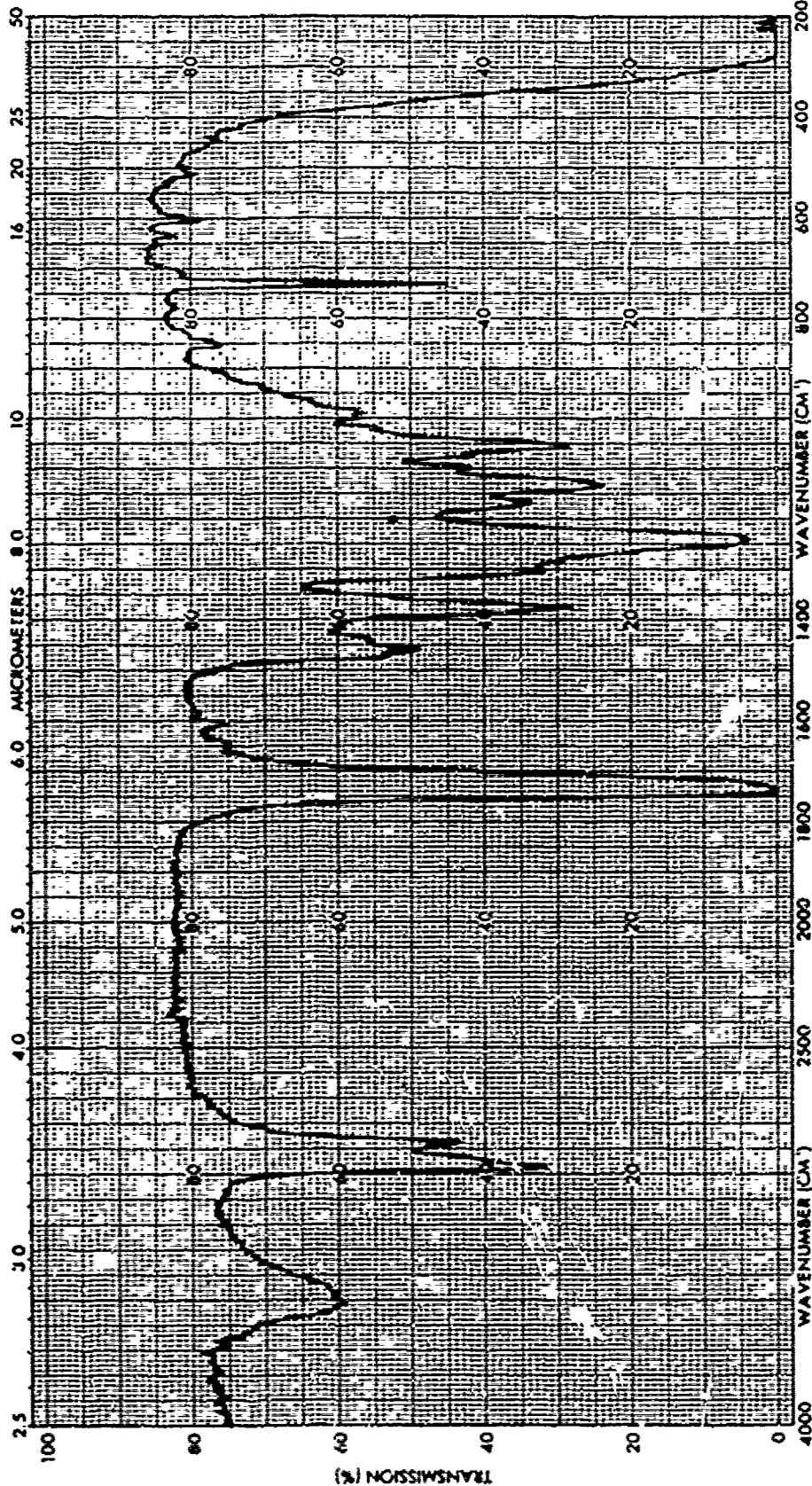
REF. NO. NAVY III (URET)

EXPANSION	ABSCISSA	ORDINATE	EXPANSION	SCAN TIME	REP SCAN	SINGLE BEAM
SUPPRESSION	OR	ABS.	% T	RESPONSE	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE <u>Urethane Topcoat</u>		REMARKS <u>Polymerization removed</u>		SLIT PROGRAM	OPERATOR	DATE
TS 3236-23, Comp A		by <u>supplc-contr-fuge</u>		SOLVENT	CELL PATH	0.010 mm
ORIGIN <u>Hughson Chemical</u>		CONCENTRATION		REFERENCE	XBw window	

Figure A39. Infrared analysis: Hughson TS 3236-23 topcoat, component A.

CHART NO. 283.1259

PERKIN-ELMER *



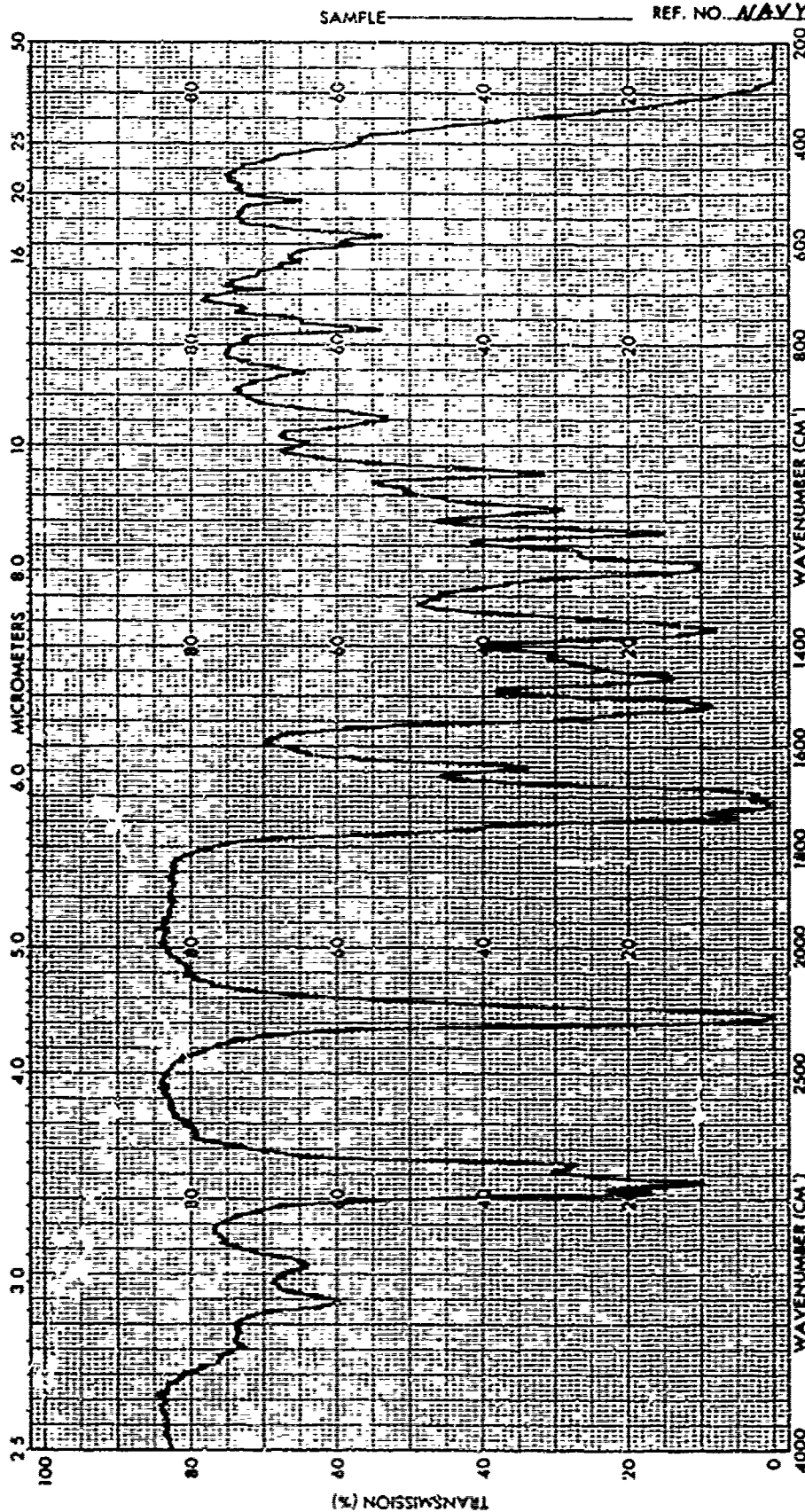
SAMPLE

REF. NO. NAVY III (POLY3)

EXPANSION	ORDINATE	SCAN TIME	REP SCAN	SINGLE BEAM
SUPPRESSION	EXPANSION	RESPONSE	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE <u>MIL-C-83286 B</u>	% T	SPLIT PROGRAM	OPERATOR	DATE
Comp I	REMARKS <u>Pigmentation removed</u>	SOLVENT	CELL PATH	0.010 mm
ORIGIN <u>DEFT COATINGS</u>	by <u>separ-centrifuge</u>	CONCENTRATION	REFERENCE	KBr window

Figure A41. Infrared analysis: MIL-C-83286, component I.

PERKIN-ELMER • CHART NO. 283-1259



SAMPLE

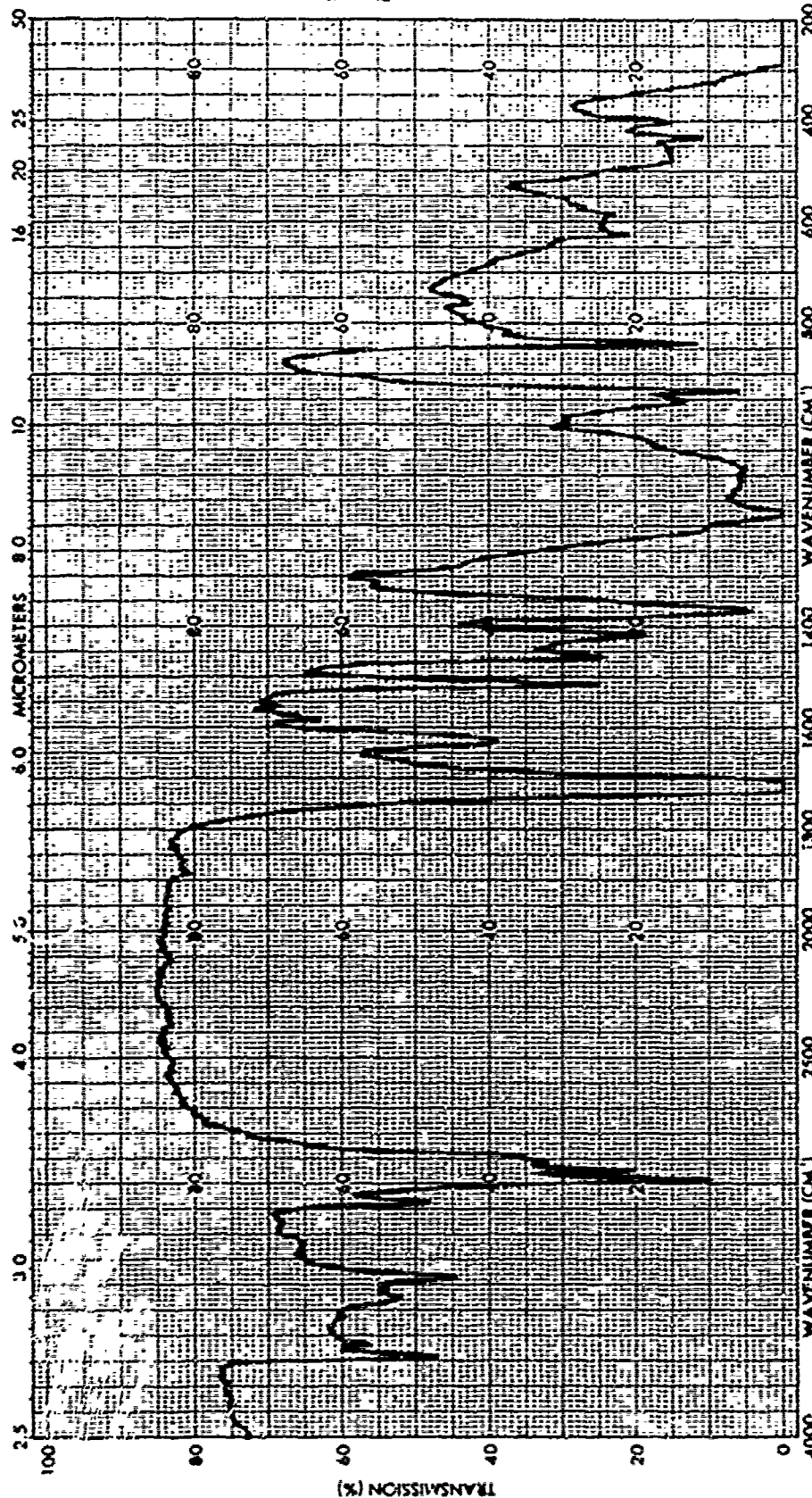
REF. NO. NAVY I (POLY 2)

EXPANSION <u>10</u>		ORDINATE		SCAN TIME <u>12 min</u>		REP SCAN <u>—</u>		SINGLE BEAM <u>—</u>	
SUPPRESSION <u>ON</u>		EXPANSION <u>1</u>		RESPONSE		TIME DRIVE		PRE SAMPLE CHOP	
SAMPLE <u>MIL-C-83286 G</u>		ABS <u>—</u>		SLIT PROGRAM <u>Normal</u>		OPERATOR <u>R. L. Raper</u>		DATE <u>2/14/62</u>	
ORIGIN <u>DEFT COATINGS</u>		REMARKS		SOLVENT		CELL PATH <u>0.010 mm</u>		REFERENCE <u>air</u>	
				CONCENTRATION					

Figure A42. Infrared analysis: MIL-C-83286, component II.

CHART NO. 283-1259

PERKIN ELMER



SAMPLE

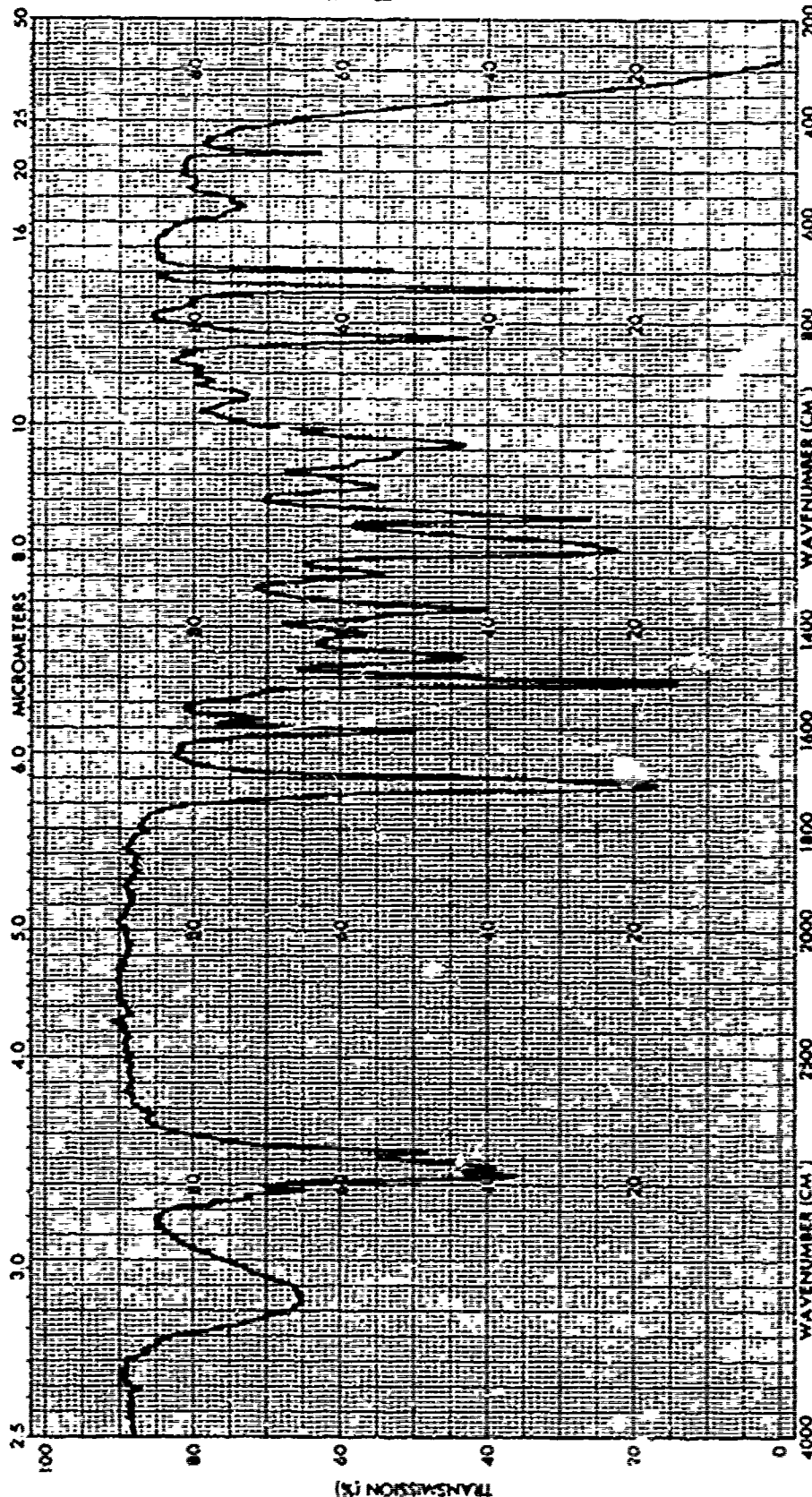
REF. NO. NAVY III (UC155)

EXPANSION <u>ON</u>		ORDINATE		SCAN TIME <u>12 min</u>		REF. SCAN		SINGLE BEAM	
SUPPRESSION <u>ON</u>		EXPANSION <u>1</u>		RESPONSE <u>1</u>		TIME DRIVE		PRE SAMPLE CHOP	
SAMPLE <u>Irathane 155</u>		% T <u>✓</u>		SPLIT PROGRAM <u>Normal</u>		OPERATOR <u>R. Campo</u>		DATE <u>10/13/82</u>	
Comp A (UC155)		REMARKS		SOLVENT		CELL PATH <u>2.010 cm</u>		KBr window	
ORIGIN <u>Irathane Systems</u>		CONCENTRATION		CONCENTRATION		REFERENCE		REF. NO.	

Figure A43. Infrared analysis: Irathane 155, component A.

CHART NO. 283-1259

PERKIN-ELMER*



TRANSMISSION (%)

SAMPLE

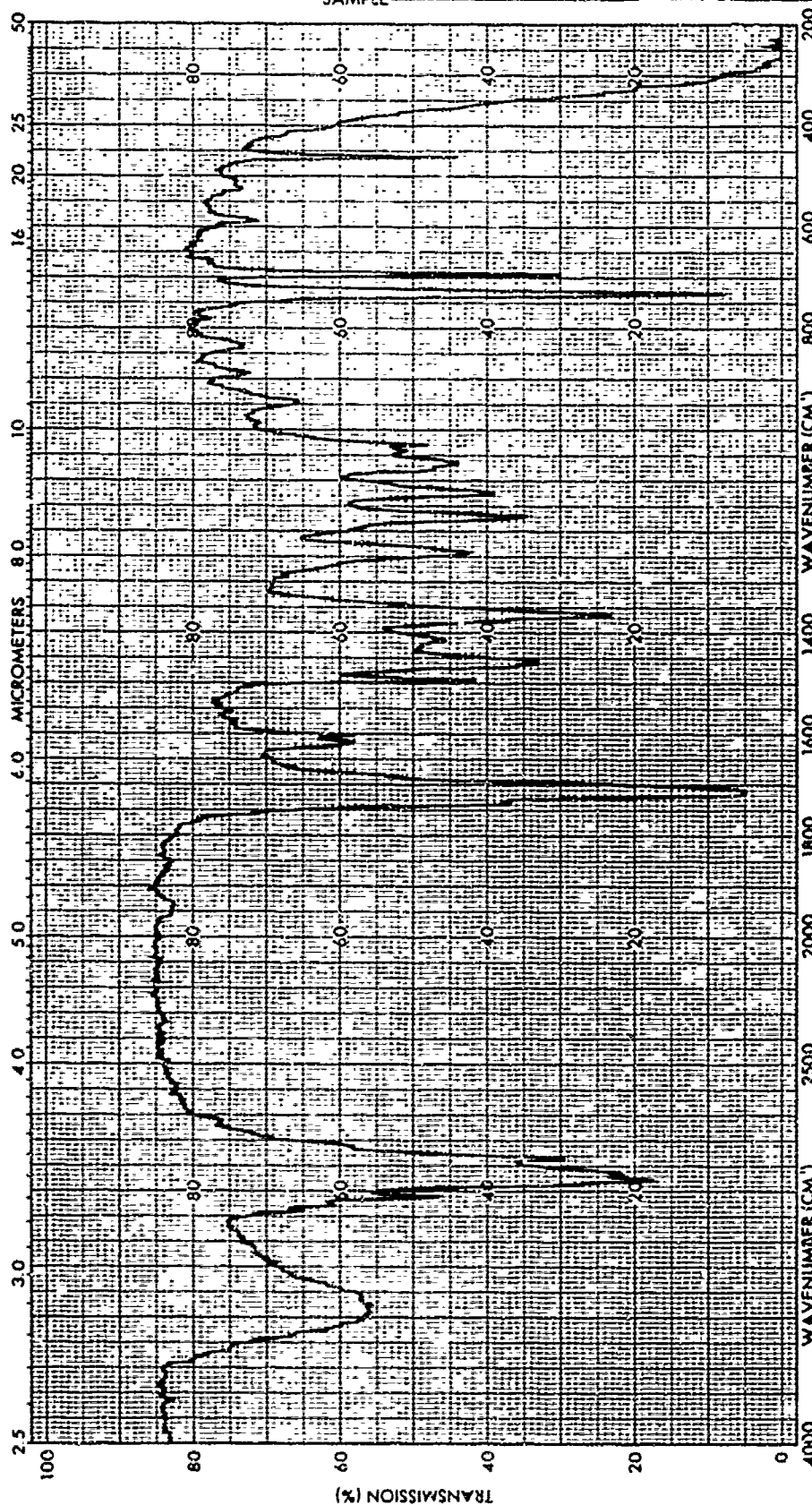
REF. NO. VAVY III (GRENZ)

EXPANSION SUPPRESSION	ABSCISSA W	ORDINATE EXPANSION % T	SCAN TIME RESPONSE	REP SCAN TIME DRIVE	SINGLE BEAM PRE SAMPLE CHOP
SAMPLE BARRIER, 50% W (GMS-10-11K), Comp A	REMARKS Pigmentating - 50% w/w by super-centrifuge	ABS.	SLIT PROGRAM Normal	OPERATOR R. Lampo	DATE 10/13/62
ORIGIN DEFT COATINGS			SOLVENT	CELL PATH KBr window	REFERENCE
			CONCENTRATION		

Figure A45. Infrared analysis: BMS-10-11K, component A.

CHART NO. 283-1259

PERKIN-ELMER



SAMPLE

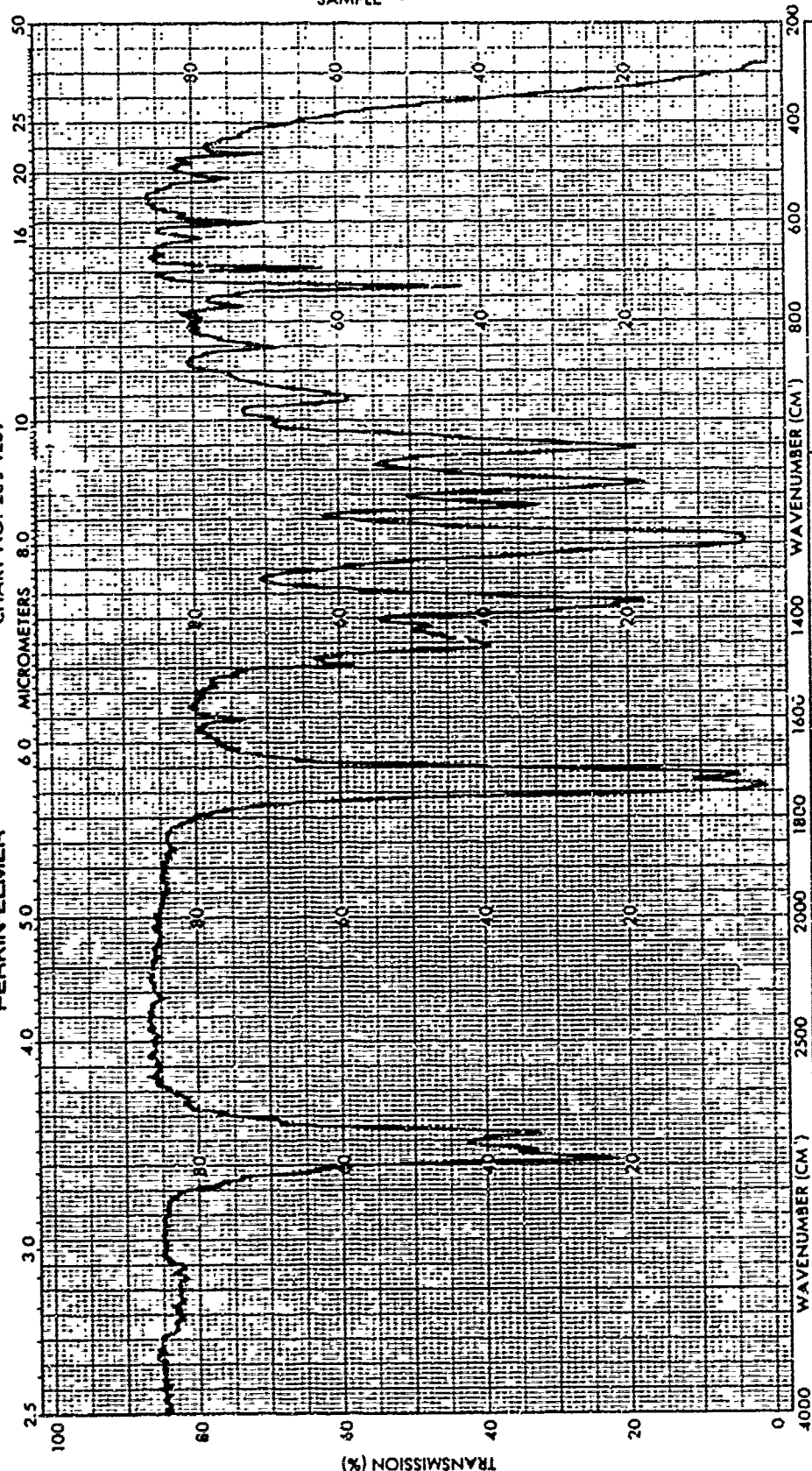
REF. NO. NAVY I (B00N2)

EXPANSION	ORDINATE	SCAN TIME	REP. SCAN	SINGLE BEAM
SUPPRESSION <u>DN</u>	EXPANSION <u>% T</u>	RESPONSE <u>12 min</u>	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE <u>Boeing Spec #</u>	REMARKS	SLIT PROGRAM <u>Normal</u>	OPERATOR <u>R. Lampe</u>	DATE <u>7/16/82</u>
ORIGIN <u>DEFT COATINGS</u>		SOLVENT	CELL PATH <u>0.010 mm</u>	REFERENCE <u>KBr window</u>
		CONCENTRATION		

Figure A46. Infrared analysis: BMS-10-11K, component B.

CHART NO. 283-1259

PERKIN-ELMER *



SAMPLE

REF. NO. NAVY (THIN)

EXPANSION	ABSCISSA	ORDINATE	REP. SCAN	SINGLE BEAM
SUPPRESSION	EXPANSION	EXPANSION	TIME DRIVE	PRE SAMPLE CHOP
SAMPLE	% T	ABS	OPERATOR	DATE
MIL-T-81772 THIN	REMARKS	SOLVENT	CELL PATH	0.010 mm
ORIGIN	DEFT	CONCENTRATION	REF. WINDOW	REFERENCE

Figure A47. Infrared analysis: MIL-T-81772/AS thinner.

APPENDIX B:

ADDITIONAL VENDOR INFORMATION

MATERIAL SAFETY DATA SHEET

FOR COATINGS, RESINS AND RELATED MATERIALS

GSF

(Approved by U.S. Department of Labor "Essentially Similar" to Form OSHA-308)

Section I

MANUFACTURER'S NAME Mobile Paint Mfg. Co., Inc. DATE OF PREP 02/16/83

STREET ADDRESS P. O. Box 717 CITY, STATE, AND ZIP CODE Theodore, AL. 36590

EMERGENCY TELEPHONE NO (205) 653-0110 PRODUCT CLASS Catalyst

INFORMATION TELEPHONE NO (205) 653-0110

MANUFACTURER'S CODE IDENTIFICATION 35-EF-51 TRADE NAME MIL-P-24441/2A, 3A, 4A, 5A, 6A
Component B

Section II—HAZARDOUS INGREDIENTS

INGREDIENT	C.A.S. NO.	PERCENT BY WT.	TLV-TWA PPM	Mg/H3	VAPOR PRESSURE
Super Hi Flash Naphtha *Not applicable	64742-94-5	24.8	35	NA*	3.0

Section III—PHYSICAL DATA

BOILING RANGE 315-400°F VAPOR DENSITY ☒ HEAVIER ☐ LIGHTER THAN AIR

EVAPORATION RATE ☐ FASTER ☒ SLOWER THAN WATER PERCENT VOLATILE BY VOLUME 34.7 WEIGHT PER GALLON 10.17

Section IV—FIRE AND EXPLOSION HAZARD DATA

FLAMMABILITY CLASSIFICATION OSHA Combustible Liquid Class II FLASH POINT °F 120°C in 0.5 (SETAFLASH)

EXTINGUISHING MEDIA

☒ FOAM ☒ ALCOHOL-FOAM ☒ CO₂ ☒ DRY CHEMICAL ☐ WATER FOG ☐ OTHER

UNUSUAL FIRE AND EXPLOSION HAZARDS During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent. Obtain medical attention. Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions.

Full protective equipment including self-contained breathing apparatus should be used. Water spray may be ineffective. If water is used, fog nozzles are preferable. Water may be used to cool closed containers to prevent pressure build-up and possible autoignition or explosion when exposed to extreme heat.

Figure B1. Vendor information: MIL-P-24441.

Section V--HEALTH HAZARD DATA 35-EF-51

EFFECTS OF OVEREXPOSURE

Inhalation: Anesthetic. Excessive inhalation can cause irritation of the respiratory tract, or acute nervous system depression characterized by the following progressive steps: Headache, dizziness, staggering gait, confusion, unconsciousness, coma and even asphyxiation.

Skin Contact: Moderate irritation, defatting, dermatitis. May be a sensitizer in some individuals.

Eye Contact: Severe irritation, redness, tearing, blurred vision. May be a sensitizer in some individuals.

Ingestion: Gastrointestinal irritation, nausea, vomiting, and diarrhea.

EMERGENCY AND FIRST AID PROCEDURES Inhalation: Remove to fresh air. Administer oxygen if breathing is difficult. Restore breathing if necessary. Treat symptomatically. Consult a physician.

Splash (skin): Wash affected areas with soap and water. Remove and launder contaminated clothing. Consult a physician if irritation persists.

Splash (eyes): Flush immediately with large amounts of water for at least 15 minutes. Take to a physician for medical treatment.

Ingestion: Drink 1 or 2 glasses of water to dilute. Do not induce vomiting. Aspiration of material into lungs due to vomiting can cause chemical pneumonitis which can be fatal. Consult physician or poison control center immediately. Treat symptomatically.

Section VI--REACTIVITY DATA

STABILITY ☐ UNSTABLE ☒ STABLE

CONDITIONS TO AVOID

High temperatures

INCOMPATIBILITY (WARNING TO AVOID)

Oxidizing materials

HAZARDOUS DECOMPOSITION PRODUCTS May produce hazardous fumes when heated to decomposition as in welding.

HAZARDOUS POLYMERIZATION ☐ MAY OCCUR ☒ WILL NOT OCCUR

Figure B1 (Cont'd).

Section VII—SPILL OR LEAK PROCEDURES 35-EF-51

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Remove all sources of ignition (flame, hot surfaces, and electrical, static, or frictional sparks.) Avoid breathing vapors. Ventilate area. Contain and remove with inert absorbent and non-sparking tools.

WASTE DISPOSAL METHOD Dispose of in accordance with local, state, and federal regulations. Incinerate in approved facility. Do not incinerate closed containers.

Section VIII—SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION In outdoor or open areas use Bureau of Mines approved mechanical filter respirator to remove solid air borne particles of overspray during spray application. In restricted ventilation areas use Bureau of Mines approved chemical-mechanical filters designed to remove a combination of particulate and gas and vapor. In confined areas use Bureau of Mines approved air line type respirators or hoods.

VENTILATION All application areas should be ventilated in accordance to OSHA Regulation 29CFR 1910.94, 1910.107, 1910.108. Remove decomposition products formed during welding or flame cutting on surface coated with this product. If baking vent fumes.

PROTECTIVE GLOVES Recommended	OTHER PROTECTIVE EQUIPMENT Use protective outerwear and prevent prolonged skin contact with contaminated clothing.
EYE PROTECTION Safety eyewear including splash guards or side shields recommended	

Section IX—SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING Do not store above 120°F. Store large quantities only in buildings designed to comply with OSHA 1910.106. Keep closures tight and container upright to prevent leakage. Do not store or use near heat, sparks or flame. Never use pressure to empty. Drum must not be washed out or used for other purposes. Drums of this material should be grounded when pouring.

Do not get in eyes. Avoid skin contact. Can cause allergic respiratory reaction. Can cause allergic skin reaction. Prevent prolonged or repeated breathing of vapor or spray mist. Avoid breathing of sanding dust. Close container after each use. Do not handle until the manufacturers safety precautions have been read and understood. Keep out of reach of children.

Figure B1 (Cont'd).

MATERIAL SAFETY DATA SHEET

FOR COATINGS, RESINS AND RELATED MATERIALS

GSF

(Approved by U.S. Department of Labor "Emergency Order" in Form OSHA-20)

Section I

MANUFACTURER'S NAME Mobile Paint Mfg. Co., Inc.

DATE OF PREP

STREET ADDRESS P. O. Box 717

CITY, STATE, AND ZIP CODE Theodore, AL. 36590

EMERGENCY TELEPHONE NO. (205) 653-0110

PRODUCT CLASS Epoxy Coating

INFORMATION TELEPHONE NO. (205) 653-0110

MANUFACTURER'S CODE IDENTIFICATION 40-AW-23

TRADE NAME MIL-P-24441/3A White T/C Formula
152-Component A

Section II—HAZARDOUS INGREDIENTS

INGREDIENT	C.A.S. NO.	PERCENT BY WT.	TLV-TWA PPM	Mg/M3	VAPOR PRESSURE
n-Butyl alcohol *This is a ceiling limit		30.8	50*	150*	6.5

Section III—PHYSICAL DATA

BOILING RANGE 240-247°F	VAPOR DENSITY ☒ HEAVIER ☐ LIGHTER THAN AIR
EVAPORATION RATE ☐ FASTER ☒ SLOWER THAN ETHER	PERCENT VOLATILE BY VOLUME 54.5 WEIGHT PER GALLON 11.94

Section IV—FIRE AND EXPLOSION HAZARD DATA

FLAMMABILITY CLASSIFICATION OSHA - Combustible liquid Class 2 FLASH POINT °F 105°F in 1.4 (SETAFLASH)

EXTINGUISHING MEDIA

☒ FOAM ☒ ALCOHOL-FOAM ☒ CO₂ ☒ DRY CHEMICAL ☐ WATER FOG ☐ OTHER

UNUSUAL FIRE AND EXPLOSION HAZARDS During emergency conditions overexposure to decomposition products may cause a health hazard. Symptoms may not be immediately apparent. Obtain medical attention. Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Closed containers may explode when exposed to extreme heat. Application to hot surfaces requires special precautions.

Full protective equipment including self-contained breathing apparatus should be used. Water spray may be ineffective. If water is used, fog nozzles are preferable. Water may be used to cool closed containers to prevent pressure build-up and possible autoignition or explosion when exposed to extreme heat.

Figure B1 (Cont'd).

Section V—HEALTH HAZARD DATA

40-AW-23

EFFECTS OF OVEREXPOSURE

Inhalation: Anesthetic. Excessive inhalation can cause irritation of the respiratory tract, or acute nervous system depression characterized by the following progressive steps: Headache, dizziness, staggering gait, confusion, unconsciousness, coma and even asphyxiation.

Skin Contact: Moderate irritation, defatting, dermatitis. May be a sensitizer in some individuals.

Eye Contact: Severe irritation, redness, tearing, blurred vision. May be a sensitizer in some individuals.

Ingestion: Gastrointestinal irritation, nausea, vomiting, and diarrhea.

EMERGENCY AND FIRST AID PROCEDURES Inhalation: Remove to fresh air. Administer oxygen if breathing is difficult. Restore breathing if necessary. Treat symptomatically. Consult a physician.

Splash (skin): Wash affected areas with soap and water. Remove and launder contaminated clothing. Consult a physician if irritation persists.

Splash (eyes): Flush immediately with large amounts of water for at least 15 minutes. Take to a physician for medical treatment.

Ingestion: Drink 1 or 2 glasses of water to dilute. Do not induce vomiting. Aspiration of material into lungs due to vomiting can cause chemical pneumonitis which can be fatal. Consult physician or poison control center immediately. Treat symptomatically.

Section VI—REACTIVITY DATA

STABILITY ☐ UNSTABLE ☒ STABLE CONDITIONS TO AVOID High temperatures
 INCOMPATIBILITY (MATERIALS TO AVOID) Oxidizing materials
 HAZARDOUS DECOMPOSITION PRODUCTS May produce hazardous fumes when heated to decomposition as in welding.

HAZARDOUS POLYMERIZATION ☐ MAY OCCUR ☒ WILL NOT OCCUR

Figure B1 (Cont'd).

Section VII—SPILL OR LEAK PROCEDURES 40-AW-23

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Eliminate all sources of ignition (flame, hot surfaces, and electrical equipment which may create frictional sparks.) Avoid breathing vapors. Ventilate area. Contain and remove with inert absorbent and non-sparking tools.

WASTE DISPOSAL METHOD: Dispose of in accordance with local, state, and federal regulations. Incinerate in approved facility. Do not incinerate closed containers.

Section VIII—SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: In outdoor or open areas use Bureau of Mines approved mechanical filter respirator to remove solid air borne particles of overspray during spray application. In restricted ventilation areas use Bureau of Mines approved chemical-mechanical filters designed to remove a combination of particulate and gas and vapor. In confined areas use Bureau of Mines approved air line type respirators or hoods.

VENTILATION: All application areas should be ventilated in accordance to OSHA Regulation 29CFR 1910.94, 1910.107, 1910.108. Remove decomposition products formed during welding or flame cutting on surface coated with this product. If baking vent fumes.

PROTECTIVE CLOVES	Recommended	OTHER PROTECTIVE EQUIPMENT	Use protective outer-wear and prevent prolonged skin contact with contaminated clothing.
EYE PROTECTION	Safety eyewear including splash guards or face shields recommended		

Section IX—SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Do not store above 120°F. Store large quantities only in buildings designed to comply with OSHA 1910.106. Keep closures tight and container upright to prevent leakage. Do not store or use near heat, sparks or flame. Never use pressure to empty. Drum must not be washed out or used for other purposes. Drums of this material should be grounded when pouring.

Do not get in eyes. Avoid skin contact. Can cause allergic respiratory reaction. Can cause allergic skin reaction. Prevent prolonged or repeated breathing of vapor or spray mist. Avoid breathing of sanding dust. Close container after each use. Do not handle until the manufacturers safety precautions have been read and understood. Keep out of reach of children.

Figure B1 (Cont'd).

ESSENTIAL DATA	PRODUCT	Industrial McPoxY Coating 40-AH-42, 40-AW-23, 40-BH-5 with Catalyst 35-EF-51		
	TYPE VEHICLE	Epoxy/Polyamide		
	WEIGHT PER GALLON	Haze Gray 10.1-10.6 # Dark Gray 10.0-10.3 # White 10.3-11.3#		
	NON-VOLATILE % BY WT. NON-VOLATILE % BY VOL.	71.0% ± 1.0% 55.5% ± 0.5%		
	THEORETICAL SPREADING RATE FOR 1 MIL DRY FILM	890 Square Feet		
	SUGGESTED DRY FILM THICKNESS PER COAT	2-3 mils		
	SPREADING RATE --	Less must be considered due to texture, porosity, and structural shape of surface, weather conditions, and application equipment, use from 70% to 85% of theoretical coverage as figured from above.		
	DRY TO TOUCH OR HANDLE (Normal Conditions) DRY TO RECOAT (Normal Conditions)	2 hours 8 hours		
	COLORS	Haze Gray, White, Dark Gray		
	THINNER	McPoxY Thinner 75-37 for cleanup		
	GLOSS OF DRY PAINT	White - Semi-Gloss Haze Gray and Dark Gray-Low Semi-Gloss		
	DATA FILM RESISTANT TO	Water, chemicals, abrasion		
	FLASH POINT OF L. S. PAINT	100°F Mixed		
FOR USE ON	TYPICAL SURFACE	Interior	Exterior	Undercoat Recommended
	WOOD			
	Siding	No	No	
	Trim, Pondering, Doors	"	"	
	Shingles, Shakes	"	"	
	Floors, Porches, Steps	"	"	
	METAL			
	Steel, Iron (Ferrous)	Yes	Yes	40-CH-1 (MIL-P-24441/1A)
	Galvanized Steel	"	"	40-CH-1 (MIL-P-24441/1A) & 9-42
	Aluminum	"	"	40-CH-1 (MIL-P-24441/1A) & 9-42
	MASONRY, PLASTER, ETC.			
	Plaster	Yes	No	Self Prime
	Concrete, Masonry	Yes	Yes	Self Prime
	Brick	Yes	Yes	Self Prime
	Asbestos Board & Shingles	Yes	Yes	Self Prime
	Gypsum Board (Drywall)	Yes	No	Self Prime
	Fiber Board (Glascrete)	Yes	Yes	Self Prime
	Open Textured Block	Yes	Yes	Fill & Self Prime
	Floors, Porches, Steps	Yes	Yes	Self Prime

Figure B1 (Cont'd).

Amercoat® 99HS

Vinyl Chloride Copolymer

Ameron.

High solids, high build, sprayable vinyl topcoat

Economical—5 mils in a single coat

Resistant to a wide range of chemicals

All purpose maintenance coating for protection on primed steel, concrete, aluminum and galvanized surfaces

Conforms to U.S. Department of Agriculture requirements for use on steel in meat packing plants

A fast-drying coating which can be applied over inorganic zinc primers

Typical Uses

Protection against splash, spillage and fumes of corrosive chemicals, water, weathering and abrasion on primed steel, concrete, aluminum, galvanizing, Dimercore® surfaces, chemical process plants, paper mills, marine structures and tank exteriors

Outstanding Characteristics

Amercoat 99HS is a high-performance chemical- and corrosion-resistant vinyl chloride copolymer. The cost is lower per square foot due to its high solids content and high build per coat necessitating fewer coats to achieve the desired thickness. It is resistant to a variety of chemical and weather environments and still retains its color and surface appearance.

Amercoat 99HS is a fast-drying, all-purpose maintenance coating which can be applied over

inorganic as well as organic zinc primers

Application Data Summary

For complete information on procedures, equipment and safety precautions, see detailed Application Instructions.

Amercoat 99HS must be applied as recommended to obtain maximum performance.

Surface Preparation—Refer to Amercoat 99HS Application Instructions or primer to be used.

Equipment—Use standard industrial spray equipment, either airless or conventional.

Safety—Since improper use and handling of Amercoat 99HS can be hazardous to health and cause fire or explosion, safety precautions included with the Application Instructions must be observed during all storage, handling, use and drying periods.

Physical Data

Finish Flat
Color White; see color card for full range of industrial colors
Surface Primed steel
Components 1
Volume solids 40% (ASTM D 2667)
Dry film thickness 5 mils (125 μ) per coat

Allow for application loss and surface irregularities.

Coats 1 (airless), 2 (conventional)

Calculated coverage at

1 mil (25 μ) 841 sq ft/gal (16 sq m/ltr)

5 mils (125 μ) 129 sq ft/gal (3.2 sq m/ltr)

Application Airless or conventional spray

Pot Life N.A.

Drying Times

@ 70°F (21°C) ASTM D1640

Set to touch 20 minutes

Dry hard 80 minutes

Dry through 2 hours

Drying time to recoat 2 hours @ 70°F (21°C)

Temperature limit Up to 100°F (dry)

Flash point (Tag Closed)

Cup, ASTM D 95 80°F (16°C)

Thinner Amercoat 6 (above 70°F)

..... Amercoat 10 (below 70°F)

Cleaner Amercoat 12

Packaging 5-gal container

Shipping weight

5-gal unit Approximately 57.5 lbs

..... (26.0 kg)

Shelf life 1 year from shipment date

when stored indoors

Resistance Table

	Splash and Spillage	Atmospheric
Acids	Good	Excellent
Alkalis	Good	Excellent
Alcohols	Good	Good
Salts	Excellent	Excellent
Petroleum products	Good	Good
Food products	Good	N.A.

Note: Amercoat 99HS should not be exposed to ketones, esters or hydrocarbons of high aromatic content.

Figure B2. Vendor information: Ameron system.

Amercoat® 99HS

Recommended Systems Using Amercoat 99HS

Substrate	Primer	No. of Coats for Amercoat 99HS
Dimetcote*		1-2
Steel	85, 62, 185, 160, 71	1-2
Concrete, aluminum galvanizing	85, 185	1-2

The chart and resistance table are only guides to show typical recommendations for Amercoat 99HS. In specific exposures and recommendations, please contact your Ameron representative who will help you evaluate your particular corrosion protection needs.

*When Amercoat 99HS is applied directly over inorganic zinc or zinc-rich primers a "mist coat" may be required to minimize application bubbling. See Application Instructions.

Warranty

Ameron's products are warranted to be free of defects in material or workmanship. If a product does not conform with this Warranty, Buyer must notify Ameron within five days of discovery of the defect, but in no event later than one year after delivery date or after expiration of the applicable shelf life, whichever is shorter. Ameron's sole obligation under this Warranty shall be at its option, to credit Buyer's account, or to supply replacement material or repair. Failure to notify Ameron of nonconforming goods under this Warranty, within the time specified above, shall bar Buyer from recovery hereunder.

It is expressly understood that Ameron makes no other

warranties concerning the goods, and the sole remedy of the Buyer and the sole liability of Ameron for product defect shall be as set forth above. No other warranties, express or implied, whether of merchantability or of fitness for any particular use shall apply. Ameron shall not be responsible for consequential damages.

Any recommendation or suggestion relating to the use of the products made by Ameron either in technical literature or in response to specific inquiry is given in good faith, but it is for Buyer to satisfy itself of the suitability of the goods for its own particular purpose and it will be deemed to have done so.

Ameron.
Protective Coatings
Division

© 1988 Ameron
44-91 1-800-888-8888
Printed in U.S.A.

Figure B2 (Cont'd).

Application Instructions

Amercoat® 86

Synthetic resin inhibitive primer

Amercoat 86 is a synthetic resin inhibitive primer used as a maintenance or marine primer for a wide range of topcoats.

To obtain the maximum performance for which Amercoat 86 is formulated, strict adherence to all application instructions, precautions, conditions and limitations is necessary.

Surface Preparation

Steel

Nonimmersion—New steel without pits or depressions; blast in accordance with SSPC-SP6^{*} Commercial Blast. Previously painted or primed steel; blast in accordance with SSPC-SP10^{*} Near White. For mild exposures; power tool cleaning in accordance with SSPC-SP3^{*} is acceptable.

Immersion—Blast all steel in accordance with SSPC-SP10^{*} Near White as a minimum. Blast to achieve a 1 mil (25 µ) profile as determined with a Keane-Tator Surface Profile Comparator or similar instrument. Remove abrasive residue and dust from surface. Apply Amercoat 86 as soon as possible to prevent rusting or other recontamination.

Newly galvanized surfaces—Remove any oil or soap film with neutral detergent or emulsion cleaner. Use zinc treatment such as Galvaprep by Amchem Products, Ambler, PA.

Weathered galvanized surfaces—If galvanizing has been exposed to exterior weathering for 6 months or more, remove corrosion with hand or power sander. Remove any oil or grease.

Dimetecote®—Surface must be clean and dry. Remove any contamination including curing residue. If surface is glazed, roughen by sweep-blasting.

^{*}See Sections P1 and G Council Specifications.

Refer to application instructions for the particular Dimetecote for any other special topcoating requirements.

Aluminum surfaces—Remove oil, grease, etc. Apply chromate-type conversion treatment such as Alodine 1200 by Amchem Products, Ambler, PA, or lightly blast with fine sand.

Previously coated surfaces—All surfaces must be free of oil and grease. Soot blast to exposed metal or mechanically clean to remove rust or other contaminants. Before using Amercoat 86, test to see if solvents in Amercoat 86 will cause wrinkling, bleeding or lifting of coating.

Environmental Conditions

Air temperature—35 to 120°F (1.7 to 49°C)

Surface temperature—35 to 120°F (1.7 to 49°C)

The surface temperature must be at least 5°F (3°C) above the dew point to prevent moisture condensation.

Application Equipment

The following equipment is listed as a partial guide and suitable equipment from other manufacturers may be used. Adjustments of pressures and change of tip size may be needed to achieve the proper spray characteristics.

Airless spray—Standard airless spray equipment such as Graco Bulldog Hydra-Spray or larger with a 0.013-in. to 0.015-in. orifice.

Conventional spray—Industrial equipment such as DeVilbiss MIBC or JGA spray gun. Separate regulators for air and fluid pressure, mechanical pot agitator and a moisture and oil trap in the main air supply line are recommended.

Power mixer—Mixer such as Jiffy Mixer, manufactured by the Jiffy Mixer

Company, Inc., San Francisco, California, powered by an explosion-proof electric motor.

Application Procedure

1. Clean equipment with Amercoat 12 before use.
2. Stir material thoroughly with a power mixer until uniformly blended to a workable consistency.
3. Thin with up to 1 pint Amercoat 9 per gallon of Amercoat 86 for brush or roller, 1 quart Amercoat 9 per gallon of Amercoat 86 for spray. Use only Amercoat 9 for thinning.
4. Apply a heavy, wet coat in even, parallel passes overlapping each pass 50% to avoid holidays, bare areas or pinholes.
5. Double coat all welds, rough spots, sharp edges and corners, rivets, bolts, etc.
6. For concrete surfaces, thin first coat with equal parts of Amercoat 9 only. Apply by brush. Apply second coat by spray brush or roller. Extremely rough, pitted or porous concrete may require additional coats.
7. Allow at least one hour at 70°F (21°C) before recoating or handling.
8. Clean all equipment with Amercoat 12 immediately after use.

Safety Precautions

Caution! Combustible. Contains MIBK, cyclohexanone and glycol ether ester. Irritating to skin, eyes and mucous membranes. Inhalation of high concentrations of vapors can cause headache, nausea or dizziness. Keep away from open flames, heat or sparks. Avoid breathing of vapor or skin and eye contact. Keep container closed when not in use. Use adequate ventilation. Wear approved respiratory equipment and skin and eye protection.

Figure B2 (Cont'd).

First aid—Excessive exposure to vapor, provide fresh air. Give artificial respiration if breathing is labored. For skin contact, wash thoroughly with soap and water. For eyes, flush immediately with plenty of water for at least 15 minutes and get medical attention. Launder contaminated clothing before reuse.

In case of fire—blanket flames with dry chemical, carbon dioxide or foam. Wear self-contained breathing apparatus.

In case of spillage—eliminate all sources of ignition. Absorb and dispose of in accordance with all applicable regulations. Improper use and handling of this product can be hazardous to health and cause fire or explosion. Consult Code of Federal Regulations Title 29, Labor, parts 1910 and 1915 concerning occupational safety and health standards and regulations, as well as any applicable state and local regulations on safe practices in coating operations. Necessary safety equipment must be used and ventilation requirements carefully observed, especially in confined or enclosed spaces.

If you do not fully understand these warnings and instructions, or if you cannot strictly comply with them, do not use the product.

Notice—This product is for industrial use only.

Warranty

Ameron's products are warranted to be free of defects in material or workmanship. If a product does not conform with this Warranty, Buyer must notify Ameron within five days of discovery of the defect, but in no event later than one year after delivery date or after expiration of the applicable shelf life, whichever is shorter. Ameron's sole obligation under this Warranty shall be at its option, to credit Buyer's account, or to supply replacement material or repair. Failure to notify Ameron of nonconforming goods under this Warranty, within the time specified above, shall bar Buyer from recovery hereunder.

It is expressly understood that Ameron makes no other warranties concerning the goods, and the sole remedy of the Buyer and the sole liability of Ameron for product defect shall be as set forth above. No other warranties, express or implied, whether of merchantability or of fitness for any particular use shall apply. Ameron shall not be responsible for consequential damages.

Any recommendation or suggestion relating to the use of the products made by Ameron either in technical literature or in response to specific inquiry is given in good faith, but it is for Buyer to satisfy itself of the suitability of the goods for its own particular purpose and it will be deemed to have done so.

201 North Berry Street
Brea, California 92621

Ameron

Protective Coatings
Division

© 1984 Ameron
100-111-0000-00-00-00
Printed in U.S.A.

Figure B2 (Cont'd).

Safety Precautions

To protect personnel against toxic hazards

To prevent fire or explosion

Whenever coatings containing volatile solvents or toxic substances are used, proper ventilation and protective measures must be provided during application and drying to keep solvent vapor concentrations within safe limits and to protect personnel against toxic hazards. This is especially true in confined spaces such as tank interiors. Consult Code of Federal Regulations Title 29, Labor, parts 1910 and 1916 concerning occupational safety and health standards and regulations, as well as any applicable state and local regulations on safe practices in coating operations. Necessary safety equipment must be used and ventilation requirements carefully observed, especially in confined or enclosed spaces.

Keep solvent-containing materials away from heat, sparks, and open flame. Avoid inhalation of vapors or spray mist. Avoid contact with eyes or skin. Keep containers tightly closed and upright to prevent leakage when not in use.

Refer to application instructions for the material being applied for further detailed safety precautions. Department of Labor Material Safety Data Sheets are available on request.

If you do not fully understand these warnings and instructions, or if you cannot strictly comply with them, do not use the product.

Notice — This product is for industrial use only.

201 North Berry Street
Brea, California 92621
(714) 526-1951

Ameron
Protective Coatings
Division

Copyright © 1981 Ameron Inc.
Printed in U.S.A.
SD-2

Figure B2. (Cont'd).

MATERIAL SAFETY DATA SHEET

NPCA 1-

FOR COATINGS, RESINS AND RELATED MATERIALS

(Approved by U.S. Department of Labor - Essentially Similar to Form OSHA-20)

DATE OF PREP

5-13-81

Section I

1071-246

PLAS-CHEM COATINGS

P.O. Box 40246, Jacksonville, FL 32203
(904) 786-0121



EAGLE-PICHER INDUSTRIES

5901 W. Beaver Street zip 32205
(904) 7860121

PRODUCT CLASS

2 Component Epoxy
TRADENAME

MANUFACTURERS CODE IDENTIFICATION

2135-1 White Finish

MIXED

Section II - HAZARDOUS INGREDIENTS

INGREDIENT	PERCENT	TLV skin		LEL	VAPOR PRESSURE @ 20°C
		ppm	mg/m³		
2-Ethoxy Ethanol	less than 5	100	370	1.0	5.3 @ 25° C
SC-100	30	100	---	1.0	< 1
N-Butyl Alcohol	less than 5	50	150	1.2 @ 25° C	4.39
N.-Butyl Acetate	less than 5	150	710	1.7	7.8

Section III - PHYSICAL DATA

BOILING RANGE 243-262° F VAPOR DENSITY ☒ HEAVIER ☐ LIGHTER THAN AIR
EVAPORATION RATE ☐ FASTER ☒ SLOWER THAN ETHER PERCENT VOLATILE BY VOLUME 52 WEIGHT PER GALLON 10.2 ± .15

Section IV - FIRE AND EXPLOSION HAZARD DATA

GOT CATEGORY Flammable Liquid-Class 1 C FLASH POINT 76° F TCC LEL 1.0

EXTINGUISHING MEDIA

Chemical Extinguishers, Foam, Sand, CO₂

UNUSUAL FIRE AND EXPLOSION HAZARDS

None

SPECIAL FIRE FIGHTING PROCEDURES

Prevent spread of fire by cooling adjacent containers with water fogging or removal if possible.

Figure B3 (Cont'd).

Section V — HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE

Inhalation: Dizziness, headache
Skin Contact: Redness, rash

EMERGENCY AND FIRST AID PROCEDURES

Inhalation: Fresh air
Skin contact: Wash with soap and water; apply hand cream
Eye contact: Rinse with large amounts of water

Section VI — REACTIVITY DATA

STABILITY ☐ UNSTABLE ☒ STABLE

CONDITIONS TO AVOID

INCOMPATIBILITY (Materials to avoid)

HAZARDOUS DECOMPOSITION PRODUCTS

Carbon monoxide and carbon dioxide

HAZARDOUS POLYMERIZATION ☐ MAY OCCUR ☒ WILL NOT OCCUR

CONDITIONS TO AVOID

Section VII — SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Scoop up in container - Rinse with water

WASTE DISPOSAL METHOD

Burying or incineration in accordance with local, state, and federal regulations

Section VIII — SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION

Not normally necessary when working with small amounts. For large spray applications, BU Mines filter respirator for organic solvents is advisable.

VENTILATION

Exhaust ventilation from enclosed areas recommended

PROTECTIVE GLOVES protective hand cream

EYE PROTECTION goggles

OTHER PROTECTIVE EQUIPMENT

Section IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE

Do not store in direct sun. Keep protected from exposure to heat.

OTHER PRECAUTIONS

Do not use in close proximity to heat and open flame welding and other ignition hazards.

Figure B3 (Cont'd).

MATERIAL SAFETY DATA SHEET

NPCA 1-

FOR COATINGS, RESINS AND RELATED MATERIALS

(Approved by U.S. Department of Labor - Essentially Similar to Form OSHA-20)

DATE OF PREP

5-13-81

Section I

1071-249

PLAS-CHEM COATINGS

P.O. Box 40246, Jacksonville, FL 32203
(904) 786-0121

EAGLE-PICHER INDUSTRIES

5901 W. Beaver Street zip 32205
(904) 7860121

PRODUCT CLASS

MANUFACTURERS CODE IDENTIFICATION

2 Component Epoxy
TRADE NAME

2135-1 White Finish

MIXED

Section II - HAZARDOUS INGREDIENTS

INGREDIENT	PERCENT	PPM	TLV skin mg/m ³	LEL	VAPOR PRESSURE @ 20° C
2-Ethoxy Ethanol	less than 5	100	370	1.0	5.3 @ 25° C
SC-100	30	100	---	1.0	< 1
N-Butyl Alcohol	less than 5	50	150	1.2 @ 25° C	4.39
N.-Butyl Acetate	less than 5	150	710	1.7	7.8

Section III - PHYSICAL DATA

BOILING RANGE 243-262° F

VAPOR DENSITY

☒ HEAVIER

☐ LIGHTER THAN AIR

EVAPORATION RATE

☐ FASTER

☒ SLOWER THAN ETHER

PERCENT VOLATILE
BY VOLUME

52

WEIGHT PER
GALLON

10.2 ± .15

Section IV - FIRE AND EXPLOSION HAZARD DATA

LC50 CATEGORY

Flammable Liquid-Class 1 C

FLASH POINT 75° F TCC

LEL 1.0

EXTINGUISHING MEDIA

Chemical Extinguishers, Foam, Sand, CO₂

UNUSUAL FIRE AND EXPLOSION HAZARDS

None

SPECIAL FIRE FIGHTING PROCEDURES

Prevent spread of fire by cooling adjacent containers with water fogging or removal if possible.

Figure B3 (Cont'd).

Section V — HEALTH HAZARD DATA	
THRESHOLD LIMIT VALUE EFFECTS OF OVEREXPOSURE	See Section II Inhalation: Dizziness, nausea, headache Ingestion: Skin contact: Eczema, rash
EMERGENCY AND FIRST AID PROCEDURES	Eye contact: Flood with stream of water Inhalation: Fresh Air Ingestion: Call Physician for advice. DO NOT induce vomiting Skin contact: Wash off with solvent, followed by soap and water Apply skin cream
Section VI — REACTIVITY DATA	
STABILITY ☐ UNSTABLE ☒ STABLE INCOMPATIBILITY (Materials to avoid) HAZARDOUS DECOMPOSITION PRODUCTS	At normal conditions Extreme heat Carbon Mono and Dioxide.
HAZARDOUS POLYMERIZATION ☐ MAY OCCUR ☒ WILL NOT OCCUR CONDITIONS TO AVOID	
Section VII — SPILL OR LEAK PROCEDURES	
STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED WASTE DISPOSAL METHOD	Scoop up in container using non-sparking tools. Soak remainder up with sand. Keep waste in closed container for disposal. Clean with suitable solvent under proper ventilation. Dispose of waste by burying or incineration in accordance with local, state and federal regulations.
Section VIII — SPECIAL PROTECTION INFORMATION	
RESPIRATORY PROTECTION VENTILATION PROTECTIVE GLOVES EYE PROTECTION OTHER PROTECTIVE EQUIPMENT	Bu Mines approved filter respirator for organic solvents. Suction ventilation from lower reaches of enclosed areas. Protective skin cream recommended. Goggles
Section IX — SPECIAL PRECAUTIONS	
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING OTHER PRECAUTIONS	Store in well ventilated area protected from undue exposure to heat, sun and freezing. Use explosion proof lights and motors in work areas. Avoid welding and other ignition hazards in vicinity of use or handling.

Figure B3 (Cont'd).



Plas-Chem Coatings TECHNICAL BULLETIN

Chem-Pon 2135
Epoxy Lining System

6-15-80

GENERAL DESCRIPTION

The Chem-Pon 2135 coating system consists of one primer and one finish. It is a unique, modified epoxy-polyamide that combines a rapid cure with unusually long pot life. This system is specifically designed to resist all types of aviation fuels, water and aliphatic solvents in immersion service. It also has good resistance to many herbicides, fungicides, pesticides and fumigants. Chem-Pon 2135 has outstanding adhesion, impact resistance and resistance to steam. It complies with MILC-4556C and is on the qualified product listing for aviation fuels.

USE

As a lining system over sandblasted metal to line tanks, for jet and aviation fuels, gasoline, aliphatic hydrocarbons, water and salt water subject to temperatures up to 140° F. It may also be used as a lining material for certain herbicides, fungicides at various concentrations. Chem-Pon 2135 may be used for external and splash zone use in the same application as well as splash zone protection for alkali or acid environments.

PHYSICAL PROPERTIES

Chemical Resistance:	Acids - Good Alkalis - Very Good Water - Excellent Solvents - (Aliphatic) Excellent Salts - Excellent Herbicides - Very Good * Pesticides - Very Good *
Temperature Resistance:	200° F. Continuously; 230° F. Intermittently
Flexibility:	Good
Weathering:	Very Good (Moderate Chalking)
Abrasion Resistance:	Excellent
Solids(Catalyzed 4:1 by volume):	Primer - 68%±1 by weight, 50%±1 by volume Finish - 62%±1 by weight, 50%±1 by volume
Theoretical Coverage:	802 mil square feet per gallon
Recommended Coverage:	Minimum 3 mils per coat (Fuel Service) Standard 5 mils per coat
Number of Coats:	1 each of primer and finish
Surface Preparation:	SSPC-SP5-63 for immersion lining applications

Plas-Chem Coatings • 7901 West Beaver Street • Jacksonville, Florida 32205
Mailing Address: P.O. Box 40246 • Jacksonville, Florida 32203 • Telephone (904) 786-0121

These data are based on tests believed to be reliable and are given for information only. No warranty is made by Plas-Chem Coatings, Inc. or its subsidiaries for use of the product in connection with the use of the product relative to coverage, performance or injury. Nothing contained herein shall be construed as a recommendation to use this product in contact with any working medium.

Figure B3 (Cont'd).

PHYSICAL PROPERTIES(cont'd)

Colors: Primer - Orange
Finish - Off White

Flash Point: 95^{±5}° F. Pinsky Martin
115^{±5}° F. COC

APPLICATION

Method: Spray, brush or roller

Pot Life: Minimum of 8 hours

Mixing Ratio: 4 parts of base to 1 part of catalyst by volume

Dry Time: 18 hours @ 75° F. between coats
Final - 36 hours @ 75° F.

Thinner: Standard: No. 146 Thinner
Military Thinner: Chem-Pon 2136 Thinner

Clean Up: MEK or any of the above thinners

ORDERING INFORMATION

Availability: 1½ gal. kits (1 gal base and ½ gal catalyst)
5 gal kits (4 gal base and 1 gal catalyst)

Approximate shipping weight: Primer Base 12.5 lbs. per gal.
Finish Base 11.7 lbs. per gal.
Catalyst 2.5 lbs. per quart

Freight Classification: Paint compound NO18M Non-Red Label

*Due to many types and variations of these materials, contact Plas-Chem Coatings, Technical Services Dept. for specific recommendations before using in immersion service.

Figure B3 (Cont'd).



Plas-Chem Coatings

APPLICATION INSTRUCTIONS

CHEM-PON 2135
MEETS MIL-C-4556 C
FOR JET FUEL SERVICE

2-1-83

SURFACE PREPARATION

1. Immersion Service

- a. Sandblast to white metal in accordance with Steel Structures Painting Council Blast Specification (SSPS) SP5-63T. Mil profile shall be a minimum of 1.5 - 2 mils.
- b. Remove all loose dirt and abrasive media by vacuuming or sweeping.
- c. Apply prime coat of material as soon as possible after blasting to prevent re-rusting.
- d. If re-rusting has occurred, surface should be reblasted.

2. Non-Immersion Service

- a. Sandblast in accordance with SSPC SP6-63 Commercial Blast.
- b. Remove blasting dust by blowing surface with clean dry air free of oil and moisture.
- c. Paint surfaces before re-rusting occurs.

MIXING

1. Mix materials (base and catalyst) as supplied in kit form. Mixing ratio is 4 parts base to 1 part of catalyst by volume.
2. After mixing base and catalyst, allow 1/2 hour induction time before applying.

POT LIFE: Less than 15 % viscosity increase in 6 hours at 75° F.

THINNING: None normally required. However, if circumstances should dictate, use only a thinner and amounts listed below.

- a. Military Specification: Use only Chem-Pon 2135 M.S.T. Thinner up to 1/2 pint per gallon of mixed material.
- b. Non-Military Specification: Use Plas-Chem No. 146 Thinner up to 1/2 pint per gallon of mixed material.

Plas-Chem Coatings • 5901 West Beaver Street • Jacksonville, Florida 32206
Mailing Address: P.O. Box 40246 • Jacksonville, Florida 32203 • Telephone (904) 786-0121

These data are based on tests believed to be reliable and are given for information only. Since conditions of use are beyond our control, we cannot and do not assume any liability in connection with the use of the product relative to coverage, performance or value. Nothing contained herein shall be construed as a recommendation to use this product in contact with any existing paint.

Figure B3 (Cont'd).

APPLICATION

AIRLESS	CONVENTIONAL AIR
Pump: 30:1 or larger	Pressure pot or 2:1 fluid pump
Oriface: .013-.029 depending on volume requirements	Guns: Binks 7, 18, 19, 62 DeVilbiss JGA, MBC or PMBC
Angle: 40 - 60 depending on surface requirements. Work close to surface to minimize drift and drop out.	Fluid Tip: .041-.070
Hose: 5/16" STD High Pressure Fluid	Air Cap: 7-13 CFM
Pressure: 2600-3000 PSI	Hose: 3/8" ID Fluid Hose
Thinning: None normally required	Pos Pressure: 5-20 PSI depending on hose length.
	Atomizing Pressure: 45-65 PSI
	Thinning: None normally required
Brushing or rolling is not recommended for immersion applications and should be used for touch up work only. Use High Quality natural bristle brush of medium length. Apply by flowing long strokes. Avoid re-brushing. Rolling - Use lambs-wool or mohair phenolic core roller of appropriate knapp length. Roll in one direction. Avoid "scrubbing" of surface.	

THEORETICAL COVERAGE: 800 mil square feet per gallon.

INTER-COAT TIME: 18 hours at 75° F (Military Specification).
12 hours at 90° F

CURING: If possible, due to the slow solvent system used, it is advisable to force high volumes of slightly warm air at 75°-85° F for two hours through enclosed tanks. Increase temperature to 115°-125° F for 8 - 10 hours.

CURE TIME: 3 days at 75° F
For shorter time see "CURING".

CLEAN-UP: Plas-Chem No. 146 Thinner, Mil Spec Thinner, or MEK.

CAUTION:

1. Contains flammable solvent.
2. Keep away from open flame and sparks. Use only approved explosion proof equipment. In tank lining applications workmen must wear Air Respirators provided with a source of fresh air.
3. Remove any spilled catalyst from hands or skin at once with water, then wash with soap and water.
4. If catalyst is spilled on clothing, remove clothing at once, wash skin as above.
5. Mix and apply Chem-Pon 2310 in a well ventilated area. Keep away from sparks and open flame. In tank lining applications, workmen must wear air respirators equipped with a source of fresh air.
6. HYPERSENSITIVE PERSONS SHOULD WEAR GLOVES OR USE PROTECTIVE CREAM. ALL ELECTRIC EQUIPMENT AND INSTALLATIONS SHOULD BE MADE AND GROUNDED IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE. IN AREAS WHERE EXPLOSION HAZARDS EXIST, WORKMEN SHOULD BE REQUIRED TO USE NON-FERROUS TOOLS AND WEAR CONDUCTIVE AND NON-SPARKING SHOES.

Figure B3 (Cont'd).

CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CH
ATTN: DAEN-CVE
ATTN: DAEN-CWR-W
ATTN: DAEN-CWG
ATTN: DAEN-CWP
ATTN: DAEN-ECC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ZCF
ATTN: DAEN-ECB
ATTN: DAEN-RO
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZC2
ATTN: DAEN-ZCE
ATTN: DAEN-ZGI
ATTN: DAEN-ZCM

FESA, ATTN: Library 22060

FESA, ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library
Alaska 99501
Al Batin 09616
Albuquerque 87103
Baltimore 21203
Buffalo 14207
Charleston 29402
Chicago 60604
Detroit 48231
Far East 96301
Fort Worth 76102
Galveston 77550
Huntington 25721
Jacksonville 32232
Japan 96343
Kansas City 64106
Little Rock 72203
Los Angeles 90051
Louisville 40201
Memphis 38103
Mobile 36628
Nashville 37202
New England 02154
New Orleans 70146
New York 10007
Norfolk 23510
Omaha 68102
Philadelphia 19106
Pittsburgh 15222
Portland 97208
Riyadh 09036
Rock Island 61201
Sacramento 95814
San Francisco 94105
Savannah 31402
Seattle 98124
St. Louis 63101
St. Paul 55101
Tulsa 74102
Vicksburg 39180
Walla Walla 99362
Washington 28401

US Army Engineer Divisions
ATTN: Library
Europe 09757
Huntsville 35807
Lower Mississippi Valley 39100
Middle East 09038
Middle East (Pearl) 22601
Missouri River 68101
North Atlantic 10007
North Central 60605
North Pacific 97208
Ohio River 45201
Pacific Ocean 96858
South Atlantic 39303
South Pacific 64111
Southwestern 75202

US Army Europe
HQ, 22nd Army Training Command 09114
ATTN: ACTG-DEM (5)
HQ, 7th Army GDCS/Engr. 09403
ATTN: AEAEN-EN (4)
V. Corps 09679
ATTN: ACTVDEM (5)
VII. Corps 09154
ATTN: ACTSDEN (5)
21st Support Command 09125
ATTN: AEREN (5)
Berlin 09742
ATTN: ALBA-EN (2)
Southern European Task Force 09162
ATTN: AESS-ENG (3)
Installation Support Activity 09403
ATTN: AEUES-2P

8th USA, Korea
ATTN: EAFE-IB 96301
ATTN: EAFE-F 96358
ATTN: EAFE-ID 96224
ATTN: EAFE-AM 96208

8th USA, Korea
ATTN: EAFE-H 96271
ATTN: EAFE-P 96259
ATTN: EAFE-T 96212

ROK/US Combined Forces Command 96301
ATTN: EUSA-HMC-CFC/Engr

USA Japan (USAAJ)
Ch. FE Div, AJEN-FE 96343
Fac Engr (Nonshu) 96343
Fac Engr (Onshu) 96331

Pokey Mt. Area 90933

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

Western Area Office, CE
Vandenberg AFB, CA 93437

416th Engineer Command 50623
ATTN: Facilities Engineer

US Military Academy 10496
ATTN: Facilities Engineer
ATTN: Dept of Geography &
Computer Science
ATTN: DSCPER/MAEN-A

Engr. Studies Center 20315
ATTN: Library

AMARC, ATTN: DRXMB-WE 02172

USA ARCOM 61299
ATTN: OPCIS-RI-I
ATTN: DRSAM-IS

DARCOM - Dir., Inst., & Secs.
ATTN: Facilities Engineer
ABRACOM 07801
Aberdeen Proving Ground 21005
Army Mater. and Mechanics Res. Ctr.
Corpus Christi Army Depot 78419
Harry Diamond Laboratories 20783
Dugway Proving Ground 84022
Jefferson Proving Ground 47250
Fort Monmouth 07703
Letterkenny Army Depot 17201
Maitich RAO Ctr. 01760
New Cumberland Army Depot 17070
Pueblo Army Depot 81001
Red River Army Depot 75501
Redstone Arsenal 35899
Rock Island Arsenal 61299
Savanna Army Depot 61074
Sharpe Army Depot 95331
Seneca Army Depot 14541
Tobynonne Army Depot 18466
Tennel Army Depot 84074
Walterville Arsenal 12185
Yuma Proving Ground 95264
White Sands Missile Range 88002

CLA ATTN: OLA-WI 72316

FORSCOM
FORSCOM Engineer, ATTN: AFEB-FE
ATTN: Facilities Engineer
Fort Buchanan 00934
Fort Bragg 28307
Fort Campbell 42223
Fort Carson 80913
Fort Devens 01453
Fort Drum 13601
Fort Hood 76544
Fort Indianapolis Gap 17003
Fort Irwin 92111
Fort San Houston 78234
Fort Lewis 98433
Fort McCoy 54654
Fort McPherson 30130
Fort George G. Meade 20755
Fort Ord 93941
Fort Polk 71459
Fort Richardson 99505
Fort Riley 66442
Presidio of San Francisco 94129
Fort Sheridan 60037
Fort Stewart 31113
Fort Walworth 93703
Vancouver Bks. 96460

NSC
ATTN: NSLO-F 78234
ATTN: Facilities Engineer
Fitzsimons AMC 80240
Walter Reed AMC 20012

INSCOM - Ch. Instit. Div.
ATTN: Facilities Engineer
Arlington Hall Station (2) 22212
Vint Hill Farms Station 22186

NSA
ATTN: Facilities Engineer
Cameron Station 22314
Fort Lesley S. McNair 20319
Fort Meade 22211

NTMC
ATTN: NTMC-SA 20315
ATTN: Facilities Engineer
Oakland Army Base 94626
Bayonne MDT 07002
Sunny Point MDT 28441

NARACOM, ATTN: D05HA-F 071160

TARCOM, Fac. Div. 48099

TRADOC
HQ, TRADOC, ATTN: ATEN-FE
ATTN: Facilities Engineer
Fort Belvoir 22060
Fort Benning 31905
Fort Bliss 79916
Carlisle Barracks 17013
Fort Chaffee 72902
Fort Dix 08640
Fort Eustis 23604
Fort Gordon 30905
Fort Hamilton 11252
Fort Benjamin Harrison 46216
Fort Jackson 29207
Fort Knox 40121
Fort Leavenworth 66027
Fort Lee 23801
Fort McClellan 36205
Fort Monroe 23451
Fort Rucker 36362
Fort Sill 73103
Fort Leonard Wood 65473

TSARCOM, ATTN: STSAS-F 63120

USACE
ATTN: Facilities Engineer
Fort Monmouth 08413 (2)
Fort Ritchie 21719

WESTCOM
ATTN: Facilities Engineer
Fort Shafter 94458
ATTN: APEN-IR

SHAPE 09055
ATTN: Survivability Section, CCR-OPS
Infrastructure Branch, LAMBA

HQ USEUCOM 09128
ATTN: EC 477-LOE

Fort Belvoir, VA 22060
ATTN: ATZA-BTE-EP
ATTN: ATZA-BTE-SW
ATTN: ATZA-FE
ATTN: Engr. Library
ATTN: Canadian Liaison Office (2)
ATTN: IIR Library

Cold Regions Research Engineering Lab 03755
ATTN: Library

ETL, ATTN: Library 22060

Waterways Experiment Station 39180
ATTN: Library

HQ, XVIII Airborne Corps and 26307
Ft. Bragg
ATTN: AFZA-FE-EE

Chemate AFB, IL 61868
3345 CES/OC, Stop 27

Morton AFB 93409
ATTN: AFACE-ME/DEE

Tyndall AFB, FL 32403
AFESC/Engineering & Service Lab

NAFEC
ATTN: ROTAF Liaison Office
Atlantic Division 23511
Chesapeake Division 29374
Southern Division 29411
Pacific Division 06840
Northern Division 19112
Western Division 64046
ATTN: Sr. Tech. FAC-GST 22312
ATTN: Asst. CDR RAO, FAC-GS 22332

NEEL 93041
ATTN: Library (Come LOBA)

Defense Technical Info. Center 22319
ATTN: CCA (12)

Engineering Societies Library 10017
New York, NY

National Guard Bureau 20310
Installation Division

US Government Printing Office 22304
Receiving Section/Depository Copies (2)

Metallurgy Team Distribution

Chief of Engineers
ATTN: DAEM-ZCF-U
ATTN: DAEM-ECZ-A
ATTN: DAEM-ECS

US Army Engineer District
Philadelphia 19106
ATTN: Chief, MAPEN-D
Baltimore 21203
ATTN: Chief, Engr Div
Norfolk 23510
ATTN: Chief, JAQEN-D
Wilmington 28401
ATTN: Chief, SAMEN-D
Charleston 29402
ATTN: Chief, Engr Div
Savannah 31402
ATTN: Chief, SASAS-L
Jacksonville 32232
ATTN: Const Div
Mobile 36628
ATTN: Chief, SAMEN-C
ATTN: Chief, SAMEN-D
Memphis 38103
ATTN: Chief, LHMED-DM
Vicksburg 39186
ATTN: Chief, Engr Div
Louisville 40201
ATTN: Chief, Engr Div
St. Paul 55101
ATTN: Chief, ED-D
Omaha 68102
ATTN: Chief, Engr Div
New Orleans 70160
ATTN: Chief, LHMED-DC
Little Rock 72203
ATTN: Chief, Engr Div
San Francisco 94105
ATTN: Chief, Engr Div
Sacramento 95814
ATTN: Chief, SPEKD-U
Portland 97208
ATTN: Chief, DS-6
Seattle 98124
ATTN: Chief, NPSCO
Walla Walla 99362
ATTN: Chief, Engr Div
Alaska 99501
ATTN: Chief, NPASA-2

US Army Engineer Division
New England
ATTN: Chief, NEMED-T
North Atlantic 16007
ATTN: Chief, NADEN-T
South Atlantic 30303
ATTN: Chief, SADMEN-TS
Huntsville 35807
ATTN: Chief, NEMED-CS
ATTN: Chief, NEMED-SR
Ohio River 45201
ATTN: Chief, Engr Div
Southwestern 75202
ATTN: SWMED-TN
Pacific Ocean 94558
ATTN: Chief, Engr Div
North Pacific 97208
ATTN: Chief, Engr Div

USA-WES 39180
ATTN: C/Structures

West Point, NY 10996
ATTN: Dept of Mechanics
ATTN: Library

Fort Leavenworth, KS 66027
ATTN: ATZLCA-SA

Fort Clayton Canal Zone 34004
ATTN: DTAE

Fort McPherson, GA 30330
ATTN: AFEN-CD

Fort Monroe, VA 23651
ATTN: ATEN-AD (3)

6th US Army 94129
ATTN: AFEC-EN

7th US Army 09407
ATTN: AETM-NED-EMD

US Army Science & Technology 96301
Center - Far East Office

Tyndall AFB, FL 32403
AFESC/PRT

Tinker AFB, OK 73145
2854 ABC/DEE

Patrick AFB, FL 32923
ATTN: EMQ

Naval Air Systems Command 20340
ATTN: Library

Naval Facilities Engr Command 22332
ATTN: Code 04

Transportation Research Board 20418

Dept of Transportation Library 20590

National Defense Headquarters
Ottawa, CANADA KIA 0K2

Airports and Construction Services Dir
Ottawa, CANADA KIA 0M6

Mr. H. Pearl (10)
Naval Underwater
Systems Center
Materials Lab
Code 36622
Newport, RI 02840