AD-A098 024　WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER B--ETC F/G 9/1
FLEXIBLE PRINTED CIRCUITS WITH INTEGRAL MOLDED CONNECTORS. A MA--ETC(U)
MAR 81 J A HENDERSON DAAK40-79-C-0212
UNCLASSIFIED 81-0209 NL

1 of 2

(2) LEVEL II

AD A098024

# FLEXIBLE PRINTED CIRCUITS WITH INTEGRAL MOLDED CONNECTORS

## FINAL REPORT

## A MANUFACTURING METHODS AND TECHNOLOGY PROGRAM

**Contract: DAAK40-79-C-0212**

**August 1979 Through November 1980**

**Sponsored By**

**U.S. ARMY MISSILE COMMAND**
**DRSMI-ET**
**Redstone Arsenal, Alabama**
**Project Officer: Gordon D. Little**



**Performed By**

**WESTINGHOUSE ELECTRIC CORPORATION**
**Defense and Electronic Systems Center**
**Baltimore, Maryland**

14

81-0209

6

# FLEXIBLE PRINTED CIRCUITS WITH INTEGRAL MOLDED CONNECTORS .

11 12 Mar 81

12 148

## FINAL REPORT

## A MANUFACTURING METHODS AND TECHNOLOGY PROGRAM

15

**Contract: DAAK40-79-C-0212**

9 Final rept.

**Aug[redacted] 1[redacted]79 [redacted]-Nove[redacted]r [redacted]80**

**Sponsored By**

**U.S. ARMY MISSILE COMMAND**
**DRSMI-ET**
**Redstone Arsenal, Alabama**
**Project Officer: Gordon D. Little**

10 James A. Henderson

**Performed By**

**WESTINGHOUSE ELECTRIC CORPORATION**
**Defense and Electronic Systems Center**
**Baltimore, Maryland**



390 358

14

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. AD-A098 024 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) Flexible Printed Circuits with Integral Molded Connectors (Final Report) A Manufacturing Methods and Technology Program | | 5. TYPE OF REPORT & PERIOD COVERED<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) James A. Henderson | | 8. CONTRACT OR GRANT NUMBER(s) DAAK40-79-C-0212 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Westinghouse Defense & Electronic System Center | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS US Army Missile Command Redstone Arsenal, Alabama 35898 Gordon D. Little Project Officer | | 12. REPORT DATE 3/12/81<br>13. NUMBER OF PAGES |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Air Force Plant Representation Office (AFPRO) | | 15. SECURITY CLASS. (of this report) UNCLASSIFIED<br>15a. DECLASSIFICATION DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

**DISTRIBUTION STATEMENT A**
**Approved for public release; Distribution Unlimited**

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

| | | |
|---|---|---|
| Flexicon | Ablation | Automated Facility |
| Flexible Printed Wiring | Welding | Processes |
| Flexible Circuits | Liquid Injection Molding | |
| Connectors | LIM | |
| Laser | Automation | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Three new processes used in termination of Flexible Printed Wiring (FPW) to connectors were developed on this program. They are laser ablation (removal) of insulation by $CO_2$ Laser, laser welding by Nd:YAG Laser, and liquid injection molding of small parts. The integration of these processes into a fully automated facility capable of one assembly per minute production was then projected (Automated Facility Report).

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

## LIST OF TABLES





RE: Pages 18, C-1, C-2, H-1, H-2 do not contain proprietary information per Mr. Gordon Little, Army Missile Command, DRSMI-ET

## 1.0 INTRODUCTION

This is the final report of the program on Flexible Printed Circuits with Integral Molded Connectors (FLEXICON). Performed under contract with the U.S. Army Missile Command, Redstone Arsenal, Alabama, it concentrated on the improvement of Flexible Printed Wiring (FPW) terminations for cable-to-cable, cable-to-printed wiring board, and cable-to-chassis applications. During the course of this program, several significant advances have been made in termination processes as well as in automated facility configuration and operation. This report details these developments, referencing several additional documents and reports. The final outcome can be simply summarized. Through the use of industrial laser technology, new high speed epoxy developments, and microprocessor controlled automation, processes for termination of FPW to connectors have been developed which can result in 6 to 1 cost reduction of terminated systems with significantly improved system reliability and maintainability.

The technical monitor for this program at MICOM has been Gordon D. Little. His continuous support was very greatly appreciated.

## 2.0 TECHNOLOGY BACKGROUND

Flexible printed wiring (FPW) and flat conductor cable (FCC) have been available for many years for use with military systems. The primary advantages, listed in Table 1, have held promise of significant benefit in electronic systems, particularly as interconnection wiring has become increasingly more complex with each passing year. There have been two major factors which have inhibited its greater use in military electronics. First, since it is a "printed" technology, wiring changes as defined for hand-formed harnesses could not be performed, and design engineers who were accustomed to the freedom of frequent design change did not wish to become "trapped". Second, the available processes for termination to mil-qualifiable connectors, particularly for humid airborne environments, were expensive, difficult to control, and not cost effective. Even so, the cost benefits of using FPW over hand-formed harnesses could be substantial for production quantity systems, not only from acquisition cost, but from reduced quality control requirements and life cycle cost benefits of weight and volume savings.

In the past few years, the ingrained resistance has been replaced with substantial knowledge of benefits as design philosophies have changed. Digital systems with data bus configurations are well-behaved with the repeatable, designable electrical characteristics of FPW and FCC. Dramatic increases in equipment density have forced many systems to use this cable style because space was no longer available for the round wire harnesses. And the trend to more production systems with less changes in interconnection between sub-assemblies has led to a greater cost benefit. The only major hurdle remaining was the termination process/connector interface.

### 1.1 AN EXAMPLE

An example of the termination dilemma can be seen with the evolution of a new production electronic system at Westinghouse. When the program was conceptually developed in the early 1970's, it was determined that the modular interchangeable location of the separate sub-assemblies and the parallel data bus requirements could be best suited with the use of FCC. This was particularly beneficial because the lack of volume for wiring rendered the use of round wire impractical. In the initial four units, these cables were configured as shown in Figure 2-1. The connectors were three layer 141 pin connectors with the FCC welded to the contact tails by resistance welding. The backs of each wafer were then slid onto the contact wafers and filled with epoxy. These connectors, designed to MIC-C-55544, were expensive, fragile, and difficult to assemble. Rework was virtually impossible.

With the shift of this program into production, this connector was replaced with a connector that was soldered (lower reliability) with a gang-solder technique. Repairable, of adequate reliability, and infinitely more easy to assemble than the prototype units, this configuration still had two major deficiencies, cost and process control. Another termination technique used on this same program was the crimping of contacts through the insulation. The process control and reliability of these joints have both been in question. These difficulties had to be approached with deliberate thoroughness and resolved.

TABLE 1

Principal Benefits of Flexible Printed Wiring

Basic Cost Reduction $\sim$ 30-50%

Weight Reduction $\sim$ 70%

Volume Reduction $\sim$ 80%

Repeatable Electrical Characteristics

Substantial Quality Improvement

Improved Aesthetics

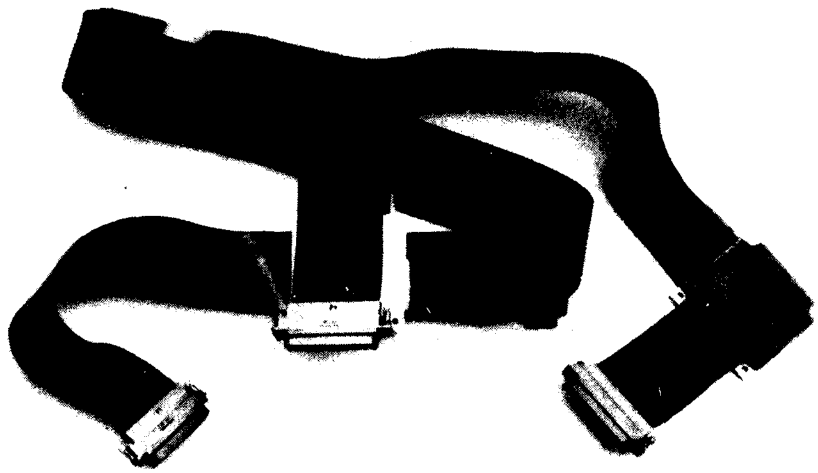


Figure 2-1

THE RESISTANCE WELDED TERMINATION OF CONNECTORS ON THIS ASSEMBLY WAS EXPENSIVE AND DIFFICULT.

## 3.0 PROGRAM REQUIREMENTS AND ORGANIZATION

The principal requirement was the development and demonstration of a flexible printed wiring termination technique which was consistently low in cost and reliable in the military airborne environment. To accomplish this, three basic items were needed, low cost connectors and FPW, low cost reliable termination processes, and a high degree of automation. To provide this, the program was organized to:

a. Select connectors for demonstration.

b. Select termination processes.

c. Demonstrate the necessary techniques.

d. Develop semi-automated process stations and operate them successfully.

e. Define a fully automated facility which could terminate up to 500 assemblies per eight hour shift using the developed processes.

The program organization for accomplishing this is shown in Figure 3-1. Since this program spanned a broad area of technology and process expertise, a fairly large advisory staff was available for consultation and review.

A documentation summary of the program is shown in Figure 3-2. The documents are included as appendices, as referenced in the figure.

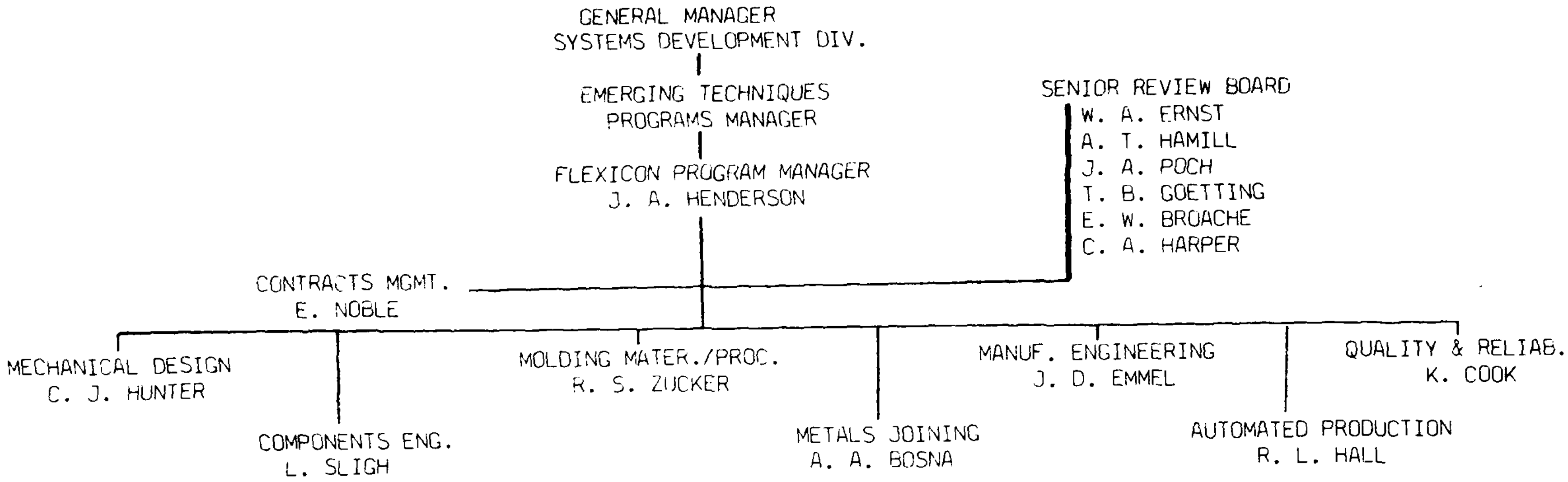



Figure 3-1: The Program Organization for FLEXICON Spanned Many Areas of Technological Expertise.

| PARTS | + | PROCESSES | = | ASSEMBLY |
|---|---|---|---|---|
| CONNECTORS<br>AMP<br>584R650<br>(APPENDIX A) | | INSULATION REMOVAL<br>(APPENDIX D) | | 685R539<br>(APPENDIX H) |
| HUGHES<br>584R701<br>(APPENDIX B) | | WELDING<br>(APPENDIX E) | | |
| | | SEALING<br>(APPENDIX F) | | |
| FLEXIBLE PW & PWB<br>685R383<br>(APPENDIX C) | | MOLDING<br>(APPENDIX G) | | |

Figure 3-2: FLEXICON Documentation

# 4.0 PROGRAM RESULTS

The FLEXICON program resulted in the development of three new processes in the termination and molding of flexible printed wiring to connectors as well as the definition of a fully automated facility for producing these connector assemblies at the rate of 500 assemblies per eight hour shift; that is, one per minute. In this section, we discuss the selection and the design of connectors for the processes, the development and selection of the processes, the semi-automated process demonstrations, environmental evaluations, the definition of the fully automated facility, the implementation plans through which the results of this program are incorporated in Westinghouse internal programs as well as advertised to the outside industry, and the cost benefits recognized from the program. Much of this is summarized in a series of technical reports prepared for the industry introduction presentations which are included as Appendix I of this report.

## 4.1 CONNECTORS

Flexible printed wiring is a planar technology, that is, all the conductors are in a single common insulation on a plane; therefore, connectors that lend themselves to the planar technology were selected. In this program, they were limited to two-row connectors. Connectors of 50 mil pitch, that is, 50 thousandths of an inch center-to-center spacing on the contacts, and connectors with 100 mil pitch were both demonstrated in this program. The bulk of the program was worked with the 50 mil connectors. Dual-row connectors with 40 contacts per row were primarily used.

### 4.1.1 Selection Technique and Results

The selection technique which is used for evaluation and selection of connectors and later extended into selection of the processes as shown in paragraph 4.2.1 was developed as an extension of a technique used by the National Institutes of Health in the 1960's. As shown in Figure 4-1, a matrix of values was first established for the connectors that were under consideration establishing the relative score of the connectors one to another for each of several factors. The columns in this matrix were determined independently, that is, relative cost of connectors had no direct interaction at this point with any of the other columns in the matrix. In this way, the relative weighting of the seven factors for importance was separately determined. By post-multiplying the factor matrix with the factor weighting which is shown on the right side of Figure 4-1, a value matrix which is weighted is realized with the sum of each row indicating the total value. This is shown in Figure 4-2. The algebraic matrix notation is $[A]\{B\} = [C]$. The way these matrixes were established, the lowest number indicated the best selection. These results indicate that the Amp mini-box connector should be considered first. A close second was the Hughes IBM connector. Two further considerations not shown in the evaluation were that the Amp mini-box connector already had met QPL of MIL-C-55302/117, 118, 119, 31 (with no interfacial seal), and that Burndy could be a second source for the Hughes connector. Both of these connectors selected have now been modeled with an interfacial seal. All suppliers evaluated are listed in Table 2.

| Connectors \ Variable Factors | Relative cost of connector | Degree of tooling req'd | Mat'l/parts available | Current carry capacity | Adaptability to mold | Reliability | Process compatibility |
|---|---|---|---|---|---|---|---|
| BURNDY ML 80 | 4 + | 2 | 2 | 4 | 2 | 5 | 5 |
| ITT MEB or MT | 8 | 2 | 1 | 1 | 5 | 6 | 8 |
| AMP Minibox | 2 | 4 | 1 | 3 | 5 | 3 | 3 |
| Hughes 1093212 | 4 | 2 | 2 | 4 | 2 | 5 | 5 |
| $[A]_{ij}$ | 9-high 1-low | 9-much 1-little | 9-poor 1-good | 9-poor 1-good | 9-poor 1-good | 9-poor 1-good | 9-poor 1-good |

| Relative Weight | |
|---|---|
| Cost | .20 |
| Tooling | .16 |
| Available | .06 |
| Current | .02 |
| Moldable | .21 |
| Reliable | .22 |
| Proc.Comp. | .13 |
| | 1.00 |

$\{B\}_j$

Figure 4-1: Relative Position of Candidate Connectors (for all variables which differ)

| | Relative cost of connector | Degree of tooling req'd | Mat'l/parts available | Current carry capacity | Adaptability to mold | Reliability | Process compatibility | Totals | Rating |
|---|---|---|---|---|---|---|---|---|---|
| Burndy ML 80 | .8 + | .32 | .12 | .08 | .42 | 1.10 | .65 | 3.49 + | 3 |
| ITT | 1.6 | .32 | .06 | .02 | 1.05 | 1.32 | 1.04 | 5.41 | 4 |
| AMP | .4 | .64 | .06 | .06 | 1.05 | .66 | .39 | 3.26 | 1 |
| Hughes | .8 | .32 | .12 | .08 | .42 | 1.10 | .65 | 3.49 | 2 |

$[C]_{ij}$

Figure 4-2: Connector Weighted Matrix and Selection

TABLE 2

SUPPLIERS EVALUATED FOR THE FLEXICON PROGRAM

AMP, Inc.
Harrisburg, Pa. 17105
(717) 564-0100

Bendix
Electrical Components Division
Sidney, New York 13838
(607) 563-5304

Berg Electronics
New Cumberland, Pa. 17070

Burndy
Norwalk, Conn. 06856
(203) 838-4444

Cambion Thermionic Corp.
445 Concord Avenue
Cambridge, Mass. 02238
(617) 491-5400

Cannon ITT Electric
666 E. Dyer Road
Santa Ana, Ca. 92702
(714) 557-4700

Continental Connector Corp.
34-63 56th Street
Woodside, New York 11377
(212) 889-4422

GTE Sylvania, Inc.
Titusville, Pa. 16354
(814) 589-7071

Hughes Connecting Devices
17150 Von Karman Avenue
Irvine, Ca. 92714
(714) 549-5701

KEL-AM, Inc.
P.O. Box 313
Eldon, Mo. 65026
(314) 392-7174

Methode Electronics
7444 West Wilson Avenue
Chicago, Ill. 60656
(312) 867-9600

Micro Plastics, Inc.
Connector Division
9180 Gazette Avenue
Chatsworth, Ca. 91311
(213) 882-0244

RN Robinson Nugent, Inc.
800 East Eight Street
New Albany, Ind. 47150
(812) 945-0211

T. B. Ansley Electronics Corp.
3208 Humboldt Street
Los Angeles, Ca.
(213) 223-2331

Teledyne Kinetics
410 South Cedros Avenue
P.O. Box 427
Solana Beach, Ca. 92075
(714) 755-1181

Teradyne Components, Inc.
4 Pittsburgh Avenue
Nashua, New Hampshire 03060
(603) 889-5156

TRW Cinch Connectors
7111 Marriotville Road
Baltimore, Md. 21104
(301) 795-5775

U. S. Components, Inc.
35 Carlough Road
Bohemia, New York 11716
(516) 589-8080

Vicking Connectors
Rep-TRON, Inc. (REP)
10632 Little Patuxent Parkway
Columbia, Md. 21044
(301) 995-1433

### 4.1.2 Detailed Design and Modifications

The detailed design of the connectors selected is shown in Appendices A and B for the Amp and Hughes connectors respectively. Two basic modifications were necessary to both connectors to make them usable in the MIL airborne environment. The first involved the realignment of the contacts and contact tails so that instead of four rows of contact tails out the back of the connectors there were only two. The second modification required the addition of an interfacial seal. This was performed for low cost on a temporary basis in the Amp connector by laser drilling holes in a thin sheet of silicon material. In the Hughes connector, this was done by using a modified connector as a mold and pouring thin layers of the silicon rubber. In the cases of both connectors, the modifications for the contact tails and for the interfacial seals were considered to be of a temporary or prototype nature. Both must have some consideration in the form of slight design changes and proper tooling for production capability.

One further modification had to be demonstrated for these connectors. Since neither of the connectors had available jacking (mating) hardware the Amp connector was selected for a small development effort to design and demonstrate the availability of jacking hardware for this size connector. This has already been extended by Amp, Inc. to the point that there are now at least four different styles and sizes of jacking hardware available for the Amp mini-box series of connectors.

The Amp connectors are also available for termination to printed wiring boards both at right angles (as with plated-through holes) and straddle mount (as with surface-mounted components).

The designs of the flexible printed wiring and printed wiring boards for the demonstration of the techniques on this program are shown in Appendix C. In the case of flexible printed wiring, double sided with plated-through holes wiring was used so that we would have no problem with termination of the flex cable to round wire for the testing of the assemblies.

## 4.2 PROCESSES

Insulation removal of organic coatings and insulations from the one to two mil thick copper wiring without damage to the conductors has always been a challenge. Present flexible printed wiring approaches include skiving (mechanical abrading) or use non-insulated areas. In skiving, mechanical action against the conductor is necessary, often resulting in scored, scratched and even broken conductors. In non-insulation, custom design of each circuit cover coat is required. Sometimes pre-punching of the base insulation even before lamination of the copper foil is required.

Conductor termination of flexible printed wiring to many sizes and varieties of connectors is possible. A technique which does not limit the process to only a few connectors was desired. Crimping systems, solder systems and parallel gap welding systems have been the major approaches taken to date. Each has serious drawbacks. What was needed was a high speed, reliable, easily tested approach which could be applied with ease to a large variety of planar connectors.

For molding, a fast curing semi-flexible, environmentally resistant material must be used. This material must be rigid enough to support the weld terminations yet flexible at the exit point of the cable to prevent circuit breakage when cables are flexed at the connector.

In each of these three areas, significant advancement has been made by this program in the development and demonstration of processes beneficial to the termination of flexible printed wiring to connectors.

### 4.2.1 Selection Technique and Results

The evaluation of processes for the termination of flexible printed wiring to connectors as well as connectors to printed wiring boards was conducted using the same technique as used for connectors (paragraph 4.1.1). The unweighted factor matrix, previously referred to as Matrix A, is shown in Figure 4-3. The vector for post-multiplication is shown in Figure 4-4 for both the connector to FPW and connector to PWB cases. The resulting weighted matrixes for connector to FPW and connector to PWB are shown in Figures 4-5 and 4-6 respectively. As can be seen, the process selected for the termination of the flexible printed wiring to connectors was the use of laser welding, and for the termination of connectors to printed wiring boards was wave solder for right angle termination connectors and laser welding or vapor phase reflow for the termination of connectors to printed wiring boards on surface mount. At this point, we would recommend the use of the vapor phase reflow since no further development work was done on the laser welding termination to printed wiring boards.

### 4.2.2 Wiring Preparation (Laser Stripping)

The process developed for the removal of insulation from flexible printed wiring with no mechanical handling of the conductors is laser stripping using the 10.6 micron wavelength of the $CO_2$ laser. This technique allows the complete ablation of the insulation material with no thermal, mechanical or metallurgical deformation of the conductors of the flexible printed wiring. The process specification for laser stripping is included as Appendix D to this report and detailed technical information is included in the technology introduction reports, part of Appendix I. There is a wide range of laser power requirements and spot diameters over which this technique will work. Primarily, the use of 100 kilowatts per square inch power incident at the surface of the insulation has been found to be optimal. The polyimide insulation absorbs the laser energy, and rapidly and locally reaches ablation temperature, breaking down into its primary chemical constituents. These vapors can be easily vented away and/or filtered. We have found that the best approach is to only remove the insulation from one side of the cables. This completely opens the windows between the conductors but leaves insulation material on the backside of the conductor which significantly enhances the welding operation which follows. Cleaning of the flexible printed wiring after the laser ablation is easily accomplished with a solvent rinse accompanied with a very light brushing to remove any particulate which is left. Testing of circuits thus prepared with 25 mil spacing between the conductors showed that there was a 55 megohm resistance from conductor to conductor after the laser stripping (before cleaning) and that after cleaning the insulation resistance was on the order of $2 \times 10^6$ megohms using 500 volt potential at one minute time duration.

| Termination \ Variable Factors | | Relative cost | Reliability | Ease of inspection | Process repeatibility | Degree of proc tolerancing | Dissimilar metals | Mechanical strength | Electrical properties | Process safety | Degree of part prep | Adjacent joint effect | Rework/repair capability | Process flexibility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soldering | IR Reflow | 6 | 3 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 6 | 7 | 3 | 5 |
| | Vapor Phase | 5 | 3 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 6 | 6 | 3 | 5 |
| | Wave Solder | 3 | 2 | 3 | 3 | 4 | 3 | 3 | 2 | 3 | 3 | 4 | 4 | 4 |
| Welding | Parallel gap | 9 | 5 | 7 | 7 | 6 | 9 | 5 | 6 | 2 | 3 | 8 | 6 | 7 |
| | Resistance | 8 | 4 | 7 | 6 | 4 | 7 | 5 | 2 | 2 | 3 | 8 | 6 | 3 |
| | Ultra-sonic | 8 | 5 | 8 | 6 | 5 | 5 | 5 | 2 | 3 | 3 | 9 | 8 | 4 |
| | Laser | 2 | 2 | 2 | 3 | 3 | 7 | 4 | 2 | 3 | 3 | 3 | 6 | 3 |
| Mechanical Crimp | | 9 | 5 | 6 | 5 | 4 | 5 | 5 | 4 | 2 | 2 | 3 | 7 | 7 |
| $[A]_{ij}$ | | 9-high 1-low | 9-low 1-high | 9-poor 1-good | 9-poor 1-good | 9-high 1-low | 9-poor 1-good | 9-poor 1-good | 9-poor 1-good | 9-poor 1-good | 9-high 1-low | 9-many 1-none | 9-poor 1-good | 9-poor 1-good |

Figure 4-3: Termination Processes - Comparative Values of Factors

| Factor | Connector-FPW | Connector-PWB |
|---|---|---|
| Relative cost | .04 | .04 |
| Reliability | .13 | .12 |
| Ease of inspection | .03 | .03 |
| Process repeatibility | .13 | .12 |
| Process tolerancing | .10 | .09 |
| Dissimilar metals | .02 | .02 |
| Mechanical strength | .07 | .06 |
| Electrical properties | .14 | .13 |
| Process safety | .04 | .04 |
| Amount of part prep | .10 | .09 |
| Adjacent joint effect | .10 | .10 |
| Rework/repair | .03 | .12 |
| Process Flexibility | .06 | .05 |
| | 1.00 | 1.00 |
| | $\{B_{FPW}\}_j$ | $\{B_{PWB}\}_j$ |

Figure 4-4: Termination Processes - Factor Relative Weighting

| | | Relative cost | Reliability | Ease of inspection | Process repeatability | Degree of proc tolerancing | Dissimilar metals | Mechanical strength | Electrical properties | Process safety | Degree of part prep | Adjacent joint effect | Rework/repair capability | Process flexibility | Total | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soldering | IR Reflow | .24 | .39 | .09 | .39 | .40 | .06 | .21 | .28 | .12 | .60 | .70 | .09 | .30 | 3.87 | 4 |
| | Vapor Phase | .20 | .39 | .09 | .39 | .40 | .06 | .21 | .28 | .12 | .60 | .60 | .09 | .30 | 3.73 | 3 |
| | Wave Solder | .12 | .26 | .09 | .39 | .40 | .06 | .21 | .28 | .12 | .30 | .40 | .12 | .24 | 2.90 | 2 |
| Welding | Parallel gap | .36 | .65 | .21 | .91 | .60 | .18 | .35 | .84 | .08 | .30 | .80 | .18 | .42 | 5.88 | 8 |
| | Resistance | .32 | .52 | .21 | .78 | .40 | .14 | .35 | .28 | .08 | .30 | .80 | .18 | .18 | 4.54 | 6 |
| | Ultra-sonic | .32 | .65 | .24 | .78 | .50 | .10 | .35 | .28 | .12 | .30 | .90 | .24 | .24 | 5.02 | 7 |
| | Laser | .08 | .26 | .06 | .39 | .30 | .14 | .28 | .28 | .12 | .30 | .30 | .18 | .18 | 2.87 | 1 |
| Mechanical Crimp | | .36 | .65 | .18 | .65 | .40 | .10 | .35 | .56 | .08 | .20 | .30 | .21 | .42 | 4.46 | 5 |

$[C_{FPW}]_{ij}$

Figure 4-5: Termination Processes - Weighted Matrix - FPW

| | | | | | | | | | | | | | | | Total | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soldering | IR Reflow | .24 | .36 | .09 | .36 | .36 | .06 | .18 | .26 | .12 | .54 | .70 | .36 | .25 | 3.88 | 4 |
| | Vapor Phase | .20 | .36 | .09 | .36 | .36 | .06 | .18 | .26 | .12 | .54 | .60 | .36 | .25 | 3.74 | 3 |
| | Wave Solder | .12 | .24 | .09 | .36 | .36 | .06 | .18 | .26 | .12 | .27 | .40 | .48 | .20 | 3.19 | 1 |
| Welding | Parallel gap | .36 | .60 | .21 | .84 | .54 | .18 | .30 | .78 | .08 | .27 | .80 | .72 | .35 | 6.03 | 8 |
| | Resistance | .32 | .48 | .21 | .72 | .36 | .14 | .30 | .26 | .08 | .27 | .80 | .72 | .15 | 4.81 | 6 |
| | Ultra-sonic | .32 | .60 | .24 | .72 | .45 | .10 | .30 | .26 | .12 | .27 | .90 | .96 | .20 | 5.44 | 7 |
| | Laser | .08 | .24 | .06 | .36 | .27 | .14 | .24 | .26 | .12 | .27 | .30 | .72 | .15 | 3.21 | 2 |
| Mechanical Crimp | | .36 | .60 | .18 | .60 | .36 | .10 | .30 | .52 | .08 | .18 | .30 | .84 | .35 | 4.77 | 5 |

$[C_{PWB}]_{ij}$

Figure 4-6: Termination Processes - Weighted Matrix - PWB

### 4.2.3 Wiring Termination (Laser Welding)

The laser welding of flexible printed wiring to connector contact tails has been performed using a Neodymium: YAG Laser operating at 1.06 micron wavelength. The process specification for laser welding to connectors is included as Appendix E of this report and further details are also contained in the technology introduction reports in Appendix I. In addition to these reports, one particular emphasis needs to be made in regard to the laser welding. This technique has a wide latitude of weld schedule providing a much higher reliability of finished product because the weld schedule is easy to maintain. This was done, however, on conductors that were a mil and one-half thick against contact tails that were eight to ten mils thick. In this approach when we hit with two pulses from the laser on each contact within a few milliseconds of each other, the first pulse tended to vapor gas the insulation, providing a much higher pressure of contact for excellent thermal transmission between the upper conductor and the lower contact tail when the second pulse hit. This provided an excellent weld. One of the prime reasons that the weld schedule is so large is because of the amount of thermal transfer that can occur into the eight to ten mil thick contact tail without having a loss or a vaporization of the metal of the copper on the surface. Welding using this approach to a thinner contact tail, say one mil or one and one-half mils, as in trying to weld flex cable to printed wiring boards, may require a much tighter and much more closely controlled weld schedule. This was not investigated within the confines of this program.

Several tests were conducted of welds made using this technique, from welds which were just barely complete to welds which had blown away 50% of the material of the conductor and the contact tail. In all cases, failure of the conductor occurred away from the weld area with no failure at the weld itself. Metallurgical examination of the welds showed excellent weld cross-section with some gas trapping as a result of the rapid cooling. Remember that laser welding heats up only a very small amount of the material. There was a very high degree of consistency of the welds and a high degree of consistency of the visual appearance of the good welds; thus making visual inspection a very practical way of guaranteeing an excellent weld product.

### 4.2.4 Environmental Protection (Molding)

The principal requirements for molding of this termination are two: one is to provide the strain relief so that there is no loading or flexing of the circuits at the weld interface; the second is to provide a shield against contamination and dirt and, particularly in the military airborne environment, against moisture. To select a molding compound which would meet all of these requirements was not easy. The majority of molding compounds which are rapid curing are also rigid in their cured state. When a molding compound is applied to flexible printed wiring, it tends to terminate at the wiring in a fine miniscus which leaves a sharp point of material against the flexible printed wiring. Thus, the material must be somewhat flexible or that miniscus acts as a knifepoint which will break the circuit in a few flexes when it bends right at the connector. Therefore, selection of a semi-flexible compound which would support the welds, adhere well to the flexible printed wiring, particularly the organic polyimide material, and would also be semi-flexible at egress of the cable was important.

One other item needed to be considered in the area of molding of the connectors for this program. Most connectors supplied from vendors today are manufactured by the use of a basic mold block of insulating material into which contacts are inserted. This leaves a gap of air or space around the contacts of the connectors. This space must be filled and sealed prior to the use of a molding compound or that molding compound will run through and fill up the cavities that the pins are in. The process specification for the pin sealing of connectors is contained in this report as Appendix F. The process specification for the molding operation with hydantoin epoxy is contained in Appendix G. Both of these processes also have further information shown in Appendix I, the technical reports.

The molding operation with the Hydantoin epoxy, as shown in the technical reports, proved to be an excellent process with connectors of a thermoset epoxy such as the Diallyl Phthalate. A thermoplastic material such as Valox, though, did not work well with this process because it required too high a temperature. Therefore, another epoxy formulation was developed for use with the thermoplastic connectors. This formulation is shown in Table 3.

## 4.3 SEMI-AUTOMATED DEMONSTRATIONS

The three major processes established for the termination of flexible printed circuits with integral molded connectors were set up in semi-automated form for industry demonstrations and for the purpose of establishing cost information for the program. The molding operation was the simplest and required only a timer to operate the pneumatic control system for the molding. In both the laser insulation removal and the laser welding operations, an Aerotech controller was used. A sample program for the laser welding for the Amp Mini-box connector is shown as Appendix J. Most of the details of the semi-automated equipment are shown in the motion picture film which was prepared for the project. Much of the information learned from the semi-automated operations was applied to the fully-automated facilities development program which will be discussed later in this report.

## 4.4 ENVIRONMENTAL EVALUATIONS

Throughout this program several evaluations and tests were conducted on materials and processes to verify that the approaches taken would be acceptable within the military airborne environment. The testing is broken down into basically three steps. The first step involved evaluation of the flexible printed wiring after laser insulation removal to verify that the particulate matter left did not short out the system. The second step was to evaluate the welding and mold materials after the initial selection of process and material had been made. The third step was specific environmental testing of the assembled cable connector systems after they had been terminated in semi-automated facilities. The basic conclusions of the tests can be simply stated. The use of the $CO_2$ laser for insulation ablation was found to have no detrimental effect on the dielectric characteristics of the organic insulation. The laser welds were found to have superior strength to normal welding. From welds which appeared to be only partial all the way up to 50% material burn-out, they exhibited greater strength in a tension test than the basic copper track on the flexible printed wiring. The Hydantoin epoxy molding material was found to have excellent characteristics from moisture resistance. The Bisphenol epoxy formulation used for the Amp connector was found to have inadequate characteristics for the humidity environment.

TABLE 3

FAST CURING BISPHENOL EPOXY COMPOUND RZ 48-2

| | | |
|---|---|---|
| Bisphenol Epoxy Resin, EEW 190 (EPON 828) | | 100 PBW |
| Jeffamine D400 Polyoxypropyleneamine Hardener, EW 101 | | 52 |
| Jeffamine D2000 Polyoxypropyleneamine Hardener, EW 526 | | 8 |
| Jefferson 399 Accelerator (AEP, TEA, Pioeraline Proprietary Mixture) | | 10 |
| Mica Dust (-325 Mesh) Filler | | 43 |
| | TOTAL | 213 |

Cure 7 minutes at 100°C.

Post-cure 1 hour at 100°C.

Hardness Shore D 70

4.4.1 Test Program

During the latter part of phase 1 of this program, it was decided that we should verify the approaches taken to the best of our ability at that time regarding the environmental requirements of the military airborne environment. With insulation removal, since the ablation of the insulation left a particulate char, and that residue might be conductive, it was felt that resistivity measurements should be taken from circuit to circuit on a sample of flexible printed wiring to establish what the circuit to circuit resistance was. This was done first without the particulate char removed and second after cleaning in a light solvent and a light brushing. At the same time, initial welds had been completed with the Nd:Yag laser. The depth penetration of the weld had to be checked as well as the strength of the weld to tension pull. It was felt that the tension pull test would be more than adequate as far as a strength test was concerned because this was the only mode in which the circuit would be stressed once the molding compound had been applied, and then only if the mold material failed to bind adequately to the insulation of the flexible printed wiring. Therefore, tension pull testing of weld areas and metallagraphic inspection of weld cross-sections were both conducted. Since the formulation of the Hydantoin epoxy was currently being used in a non-accelerated type in the E3A program, no initial testing of this material was felt to be necessary.

4.4.2 Evaluation Results

Testing of the flexible printed wiring dielectric strength in air immediately after laser stripping (before cleaning) and then after cleaning was conducted on circuits that had approximately 30 mils space between the circuits. These were 20 mil circuits on 50 mil centers. Prior to breakdown, the resistivity measured at 85 volts in air was approximately 55 megohms. This was tested separately on several parallel sets of circuits. After solvent rinse and light brushing, readings taken for one minute at 500 volts indicated from $1.9 \times 10^6$ to $2.7 \times 10^6$ megohms resistance from circuit to circuit on parallel circuits. Again in this instance, six sets of parallel circuits were measured. These results indicate that a light solvent rinsing and light brushing after laser insulation removal prevents problems in the resistivity of the dielectric material caused by laser ablation.

DC resistance measurements of the welded joints per Mil Standard 202, Method 303 indicate that the DC resistance on the seven joints measured ranged from a little less than three milliohms to a little more than five and one-half milliohms on the weld joint (after subtracting the bulk resistance of the circuit length included in the measurement). Pull tests on eight weld joints, some samples ranging from partially welded to where 50% of the weld material had been blown away, showed weld width reductions from one-half to seven-eighths of the initial width of the weld. Although this amount of neck-down occurred at the weld areas, in no case did a failure of the joint occur. All failures ultimately occurred in the conductor, not at the weld region.

Insulation resistance tests measured on circuits molded with the preferred Hydantoin epoxy mold compound per Mil Standard 1344, Method 3003 using 500 volts indicated greater than 20 x $10^6$ megohms initial insulation resistance. After the moisture resistance tests, the measurements ranged from 1.5 x $10^3$ megohms to 3.6 x $10^3$ megohms, with one reading standing at 6.2 x $10^3$ megohms. All circuits subsequently passed 1,000 volt for one minute on adjacent pairs of circuits dielectric withstanding voltage tests. Final assembled units run through thermal shock per Mil Standard 202, Method 107, Test Condition B for 50 cycles showed less than five-tenths of 1% of variation in circuit resistance on any one of many circuits tested, thus thermal shock was also found to cause no problems on the Flexicon assemblies.

Moisture resistance testing on completed Flexicon assemblies was performed in a way which invalidated the results being used for absolute value. However, trends of the data clearly show certain conclusions. The cause of the invalidation is that the joint between the flexible printed wiring and the round wire which was used for the instrumentation of the cable assemblies was not sealed in any kind of molding compound prior to being inserted into the moisture chamber. Therefore, as soon as the moisture environment started, a direct surface track was available between all pairs of circuits and it showed on the data with the measurements from pretest ranging around $10^3$ megohms dropping all the way down to three and two megohms typically. These values held constant throughout all ten cycles of the moisture resistance tests as they were measured at the high temperature portion of the cycle. They also held true when the chamber was opened immediately after test and another set of measurements made. However after 24 hours with the door open, with the cables still in chamber, the megohm resistances again rose on the order of $10^2$ megohms on the samples for the Bisphenol epoxy and all the way up to $10^4$ megohms on the samples with the Hydantoin epoxy. Also it should be noted at this time that the normal dark grayish-brown Bisphenol epoxy color had changed to a milky white in the moisture environment. After the 24 hour room measurement, the connectors were all unmated, blown dry with nitrogen and then remated, then measurements taken again. There was no change in the measurements of any significance between these two sets of data. These results clearly indicate that the interfacial seals of the connectors as they were set up for this experiment were quite functional. The connector assemblies were then subjected to a 24 hour bake-out at 250° Fahrenheit and they were then again measured for insulation resistance. The readings which were taken at this time were in the $10^5$ and $10^6$ megohms range, clearly indicating that for both the Bisphenol epoxy and Hydantoin epoxy connectors there had been some moisture absorption into the epoxy; however, it must be pointed out again the Hydantoin epoxy was well above the Bisphenol epoxy in final measurements before the bake-out. After bake-out, the Bisphenol epoxy had returned to its original grayish-brown color.

As a result of these test results, we recommend the use of the Hydantoin epoxy for any thermoset connector as meeting the requirements of Mil Standards for airborne equipment. The Bisphenol epoxy, on the other hand, should be re-examined for formulation to determine what particular ingredient in this formulation or combination of ingredients caused the reduction in moisture resistance to the normally excellent Bisphenol epoxy family.

### 4.5 FULLY AUTOMATED FACILITY

The fully automated facility has been described in the motion picture film produced for this program. It is also described in full detail in the separate report entitled "Automated Facilities Report".

## 4.6 IMPLEMENTATION

The value of a manufacturing technology program can only be realized with the reduction of results to actual utilization in the manufacturing environment. Since this was recognized early in the program, a comprehensive plan for both internal and external implementation was prepared. This plan and its initial results was reported on at the Manufacturing Technology Advisory Group (MTAG) meeting, and is shown for reference in Appendix K.

The implementation results as of December, 1980 are listed below:

A. INTERNAL

1. AN/ALQ-131 (V) - Conversion of all FCC and FPW terminations to FLEXICON process, including those of prior "state-of-the-art" techniques. IN PRODUCTION

2. APG-66 - Advanced Signal Processor I/O Cable. PRODUCTION 1981

3. E3A-AWACS RADAR - On-board test equipment update - PRODUCTION 1981

4. AQUILA - Army RPV Sensor - PRE PRODUCTION 1981

B. EXTERNAL

| | Meeting | Location | Month (1980) | Approx. No. of People |
|---|---|---|---|---|
| 1. | SAE-A2H | San Diego, Ca. | Feb. | 50 |
| 2. | IPC | Orlando, Fla. | Apr. | 250 |
| 3. | Industry Demo | Baltimore, Md. | Aug. | 60 |
| 4. | ECSG | Philadelphia, Pa. | Oct. | 300 |
| 5. | Metals Joining | Charlotte, N.C. | Oct. | 200 |
| 6. | MTAG | Miami, Fla. | Oct. | 50 |
| 7. | GOMAC | Houston, Texas | Nov. | 50 |
| 8. | Westinghouse | Productivity Symp. | Sep. | 200 |
| 9. | Westinghouse | IR&D Symp. | Oct. | 500 |
| 10. | Motion Picture Film (10 Minutes) | | | |

In addition, two connector suppliers and two laser machining services suppliers have shown significant interest. The two laser service organizations, already performing work for us, are Laser Associates (Baltimore, Maryland) and Ebtech (Agawam, Massachusetts). These are not automated facilities.

One further note, there has been some detailed follow-up on the part of several other user organizations, some with much larger volume requirements than those tasked on this program.

## 4.7 COST/BENEFITS

The basic cost savings for military environment qualifiable connectors is shown in Table 4. These show the savings as they would be realizable in a fully automated facility. The basic cost of that facility is listed in Table 5.

The intangible benefits in quality control and reliability have not been estimated. Those savings will be significant as in the predictable automation of any previously hand-performed operation.

TABLE 4

COST COMPARISONS OF CONNECTOR ASSEMBLIES

| | Present Practice | FLEXICON |
|---|---|---|
| Connectors (Mated Pair) | $450. | $50. |
| Flexible Printed Wiring (4 layers) | 80. | 45. |
| Assembly (Value Added) | 90. | 4. |
| Maintenance Expenses | 1.2 | .2 |
| | $620. | $99. |

TABLE 5

COST OF FULLY AUTOMATED FACILITIES (ESTIMATED)

| | |
|---|---|
| Lasers - $CO_2$ | \$ 50K |
| Nd:YAG | 20K |
| X-Y Table and Base | 20K |
| Controller | 30K |
| Tooling & Structure | 50K |
| Molds and Injector | 80K |
| Miscellaneous & Set-Up | 50K |
| | \$300K |

# 5.0 ADDITIONAL CONSIDERATIONS

## 5.1 PITFALL AVOIDANCE

There are two areas in which attention to detail can remove two specific pitfalls. Both of these were worked around to permit the continuation of the program, and both point to probable design improvements in the connectors which can benefit actual connector use. These areas involve physical construction of the connector tabs and the use of molded block dielectric into which connector contacts are inserted at a later stage.

### 5.1.1 Connector Tabs

Several of the connectors with which we worked had been designed for two rows of .050 inch connector contacts and four rows of .100 inch contact tabs for insertion into PWB's. As a result, the tabs were offset from the center of the contacts. When the contacts were reversed in the connector block to provide a dual row .050 inch tab configuration, they had very little space (.002-.010) between them. A redesign of this area on certain connectors will solve the problem.

### 5.1.2 Molded Block Dielectric

The practice of molding the connector bodies as separate (from the contacts) items and assembling contacts in a subsequent operation created difficulties in the FLEXICON molding operation which were solved by "pin sealing" (see Appendices). Care must be taken in connector selection and design of molds that the low pressure compound injection does not push epoxy into the connector contacts from the back of the connectors. If the dielectric block of the connector is molded around the contacts, there is no difficulty. Pin Sealing, if ultimately required, could be automated as a batch process prior to entry to the FLEXICON Processes.

## 5.2 ADDITIONAL DEVELOPMENT RECOMMENDED

Two specific additional developments have been recommended; both involve the molding operation. First, it is suggested that the use of material other than glass-filled polyester be considered for connectors, and that cost-effective alternatives be explored. This should be accomplished toward the end of being able to use the Hydantoin Epoxy (and its cure temperature) instead of the Bisphenol. Second, it is recommended that further materials research be performed in the epoxy area to try and improve cure times and temperatures for LIM epoxies. Both of these would improve producibility.

## 6.0 SUMMARY AND CONCLUSIONS

The Army-sponsored project for the termination of Flexible Printed Wiring with Integral Molded Connectors has resulted in three significant advances in manufacturing technology. The use of a $CO_2$ laser for insulation removal obviates the need for any other insulation removal or exclusion practice. The welding with the Nd:YAG laser is a substantial reliability improvement over all other prior practices. The reduction of Liquid Injection Molding to small scale molding operations enhances productivity because of the relatively short cure time. The value of these to Westinghouse alone is evidenced by the rapid acceptance into four major programs. The value to the industry in general has been seen from the large attendance and interest at industry meetings. FLEXICON has been a very beneficial manufacturing technology program for industry and DOD programs.

APPENDIX A

AMP CONNECTOR SPECIFICATIONS
(584R650)

| REVISIONS | | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVAL |
| | | | |

APPENDIX A

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DO NOT SCALE

| TOLERANCES | | |
|---|---|---|
| DECIMALS | | ANGLES |
| 2 PLACES | 3 PLACES | |
| ± XX | ± .005 | ± .5° |

SELECTED ITEM

DRAWING TO BE CHANGED ONLY
BY APPROVAL OF PARTS ENGINEERING

| LATEST REV LTR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH NO. | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| LATEST REV LTR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SH NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |

SHEET REVISION STATUS

| | |
|---|---|
| CONTRACT NO. | |
| ORIGINAL DATE APPD | |
| DRAWN BY | AUTH |
| CHKD K. Benet | PARTS ENGR L. Slich |
| APPD | APPD |
| DESIGN ACTIVITY APPROVAL | |
| PROCURING ACTIVITY APPROVAL | |

**Westinghouse Electric Corporation**
DEFENSE & ELECTRONIC SYSTEMS CENTER — BALTIMORE, MD., U. S. A. 21203

FED. SUP. CLASS

CONNECTOR, ELECTRICAL, FLEXIBLE PRINT CIRCUIT AND P.C. BOARD. (.050 CENTERS)

| SIZE | CODE IDENT NO. | DWG NO. |
|---|---|---|
| A | 97942 | 584R650 |
| SCALE NONE | WEIGHT | SHEET 1 OF 20 |

FORM NO. 8AA1373F18 — A — W&F BALTIMORE 10 1131 HERCULENE 8-73 MC 9814

| WESTINGHOUSE P/N | FIG | DESCRIPTION | DIMENSIONS | | | MANUFACTURERS P/N |
|---|---|---|---|---|---|---|
| | | | 'A' DIA REF. | 'B' DIA REF | C ±.001 | AMP |
| 584R650 H01 | 1 | CONNECTOR, MALE | — | — | — | TO BE ASSIGNED |
| H02 | 2 | CONNECTOR, FEMALE | — | — | — | |
| H03 | 3 | CONNECTOR, MALE, RIGHT ANGLE | — | — | — | |
| H04 | 4 | JACKSCREW, RECEP. | — | — | — | |
| H05 | 5 | JACKSCREW, PLUG | — | — | — | |
| H06 | 6 | SNAP RING | .140 | .050 | .010 | |
| H07 | 6 | SNAP RING | .187 | .075 | .015 | |

| APPROVED MFR'S | H4-1 |
|---|---|
| NAME | CODE |
| AMP INC. | 00779 |

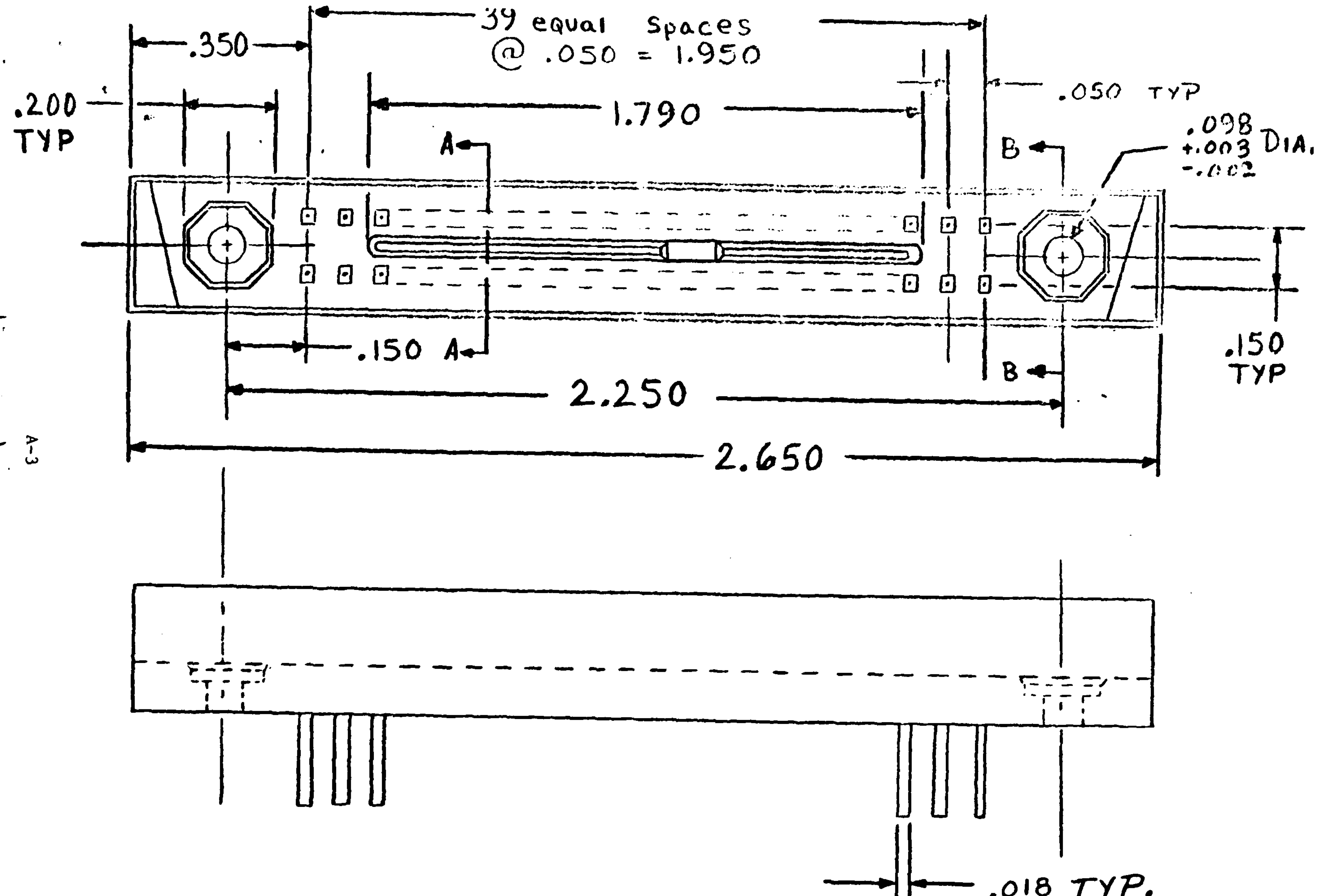
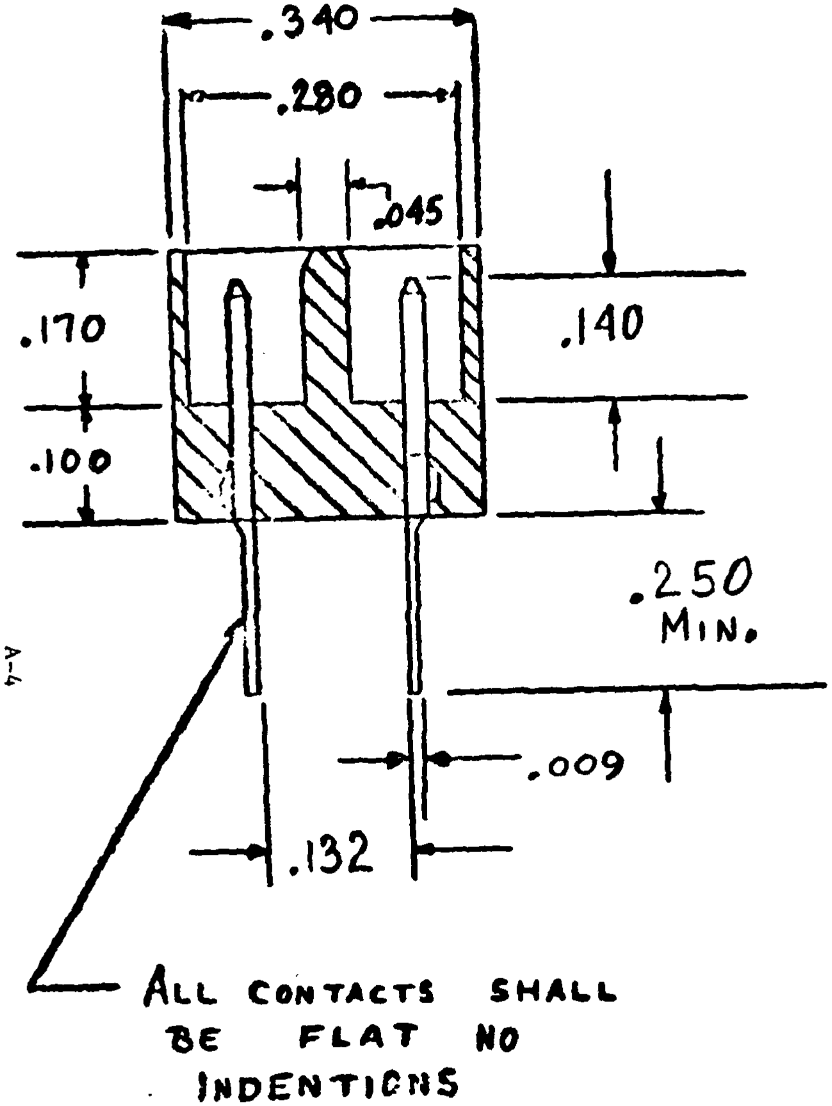
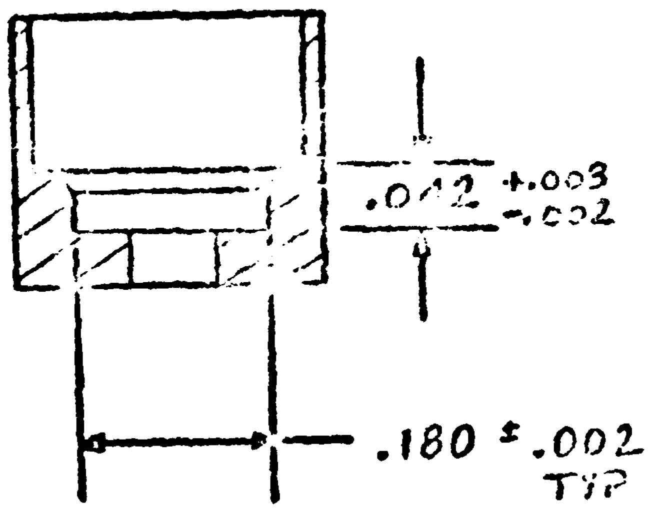



Figure 1. Connector, Male, Shrouded




SECTION A-A




SECTION B-B

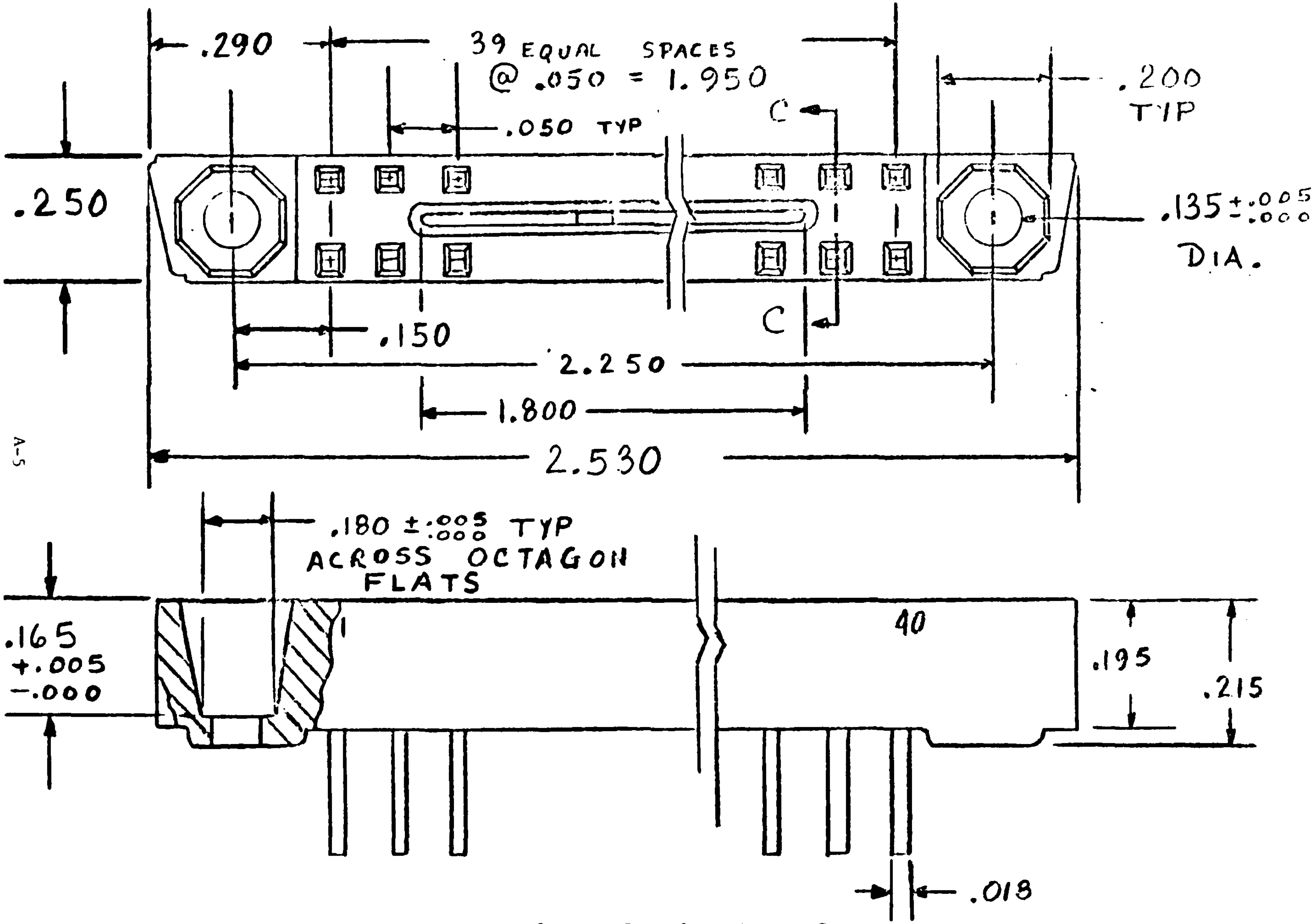
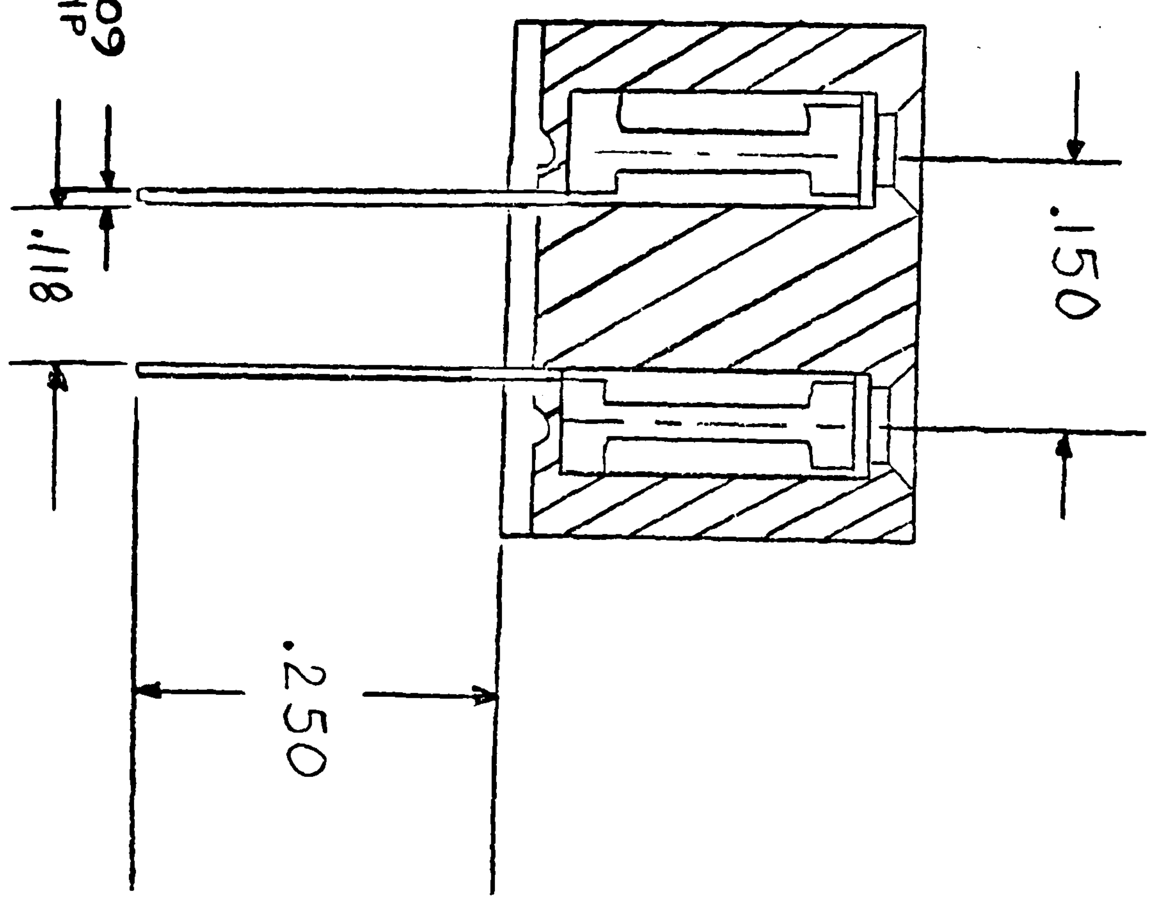



Figure 2. Connector, Receptacle, Female

SECTION C-C



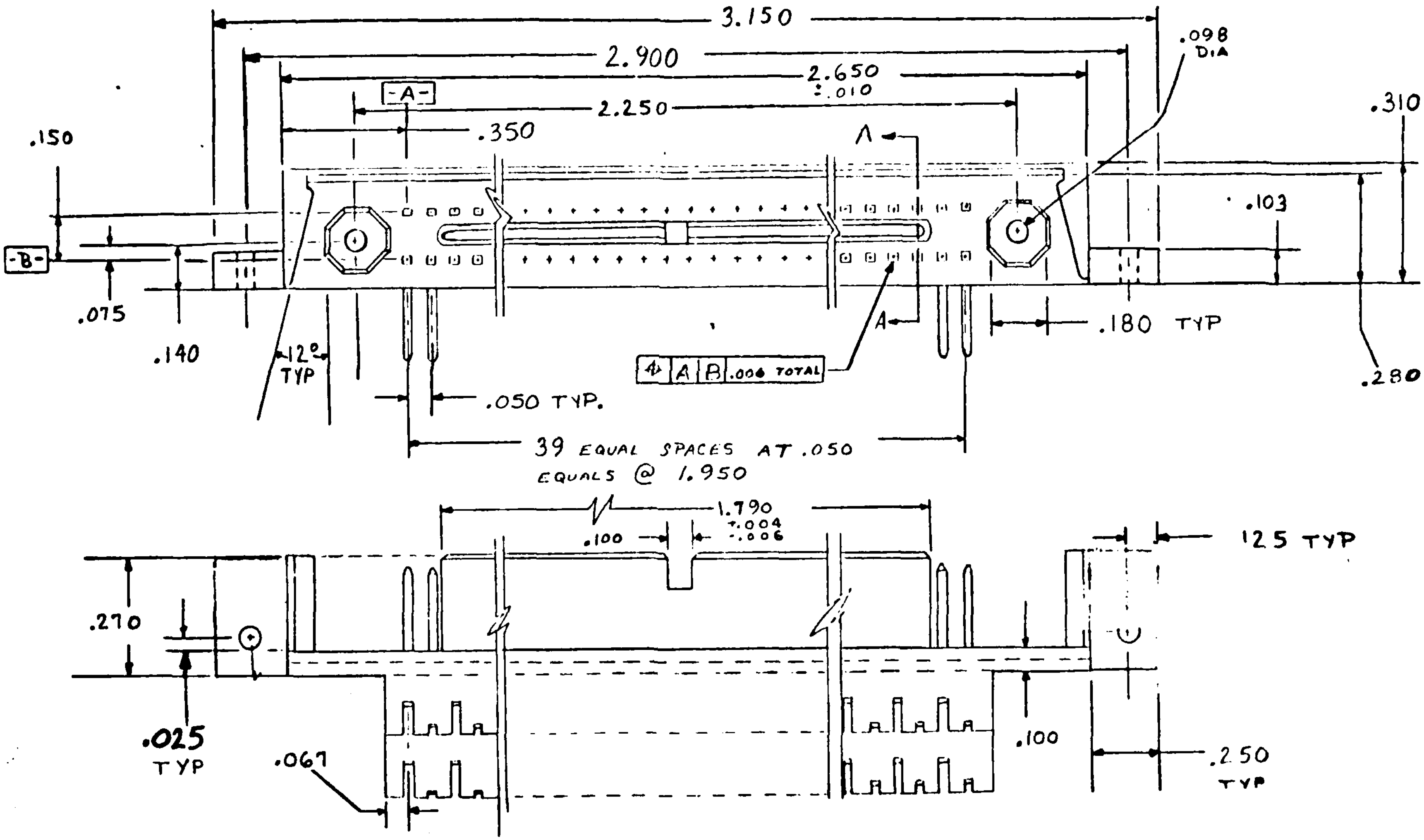
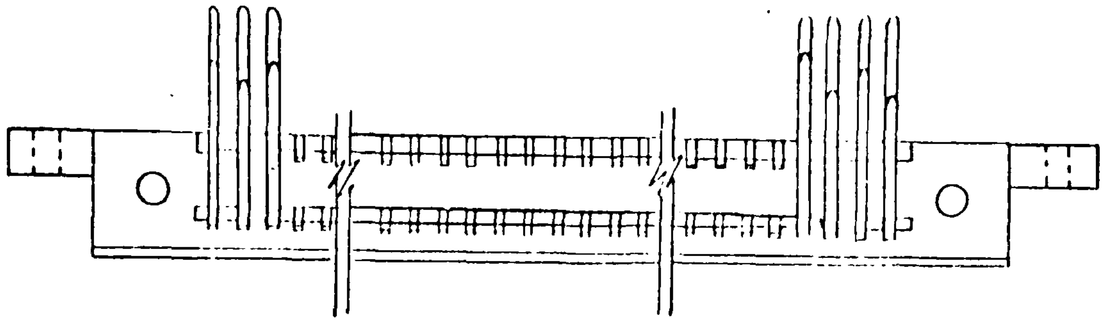
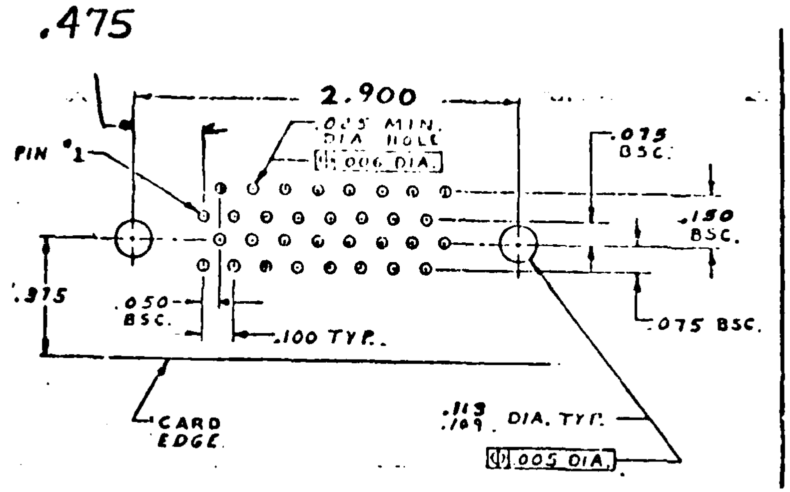
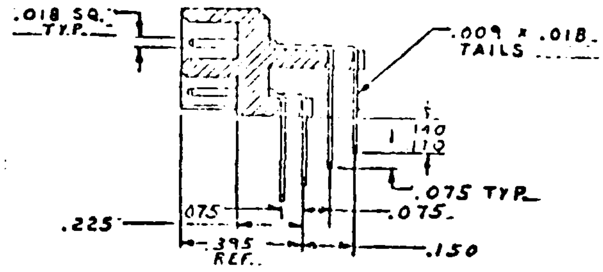



Figure 3. Connector, Plug, Right Angle Contacts
(Sheet 1 of 2)






RECOMMENDED MOUNTING




SECTION A-A

Figure 3. (Sheet 2 of 2)

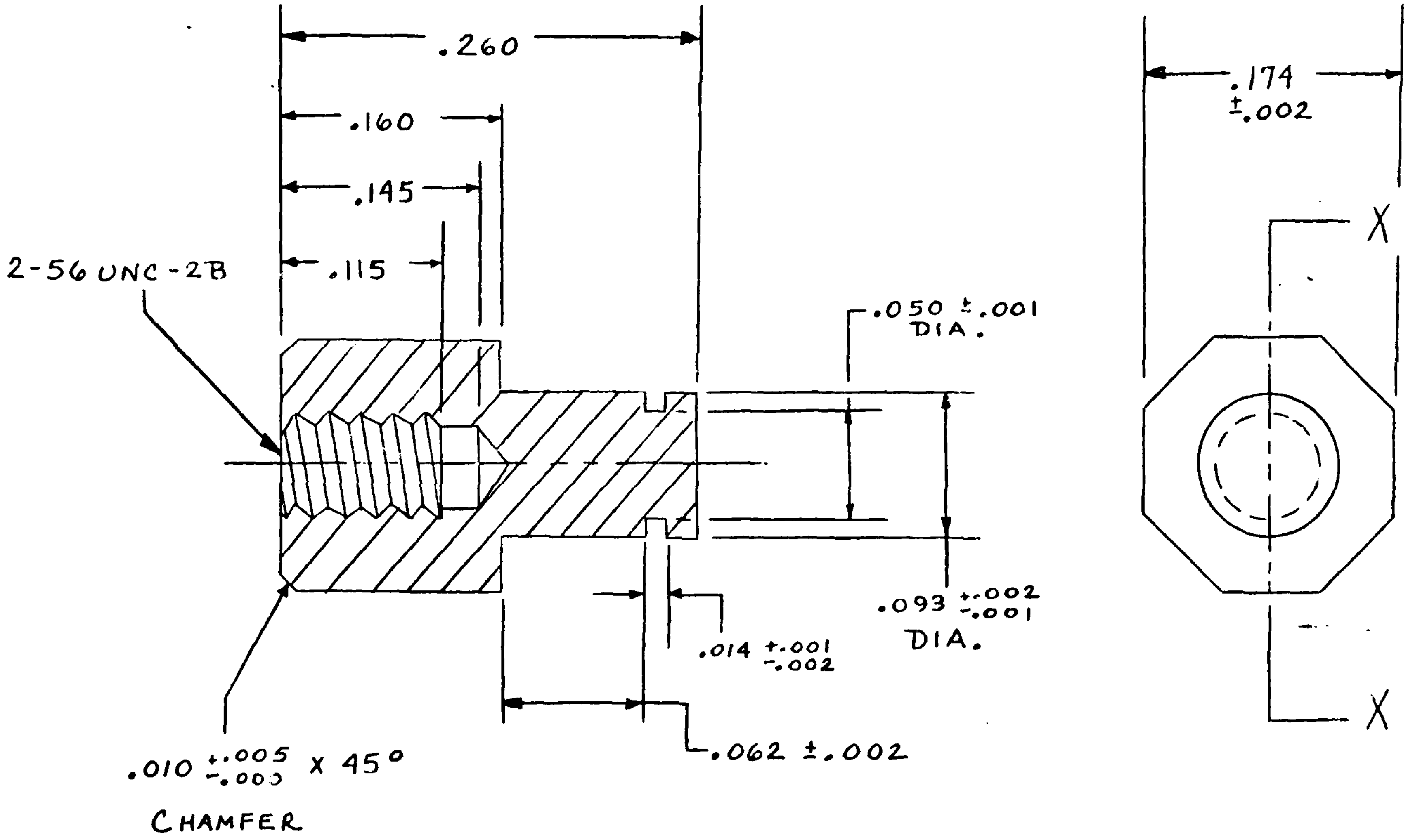



*Figure 4. Jackscrew (Receptacle)

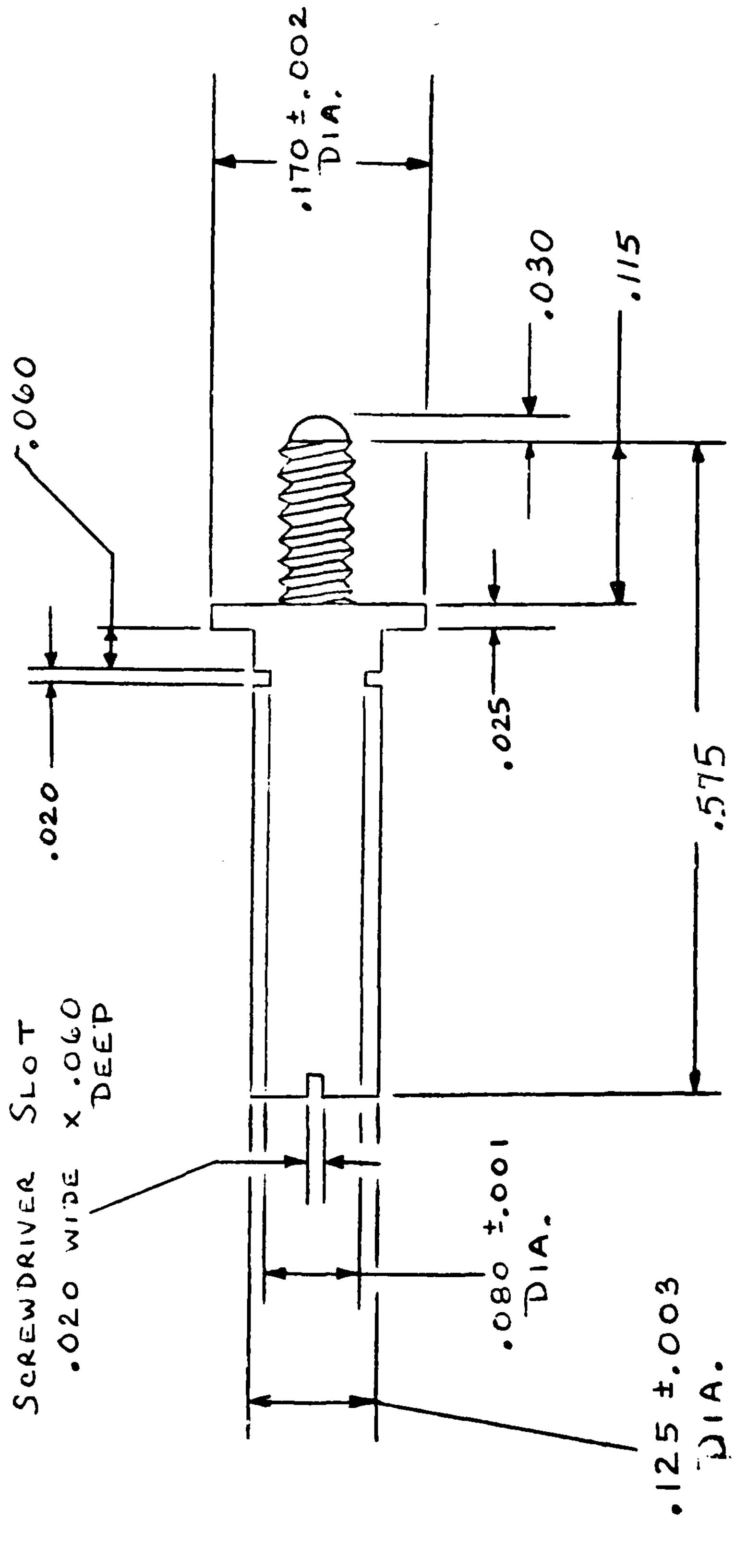



*Figure 5. Jackscrew (Plug)

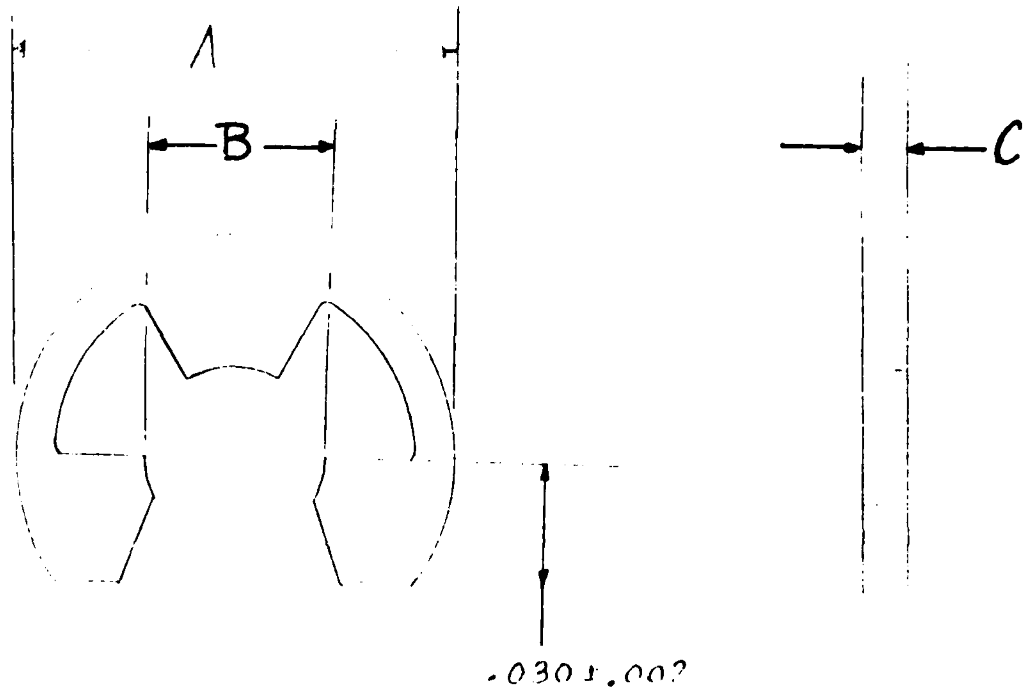



*Figure 6. Snap Ring

1. SCOPE. This drawing delineates the requirements for multi-contact, environment-resistant, electrical connectors for use with flexible printed circuitry. Requirements specified herein but which are not specified or controlled in the manufacturer's published specification are indicated by an asterisk (*).

2. Applicable Documents. The following documents of the revision indicated shall form a part of this document to the extent specified herein. Documents listed without a revision status shall be those in effect on the latest revision date of this document (See 3.1).

Government and Nationally Recognized Publication.

| | |
|---|---|
| QQ-P-35 | PASSIVATION |
| QQ-N-290 | Nickel plate |
| QQ-C-533 | Beryllium Copper |
| QQ-S-764 | STAINLESS STEEL |
| MIL-D-1000 | Engineering Drawing |
| MIL-M-24519 | Thermoplastic |
| MIL-G-45204 | Gold Plate |
| MIL-C-55302 | Multi-Pin Connector |
| MIL-STD-129 | Package Marking |
| MIL-STD-202 | Test Method |
| MIL-STD-1285 | Part Marking |
| H4-1 | Federal Code for supplier |
| 97942 | Westinghouse |

*3. Requirement. The connector shall meet the requirements of MIL-C-55302, unless otherwise specified herein.

3.1 Drawing Precedence. This drawing takes precedence over documents referred to herein and shall be interpreted in accordance with MIL-D-1000. A later revision of any document listed in section 2 without a specific revision letter may be used if requirements of the later revision are not degraded below those specified in the earlier revision.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R650 |
| SCALE | REV | SHEET 12 |

*3.2 Electrical.

3.2.1 Insulation Resistance. The insulation resistance shall not be less than the values specified below:

A) Before Humidity . . . . . . . . 5,000 megohms.

B) During and After Humidity . . . 100 megohms.

3.2.2 Dielectric Withstanding Voltage. When tested in accordance with 4.4.2, the dielectric withstanding voltage shall be as specified below:

A) Sea Level . . . . . . . . . . . . 600 $V_{RMS}$

B) 70,000 feet . . . . . . . . . . . 150 $V_{RMS}$

3.2.3 Millivolt Drop (Contact Resistance). The individual contact millivolt drop shall not exceed 18 millivolt.

3.2.4 Current Rating. The current rating shall be 1.5 amperes maximum for each individual contact.

*3.3 Mechanical.

3.3.1 Physical. The connectors shall meet the dimensional characteristics of the applicable figure.

3.3.2 Contact engagement and separation forces. The contact engagement and separation forces shall be as specified below:

A) Six (6) ounces maximum (See 4.4.3A)

B) One tenth (.10) ounce minimum (See 4.4.3B)

3.3.3 Connector mating and unmating forces. The connectors shall be capable of being mated and unmated without the aid of special tools. The forces shall be as specified below:

A) Maximum mating force shall not exceed 0.30 pounds times the number of contacts in one connector housing.

B) Minimum force to unmate shall be 0.03 pounds times the number of contacts in one connector housing. This force shall not exceed the total force of 3.3.3 A.

3.3.4 Durability. After 500 cycles of mating and unmating, there shall be no evidence of electrical degradation or change in mating characteristics. The requirements of 3.3.3 shall be met. See 4.4.9.

3.3.5 Contact Retention. Each individual contact shall withstand an axial load of 2 pounds without becoming dislodged from the connector housing.

3.3.6 Polarization. All connectors shall feature a polarization method to avoid mating in more than one position. Polarization shall be accomplished before engagement of contacts.

3.3.7 Marking. When tested in accordance with 4.4.4, all marking shall be clear and legible before, during and after solvency test.

*3.4 Material.

3.4.1 Connector Housing. The connector housing shall be Thermoplastic polyester in accordance with MIL-M-24519, type GPT-30F.

3.4.2 Contacts. The contacts shall be beryllium copper in accordance with QQ-C-533, halfhard.

3.4.3 Seal. The interfacial seal shall be in accordance with J.B.L. Manufacturer, composition 5557 or equivalent.

3.4.4 ATTACHED SHEET

*3.5 Finish.

3.5.1 Contacts. The contacts shall be plated as specified below:

(A) The contact tails shall be Nickel Plated in accordance with QQ-N-290, Class 3.

(B) The mating end of the contact shall be gold plated in accordance with MIL-G-45204, Type II, class 1, grade B. 0.00005 inch minimum thickness over Nickel plate in accordance with QQ-N-290, Class 2, 0.00003 inch thickness minimum.

3.5.2 ATTACHED SHEET

*3.6 Environmental. The requirements of MIL-C-55302 shall be met, except as modified herein. The connectors shall be terminated and potted with molding compound.

3.6.1 Salt Spray. When tested in accordance with 4.4.5, there shall be no evidence of corrosion or exposure to base materials. The requirements of 3.2 shall be met before during and after Salt Spray test.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R650 |
| SCALE | REV | SHEET 14 |

3.4.4 Jackscrews and Hardware. Jackscrews and hardware shall be corrosion resistant steel in accordance with QQ-S-764, Series 303, Composition A.

3.5.2 Jackscrews and Hardware. Jackscrews and hardware shall be passivated in accordance with QQ-P-35, Type I, II, or III.

3.6.2 Temperature Cycling. When tested in accordance with 4.4.6, there shall be no evidence of corrosion or exposure to base materials.

3.6.3 Moisture Resistance. When tested in accordance with 4.4.1, there shall be no evidence of corrosion or exposure to base materials. The requirements of 3.2 shall be met before and after the moisture resistance.

3.6.4 Vibration. When tested in accordance with 4.4.7, there shall be no evidence of the contacts loosening from the connector body or evidence of intermittency greater than 2 nanoseconds. The requirements of 3.2 shall be met before and after vibration test.

3.6.5 Shock. When tested in accordance with 4.4.8, there shall be no evidence of mechanical degradation or evidence of intermittency greater than 2 nanoseconds. The requirements of 3.2 shall be met before and after the shock test.

*3.7 Identification and Marking.

3.7.1 Part Marking. The connector body shall be marked in accordance with MIL-STD-1285 with the following information:

(A) Westinghouse H4-1 code identification number (97942) followed by a dash and the Westinghouse part number. Example: 97942-584R650H01. . . .

(B) Actual Manufacturer's number, register trademark or H4-1 code identification number.

(C) Date Code

3.7.2 Additional Marking. The contacts positions shall be identified.

*3.8 Workmanship. Workmanship shall be in accordance with MIL-C-55302.

*4.0 Quality Assurance Provision. The quality assurance provision of MIL-C-55302 shall be met except as modified herein.

4.1 Responsibility For Inspection.

4.1.1 Manufacturer. The manufacturer is responsible for controlling the quality of his product and for offering to the procuring agency only those items that conform to the requirements specified herein.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R650 |
| SCALE | REV | SHEET 16 |

4.1.2 Procuring Agency. The procuring agency reserves the right to perform any test it deems necessary to assure the parts conform to the specified requirements.

4.2 Qualification Testing. Parts shall be subjected to qualification testing when requested, in writing, by the procuring agency. See Table I.

4.3 Acceptance Testing (Group A). Acceptance testing shall be performed on all lots sent to the procuring agency. See Table II.

(A) With each shipment the manufacturer shall certify parts meet all acceptance tests and requirements of this drawing.

(B) The manufacturer shall maintain acceptance test data, in a safe place at his facility, for a period of (3) three years.

*4.4 Test Methods

4.4.1 Moisture Resistance (humidity). Test shall be conducted in accordance with MIL-STD-202, Method 106 except step 7B (vibration) shall be deleted. Connectors in a mated condition. Readings during humidity shall be taken during the high temperature portion of each days cycle. Readings before and after humidity shall be taken at room conditions +25 ± 5°C and 40-60% RH. See 3.6.3.

4.4.2 Dielectric Withstanding Voltage. The dielectric withstanding voltage test shall be conducted in accordance with MIL-STD-202, method 301. The rate of applied voltage shall not exceed 50 volts per second. The initial voltage shall be 50 volts. See 3.2.2.

4.4.3 Contact Engagement and Separation forces. A steel hardened test pin as specified below with a 4 microinch finish shall be inserted .100 and withdrawn and the measured force shall be as specified in 3.3.2.

A. Engagement: $0.0190 \begin{smallmatrix}+.0000\\-.0001\end{smallmatrix}$ X $0.0190 \begin{smallmatrix}+.0000\\-.0001\end{smallmatrix}$
See 3.3.2A.

B. Separation: $.0170 \begin{smallmatrix}+.0001\\-.0000\end{smallmatrix}$ X $.0170 \begin{smallmatrix}+.0001\\-.0000\end{smallmatrix}$

See 3.3.2B.

4.4.4 Marking Solvency Test. Marking solvency test shall be conducted in accordance with MIL-STD-202, Method 215. See 3.3.7.

4.4.5 Salt Spray. The Salt spray test shall be conducted in accordance with MIL-STD-202, Method 101, condition B. See 3.6.1.

4.4.6 Temperature Cycling. The temperature cycling test shall be conducted in accordance with MIL-STD-202, method 107, condition B, -65°C to +125°C see 3.2.2 and 3.6.2. Connector shall be in a mated condition.

4.4.7 Vibration. The vibration test shall be conducted in accordance with MIL-STD-202, Method 204, condition B. See 3.6.3. Connectors shall be in mated condition.

4.4.8 Shock. The shock test shall be conducted in accordance with MIL-STD-202, method 205, condition C. Connectors shall be in a mated condition. See 3.6.4.

4.4.9 Durability. The rate of mating and unmating shall not exceed 20 cycles per minute. See 3.3.4.

4.4.10 Millivolt Drop (Contact resistance). The test shall be conducted in accordance with MIL-STD-202, method 303. The test shall include a mating contact. The mating contact material shall be gold plated over nickel plate. The point of test on the mating contact shall be as close to the female contact as deemed possible. Requirements of 3.2.3 shall be met.

*5. Preparation for Delivery.

5.1 Preservation, Packing and Packaging. Preservation packing and packaging shall be in accordance with Level C of MIL-C-55302.

5.2 Unit Container. The smallest unit container shall be marked in accordance with MIL-STD-129 with the following information:

(A) Westinghouse H4-1 code identification number (97942) followed by a dash and the Westinghouse part number. Example: 97942-584R650H01.

(B) Manufacturer's name, registered trademark or H4-1 code identification number.

(C) Manufacturer's part number.

(D) Date of Packaging in accordance with MIL-STD-1285.

5.3 Shipping Container. The shipping container shall be marked in accordance with MIL-STD-129 with the following information:

(A) Westinghouse H4-1 code identification number (97942) followed by a dash and the Westinghouse part number. Example: 97942-584R650H01

(B) Manufacturer's name or registered trademark.

(C) Procuring Agency purchase order number.

(D) Month and year of preservation and packaging.

6. NOTES.

6.1 Approved Sources. Identification of approved source(s) hereon is not to be construed as a guarantee of present or continued availability as a source of supply for the item described on this drawing.

6.2 Westinghouse Internal.

6.2.1 Manufacturing-Receiving Inspection. Parts shall be retained in the shipping container unless required for inspection or assembly.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R650 |

| SCALE | REV | SHEET 19 |
|---|---|---|

## QUALIFICATION TESTING - TABLE I

| Examination and Test | Req't Para. | Test Method | Quantity |
|---|---|---|---|
| **Group A** | | | |
| Visual & Mechanical | | | 6 Parts |
| Finish | 3.5.1(A&B) | Inspection | |
| Dimension | Figure | - | 100% |
| Marking | 3.3.7 | 4.4.4 | |
| Workmanship | 3.8 | Inspection | No Failures |
| Dielectric Withstanding Voltage | 3.2.2 | 4.4.2 | Allowed |
| **Group B** | | | |
| Moisture Resistance | 3.6.3 | 4.4.1 | 3 Parts |
| Vibration | 3.6.4 | 4.4.7 | From Group A |
| Durability | 3.3.3 | 4.4.9 | |
| Salt Spray | 3.6.1 | 4.4.5 | No Failures |
| Millivolt Drop (contact resistance) | 3.2.3 | 4.4.10 | Allowed |
| **Group C** | | | |
| Temperature Cycling | 3.6.2 | 4.4.6 | 3 Parts |
| Shock | 3.6.5 | 4.4.8 | From Group A |
| Contact Engagement & Separation Forces | 3.3.2 (A&B) | 4.4.3 (A&B) | No Failures Allowed |

## ACCEPTANCE TESTING - GROUP A - TABLE II

| Examination or Test | Req't Para. | Test Method | Quantity |
|---|---|---|---|
| Visual & Mechanical | | | |
| Finish | 3.5.1(A&B) | Inspection | 100% |
| Dimension | Figures | - | No Failures |
| Marking | 3.3.7 | 4.4.4 | Allowed |
| Workmanship | 3.8 | Inspection | |
| Dielectric Withstanding Voltage | 3.2.2 | 4.4.2 | |

| SIZE | FSCM NO. | DWG NO | |
|---|---|---|---|
| A | 97942 | 584R650 | |
| SCALE | REV | | SHEET 20 |

# APPENDIX B

## HIGHER CONNECTORS SPECIFICATION

(584R701)

| REVISIONS | | | |
|---|---|---|---|
| LTR | DESCRIPTION | DATE | APPROVAL |
| | APPENDIX B | | |

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DO NOT SCALE

| TOLERANCES | | |
|---|---|---|
| DECIMALS | | ANGLES |
| 2 PLACES | 3 PLACES | |
| ± .03 | ± .010 | ± .5° |

SELECTED ITEM

DRAWING TO BE CHANGED ONLY
BY APPROVAL OF PARTS ENGINEERING

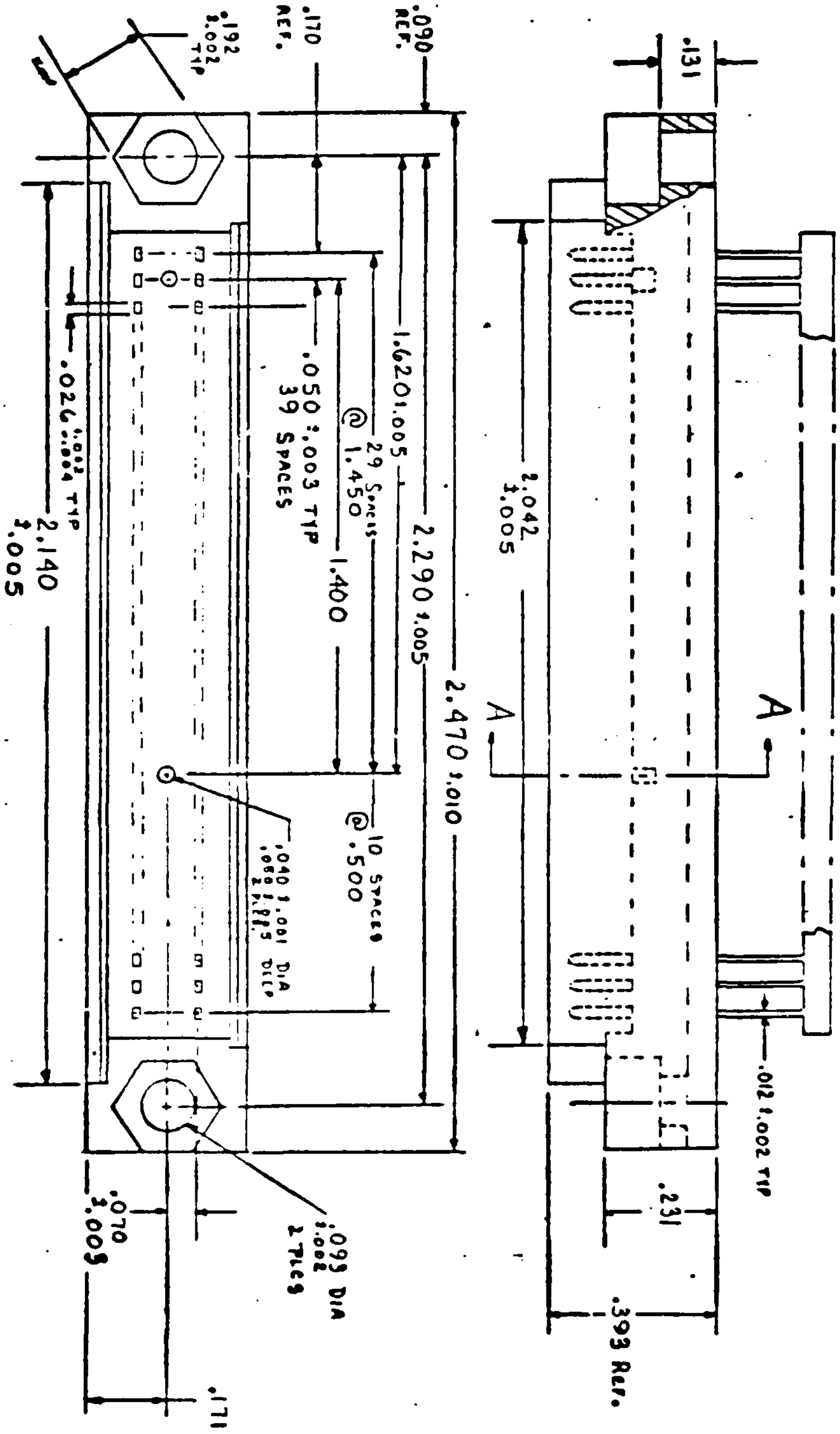
| LATEST REV LTR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH NO. | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| LATEST REV LTR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SH NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |

SHEET REVISION STATUS

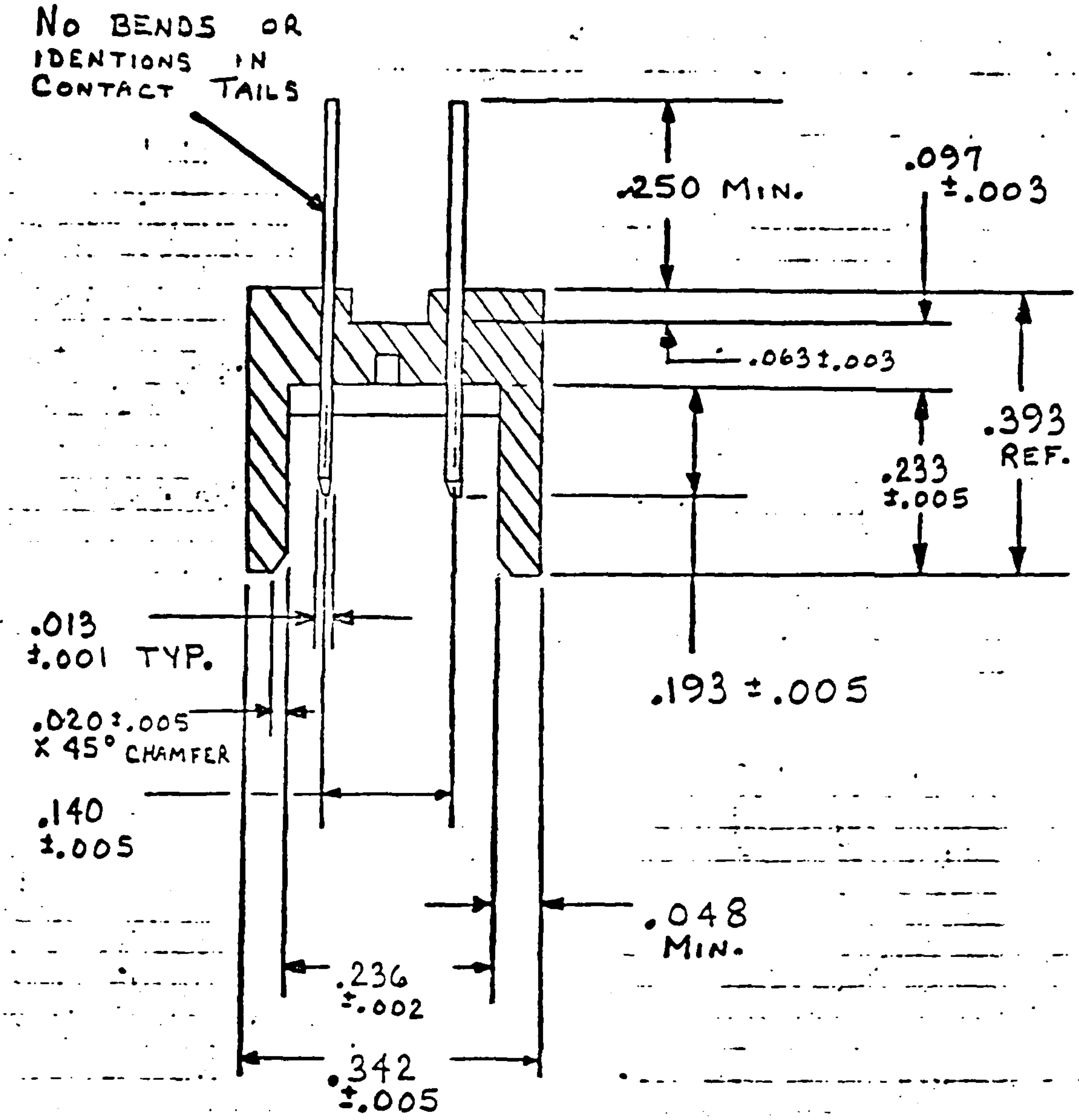
| | | |
|---|---|---|
| CONTRACT NO. | | **Westinghouse Electric Corporation**<br>DEFENSE & ELECTRONIC SYSTEMS CENTER — BALTIMORE, MD., U. S. A. 21203 |
| ORIGINAL DATE APPD | | |
| DRAWN BY | AUTH | FED. SUP. CLASS |
| CHKD K. Benet | PARTS ENGR L. Sligh | CONNECTOR, ELECTRICAL, FLEXIBLE PRINT CIRCUIT AND P.C. BOARD. (.050 CENTERS) |
| APPD | APPD | |
| DESIGN ACTIVITY APPROVAL | | SIZE A — FSCM NO. 97942 — DWG NO. 584R701 |
| PROCURING ACTIVITY APPROVAL | | SCALE NONE — WEIGHT — SHEET 1 OF 14 |

| (W) PART NUMBER | FIG | DESCRIPTIONS | MFR'S P/N | |
|---|---|---|---|---|
| | | | HUGHES | BURNDY |
| 584R701 H01 | 1 | CONNECTOR, PLUG | TO BE ASGN | TO BE ASGN |
| H02 | 2 | CONNECTOR, RECEPTACLE | | |
| H03 | 3 | CONNECTOR, PLUG, RIGHT ANGLE. P.C.B | | |

FIGURE 1. CONNECTOR, PLUG



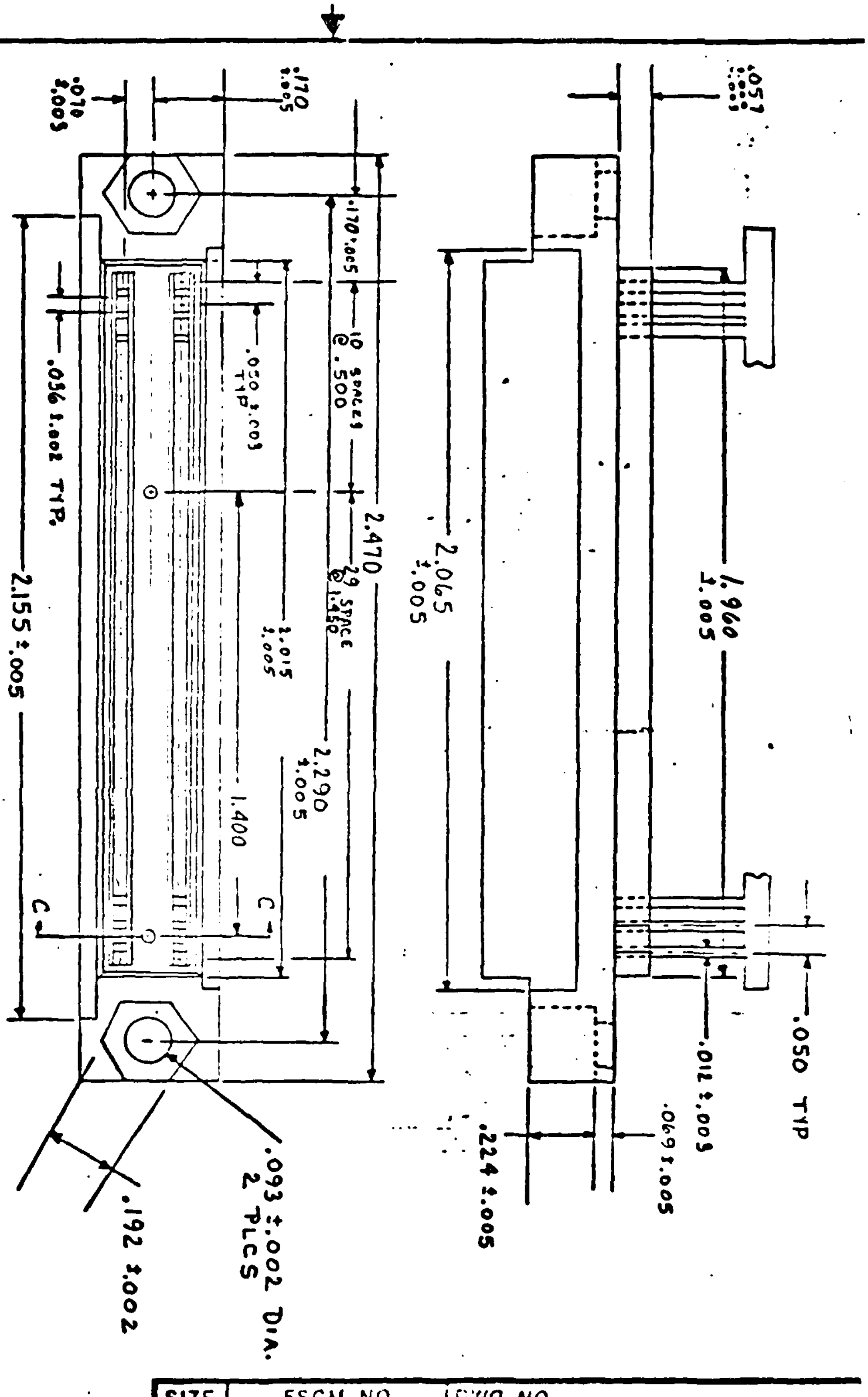
| SIZE | FSCM NO. | DWG NO |
| --- | --- | --- |
| A | 97942 | 584R701 |
| SCALE | REV | SHEET |



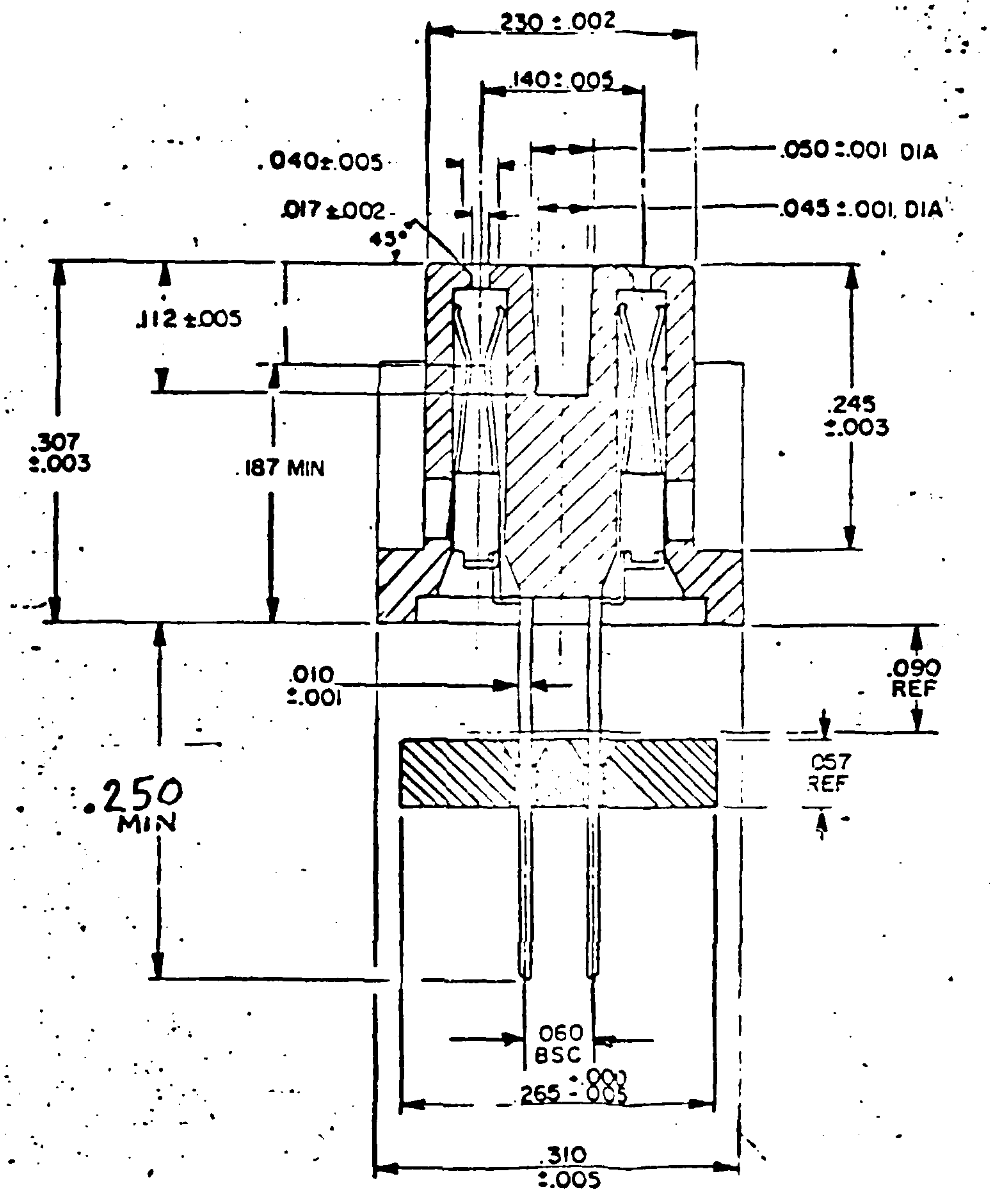

SECTION A-A

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET |

FIGURE 2. CONNECTOR, RECEPTACLE




| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET 5 |




SECTION C-C

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET |

1. SCOPE. This drawing delineates the requirements for multi-contact, environment-resistant, electrical connectors for use with flexible printed circuitry. Requirements specified herein but which are not specified or controlled in the manufacturer's published specification are indicated by an asterisk (*).

2. Applicable Documents. The following documents of the revision indicated shall form a part of this document to the extent specified herein. Documents listed without a revision status shall be those in effect on the latest revision date of this document (see 3.1).

Government and Nationally Recognized Publication.

| | |
|---|---|
| QQ-N-290 | Nickel plate |
| QQ-C-533 | Beryllium Copper |
| MIL-C-14550 | Copper Strike |
| MIL-D-1000 | Engineering Drawing |
| MIL-M-14 | Diallyl Phthalate |
| MIL-G-45204 | Gold Plate |
| MIL-C-55302 | Multi-Pin Connector |
| MIL-STD-129 | Package Marking |
| MIL-STD-202 | Test Method |
| MIL-STD-1285 | Part Marking |
| H4-1 | Federal Code for supplier |

Other Publications

| | |
|---|---|
| J.B.L. Manufacturers Composition 5557 | (28704) Rubber |
| Hughes Aircraft Composition 24776 | (53669) Molding Compound |

*3. Requirement. The connector shall meet the requirements of MIL-C-55302, unless otherwise specified herein.

3.1 Drawing Precedence. This drawing takes precedence over documents referred to herein and shall be interpreted in accordance with MIL-D-1000. A later revision of any document listed in section 2 without a specific revision letter may be used if requirements of the later revision are not degraded below those specified in the earlier revision.

| SIZE | FSCM NO. | DWG NO | |
|---|---|---|---|
| A | 97942 | 584R701 | |
| SCALE | REV | | SHEET 7 |

*3.2 Electrical.

3.2.1 Insulation Resistance. The insulation resistance shall not be less than the values specified below:

A) Before Humidity . . . . . . . . . 5,000 megohms.

B) During and After Humidity . . . 100 megohms.

3.2.2 Dielectric Withstanding Voltage. When tested in accordance with 4.4.2, the dielectric withstanding voltage shall be as specified below:

A) Sea Level . . . . . . . . . . . . . 600 $V_{RMS}$

B) 70,000 feet . . . . . . . . . . . . 150 $V_{RMS}$

3.2.3 Millivolt Drop (Contact Resistance). The individual contact millivolt drop shall not exceed 18 millivolt.

3.2.4 Current Rating. The current rating shall be 1.5 amperes maximum for each individual contact.

*3.3 Mechanical.

3.3.1 Physical. The connectors shall meet the dimensional characteristics of the applicable figure.

3.3.2 Contact engagement and separation forces. The contact engagement and separation forces shall be as specified below:

A) Six (6) ounces maximum (See 4.4.3A)

B) One tenth (.10) ounce minimum (See 4.4.3B)

3.3.3 Connector mating and unmating forces. The connectors shall be capable of being mated and unmated without the aid of special tools. The forces shall be as specified below:

A) Maximum mating force shall not exceed 0.30 pounds times the number of contacts in one connector housing.

B) Minimum force to unmate shall be 0.03 pounds times the number of contacts in one connector housing. This force shall not exceed the total force of 3.3.3 A.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET |

3.3.4 Durability. After 500 cycles of mating and unmating, there shall be no evidence of electrical degradation or change in mating characteristics. The requirements of 3.3.3 shall be met. See 4.4.9.

3.3.5 Contact Retention. Each individual contact shall withstand an axial load of 2 pounds without becoming dislodged from the connector housing.

3.3.6 Polarization. All connectors shall feature a polarization method to avoid mating in more than one position. Polarization shall be accomplished before engagement of contacts.

3.3.7 Marking. When tested in accordance with 4.4.4, all marking shall be clear and legible before, during and after solvency test.

*3.4 Material.

3.4.1 Connector Housing. The connector housing shall be Diallyl Phthalate in accordance with MIL-M-14, Type 50G-F, color green, durez molding No. 24776 or equivalent.

3.4.2 Contacts. The contacts shall be beryllium copper in accordance with QQ-C-533, halfhard.

3.4.3 Seal. The interfacial seal shall be in accordance with J.B.L. Manufacturer, composition 5557 or equivalent.

*3.5 Finish.

3.5.1 Contacts. The contacts shall be plated as specified below:

(A) The contact tails shall not be plated.

(B) The mating end of the contact shall be gold plated in accordance with MIL-G-45204, Type II, class 1, grade B, 0.00005 inch minimum thickness over Nickel plate in accordance with QQ-N-290, Class 2, 0.00005 inch thickness minimum, over copper strike in accordance with MIL-C-14550.

*3.6 Environmental. The requirements of MIL-C-55302 shall be met, except as modified herein. The connectors shall be terminated and potted with molding compound.

3.6.1 Salt Spray. When tested in accordance with 4.4.5, there shall be no evidence of corrosion or exposure to base materials. The requirements of 3.2 shall be met before during and after Salt Spray test.

3.6.2 Temperature Cycling. When tested in accordance with 4.4.6. there shall be no evidence of corrosion or exposure to base materials.

3.6.3 Moisture Resistance. When tested in accordance with 4.4.1, there shall be no evidence of corrosion or exposure to base materials. The requirements of 3.2 shall be met before and after the moisture resistance.

3.6.4 Vibration. When tested in accordance with 4.4.7, there shall be no evidence of the contacts loosening from the connector body or evidence of intermittency greater than 2 nanoseconds. The requirements of 3.2 shall be met before and after vibration test.

3.6.5 Shock. When tested in accordance with 4.4.8, there shall be no evidence of mechanical degradation or evidence of intermittency greater than 2 nanoseconds. The requirements of 3.2 shall be met before and after the shock test.

*3.7 Identification and Marking.

3.7.1 Part Marking. The connector body shall be marked in accordance with MIL-STD-1285 with the following information:

(A) Westinghouse H4-1 code identification number (97942) followed by a dash and the Westinghouse part number. Example: 97942-584R701H01.....

(B) Actual Manufacturer's number, register trademark or H4-1 code identification number.

(C) Date Code

3.7.2 Additional Marking. The contacts positions shall be identified.

*3.8 Workmanship. Workmanship shall be in accordance with MIL-C-55302.

*4.0 Quality Assurance Provision. The quality assurance provision of MIL-C-55302 shall be met except as modified herein.

4.1 Responsibility For Inspection.

4.1.1 Manufacturer. The manufacturer is responsible for controlling the quality of his product and for offering to the procuring agency only those items that conform to the requirements specified herein.

4.1.2 Procuring Agency. The procuring agency reserves the right to perform any test it deems necessary to assure the parts conform to the specified requirements.

4.2 Qualification Testing. Parts shall be subjected to qualification testing when requested, in writing, by the procuring agency. See Table I.

4.3 Acceptance Testing (Group A). Acceptance testing shall be performed on all lots sent to the procuring agency. See Table II.

(A) With each shipment the manufacturer shall certify parts meet all acceptance tests and requirements of this drawing.

(B) The manufacturer shall maintain acceptance test data, in a safe place at his facility, for a period of (3) three years.

*4.4 Test Methods

4.4.1 Moisture Resistance (Humidity). Test shall be conducted in accordance with MIL-STD-202, Method 106 except step 7B (vibration) shall be deleted. Connectors in a mated condition. Readings during humidity shall be taken during the high temperature portion of each days cycle. Readings before and after humidity shall be taken at room conditions +25 ± 5°C and 40-60% RH. See 3.6.3.

4.4.2 Dielectric Withstanding Voltage. The dielectric withstanding voltage test shall be conducted in accordance with MIL-STD-202, method 301. The rate of applied voltage shall not exceed 50 volts per second. The initial voltage shall be 50 volts. See 3.2.2.

4.4.3 Contact Engagement and Separation forces. Shall be determined.

4.4.4 Marking Solvency Test. Marking solvency test shall be conducted in accordance with MIL-STD-202, Method 215. See 3.3.7.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET 11 |

4.4.5 Salt Spray. The Salt spray test shall be conducted in accordance with MIL-STD-202, Method 101, condition B. See 3.6.1. Connector shall be terminated and in a mated condition.

4.4.6 Temperature Cycling. The temperature cycling test shall be conducted in accordance with MIL-STD-202, method 107, condition B, -65°C to +125°C see 3.2.2 and 3.6.2. Connectors shall be terminated and in a mated condition.

4.4.7 Vibration. The vibration test shall be conducted in accordance with MIL-STD-202, Method 204, condition B. See 3.6.3. Connectors shall be terminated and in mated condition.

4.4.8 Shock. The shock test shall be conducted in accordance with MIL-STD-202, method 205, condition C. Connectors shall be terminated and in a mated condition. See 3.6.4.

4.4.9 Durability. The rate of mating and unmating shall not exceed 20 cycles per minute. See 3.3.4.

4.4.10 Millivolt Drop (Contact resistance). The test shall be conducted in accordance with MIL-STD-202, method 303. The test shall include a mating contact. The mating contact material shall be gold plated over nickel plate over copper strike. The point of test on the mating contact shall be as close to the female contact as deemed possible. Requirements of 3.2.3 shall be met.

*5. Preparation for Delivery.

5.1 Preservation, Packing and Packaging. Preservation packing and packaging shall be in accordance with Level C of MIL-C-55302.

5.2 Unit Container. The smallest unit container shall be marked in accordance with MIL-STD-129 with the following information:

(A) Westinghouse H4-1 code identification number (97942) followed by a dash and the Westinghouse part number. Example: 97942-584R701H01

(B) Manufacturer's name, registered trademark or H4-1 code identification number.

(C) Manufacturer's part number.

(D) Date of Packaging in accordance with MIL-STD-1285.

| SIZE | FSCM NO. | DWG NO | |
|---|---|---|---|
| A | 97942 | 584R701 | |
| SCALE | | REV | SHEET 12 |

5.3 Shipping Container. The shipping container shall be marked in accordance with MIL-STD-129 with the following information:

(A) Westinghouse H4-1 code identification number (97942) followed by a dash and the Westinghouse part number. Example: 97942-584R650H01

(B) Manufacturer's name or registered trademark.

(C) Procuring Agency purchase order number.

(D) Month and year of preservation and packaging.

6. NOTES.

6.1 Approved Sources. Identification of approved source(s) hereon is not to be construed as a guarantee of present or continued availability as a source of supply for the item described on this drawing.

6.2 Westinghouse Internal.

6.2.1 Manufacturing-Receiving Inspection. Parts shall be retained in the shipping container unless required for inspection or assembly.

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET |

## QUALIFICATION TESTING - TABLE I

| Examination and Test | Req't Para. | Test Method | Quantity |
|---|---|---|---|
| Group A | | | |
| Visual & Mechanical | | | 6 Parts |
| Finish | 3.5.1(A&B) | Inspection | |
| Dimension | Figure | - | 100% |
| Marking | 3.3.7 | 4.4.4 | |
| Workmanship | 3.8 | Inspection | No Failures |
| Dielectric Withstanding Voltage | 3.2.2 | 4.4.2 | Allowed |
| Group B | | | |
| Moisture Resistance | 3.6.3 | 4.4.1 | 3 Parts |
| Vibration | 3.6.4 | 4.4.7 | From Group A |
| Durability | 3.3.3 | 4.4.9 | |
| Salt Spray | 3.6.1 | 4.4.5 | No Failures |
| Millivolt Drop (contact resistance) | 3.2.3 | 4.4.10 | Allowed |
| Group C | | | |
| Temperature Cycling | 3.6.2 | 4.4.6 | 3 Parts |
| Shock | 3.6.5 | 4.4.8 | From Group A |
| Contact Engagement & Separation Forces | 3.3.2 (A&B) | 4.4.3 (A&B) | No Failures Allowed |

## ACCEPTANCE TESTING - GROUP A - TABLE II

| Examination or Test | Req't Para. | Test Method | Quantity |
|---|---|---|---|
| Visual & Mechanical | | | |
| Finish | 3.5.1(A&B) | Inspection | 100% |
| Dimension | Figures | - | No Failures |
| Marking | 3.3.7 | 4.4.4 | Allowed |
| Workmanship | 3.8 | Inspection | |
| Dielectric Withstanding Voltage | 3.2.2 | 4.4.2 | |

| SIZE | FSCM NO. | DWG NO |
|---|---|---|
| A | 97942 | 584R701 |
| SCALE | REV | SHEET 14 |

REVISION NOTICE

| | | | | | |
|---|---|---|---|---|---|
| 469 | 1 | B. HET | N.S. | 1 | JARRETT |
| 189 | 1 | SLIGH | N.S. | 2 | PEC INSP |
| 291 | 1 | RAINIER | 125 | 1 | HENDERSON |
| | | | 125 | 1 | HUNTER |

ACTION / AFFECTED: PURCHASING

RN- FG 437

SHEET 1 of 1

| ITEM | CIRCUIT SYMBOL | REQD | UM | CODE IDENT | PART NUMBER | ACTUAL V/P/C | SPEC NO. | NAME/DESCRIPTION/MATL | WT |
|---|---|---|---|---|---|---|---|---|---|

REF. DOC. 584R701 REV. —

(2) REVISE PARA. 3.5.1 (A) AS SHOWN:

3.5.1(A). THE CONTACT TAILS SHALL BE NICKEL PLATED IN ACCORDANCE WITH QQ-N-290, CLASS 2, 0.0001 -3 INCH THICKNESS MINIMUM.

(3) APPLY TO ALL FUTURE REQUISITIONS.

(4) INSPECT TO THE ABOVE.

(19) TO CLARIFY CONTACT TAIL PLATING.

RECEIVED MAR 18 1980 IN VAULT

F 7

| 20. EQUIP. | 21. UNIT | 30. C.E.I. NO. | 31. NEXT ASSY. | 32. LOWEST SERIALIZED ASSY. | 33. B.I.P. | 34. S.O. | 36. SUPERVISOR | DATE |
|---|---|---|---|---|---|---|---|---|
| LEXICON | — | — | — | — | RNRD | — | J. Loyd | 3/3/80 |

22. ORIGINATOR (PRINT): L. SLIGH EXT. 2268 DATE 3/3/80

23. DRAWING NAME: CONNECTOR

24. SEPARATE PARTS LIST: X

25. E.C.P. NO.: —

26. DRAWING NO.: 584R701

27. REV. TO: A

RN- 28 NO: FG437 SUB 1 of 1

29. REL. DATE: 3/18/80

Ned Rashear

35. M.I. ACTION: —

43. COMPLETE REVISION CONSISTS OF: THIS RN

44. DRAFTING CHARGE: A55691AALA

MAR 14 1980

37. ME: — 37A. I.E.

38. MSE/SPARES: — DATE

39. —

40. —

41. CCB DES ACTIVITY: [signature] DATE 3-3-80

42. CUSTOMER: — DATE

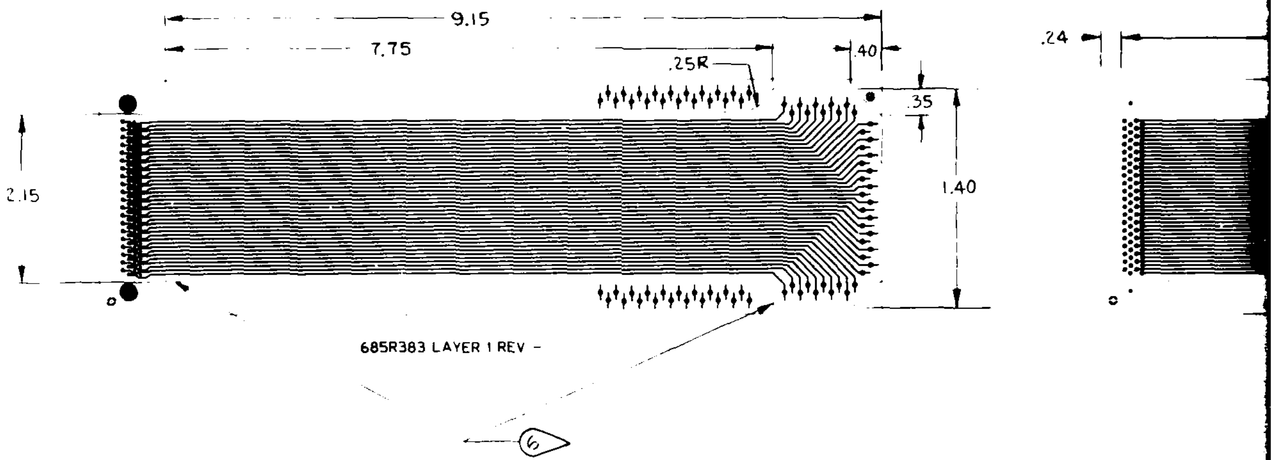
# APPENDIX C

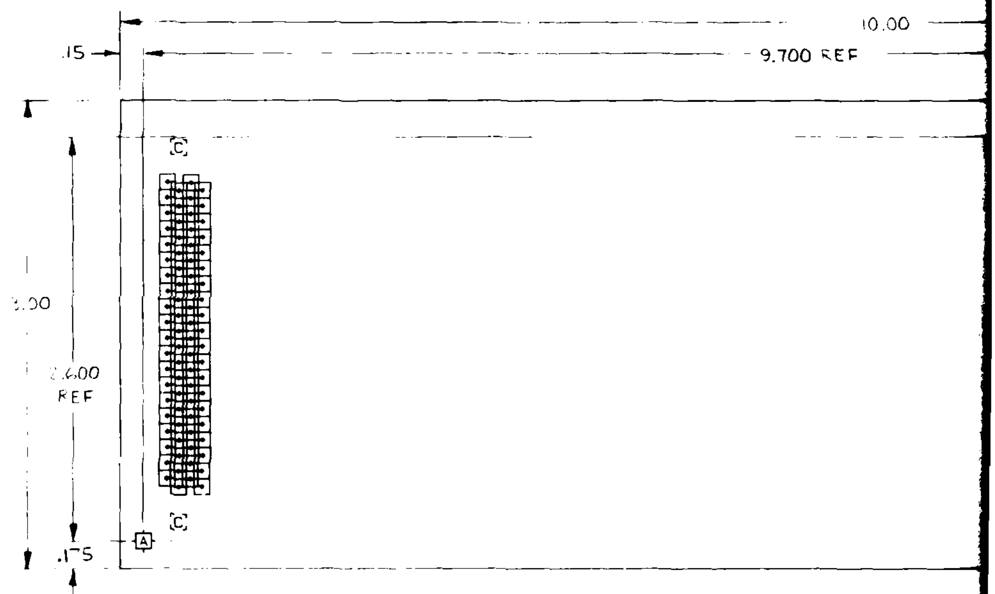
## FLEXIBLE PW AND PWB DRAWING

(685R383)

8 7 6 5

PARENTHETIC IDENTITIES ARE FOR WESTINGHOUSE REFERENCE ONLY




D

C

B

A

1 FABRICATE PER MIL-P-55110(PS802825A) FOR H01
FABRICATE PER PS80306MC FOR G01
ETCH PER ARTWORK 685R383

COMPONENT SURFACE — 1

| LAYER | 1 | 2 |
|---|---|---|
| REVISION | - | - |
| ETCH Δ | S | S |

Δ S=STR ETCH; R=RVS ETCH; B=BLANK(NO FOIL)SURFACE

2 CONDUCTOR REQUIREMENTS, UNLESS OTHERWISE SPECIFIED, SHALL BE:

| SURFACE | EXT |
|---|---|
| MINIMUM CLEARANCE | .010 |
| MINIMUM WIDTH | .010 |

3 THE INTERSECTION OF THE LOCATING BASE LINES AND ALL HOLES SHALL BE LOCATED ON A .025 BASIC GRID, TRUE POSITIONED WITHIN .006 DIA UNLESS OTHERWISE SPECIFIED.

4 MIL-P-13949/4, FL-GFN 062C1/1A2A.

5 MASK CIRCUITRY AND PADS IN THIS AREA BEFORE ETCHING FOR G01, RETAIN REGISTRATION MAR

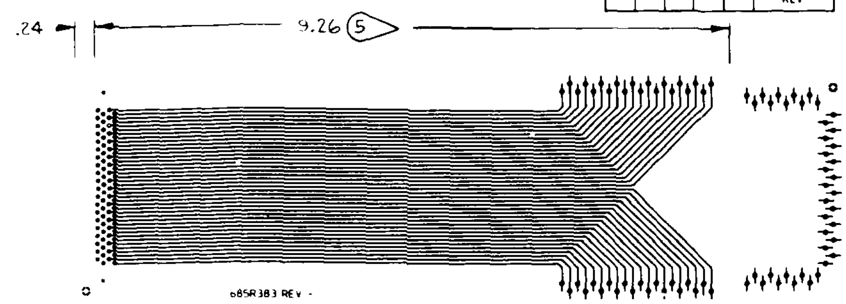
6 CUT ALONG TRIM LINES FOR G01

8 206 E 7 6 5

DWG NO. 685R383 SH

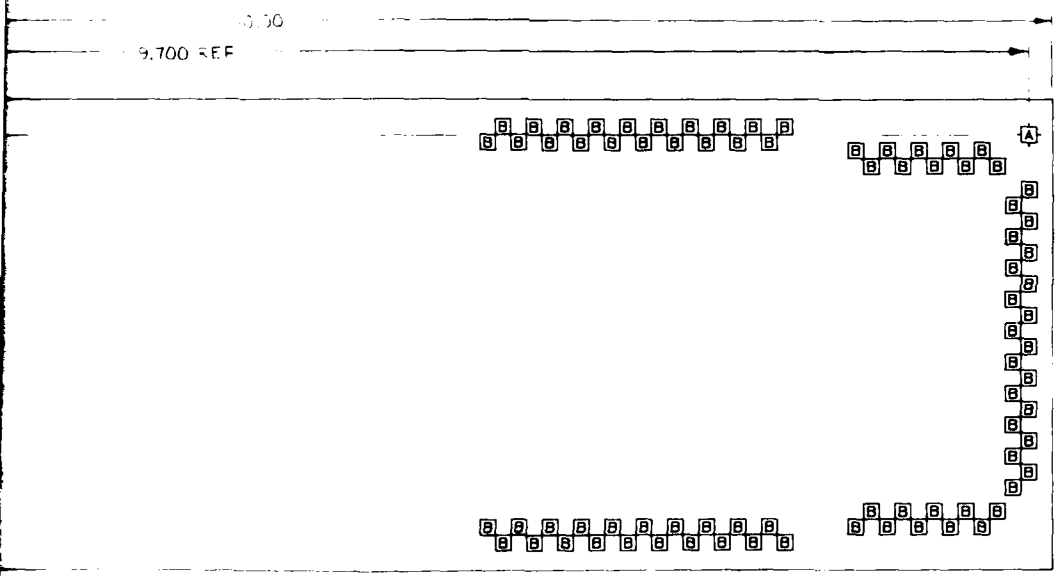
| SHEET REVISION STATUS | | | | | |
|---|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 | SHEET NO |
| | | | | | REV |

| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | – | DRAWING RELEASED | – | |




685R383 LAYER 2 REV –

| SYMBOL LEGEND | |
|---|---|
| SYMBOL | DENOTES |
| | REGISTRATION PLTG OPTL |
| | PLATED THRU HOLE |
| | HOLE, PLATING OPTIONAL |




| HOLE LEGEND | |
|---|---|
| SYMBOL | FINISHED SIZE |
| • | .025 +.004 −.003 DIA |
| A | .063 +.002 −.006 DIA |
| B | .037 +.004 −.003 DIA |
| C | .098 +.003 −.002 DIA |

OF THE LOCATING BASE LINES AND
E LOCATED ON A .025 BASIC GRID.
ITHIN .006 DIA UNLESS
ED.

-GFN 062C1/1A2A.

Y AND PADS IN THIS AREA BEFORE
, RETAIN REGISTRATION MARK
M LINES FOR G01

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | | 685R383H03 | | 10.00 X 3.00 OF .001 KAPTON | | M447293Q | 3 |
| 1 | | 685R383H02 | | 10.00 X 3.00 OF CLAD KAPTON | | M447698R | 2 |
| – | | 685R383H01 | | 10.00 X 3.00 OF .062 EPOXY GL | 4 | M441658Q | 1 |
| G01 | FSCM NUMBER | PART NO. | SYM | DESCRIPTION | GOVT SPEC | W SPEC | FIND NO |

QTY REQD | SYM | B = BULK MATERIAL V = VENDOR ITEM SEE CONTROL DWG | PARTS LIST SEE PL

| | |
|---|---|
| 685R539 | |
| NEXT ASSY | USED ON |
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DO NOT SCALE TOLERANCES ON DIM.

| 2 PLACE | 3 PLACE | ANGLES |
|---|---|---|
| ±.02 | ± — | ± — |

W SPEC 90S01 APPLIES

PROCESS SPEC

CONTR NO

ORIGINAL DATE OF DWG 7 DEC 79

DRAFTSMAN W S Kenny | APPD

CHECKED W S Kenny | APPD

APPD | APPD W R Samenuk

DESIGN ACTIVITY APPROVAL

PROCURING ACTIVITY APPROVAL

**Westinghouse Electric Corporation**
AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
BALTIMORE, MARYLAND 21203

PRINTED WIRING BOARD
TEST PATTERN
FLEXICON

| SIZE | FSCM NO | DWG NO. |
|---|---|---|
| D | 97942 | 685R383 |
| SCALE 2/1 | WEIGHT | SHEET 1 OF 1 |

# APPENDIX D

## PROCESS SPECIFICATION FOR LASER STRIPPING OF FLEXIBLE PRINTED WIRING

APPENDIX D

SPECIFICATION NUMBER PS81228MS

| REV LTR | DATE | REVISION NOTICE NUMBER | PAGES AFFECTED | APPROVED |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | 9/19/80 | ---------- | -------------------------------- | ------------------ |

REVISIONS

| | | | |
|---|---|---|---|
| ORIGINALLY PREPARED FOR CONTRACT NO F33657-72-C-1002 | | Westinghouse Electric Corporation DEFENSE & ELECTRONIC SYSTEMS CENTER BALTIMORE MD U.S.A | |
| ELECTRICAL DESIGN | ORIGINATOR 9-10-80 J.C. Neumaster | TITLE LASER STRIPPING (FLEXIBLE PRINTED CIRCUIT) | |
| MECHANICAL DESIGN J.N. Burshaw 9-16 | R.W. Ostermann | | |
| QUALITY-REL ASSUR. Carroll Manion | J.T. Johnson | | |
| CONFIGURATION ENGRG | | | |
| PAGE 1 OF 3 PAGES | SPECIFICATION TYPE PROCESS | FSCM NO 97942 | SPECIFICATION NUMBER PS81228MS |

BA 6033

1. SCOPE

1.1 This specification describes laser stripping of flexible printed circuitry.

2. APPLICABLE DOCUMENTS

2.1 The following documents for a part of this specification to the extent specified herein.

Material

| Government Designation | Westinghouse No. | Name |
|---|---|---|
| MIL-T-81533 | (M51550FC) | Inhibited Methychloroform |

2.2 Parenthesis. Identifications shown in parenthesis in this specification are for the use of Westinghouse and its subcontractors only and are not required by others to perform the process outlined.

3. REQUIREMENTS

3.1 Safety. Materials used in performing this process may be hazardous. Safety precautions shall always be applied. The environment, equipment, and tools necessary for the performance of any part of this specification shall be designed, fabricated, installed, and used in accordance with the applicable occupational safety and health standards. When applicable, Safe Practice Data Sheets (SPDS) and Safe Practice Procedure Sheets (SPPS) are specified herein. When necessary, consult Industrial Hygiene and Safety.

3.2 Handling. Flexible printed cable shall not be folded, creased, or torn. Tooling shall not damage circuitry.

3.3 Equipment. Laser stripping equipment meeting the following minimum performance characteristics shall be used:

(a) $CO_2$ Laser, 10.6 micrometers wavelength.

(b) Rated Output - 150 watt average power.

(c) Pulse Rate - 1 to 1000 pulses per second.

(d) Pulse Duration - .01 to 1.0 millisecond.

3.4 Material preparation. The flexible printed circuitry shall be stabilized by heating at 94 $\pm$ 14°C (200 $\pm$ 25°F) for 3 $\pm$ 1/4 hours.

3.5 Stripping. Stripping shall be accomplished with a beam spot size and material travel speed to provide a clean laser cut or kerf in the insulation with no damage to the conductor.

3.6 Cleaning. The stripped area shall be cleaned using inhibited methylchloroform (MS1550FC) (SPDS M-9) and a soft brush, pipe cleaner, or ultrasonic cleaner. Cleaning must not distort circuit pattern.

3.7 Examination. Examine as follows:

(a) Visual. The stripped area shall be clean of debris or foreign matter. There shall be no carbonized biproducts of the stripped insulation on the curcuitry. If insulation is left on one side of the circuitry pattern, there shall be no charred insulation between circuits and the insulation on the cicuits shall not be blistered or charred. The circuitry shall not be distorted from its prestripped pattern.

(b) Insulation resistance. Unless otherwise specified, the insulation resistance of the stripped cable shall be 1.5 x $10^6$ milliohms minimum.

(c) Dielectric withstanding voltage. Unless otherwise specified, the dielectric witnstanding voltage of the stripped cable shall be 1000 volts direct current minimum.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection. Monitoring and inspection shall be provided to assure that this process is implemented in compliance with the requirements of Section 3.

5. PREPARATION FOR DELIVERY

This section is not applicable to this specification.

6. NOTES

This section is not applicable to this specification.

# APPENDIX E

## PROCESS SPECIFICATION FOR LASER WELDING OF FLEXCIRCUITS TO CONNECTORS

APPENDIX E

PROCESS SPECIFICATION FOR LASER WELDING
OF FLEXCIRCUITS TO CONNECTORS

1.0 SCOPE

This specification establishes the process requirements and quality assurance provisions for laser welding of flexible circuits to connectors.

2.0 APPLICABLE DOCUMENTS

3.0 REQUIREMENTS

3.1 Equipment - Laser welding equipment shall be available to provide welding of flexible circuits to connectors in accordance with specification requirements.

3.1.1 *Equipment Performance Characteristics*

TYPE - Nd. Yag Laser 1.06 microns (1060 manometers)

Rated Output - 200 watt Avg. Power Minimum

Pulse Rate - 1 to 200 pps

Pulse Duration - 1 ms to 7 ms.

3.1.2 Maintenance - The laser welding equipment shall be maintained in accordance with the manufacturers instructions. Replacement of lamps cleanim of optical components and replacement of filters shall be in conformance with manufacturers recommendation.

3.2 Materials to be welded shall have been previously verified as conforming to the requirements of their applicable specification and to meet the surface condition requirements as specified in the weld schedule for the particular well joint assembly.

3.3 Process

3.3.1 Process definition - The process and process control shall be contained but not limited to the items listed in sections 3.4, 3.5, 3.6, 3.7, 3.8 & 3.9

3.3.2 Process Review Approval - The proposed process shall be submitted to the responsible engineers of Research & Engineering and Quality Control in a dated and numbered document for approval.

3.3.3 Changes to Process - Once a process has been approved no changes in the essential variable or procedures are permitted without the prior written approval of the responsible engineer.

3.3.4 Personnel - Laser welding operations required by this specification shall be performed by personnel who have been trained and certified.

3.4 Surface Conditions - The surface shall be visibly clean and uniform in appearance. Acetone, MEK or alchohol may be used to remove any oil or similar contaminants. The surface condition shall comply with the requirements as outlined in the weld schedule.

3.4.1 Part cleanliness shall be maintained by storing the part in a suitable plastic container. Parts after cleaning should be handled in a manner to prevent contact or contamination of the weld surfaces.

3.5 Weld Schedule - Laser welding shall be accomplished in accordance with the established weld schedule for each applicable part to be welded. The weld schedule shall define the surface preparation, fixturing and laser welding process parameters such as energy, pulse length, pulse rate, speed focal distance, filler material, size and shape, gas flow and specific unique alignment requirements.

3.5.1 Filler material: Filler material, if used, shall meet material and weld schedule specifications. Filler material shall be handled with the same cleanliness and care as the parent materials and parts.

3.6 Weld Requirements - Weldments shall conform to the requirements of the engineering drawing referencing this specification and be in accordance with the following criteria.

3.6.1 Weld Appearc.

The wel[illegible] be uniform in appearance and there shall be visible signs of metal fusion at the interface of conductors and pins. Under [illegible] or thinning shall not exceed 50% of the total thickness.

3.6.2 Cracks

There shall be no cracks in the welds when examined at a magnification of 7 to 10X.

3.7 Repairs

Repair of imperfections or defects in the weld zone may be permissable with the following limitations.

3.7.1 Repairs do not cause damage to the connector or flexible circuit.

Repairs do not interfere with the sealing or potting of the connector flexcircuit combination. Minimum of (3) repairs are permissible per connector.

All drawing requirements are met after repair.

3.8 Handling

The welded assembly shall be handled with care prior to potting to prevent damage to welded connectors. Operators shall use handling aids provided.

3.9 Safety

The laser welding equipment shall be operated in accordance to government and manufacturers safety guides and regulations. Interlocks, safety signs and safety goggles shall be employed to prevent injury to pe sonnel.

4.0 SURFACE PREPARATION

Quality Assurance shall determine that the surface preparation procedures used prior and during the welding operation shall be in accordance with the specification requirement.

Normally flexible circuits whose insulation is removed by laser, shall be left as is, without further cleaning operations other than organic solvents such as alchohol. Oxides on surfaces of conductors which are used for adhesion of the insulating film shall not be changed without notifying the supervisor in charge of laser welding.

4.1 Materials

Quality Assurance shall determine that the materials used in the welding operation are in accordance with the specification requirements.

4.2 Equipment/Operator Verification

4.2.1 Machine/operator controls

Suitable means for indicating directly or indirectly the settings for each variable which must be controlled to make a satisfactory weld shall be available.

4.2.2 Machine Maintenance

Machines shall be maintained in good mechanical and electrical condition per manufacturers recommendations and their controls checked at least every 6 months.

4.3 Equipment/Operator Certification

4.3.1 Equipment Qualification - Process approval is achieved by making satisfactory welds in accordance with this specification. Specimens shall be prepared from the same or similar materials as the parts to be welded.

4.3.2 Two simulated or production flexible cable to connector weld assemblies shall be joined to meet the requirements of this specification.

4.3.3 Operator Certification

Operator certification shall consist of satisfactorily completing the following:

a) Resetting the pulse forming network jumpers to establish the appropriate pulse length,

b) Establish the pulse rate, power settings and focus.

c) Align test specimens and verify alignment with optical or video monitors and set table speed or program.

d) Weld the two specimens per weld schedule to satisfy requirements of this specification.

4.4 It is permissable to qualify the welding machine and operator using the same set of test specimens.

Certification Status - Operator certification status shall be maintained by either completing the qualification requirements of this specification every twelve months or by maintaining a complete record of workmanship based on an approved periodic scheduled inspection of typical production welds.

4.4.1 When major changes in equipment are made, the machine shall be requalified.

4.4.2 Schedule Certification - A suitable weld schedule shall be established for each type joint that is to be welded in production. Certification of the schedule is accomplished when two connector/flex circuit assemblies are welded to meet the requirements of this specification.

4.4.3 The weld schedule shall list the following essential parameters:

1) Speed - relative speed of part to laser beam.

2) Pulse length expressed in milliseconds

3) Pulse rate - pulses/sec

4) Power level - as indicated on the PFN meter and the watt power meter

5) Focus distance - as established by the weld certification test samples.

# APPENDIX F

## PROCESS SPECIFICATION FOR PIN SEALING OF CONNECTORS

SPECIFICATION NUMBER PS82410UF

| REV LTR | DATE | REVISION NOTICE NUMBER | PAGES AFFECTED | APPROVED |
|---|---|---|---|---|
| - | 2-29-80 | ---------- | ---------- | ---------- |

**REVISIONS**

ORIGINALLY PREPARED FOR CONTRACT NO. DAAK40-79-C-0212

**Westinghouse Electric Corporation**
DEFENSE & ELECTRONIC SYSTEMS CENTER
BALTIMORE, MD., U.S.A.

| | |
|---|---|
| ELECTRICAL DESIGN | ORIGINATOR R. Z... 2/14/80 |
| MECHANICAL DESIGN J.H. Reinhardt 2/7/... | A.L. Barry Jr. 2/19/80 |
| QUALITY REL. ASSUR. ... 2/... | J. Johnson 2/27/80 |
| CONFIGURATION ENGRG. | SECURITY APPROVAL |

HYDANTOIN EPOXY ADHESIVE, THICKENED, APPLICATION OF

| PAGE 1 OF 3 PAGES | SPECIFICATION TYPE | CODE IDENT NO. | SPECIFICATION NUMBER |
|---|---|---|---|
| | PROCESS | 97942 | PS82410UF |

BA 5656–1D

1. SCOPE

1.1 This specification describes the application of hydantoin epoxy resin adhesive to an electronic part.

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein:

Materials

| Government Designation | Westinghouse No | Name |
|---|---|---|
| None | M53841US | Epoxy Resin |
| None | M54601PH | Hardener |
| None | M52514BG | Silica |

2.2 Parenthesis. Identification shown in parenthesis in this specification are for the use of Westinghouse and its subcontractors only and are not required by others to perform the process outlined.

3. REQUIREMENTS

3.1 Safety. Materials used in performing this process may be hazardous. Safety precautions shall always be applied. The environment, equipment, and tools necessary for the performance of any part of this specification shall be designed, fabricated, installed, and used in accordance with the applicable occupational safety and health standards. When applicable, Safe Practice Data Sheets (SPDS) and Safe Practice Procedure Sheets (SPPS) are specified herein. When necessary, consult Industrial Hygiene and Safety.

3.2 Operations.

3.2.1 Preparation of adhesive. The following ingredients shall be mixed together thoroughly to form the hydantoin epoxy resin adhesive.

| Ingredients | Parts by Weight |
|---|---|
| Epoxy Resin M53841US (SPDS R-5) | 100 |
| Hardener M54601PH (SPDS A-28) | 42 |
| Silica M52514BG (SPDS S-3) | 14 |

The storage stability of the prepared adhesive is one hour at room temperature.

3.2.2 Application of adhesive. Apply a uniform coat of adhesive to the parts at the juncture to be joined. The most applicable methods shall be used - brush, spray, hypodermic or spatula.

3.2.3 Curing. The part shall be cured for 1 hour at 75 $\pm$ 5°C (167 $\pm$ 9°F). Alternate cure is 7 days at 25 $\pm$ 5°C (77 $\pm$ 9°F).

3.2.4 Finishing. The part shall be cooled to room temperature and then may be ground to specified dimensions.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection. Monitoring and inspection shall be provided to assure that this procedure is implemented in accordance with the requirements of Section 3.

5. PREPARATION FOR DELIVERY

This section is not applicable to this specification.

6. NOTES

This section is not applicable to this specification.

# APPENDIX G

## PROCESS SPECIFICATION FOR MOLDING WITH HYDANTOIN EPOXY

SPECIFICATION NUMBER
PS80220HG

| REV LTR | DATE | REVISION NOTICE NUMBER | PAGES AFFECTED | APPROVED |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| - | 2-29-80 | ----------- | ------------------------------ | ----------- |

**REVISIONS**

| | |
|---|---|
| ORIGINALLY PREPARED FOR CONTRACT NO. DAAK40-79-C-0212 | **Westinghouse Electric Corporation** DEFENSE & ELECTRONIC SYSTEMS CENTER BALTIMORE, MD., U.S.A. |
| ELECTRICAL DESIGN | ORIGINATOR R. F. [illegible] 3/22/80 |
| MECHANICAL DESIGN J.H. Renshaw 2-29 | A. R. Banz Jr. 2/26/80 |
| QUALITY-REL. ASSUR. [illegible] 2/26/80 | J. T. Johnson 2/27/80 |
| CONFIGURATION ENGRG. | SECURITY APPROVAL |

HYDANTOIN EPOXY, LIQUID INJECTION MOLDING OF

| PAGE 1 OF 3 PAGES | SPECIFICATION TYPE | CODE IDENT NO. | SPECIFICATION NUMBER |
|---|---|---|---|
| | PROCESS | 97942 | PS80220HG |

BA 5656–1D

1. SCOPE

1.1 This specification describes the liquid injection molding of hydantoin epoxy resin compound.

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein:

Materials

| Government Designation | Westinghouse No | Name |
|---|---|---|
| None | M53841UR | Epoxy Resin |
| None | M51475FP | Epoxy Resin |
| None | M54601MB | Hardener |
| None | M54601FV | Accelerator |
| None | M54601PK | Curing Agent |

Process Specification

| Government Designation | Westinghouse No | Name |
|---|---|---|
| None | PS83342YN | Mold Release |

2.2 Parenthesis. Identifications shown in parenthesis in this specification are for the use of Westinghouse and its subcontractors only and are not required by others to perform the process outlined.

3. REQUIREMENTS

3.1 Safety. Materials used in performing this process may be hazardous. Safety precautions shall always be applied. The environment, equipment, and tools necessary for the performance of any part of this specification shall be designed, fabricated, installed, and used in accordance with the applicable occupational safety and health standards. When applicable, Safe Practice Data Sheets (SPDS) and Safe Practice Procedure Sheets (SPPS) are specified herein. When necessary, consult Industrial Hygiene and Safety.

3.2 Operations.

3.2.1 Preparation of compound. The following ingredients shall be mixed together thoroughly to form the hydantoin epoxy resin compound.

| Ingredients | Parts by Weight |
|---|---|
| Epoxy Resin M53841UR (SPDS R-5) | 70 |
| Epoxy Resin M51475FP (SPDS C-9) | 30 |
| Hardener M54601MB (SPDS C-9) | 157 |
| Accelerator M54601FV (SPDS A-28) | 1 |
| Curing agent M54601PK (SPDS A-28) | 3 |

The storage stability of the prepared compound is one hour at shop temperature.

3.2.2 Preparation of mold. The mold shall be prepared in accordance with PS83342YN.

3.2.3 Application of compound. The prepared compound is injected into the mold, which is heated to 140 to 160°C (284 to 320°F), until it is completely filled.

3.2.4 Pressure cycle. The mold and its contents shall be placed under pressure of 5 ± 5 pounds per square inch for 1 ± 0.1 minutes and then returned to atmospheric pressure.

3.2.5 Part removal. The part may be removed from the mold prior to curing.

3.2.6 Curing. The part shall be cured for 4 to 16 hours at 135°C ± 5°C.

3.2.7 Post curing. Post curing shall be applied only if specified. The part shall be post cured for 96 hours minimum at 150° ± 5°C.

3.2.8 Finishing. The part shall be cooled to room temperature. The part may be ground to specified dimensions. Cracks or voids shall be touched up with the compound of 3.2.1 and cured in accordance with 3.2.6. Variations in color of the cured resin are to be anticipated.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection. Monitoring and inspection shall be provided to assure that this procedure is implemented in accordance with the requirements of Section 3.

5. PREPARATION FOR DELIVERY

This section is not applicable to this specification.

6. NOTES

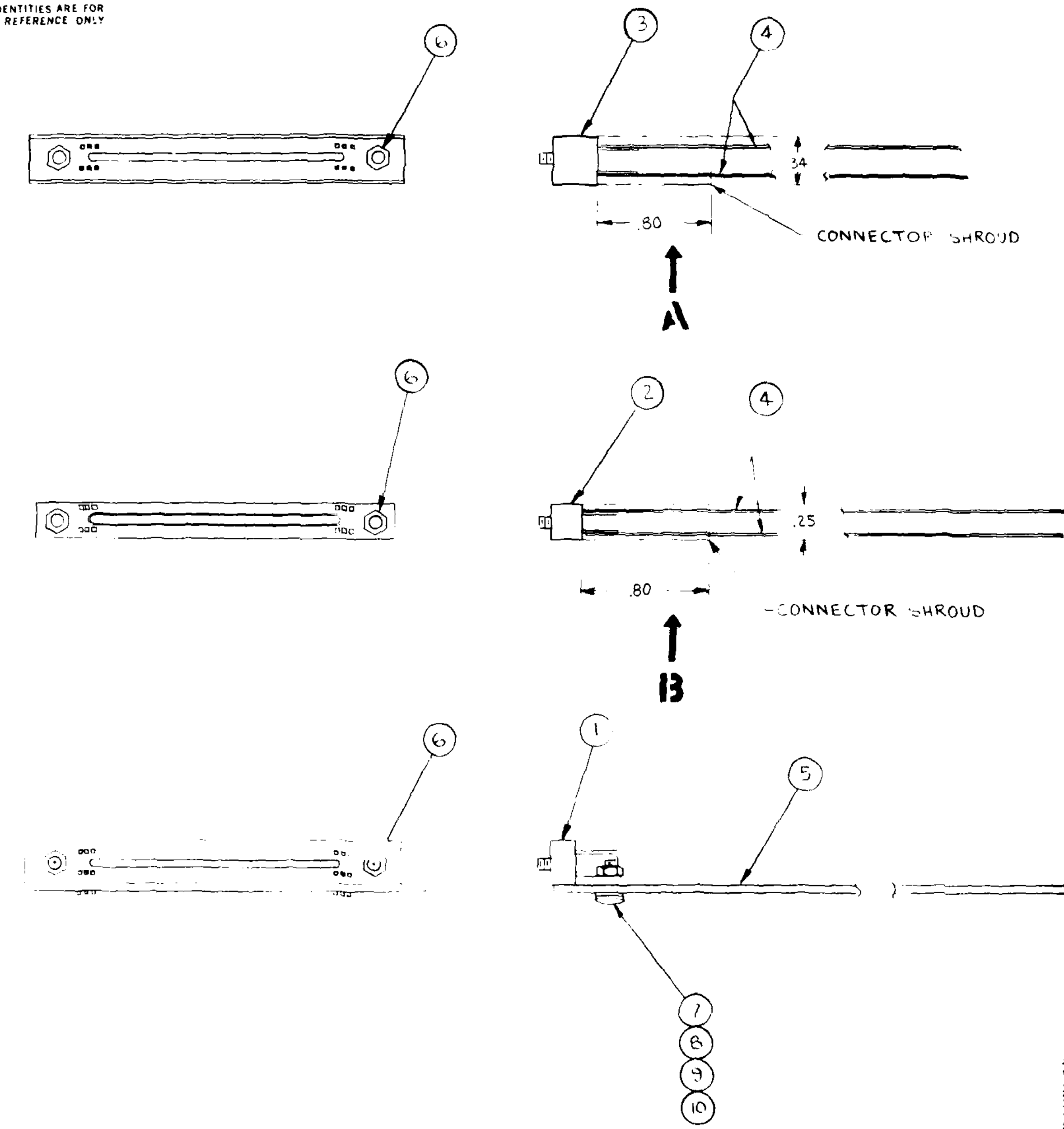
This section is not applicable to this specification.

APPENDIX H

ASSEMBLY DRAWING

(685R539)

PARENTHETIC IDENTITIES ARE FOR WESTINGHOUSE REFERENCE ONLY



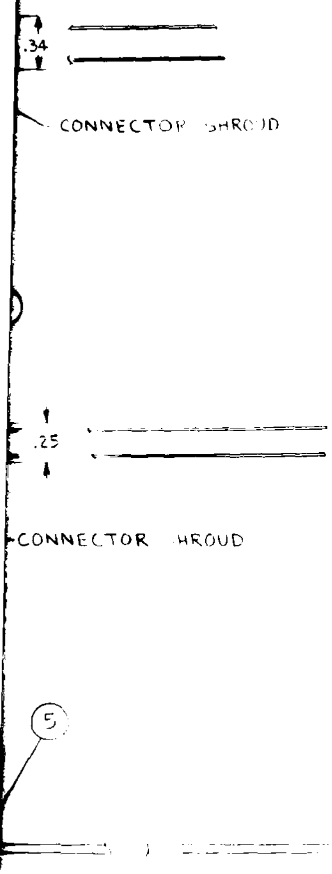
| DWG NO. | SH |
|---|---|
| | |

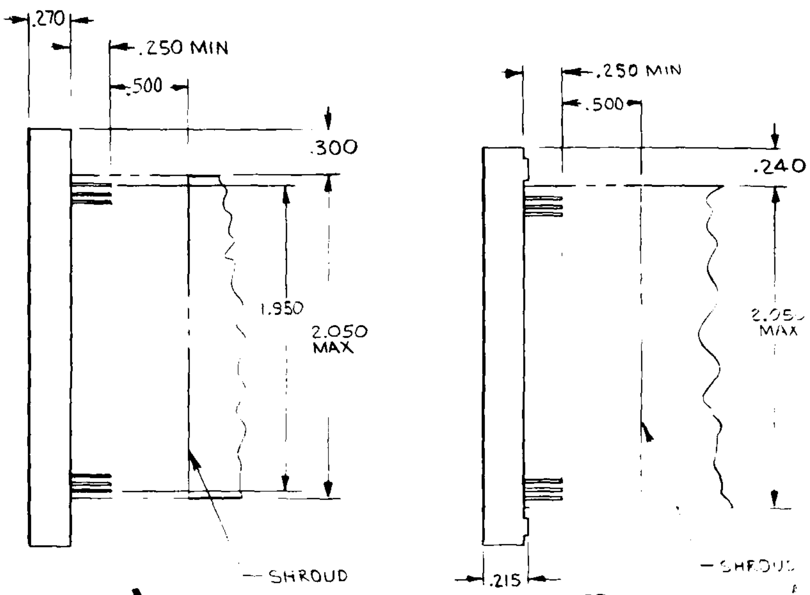
**SHEET REVISION STATUS**

| 5 | 4 | 3 | 2 | 1 | SHEET NO |
|---|---|---|---|---|---|
| | | | | | REV. |

**REVISIONS**

| ZONE | REV. | DESCRIPTION | DATE | APPROVED |
|---|---|---|---|---|
| | – | DRAWING RELEASED | | |




VIEW A

VIEW B

| G03 | G02 | G01 | FSCM NUMBER | PART NO. | SYM | DESCRIPTION | GOVT SPEC | Ⓦ SPEC | FIND NO |
|---|---|---|---|---|---|---|---|---|---|
| | - | 2 | | MS35338-153 | | WASHER LOCK-SPR | | | 10 |
| – | – | 4 | | NAS620C4 | | WASHER FLAT | | | 9 |
| – | – | 2 | | MS35649-244 | | NUT | | | 8 |
| - | – | 2 | | MS35275-205 | | SCREW FIL HD | | | 7 |
| 2 | 2 | 2 | 00779 | X5706-8 | | JACKSCREW KIT MALE | | | 6 |
| – | – | 1 | | 685R383H01 | | PRINTED WIRING BOARD | | | 5 |
| 2 | 2 | - | | 685R383H02 | | FLEX CABLE | | | 4 |
| 1 | - | – | | 584R650H01 | | CONNECTOR MALE | | | 3 |
| – | 1 | – | | 584R650H02 | | CONNECTOR FEMALE | | | 2 |
| – | – | 1 | | 584R650H03 | | CONNECTOR RT ANGLE | | | 1 |

QTY REQD — SYM: B = BULK MATERIAL, V = VENDOR ITEM — SEE CONTROL DWG

PARTS LIST — SEE PL

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DO NOT SCALE. TOLERANCES ON DIM.

| 2 PLACE | 3 PLACE | ANGLES |
|---|---|---|
| ±. | ±. | ± |

Ⓦ SPEC 90S01 APPLIES

PROCESS SPEC

CONTR NO

ORIGINAL DATE OF DWG

| DRAFTSMAN | APPD |
|---|---|
| CHECKED | APPD |
| APPD | APPD |

DESIGN ACTIVITY APPROVAL

PROCURING ACTIVITY APPROVAL

**Westinghouse Electric Corporation**
AEROSPACE AND ELECTRONIC SYSTEMS DIVISION
BALTIMORE, MARYLAND 2 203

# BOARD ASSEMBLY

FLEXICON TEST PATTERN

| SIZE | FSCM NO. | DWG NO. |
|---|---|---|
| D | 97942 | 685R539 |

SCALE 2/1 | WEIGHT | SHEET 1 OF 1



3

APPENDIX I

TECHNOLOGY INTRODUCTION REPORTS

APPENDIX I

FLEXICON, LOW COST AUTOMATABLE TERMINATION
FOR FLEXIBLE PRINTED WIRING

USE OF LASERS IN HIGH SPEED TERMINATION OF
FLEXIBLE PRINTED WIRING

HIGH SPEED LIQUID INJECTION MOLDING OF CONNECTORS

DESIGN OF AN AUTOMATED TERMINATION PROCESS
FOR FLEXIBLE PRINTED WIRING

# FLEXICON, LOW COST AUTOMATABLE TERMINATION FOR FLEXIBLE PRINTED WIRING

James A. Henderson
Westinghouse Electric Corporation
Defense and Electronic Systems Center
Baltimore, Md.

## INTRODUCTION

Flexible printed wiring (FPW) and flat conductor cable (FCC) have been promising significant weight and volume reductions for systems for many years. Much of this promise has not been realizable, however, because of the costs and difficulties associated with the termination of the wiring and cabling in systems where high reliability and environmental extremes are a requirement. At present, the termination techniques are limited in that they use processes which are sufficiently invariant in tolerance that they result in low yields and high costs as well as time-consuming steps.

Under a contract with the US Army Missile Command, Redstone Arsenal, Alabama, a thorough review of available processes and connector styles has resulted in a completely new approach which is of sufficient cost savings as to be commercially as well as militarily viable. This program has five basic features:

1. It is capable of being applied to any planar connector with one or two rows of conductor pins on the back.

2. Insulation removal by abrasive or open-cover-coat techniques is not required. The cables are stripped by a $CO_2$ laser beam.

3. Welding of FPW to connectors using a Nd:YAG laser results in a highly reliable joining with a tolerant weld schedule. This type of weld also lends itself to automatic visual (as well as electrical) inspection.

4. Sealing and molding using a new formulation of epoxy which provides both support for the weld area and flexibility for the FPW egress ensures a militarily acceptable interface.

5. Design for a fully automated facility with capability of 500 assemblies per 8 hour shift establishes the basis for a very low cost assembly.

This presentation will concentrate on an overview of the program, its cost effectiveness and projected utilization. Discussion of the adaptability to many connector designs for cable-to-cable, cable-to-chassis, and cable-to-printed wiring board will be included. More definitive papers detail the processes and use of lasers (1), the new epoxy formulation and liquid injection molding approach (2), and the design for a fully automated production facility (3).

## PROGRAM REQUIREMENTS

The specific requirements which were generated for this program were of two types. One type relates specifically to the environments and service which the assemblies are intended to see. The second type is specifically oriented toward the particular characteristics of flexible printed wiring (FPW) and flat conductor cable (FCC).

### Service Related Needs

The most important interconnection need of the military community was a low cost, highly automatable termination for FPW which is capable of meeting the airborne environmental requirements. The high density interconnection needs in the military airborne arena have virtually dictated the use of FPW and FCC technologies on many programs because of the excellent volumetric characteristics as well as the many other attendant features. However, most available terminations that would meet the temperature humidity environments require costly hand labor operations which have not been considered for automation because of low volumes. The result has been a significant avoidance of the use of FPW in many areas to avoid the costly hand operations and unnecessary high costs where the technologies have been used. A production rate of 500 assemblies per 8 hour shift was targeted.

### Technology Related Needs

Flexible printed wiring is a planar technology, that is, all of the circuits on one piece of wiring are in a single plane. Therefore, connectors and processes which consider this feature are of importance. Also, with the increased use of FPW and FCC in higher voltage applications, the selection of connector styles, materials and seals which protected these characteristics at high altitude was important. Not to be overlooked was the compatibility of materials and processes with the most popular FPW insulations in use.

## CONNECTOR EVALUATION AND SELECTION

### Specific Criteria

The selection of connectors was begun with a search for connectors of two-row, planar configuration. Because the basic FPW/FCC technologies are popularly configured on .050 inch centers (conductor-to-conductor), connectors with this feature were felt to be desirable. Materials had to be compatible with operating temperatures of -55°C to +125°C, and capable of being sealed (pin-to-pin) against the moisture and humidity conditions of the airborne environment.

### Selection Process

An industry survey was conducted. Suppliers who advertise in the various media with connectors capable of terminating FPW and FCC were solicited, and those who had the greatest potential for meeting program objectives were visited. Sketches, drawings, and samples obtained were used to evaluate termination process adaptability and to help establish any configuration changes necessary to enhance termination and ensure a mil-qualifiable product.

Those connectors considered as candidates for the final selection were evaluated relative to each other for connector cost, degree of tooling required, availability of component parts and materials, current carrying capability, final mold adaptability, reliability, and termination process compatibility. A matrix of these comparative values was generated. The relative weighting of the seven factors for importance was separately determined. By post-multiplying the factor matrix with the factor weighting, a weighted value matrix was [illegible], with the sum of each row [illegible] value. The way [illegible] set up, the lowest [illegible]. These results [illegible] AMP Minibox connector [illegible] considered first. A close [illegible]s "IBM" connector. [illegible] Further considerations were that the AMP minibox connector had already met QPL of MIL-C-55302/117, 119, 31 (with no interfacial seal), and that Burndy could be a second source for Hughes. Both connector designs have been modeled with an interfacial seal.

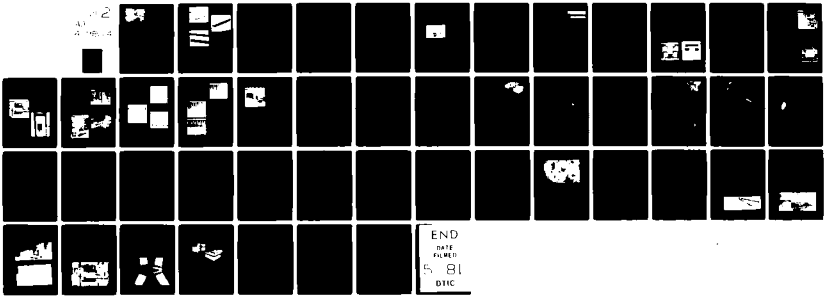
## PROCESS EVALUATION AND SELECTION

The basic approach to process selection was to minimize consideration of repairability and maximize the factors of high reliability and low cost. A basic need of the military customer is high reliability of passive components of a system, with part costs so low that repair would not be considered necessary, and "replacement" would be the dominant maintenance mode.

### Specific Criteria

The processes reviewed were divided into

AD-A098 024 WESTINGHOUSE DEFENSE AND ELECTRONIC SYSTEMS CENTER B--ETC F/G 9/1
FLEXIBLE PRINTED CIRCUITS WITH INTEGRAL MOLDED CONNECTORS. A MA--ETC(U)
MAR 81 J A HENDERSON DAAK40-79-C-0212
UNCLASSIFIED 81-0209 NL



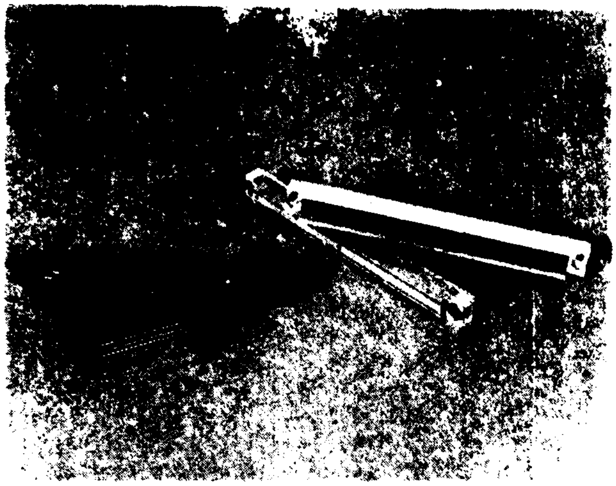


Figure 1 Two Connector Families Were Selected for Program Demonstration

three basic categories, insulation removable, connector to cable joining, and sealing and molding. Obviously for some approaches these were not all necessary, and there was some overlap. But the necessary basic criteria remained. We needed a highly reliable series of proceses which were readily adaptable to full automation and were rapid enough to provide a throughput of one assembly every minute. All basic and many exotic processes were proposed and considered, but we desired to stay as much as possible with proven technologies. One other point of consideration was necessary. Not only did the processes have to be compatible with cable and connector materials and the projected environments, they also had to be compatible with each other.

Selection

The process evaluations were conducted in a similar way as the connector selections. Those deemed candidate were compared to each other for thirteen different factors. These factors were rated together for importance and normalized. The post-multiplication of the matrix of comparative values by the relative weighting of the factors produced a weighted matrix which, when summed horizontally yielded a ranking. Analysis of variances could also be performed. The results of these clearly showed that the candidate insulation removal technique involved the use of a $CO_2$ laser, the joining technique was laser welding for FPW and wave solder, vapor phase reflow, or Nd:YAG laser welding for printed wiring boards. For sealing and molding, a semi-flexible hydantoin epoxy was initially selected.

ADAPTABILITY TO OTHER NEEDS

The prospect of providing a development of limited utilization due to non-adaptability to other interconnection media was avoided by specifically identifying connectors and techniques which could provide more than merely an FPW to FPW (or FCC) interface. As a result, the interfaces available include the following:

FPW to PWB: Alluded to earlier in the process development discussions, these are available in two configurations. In the lower part of Figure 2 there is a connector for plated-thru-hole mounting on boards such as matrix plates (backplanes) or those with components having leads that penetrate the board, such as DIPs and discrete resistors and capacitors. Above that the connector available for surface mounting is shown. This would be used on boards using devices such as hermetic chip carriers, flat packs, and leadless inverted devices, or boards which cannot have lead penetration due to heat sink techniques used.

FPW (or FCC) to Chassis Wiring: The present program used the assumption that the chassis wiring would be FPW, so the criterion could be met with a capability of mounting the connector to a bulkhead or chassis panel. This can be done with the FPW to FPW configuration, as shown in Figure 3. One of the prime connector suppliers, aware that some cases may require chassis wiring to be stranded single conductor wire, is presently developing that configuration with their own internal funding.

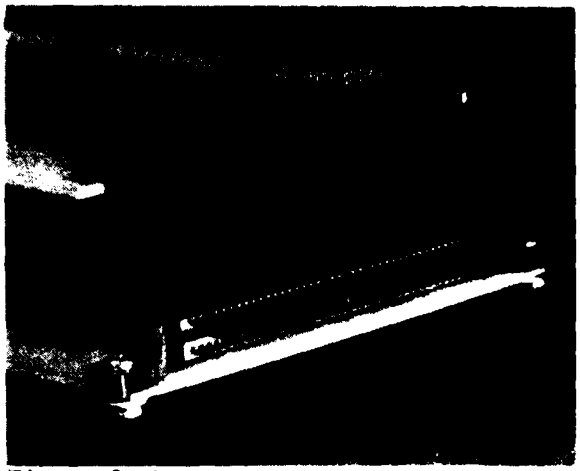


Figure 2 PWB Connectors Are Available For Surface or Plated-Thru-Hole Mounting

Figure 3 Connectors Can Be Chassis Mounted

Partial Processes: In several instances already identified at Westinghouse, there are cases where cable egress is such as to allow the use of some, but not all, of the processes. In these cases, those that can be used are done so to advantage. Of particular consideration is the molding compound which has fast cure capability and a good voltage characteristic.

Other Connectors: The adaptability of these processes to many other connectors is readily apparent. These include connectors on .100 centers, dual row .100 centers with a single plane of .050 tails (Figure 4) and others.

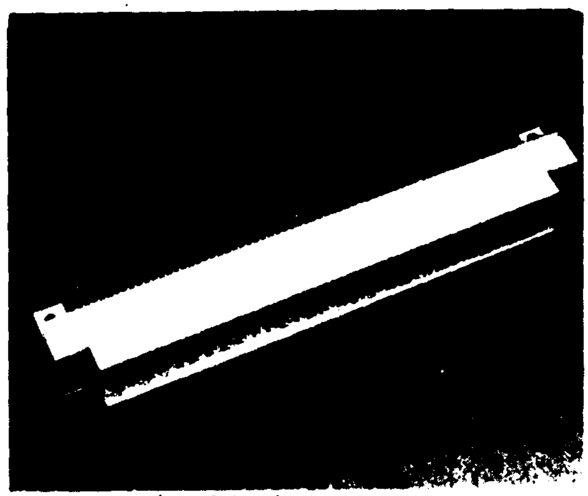


Figure 4 This 4-Row Connector Only Has Two Rows of Contact Tails

PROJECTED UTILIZATION

The initial driver to encourage utilization of these developments is indeed not process cost but the demonstrated ability of the resulting product to be failure free. That, coupled with the need for FPW due to space limitations, has led us to already include this technology on two major new program designs in-house, a remote pilotless vehicle program, and an advanced airborne radar. In addition the technologies are being incorporated into a new requirement for an existing large airborne radar system, and are replacing a troublesome process in an electronic warfare pod.

Projected cost benefits with the use of a fully automated facility could add significantly to utilization, particularly with commercial extension of this development. The connectors which have been used are less than one-eighth the cost of the more sophisticated ones previously required for Mil-qualifiable FPW assemblies. The FPW itself will cost 40 to 50 percent less because the open windows do not have to be expensively created in the fabrication process. The labor associated with the automated facility would be less than 4 man-minutes per assembled connector pair, replacing 3 hours of labor currently required with the old techniques. When capital equipment and amortization costs, and maintenance requirements are added in, the result is a significant cost reduction, with greater than 6 to 1 savings in total costs. Compared to round wire harnesses, as much as 35 to 50 percent additional savings can be realized. It is quite easy, therefore, to project increased industry use of FPW and FCC with the developments of reliable environmental terminations of this program.

EXTERNAL MARKET INFORMATION

This program has been carried out for the U. S. Army as a Manufacturing Methods and Technology program. One of the principle guidelines of MM&T programs hinges on the successful utilization of the resulting technology in future equipments, both military and commercial. The key to this utilization is not merely the success of the development, but how well others are informed of that success. Therefore, a major part of this program has been aimed at the total communication effort involved. This has included major industry advisory group presentations and feedback, an industry demonstration of the technologies with widespread dissemination of information, this program today (which is the fundamental industry introduction), and cooperative efforts with houses which would develop fully automated facilities for service to the industry as a whole.

Since Westinghouse is a user, not a supplier, of the connectors and flexible printed wiring, we have been able to perform these developments with no commercial gain as a goal. Therefore, the processes are not to be held proprietary to us, and the developments have been made with a broad base of product utilization in mind. This also is significant toward the ultimate widespread use of the technologies in many industries and for many products.

The papers following detail the processes and results of the program. Environmental tests are also being conducted as this paper is being written, and the results will be available for the conference.

REFERENCES


1. "Use of Lasers in High Speed Termination of Flexible Printed Wiring", Alexander A. Bosna and Jeffrey D. Emmel.

2. "High Speed Liquid Injection Molding for Connectors", Richard S. Zucker.

3. "Design of an Automated Termination Process for Flexible Printed Wiring", Richard L. Hall.


BIOGRAPHY

James A. Henderson, Fellow Engineer, is a 15-year employee of Westinghouse. He has the lead technology responsibility for interconnections, and is program manager of several related technology programs, including FLEXICON. His patent activities include fiber optics as well as electrical interconnections, and he has authored numerous papers in these fields. He is a member of the IPC, the SAE-A2H and -A4E Committees, and the Baltimore-Washington Chapter of the Electronic Connector Study Group.

# USE OF LASERS IN HIGH SPEED TERMINATION OF FLEXIBLE PRINTED WIRING

Alexander A. Bosna and Jeffrey D. Emmel

Westinghouse Electric Corporation
Defense and Electronics Systems Center
Baltimore, Maryland

## INTRODUCTION

High speed assembly of connectors requires precision alignment, large process tolerancing, connector design flexibility, and high reliability. The objective of high speed assembly is to construct a basic highly reliable connector at such a price that scrap or repair is eliminated. With the use of lasers ($CO_2$ at 10.6 μm wave length, for flexible printed wire preparation, and ND: YAG at 1.06 μm wave length, for connector tab-circuit welding) all the desired qualities of a high speed process are met, resulting in low cost and low waste. The longer wave length of the $CO_2$ laser is absorbed by flexible printed circuitry insulation and reflected by the copper or tinned conductor making it ideal for insulation removal of the cable through the process of high speed ablation.

Following the insulation removal, the pulsed laser welding and/or reflow soldering show definite advantages over present soldering and crimping methods. Metallographic cross section and electrical tests substantiate the adequacy of the joints. Liquid injection molding immobalize the joints, adding strength and handling capability. Speed as well as simple visual inspection are the key cost advantage factors. The work reported here was performed on a manufacturing methods and technology program sponsored by the U.S. Army, Huntsville, Alabama.[1]

## BACKGROUND

The most obvious opportunity for increased military systems use and cost reduction of flexible printed wiring (FPW) clearly has been shown to be the development of reliable, low cost, automatable terminations. As the connector/FPW systems have evolved, they have been delayed from effective military utilization because of several reasons, one of which is the lack of forgiving (adequately toleranced), cost effective, termination techniques. The use of lasers to prepare and terminate FPW has provided a viable solution to this problem.

Current FPW termination techniques are not cost effective because of the expensive FPW preparation and set-up time. FPW is currently prepared by one of several ways: (1) cover costs of insulation are prepunched and aligned where completely open circuitry is required, (2) a mechanical drilling/sciving process can be performed after lamination, (3) a caustic bath that etches desired areas can be carefully used, or (4) no preparation (for insulation piercing techniques). Current termination methods also are time consuming and expensive. Some of these methods are: (1) hand soldering of pretinned circuits, (2) crimp style piercing of insulation and/or conductor, (3) pressurized mechanical contact of specially prepared exposed conductors, (4) brazing with special alloys, and (5) electrical welding. Each of these techniques has drawbacks which tend to limit utilization.

The use of lasers for FPW preparation and termination is one method that is providing reliable, low cost, high speed FPW/connector terminations. Insulation ablation (or removal) with a continuous wave $CO_2$ laser is performed with a minimal amount of circuitry alignment or handling. This laser beam provides a non-mechanical method of removal of insulation. It works well within a large tolerance of power, permitting the removal of a variety of insulation with various patterns, leaving the metalic circuitry uneffected. A pulsed solid state ND:YAG (Neodymium-Yttrium Aluminum Garnet) laser is being used to weld the circuitry to the tabs of connectors. This termination method requires only that the circuits be clean of insulation, undistorted, and held in intimate contact with the connector tabs for good welds. The welds are readily inspectable and highly reliable terminations. The laser output is controllable and material flow is easily programmed for flexibility to weld a variety of connector styles and circuit patterns. The welded connector is then encapsulated, for a sealed, strain relieved assembly.

INSULATION REMOVAL WITH A $CO_2$ LASER

The insulation surrounding the circuitry in the weld area of the flexible printed cable needs to be removed so an adequate weld of circuit to connector tab can take place. A $CO_2$ laser beam of coherent 10.6 micrometer wave length energy is utilized for this process. The laser beam cuts and removes insulation by the process of ablation, the rapid melting and vaporization of the insulation into its basic constitutents. This process takes advantage of the phenomenon that the polymeric insulation and related adhesives absorb the longer wavelength of the $CO_2$ laser but the conductors reflect it at the low energy density levels used in this process. This ablation mechanism requires roughly 100 $KW/in^2$ incident at the surface of the insulation. The polyimide insulation absorbs the laser energy and rapidly and locally reaches ablation temperature breaking down into its primary chemical constituents. These vapors can be easily vented away and/or filtered. An assist gas of oxygen or shop air is used to accelerate the burn and keep the vapors from depositing on the circuitry. The slight bit of carbonization or vapor deposition that is present can easily be removed with a high pressure blast of acetone and/or a light mechanical brushing operation. The advantages of laser insulation removal include those listed in Table 1.

TABLE 1

| Advantages of Laser Wire Stripping |
|---|
| o Elimination of direct mechanical contact with circuitry. |
| o Narrow width of melted or vaporized zone. |
| o High temperature insulation easily stripped. |
| o Quality control requirements minimized |
| o Conductor metallurgy not affected by laser beam. |

The power density required to ablate the insulation can be easily achieved by foxusing the spot size of the incident beam. With the continuous wave operation of the $CO_2$ laser the beam can be directed rapidly across the insulation to be removed making the process fast, reliable, and flexible when coupled with the capability of programming beam location and movement.

Material Requirements and Preparation

The $CO_2$ laser insulation ablation process requires no special material preparation. This project used the polyimide insulation and acrylic adhesive system which is standard in military applications. These have higher melt temperatures and wear characteristics than the mylars or epoxies of the commercial industry. Mylars and epoxies are also polymeric materials and are expected to act similarly in the $CO_2$ process.

Normally cleaned surfaces are required of the material to prevent contaminants or foreign matter interfering with the incident beam.

The surface of the copper circuitry used in the flexible cable can be tinned, treated with an oxide surface, or untreated. The $CO_2$ beam will reflect off these metalic surfaces at this low power density at $10^5$ watts/in.$^2$. The copper circuitry surfaces used in this program were made with the normal oxide coating techniques to promote insulation adhesion. The circuitry pattern used is shown after stripping and cleaning in Figure 1.

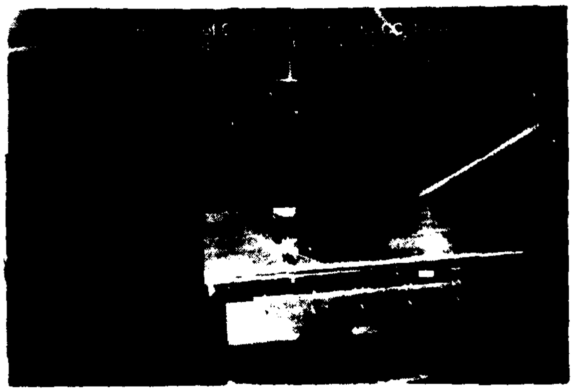


FIGURE 1

Stripping Process Parameters and Equipment

The equipment used in this $CO_2$ ablation process should be of the size and type capable to perform the operation in the designed period. These process parameters were developed with a design time of two pieces of prepared flexible circuitry per minute. The equipment used was an Coherent Radiation, Everlase 150[2], 150 watts ($TEM_{00}$) rated output power. An Aerotech NC 250[3], two axis (X/Y) numerically controlled table was used to move the cable thru the laser beam. The objective was to establish the largest beam spot size compatible with available power coupled with the highest table speed to remove the insulation in the required time.

A spot size of .033 inches with a useful power of 135 watts was developed giving a power density of 123 KW/in.$^2$ and an efficient removal of .025 inch diameter spot. The pulsing of the laser was married with the table speed to give a single pulse every .005 inches giving sufficient overlap to effectively remove the insulation and adhesive on both oxide and untreated copper surfaces. The oxided surface tended to absorb more of the incident energy than the untreated so an increased pulse rate was needed.

An assist gas of shop air, 80 CFM at 35 psig, was found necessary for several reasons: (1) to accelerate burn of the ablation process with reduced carbonization, (2) to prevent contamination of the lenses and related optics, and (3) to reduce vapor deposition on stripped circuitry.

Process Evaluation

The process was evaluated by the following criteria: effectiveness of the insulation removal, cleanliness of the conductors, straightness of the conductor leads, and effect on the conductor. Insulation was completely and reliably removed with the redundant pulses of the laser beam. The absorbtivity of the insulation and reflectivity of the copper allowed a wide tolerance of beam power, approximately 100 KW to 300 KW per square inch. Within this power range, the effect on the grain structure of a stripped conductor under 200X is nondetectable and the microhardness unaffected.[4] The deposits remaining on the flexible circuitry and surrounding insulation are carbonized biproducts that can be removed with a pressurized acetone rinse using a backup plate to prevent distortion of the conductors. Because the laser stripping and acetone rinse is a nonmechanical action, the conductors remain undistorted and largely uneffected by the entire process.

Summarizing the Laser Stripping Requirements

1. Equipment capable of accurately controlling beam energy density (spot size/energy pulse).

2. Equipment capable of providing adequate material flow and/or laser beam movement to provide desired strip rate.

3. Assist gas jets and venting.

4. Fixturing to provide support of circuitry during stripping and cleaning operation.

## WELDING OF FLEX LEADS TO CONNECTOR TABS WITH A ND:YAG LASER

The following factors influence the weldability of flex circuitry to connectors:

I. Materials and Surface Condition
II. Joint Fit-Up
III. Weld Parameters

### Materials and Surface Condition

When the laser strikes a metal surface, most of it is reflected and depending on the material and condition of the surface, a certain amount is absorbed to accomplish melting and vaporization. In order to obtain uniform results, it is vital to have a uniform surface with respect to absorbtivity, particularly in spot welding. Some materials absorb the Nd:YAG wavelength 1.06 microns better than others. Surface condition affects the absorbtivity and in this case a slight film of oxide on the surface of the copper where the insulation has been removed makes a substantial difference in the ability to absorb the radiation. This oxidized surface requires less energy to initiate melting and produces more uniform results. A solution called "Ebanol" will oxidize the copper satisfactorily. By placing the copper conductors with a uniform surface condition on the connector pins, the melting process is initiated uniformly.

The surface must also be free of contamination, specifically organiz materials. When these materials vaporize during the welding process, their vapors interfere with laser light and cause variations in the weld. Brass pins may cause porosity due to the vaporization of zinc and the best materials should be vacuum processed materials. A copper nickel alloy CA 725 is reported to have good weldability.[5]

### Joint Fit-Up

With a lap joint fit-up it is most important to have intimate contact at the interface. As a bench mark, it is intended that an area of at least three times the area of the spot size be in firm contact. This is important because the heat for melting is accomplished by conduction. Area and contact condition influence the energy transfer and lack of good fit-up will cause melt back of the copper conductor with the lack of fusion to the connector pin.

The parts themselves should not have any tendency to move during welding. This is determined mainly by the fixturing and original position of the parts. Line contact (such as shown in Figure 2) is preferred for maintaining parts in intimate thermal contact.

Precision fixturing that applies uniform pressure over the width of at least three inches is one of the prime requirements.

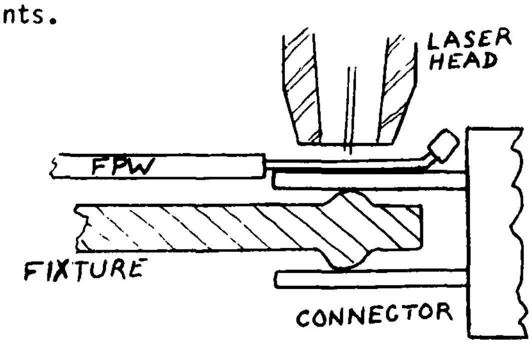



FIGURE 2 - Weld Fixturing

### Weld Parameters Process and Equipment

The parameters were developed using a 400 watt Nd:YAG pulsing laser, and applies specifically to a specially oxidized surface of 2 oz copper conductor approximately .020 wide terminating to flat or rectangular connector pins.

The weld parameters should have sufficient latitude to accommodate manufacturing and material tolerances. Excess speeds will spread the energy pulse with incomplete and erratic results.

At 10 inches per minute and at a pulse rate of 15 pulses/sec. and with a pulse width of milliseconds, each conductor receives approximately 2 pulses. This is welding on the fly and with the accuracy available in NC equipment, these pulses can be located precisely on each conductor to give uniform results.

Good inert gas shielding will also tend to produce more uniform welding results and stabilizes the plume effects.

The most important weld parameter is the energy density. Although the optical focus and laser focus are essentially the same, it is important from a reproducibility standpoint to install a dial indicator to set and maintain uniform focal length. In production this does not normally change, but it is important not only for initial set-ups, but to duplicate the same spot size when changing jobs. It is particularly useful as a reference in performing development work.

### Inspectability of the Welds

One of the main reasons for developing the laser welding process is the fact that visual inspection can be considered practically 100% reliable. Figure 3 shows typical weld beads. A melt back or burn through is readily detectable and time to evaluate a questionable joint need not be taken. Depending on the size of the conductor, if at least 50% of the crossection is fused, it should be a functional and an acceptable part.[6]

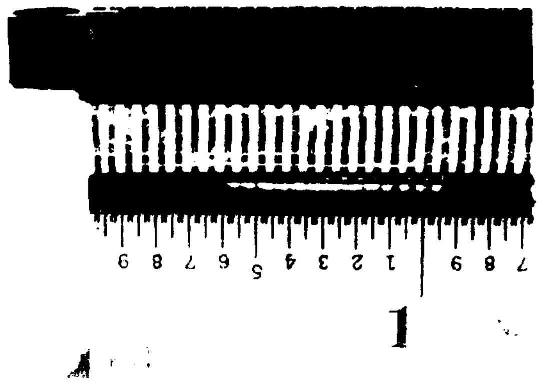


FIGURE 3 - Laser Welded FPW

Welding "on the fly" will not require sophisticated controls to coordinate table movement with the firing sequence and permits a less expensive system.

Another important criteria set which is closely related to energy density is that relating to distribution of energy in the spot, the wave shape, and pulse duration. Our experience has shown that a scope can be used to analyze the shape and pulse width. During each production run set-up, the operator can turn up the power until the wave pattern matches a preset outline on the scope. This will compensate for degradation of the lamps and alert the operator to any deviations in the power supply.

### Summarizing the Welding Requirements

1. Equipment capable of accurately controlling energy density (spot size and energy/pulse).

2. A clean surface with uniform absorbtivity.

3. Close intimate contact of parts at the area to be welded.

4. Weld parameters with adequate latitude for manufacturing tolerances.

REFERENCES


1. "Flexible Printed Circuits with Integral Molded Connectors," U.S. Army Missile Command, Contract No. DAAK40-79-C-0212.

2. Coherent Radiation, Inc., 3210 Porter Dr., Palo Alto, CA 94304.

3. Aerotech, Inc., 101 Zeta Drive, Pittsburgh, PA 15238.

4. "Selected Developments in Laser Wire Stripping," NASA Report SP-5107, pg. 9.

5. S. R. Bolin and E. T. Maloney, "Precision Pulsed Laser Welding," Tech Paper SME MR75-571.

6. "Laser Welding Speeds Relay Production," Insulation Circuits, April 1979.


BIOGRAPHY

Alexander G. Bosna
Senior Manufacturing Engineer, B.A., Fordham College, N.Y., 1941; B.S., Marine Engineering, USMMA Kings Point, 1947; B.S., Mechanical Engineering, Copper Union, 1954.

Mr. Bosna has twenty-two years experience in metals joining and manufacturing processes. He has specialized in advanced manufacturing development including managing programs on electron beam and laser welding. Mr. Bosna holds several patent and disclosure awards involving metals joining. He has presented numerous technical papers on electron beam and laser welding. He has been a program manager on past Air Force and Navy weld development contracts. He is a member of American Welding Society, and a former member of the Aerospace Advisory Committee on Reactive and Refractory Metals.

Jeffrey D. Emmel
Manufacturing Engineer, B.S. Mechanical Engineering, Pennsylvania State University, 1975; M.B.A., Finance, Loyola College, Baltimore, Maryland, 1980.

Mr. Emmel has devoted his past four years at Westinghouse as Manufacturing Engineer for an advanced ECM system, where predominent responsibilities have been in flexible printed circuit cable assembly and system final assembly and test. His experience includes two years in design and review of mechanical components and hardware for military programs including an airborne Fire Control Radar and other ECM programs. Mr. Emmel has concentrated recent efforts to redesign and improve producibility of flexible printed wiring cable and extruded flat conductor cable assemblies for module interconnect systems.

# HIGH SPEED LIQUID INJECTION MOLDING OF CONNECTORS

Richard S. Zucker

Westinghouse Electric Corporation
Baltimore, Maryland

This presentation deals with a major industry and defense requirement to achieve cost effective production rates in the manufacture of molded connectors. This is especially important with connectors integrated with flexible printed wiring (FPW). Present molded connectors are inadequate due to poor adhesion to connector components and FPW, poor flexibility as well as long processing times.

The selection of connector molding materials is based upon adhesion to the connector components and FPW, flexibility, hardness, cure rate and military environmental requirements.

A comparison of connector molding materials is shown in Table 1. The Table includes polyurethanes, silicones, polysulfides, and epoxies evaluated to the selection criteria. Adhesion studies were made of the various molding materials to typical connector bodies such as glass-filled polyester & diallylphthalate molding materials. Both plain and acrylic overcoated polyimide films were studied as well as different types of contact materials such as gold plated beryllium copper and nickel plated brass.

Figures 1 and 2 show molded connectors being used to evaluate various molding materials for adhesion and flexibility.

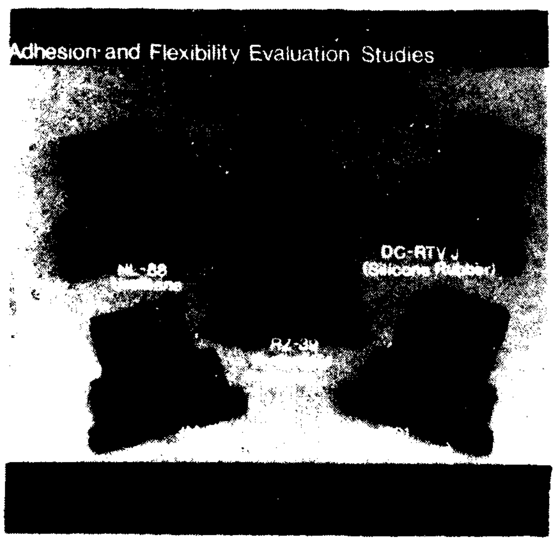



Figure 1

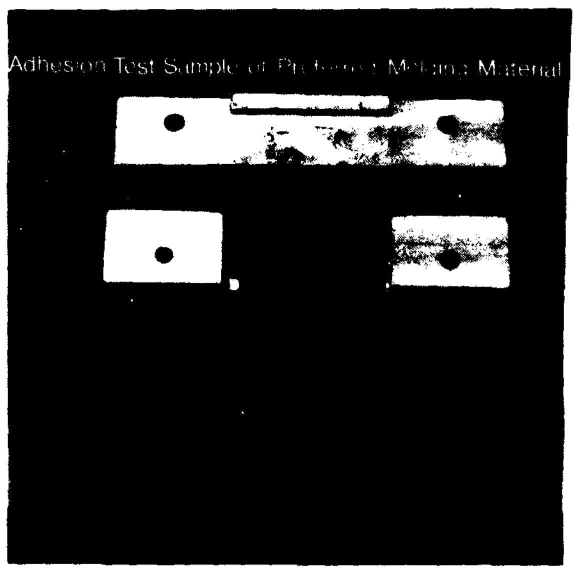


Figure 2

Table 1

# Comparison of Potential Molding Materials

| Material | Adhesion | Flexibility | Hardness | Cure Conditions | Environmental Comments |
|---|---|---|---|---|---|
| Polyurethane NL System 88 | Good | Good | D50 | 16H/25C + 4H/80C | Components are Moisture Sensitive |
| Polyurethane NL System 90 | Good | Good | D70 | 16H/25C + 4H/80C | Moisture Sensitive, Passes 5 Cycles − 65C, + 125C |
| Polyurethane REN RP-6405 | Poor | Good | D70 | 24H/23C | Battle Polymer-Poor Release From Mold |
| Polyurethane PRC PR-1524 | Excellent | Excellent | A45 | 3H/82C + 2H/82C | Contains MOCA-Carcinogen Excellent Moisture Resistance |
| Polyurethane Rimthane CPR2152 | Good (Primed) | Excellent | D55 | 3M/49C + 2H/121C | Structural Operating Range − 23C to 93C Good Moisture Resistance-Polyether Based |
| Polyurethane Pellethane 2103-55D | Poor | Excellent | D55 | Thermoplastic Elastomer | Excellent Electrical Properties Excellent Hydrolytic Stability-Polyether Based |
| Polysulfide PRC 1201 | Good (Primed) | Excellent | A45 | 72H/23C | Passes Thermal Shock |
| Silicone DC RTV J | Poor (Primed) | Excellent | A50 | 24H/25C or 30M/65C or 5M/149C | Passes Thermal Shock |
| Silicone DC 308 | Fair | Poor | D45 (Hot) | 30S/150C | Mil-S-8516 − 65C, + 175C Operating Range |
| Epoxy/Amine 3M 2216 | Fair | Fair | D70 (A93) | 24H/23C or 2H/65C or 1H/100C | Poor Moisture Resistance Fails 5 Cycles, − 65C, + 125C |
| Epoxy/Anhydride RZ-39 | Excellent | Good | D80 (A96) | 5M/150C | Passes 5 Cycles, − 65C, + 125C |

The material selected for high speed liquid injection molding of connectors is a hydantoin epoxy. This material meets all the adhesion, flexibility, hardness, rapid cure and environmental requirements. The formulation and processing conditions for the preferred liquid injection molding compound are shown in Figure 3.

Preferred Liquid Injection Molding Compound (RZ-39)

| | |
|---|---|
| Dimethyl Hydantoin Epoxy Resin, CIBA XB-2869 | 70 (EEW 155) |
| Polycarboxylic Acid Anhydride Hardener, CIBA HY-920 | 157 (EEW 243) |
| Neopentyl Glycol Diglycidyl Ether, Reactive Modifier, Viscosity Diluent, CIBA XU-193 | 30 |
| N-Butyl-T-Amine Phenate Salt Accelerator, CIBA DY-069 | 1 |
| Boron Trichloride Amine Complex Curing Agent/Accelerator, CIBA XU213 | 3 |
| Specific Gravity | 0.93 |
| Glass Transition Temperature, Tg | [illegible]°C |
| Cure Conditions | 5 Minutes at 150C (302F) |
| Optional Postcure | 1 Hour at 150C (302F) |

Figure 3

The formulation consists of a standard hydantoin epoxy resin modified with a diglycidyl ether and cured with a flexible anhydride hardener in the presence of two amine catalysts. This composition produces a flexible epoxy with a glass transition temperature of 8°C after a cure of only 5 minutes @ 150°C. The hydantoin formulation can be broken down into two components of ratio of 1 to 1.8 by volume which allows for easy packaging in coaxial cartridges for dispersing as part of the mixing system. This system is shown in Figure 4.

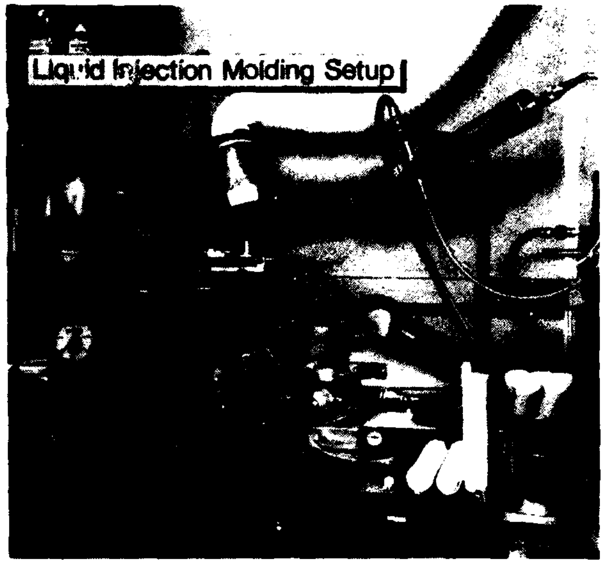



Figure 4

It includes liquid injection molding equipment, not only the cartridge storage but the static mixer (8 stage), the injection system (pneumatic) and the clamping press for holding the mold closed (heated and water cooled). Together this system with a single cavity mold can produce a molded part in a 10 minute cycle: 3 minutes heating plus 5 minutes curing and 2 minutes cooling.

A typical liquid injection mold fixture ready for molding is shown in Figure 5.

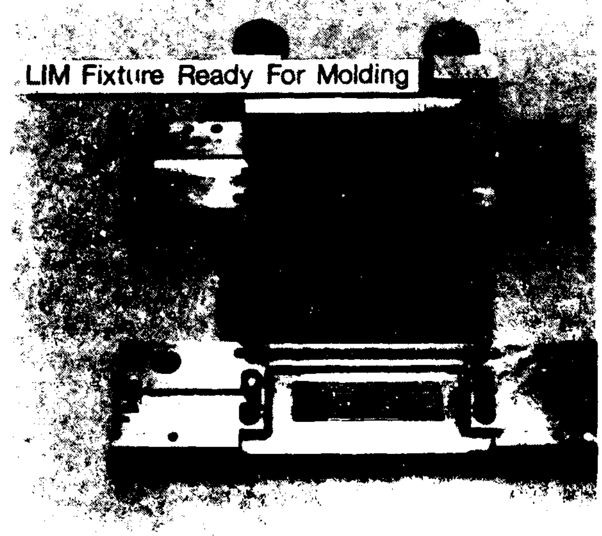



Figure 5

This mold is made of steel and may be hardened when all the injection parameters are established. Typical values are: injection pressure 20-40 psi @ room temperature, injection port - 0.19 inch diameter; fan gate - 0.006 inch per side of mold; vent gate - 0.002 inch per side of mold; sealing material - silicone rubber shore A50 or foamed silicone rubber shore A20.

A close up of the mold during the 5 minute press cycle is shown in Figure 6.

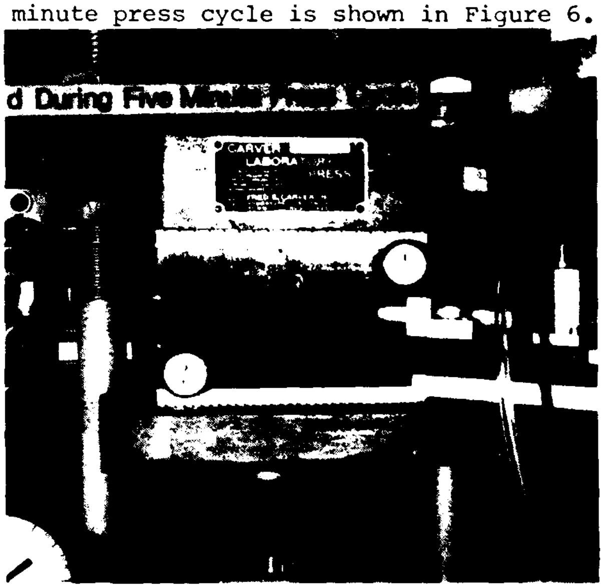



Figure 6

The injection nozzle which has an internal diameter of 0.13 inch is made of Teflon in order to reduce conduction of heat from the mold during the curing cycle and to prevent gelation of the liquid in the nozzle. At the end of the molding cycle the nozzle is withdrawn simultaneously with removal of pressure on the liquid. In practice the nozzle does not clog between cycles and does not need cleaning. With automatic positioning the cycle could be reduced from 10 minutes to 5 minutes: 1 minute heating plus 3 minutes curing and 1 minute cooling, unloading and reloading. Further acceleration of the formulation may be required as well as automatic ejection equipment in order to prevent distortion of the parts while still hot. If the connector bodies are made of thermoset plastic as compared to the thermoplastic materials such as glass-filled polyester or polyphenylene sulfide the molding temperature may be increased from 150°C to 200°C and the curing cycle may be further shortened to as little as one minute.

ALTERNATE MOLDING METHODS

There are two other molding methods which may be of interest in certain applications where speed may be of greater importance than the overall quality of the molded part. They are thermoplastic injection molding where a fully reacted plastic material is injected into the mold in a typical 1 minute cycle and RIM (reaction injection molding) which may be defined as an ultra-high speed chemical reaction molding requiring exceptionally fast mixing of the components in order to cure in as little as 20 seconds. A typical small size thermoplastic injection molding equipment is shown in Figure 7.

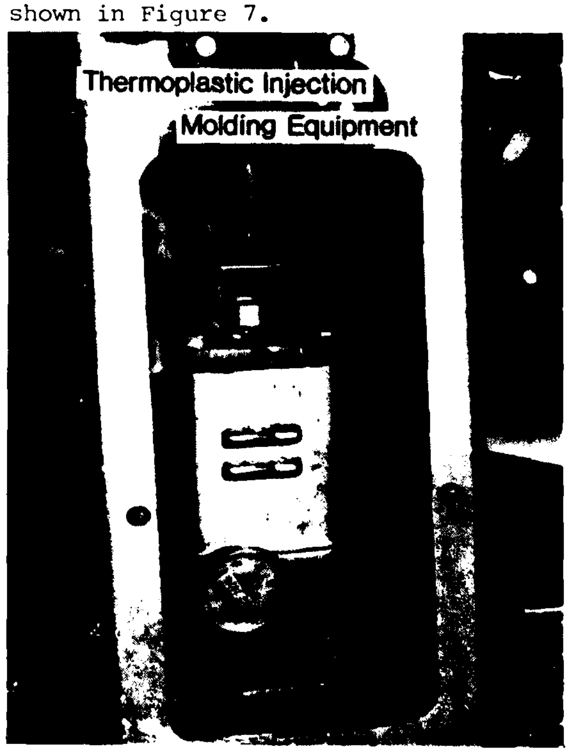



Figure 7

This has a capacity of about 1 ounce of a thermoplastic material on a typical 1-2 minute molding cycle. The main disadvantage of this type of molding is the lack of adhesion of the thermoplastic material to most materials which might be used in connectors.

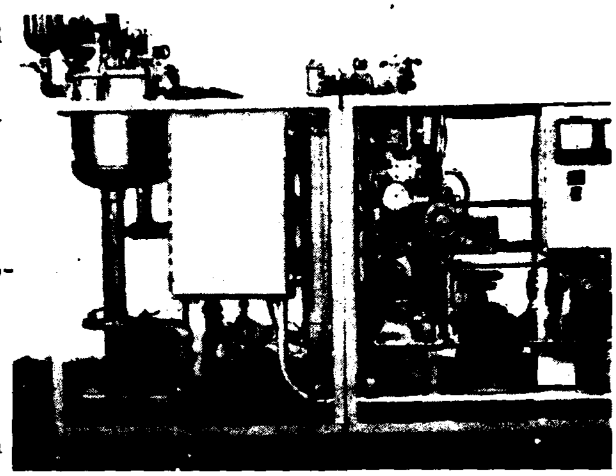


Figure 9

The RIM method of molding is usually only considered for large parts of up to 20 pounds or more. The main disadvantage of the RIM method of molding is the high cost of the equipment and the high mold cost. Part of the high cost of the equipment comes from the need for high speed mixing equipment in order to mix the required quantity of chemicals together thoroughly before chemical reaction begins to harden the material. There are two types of high speed mixers - one is a high speed rotating mixing head which rotates at speeds as high as 10,000 RPM and the other is a high pressure direct impingement of the metered chemicals into the mold chamber at pressure as high as 3000 psi. This type of equipment may require a purging system to keep the mixing head from clogging up between shots. A typical RIM installation is shown in Figures 8, 9, and 10.

Figure 8

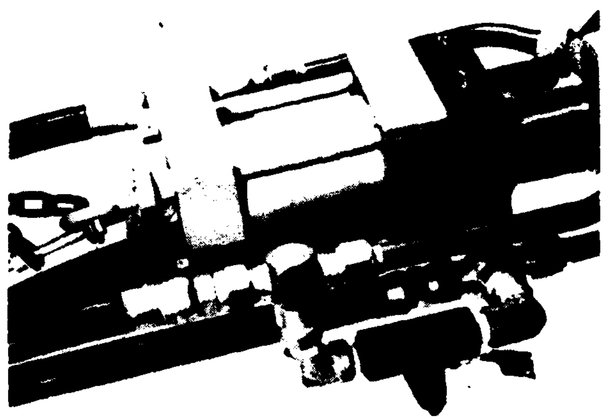


Figure 10

This equipment is capable of molding an automobile dashboard in one piece in a 3 minute cycle. The usual material used for RIM is a two component polyurethane system consisting of an isocyanate and polyol. Other RIM systems such as vinyl or epoxy are not in widespread use yet.

CONNECTOR PIN SEALING

Certain types of connectors require pin sealing in order to prevent the liquid molding compound from running through the pins and plugging up the connector during the molding operation. An example of such a connector is the box pin connector. This connector is shown in Figure 11 with two typical pin sealing materials of a filled epoxy resin type which requires high temperature curing.


Figure 11

Unfortunately, one of the disadvantages of this type of material is the difficulty of applying it uniformly and the connectors usually end up leaking in spite of every effort to provide a complete seal. In contrast to the highly filled epoxy resins shown in Figure 11, several other filled epoxy resins were tried and the results of the cross sections are shown in Figures 12 - 17 which shows the depth of penetration of the sealing compound into the box pins.

Figure 17 shows the most successful pin sealing compound with the minimum penetration into the pin area.

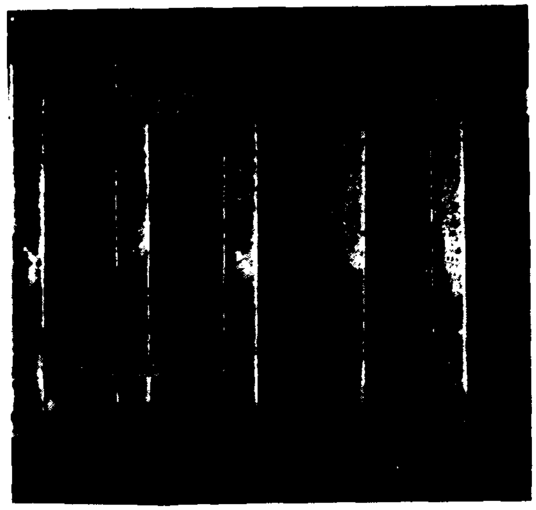


Figure 12

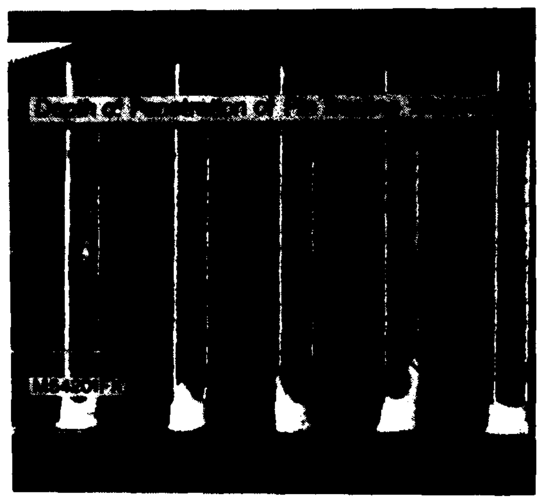


Figure 13

### Pin Sealing Compound (RZ-41)

| | |
|---|---|
| Ethyl Amyl Hydantoin Epoxy Resin, CIBA XU-229 | 100 PBW |
| Long Chain Aliphatic Amine Adduct Hardener, CIBA HY-837 | 42 |
| Fumed Silicon Dioxide, CAB-O-SIL PTG | 14 |
| Specific Gravity | 1.18 |
| Glass Transition Temperature, Tg | 53°C |
| Cure Conditions | 1 Hour at 75C (167F) |
| Alternate Cure Cnditions | 7 Days at 25C (77F) |

Figure 14

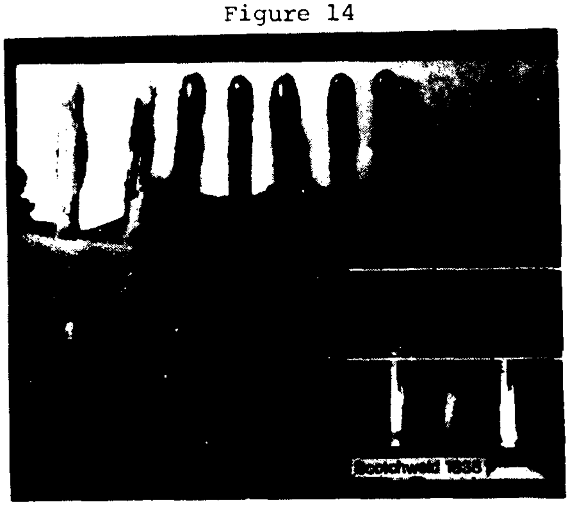



Figure 15

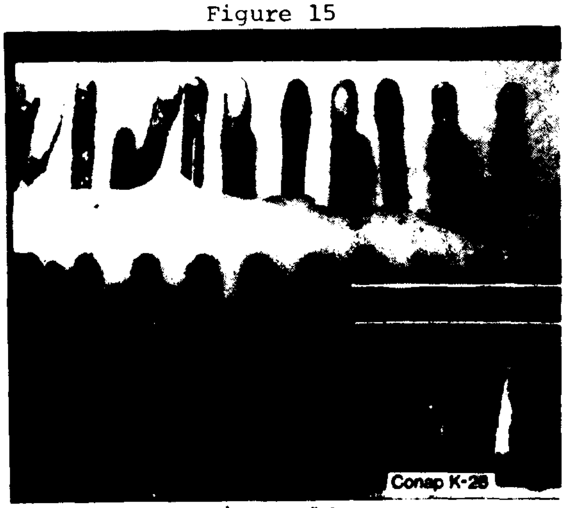



Figure 16

Figure 17

The formulation for the preferred pin sealing compound is shown in Figure 14. This formula consists of a flexible epoxy resin, and a flexible amine hardener which is thickened by a special thixotropic filler which allows the formula to be readily dispensed through a standard #18 gauge needle in a syringe under nominal pressure and then set-up to a stiff paste upon resting to prevent flow of the compound into the pin area. The degree of thixotropy required to control pin penetration and yet allow sufficient flow during dispensing to completely seal around the pin is determined through experiment and may have to be adjusted for different types of connectors. The particular grade of fumed silicon dioxide is recommended for its ease of dispersing by means of hand stirring. It should be noted that the formulation requires only a low temperature cure in contrast to the high temperature required on other materials investigated, as shown in Figures 11, 12 and 13.

An alternate method for pin sealing is the use of an ultraviolet light of high intensity for rapid photopolymerization of plastic materials at the time of injection into the pin area. If the application and curing is not done rapidly the heat from the lamp will thin the material and it will run into the pins and ruin the connector. A typical UV curing station for pin sealing is shown in Figure 18.

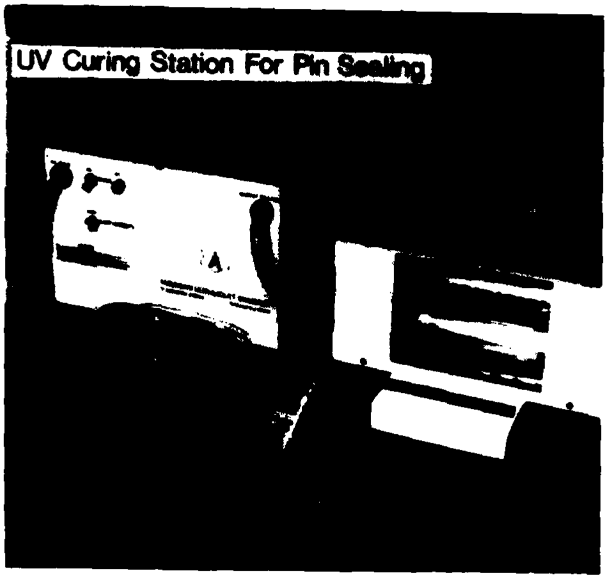



Figure 18

This consists of a 1000 watt high intensity mercury lamp which is placed 1.5 inches from the connector for 5 seconds in order to cure an adhesive around the pins of the connector. It should be noted, however, that even in this short a time, the heat generated from the lamp is sufficient to soften a thermoplastic connector body such as glass-filled polyester. Other higher softening temperature thermoplastics or thermoset materials would be satisfactory, however, for use with this pin sealing method.
The use of acrylic ester adhesive for pin sealing is a viable method and produces a fully thermoset plastic material which is compatible with the hydantoin liquid injection molding material and will not soften at the molding cure temperature of 150°C. This material will cure hard with no tackiness in 5 seconds with the 1000 watt lamp shown in Figure 18 at a distance of 1.5 inches from the surface of the lamp.

A rapid reliable molding method for FPW connectors has been developed. The method uses a hydantoin epoxy resin to provide adhesion, flexibility, and adaptability to automated techniques.

RICHARD S. ZUCKER

Senior manufacturing engineer with Westinghouse Electric Corporation, Defense and Electronics System Center. Responsibilities in manufacturing development and process technology relating to connectors and inductive components with special emphasis on new methods, equipment and improved methods for processing connectors and high voltage components.

Background includes experience in organic coatings, plastic molding materials, semiconductor devices and analytic instrumentation. He has several patents and publications in related areas and is a member of the American Chemical Society. His formal education includes BA & MS degrees in chemistry from Universities in New York City.

# Design of an Automated Termination Process for Flexible Printed Wiring

by
Richard L. Hall

Westinghouse Electric Corporation
Aerospace Division, Baltimore, MD

## INTRODUCTION:

This paper describes an automated process for the production of integral molded connector terminations on flexible printed wiring. The design was undertaken as part of a Manufacturing Methods and Technology contract with the U.S. Army Missile Command, Redstone Arsenal, Alabama.

The process features the application of industrial laser techniques to the requirements of flexible wiring cover coat stripping and to the welding of the copper foil circuit leads to the connector pins. Also, the utilization of fast-cure liquid resin injection molding (L.I.M.) permits inclusion of connector to flex circuit encapsulation as part of the in-line process.

The automated process is designed to handle planar two row connectors on .050" centers at a production rate of 500 connector assemblies per 8 hour shift. This paper deals with the specific design requirements for automated part handling and positioning to accomplish reliable, low cost flexible wiring termination and encapsulation.

In order to describe the design requirements for the automated facility, this paper has been divided into four topical sections. These sections deal with: the design strategy; the physical configuration; the tool motions, or kinematics; and the method of tool control. First, however, is presented an overview of the Flexicon system process flow.

## THE PROCESS FLOW

The automated Flexicon process has three basic steps, laser stripping of the flexible printed wiring (FPW), laser welding termination of FPW leads to connector, and assembly encapsulation. The straightline flow is charted in Figure 1. Under controlled conditions, a

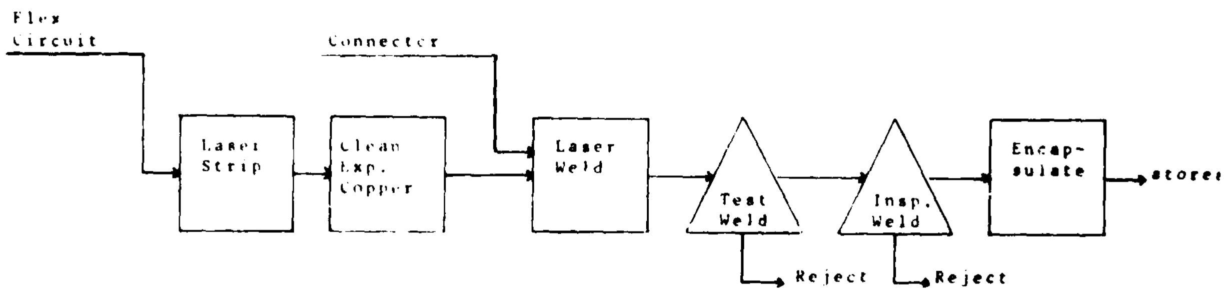



Figure 1

pulsed $CO_2$ laser is used to ablate the insulating material surrounding the copper leads in the area which is subsequently to be terminated to the connector. The focused light energy of 10.6 micron wavelength discriminates between the copper, which is highly reflective to this wavelength, and the plastic covering layers and the adhesive layers which readily absorb the energy. At the energy density levels used, this causes virtually instantaneous heating of the plastic materials to their vaporization temperature while leaving the copper undisturbed. A simple cleaning process involving bristle brush stroking and solvent wash of the exposed copper dislodges any particulate char which may remain.

A Neodymium - YAG pulsed laser is used to weld the copper FPW leads, which have been positioned and clamped, to the pin tails of the connector. The focused light energy of 1.06 micron wavelength is readily absorbed, in this case, by the copper leads. Absorption of the focused light energy rapidly raises the temperature of the metals to cause a fusion weld to be formed.

Automatic electrical test is performed on each weld termination to verify acceptable conductivity. Automatic inspection is an optional feature which may be implemented by several methods. For instance, use of the specular signature of an acceptable weld nugget could be used as criterion in an electro-optical system.

Encapsulation, which provides the necessary electrical isolation between adjacent leads and strain relief transition from connector to unsupported FPW is the last process step. A quick-cure liquid resin system is utilized which makes it possible to automatically load the mold and encapsulate the Flexicon assemblies in line with the preceeding process steps. This avoids any manual handling of the relatively fragile assemblies before molding.

## SYSTEM DESIGN STRATEGY

The primary feature of the Flexicon Automated System is the application of programmable control to all aspects of the system. This minimizes the need for hardware type tooling dedicated to a specific Flexicon assembly. By utilizing programmable control, many aspects of machine and process parameters are removed from hardware definition and are brought under software definition. While absolute fidelity to the program is maintained during the machine cycle, an infinite number of programs can be generated and rapidly changed to deal with assembly style changes or process variables. Accordingly, the geometrical character of the connector and flexible circuit (ie., pitch and number of connector leads to be welded) are controlled by software and are easily changed or modified by software with minor hardware modifications required. Also, with the specialized arrangement of the tooling used, programmable control eliminates the need for many of the complex mechanisms characteristic of automated machinery.

The application of programmable control to the Flexicon system falls into three categories:

1. Control of Processes
   - Laser Welding
   - Laser Stripping
   - Encapsulation
2. Control of Position
   - Index Entrained Connectors
   - Translate Flex Circuit past $CO_2$ Laser Beam
   - Translate Assembly past YAG Laser Beam
   - Load Welded Assembly into Encapsulation Mold
3. Control of System Timing
   - Coordinate System Events in Series and Parallel

Control of critical processes is a desirable application of programmable control since precise, repeatable, control of critical operations is achieved. In this system, for instance, we utilize software to precisely coordinate the firing of the laser for welding with the position of the target. This is done by electronically counting position command pulses to the positioning table, which is translating the FPW/connector assembly in the laser focal plane, and timing the laser firing command to the position count which corresponds to a FPW lead connector in proper weld position. With this type control the welding of connector to FPW lead can be done quite rapidly, in fact, limited only by the capacity of the laser to recharge the firing circuit between pulses.

As another example of control, a characteristic of a pulsed welding laser is the necessity to start the firing pulses in advance of the first weld in order to thermally stabilize the lasing system and establish uniform energy density at the target. One way to achieve this is to start the train of laser pulses in advance of the first target and dissipate the energy into the system's closed shutter. The shutter is then timed to open just before the first weld target is in position.

Similarly, the laser stripping process is controlled by software; cover gas, vacuum, laser pulsing, and laser shutter control are also rigidly controlled by the software program. The injection molding process parameters (e.q. time and temperature) are precisely controlled by the program. They can be changed to new parameters by a change in the program.

In the second category, programmed control of position is accomplished by mounting the parts of the system hardware which support the Flexicon assemblies on two compounded, servo controlled, machine type linear slides. In-process Flexicon assemblies can thereby be moved in a horizontal plane relative to the fixed positions of the two lasers, the molding press and the FPW and connector inputs. The FPW is translated in the focal plane of the $CO_2$ stripping laser and also the Neodymium - YAG welding laser by software control of the positioning tables with no other mechanical assist required.

At any time in the operation of the system, there are up to seven Flexicon assemblies in process. By means which will be covered in the next section, the Flexicon assembly can readily be indexed from one process station to the next by a programmed table motion controlled by the software.

System timing is the third

category where programmable control is applied. Event timing is an essential element in this automated system. In the section on kinematics in this report, it is shown how the many process events and motion routines are orchestrated by the software program. Extensive use has been made of programmed cues ported to external control hardware to initiate program subroutines such as manipulation of the FPW from input through laser stripping and subsequent transfer to the laser welding operation.

A secondary feature of the automated system design is the integration of all three primary processes steps, strip, weld, and encapsulate into one functional unit. Mechanical tolerances on the relative positions of the various elements of hardware are established and maintained very closely. The elements of hardware are mechanically linked to a common base. The dimensional precision and inertial stability required for the laser processes are assured by using a granite surface plate as the system foundation.

SYSTEM CONFIGURATION

The components of the systems are arranged to provide inline processing through all steps that end with a finished, tested Flexicon assembly. A perspective view of the Flexicon Automated System is presented in Figure 2. The system has, as its central feature, tooling mounted on a computer numerical controlled (C.N.C.) linear slide table which provides x-y motion in the horizontal plane. Programmable control of the position of the tooling relative to the fixed positions of the two lasers and the mold press allow system design to be simplified.

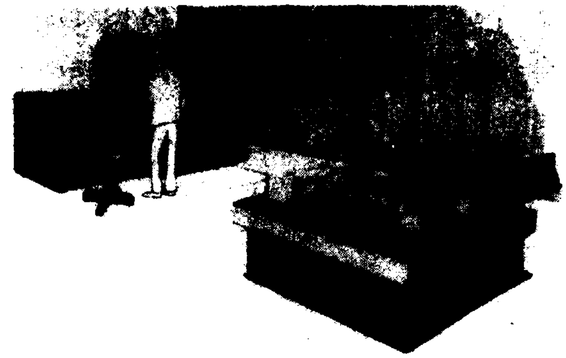


Figure 2

As depicted in Figure 3, the x-y positioning slides are mounted centrally on a granite surface plate. Tooling to support and reference the connector and FPW assembly through the welding, test and inspection process is mounted on the positioning tables,(1 in Figure 3).

In the righthand foreground of the illustration, the facility for $CO_2$ laser stripping and cleaning is positioned, (2 in Figure 3). Note that this laser, as well as the YAG laser for welding, is referenced to the granite base. Localized laser energy shielding is not shown, for clarity of illustration.

On each side of the stripping facility containers are located for presenting stacked, preoriented, FPW to the system, (3 in Figure 3). At the opposite end of the granite base is located the molding press. It is oriented horizontally, (4 in Figure 3).

The structure with the

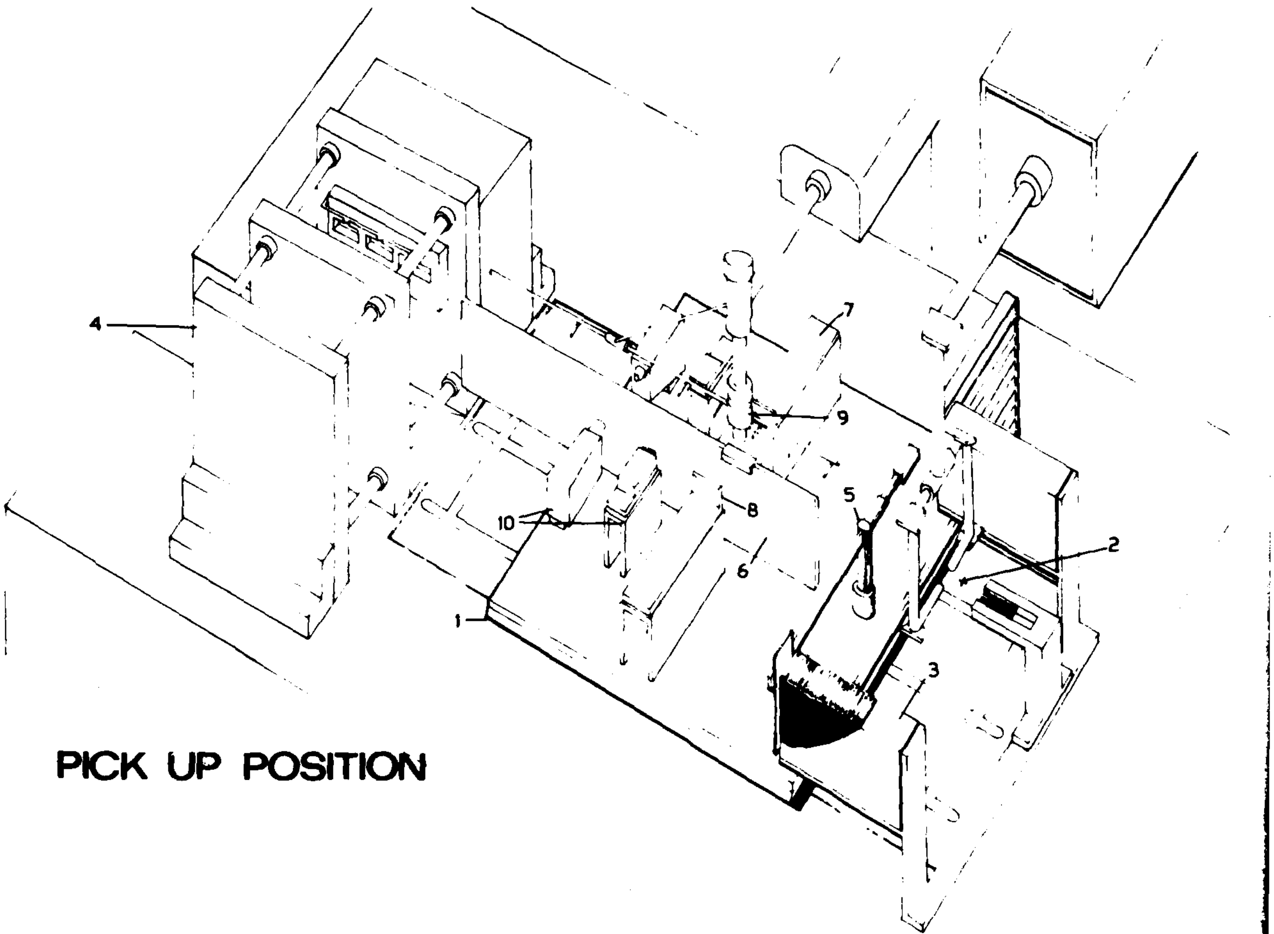



Figure 3

radial arms which is mounted on the positioning table in the foreground (5 in Figure 3), has two functions. The radial arms can be rotated in the horizontal plane. The longer arm is equipped with a doublefaced vacuum platen which is used to acquire a FPW from the preoriented stacks and manipulate the FPW through the laser stripping and cleaning process. The shorter arm is used to acquire a connector from the connector input station and transfer it to the vertical rail. The prominent tooling feature on the positioning table is the rail structure (6 in Figure 3), which supports the assembly in a vertical orientation with the pin rows straddling the top edge of the rail. The rail permits symmetrical access to each side of the connector pin rows and, also, provides vertical clearance for the trailing FPW.

On the positioning table are two small linear slides, positioned on each side of the rail (7 in Figure 3). Each slide supports a vertical vacuum platen with a comb-like feature at the upper edge, (8 in Figure 3). The comb tines interdigitate with the stripped FPW conductors to provide mechanical registration of the FPW with the system. The slides can also be rotated 90 degrees in the horizontal plane to align the slide's vector between, alternately, the radial arm for FPW transfer to the slide, and the weld position at the rail. Welding takes place as the connector and registered FPW are transported in the focal plane of the horizontally oriented YAG laser beam, (9 in Figure 3). Welding is done sequentially, first on one side of the connector and then on the opposite side. Probing and inspection stations are also located on the positioning table downstream from the weld station, (10 in Figure 3). This permits concurrent test and inspection of previously welded assemblies.

The overhang of the rail beyond the positioning tables provides temporary work-in-process storage space for queueing acceptable assemblies and then, when the queue is full, moving the table to position the assemblies in between the mold halves.

SYSTEM KINEMATICS

This section will describe in detail the many events that occur in the automated production of a Flexicon assembly. Referring to Figure 4, the overall sequence of events can be seen. First to be noted, is

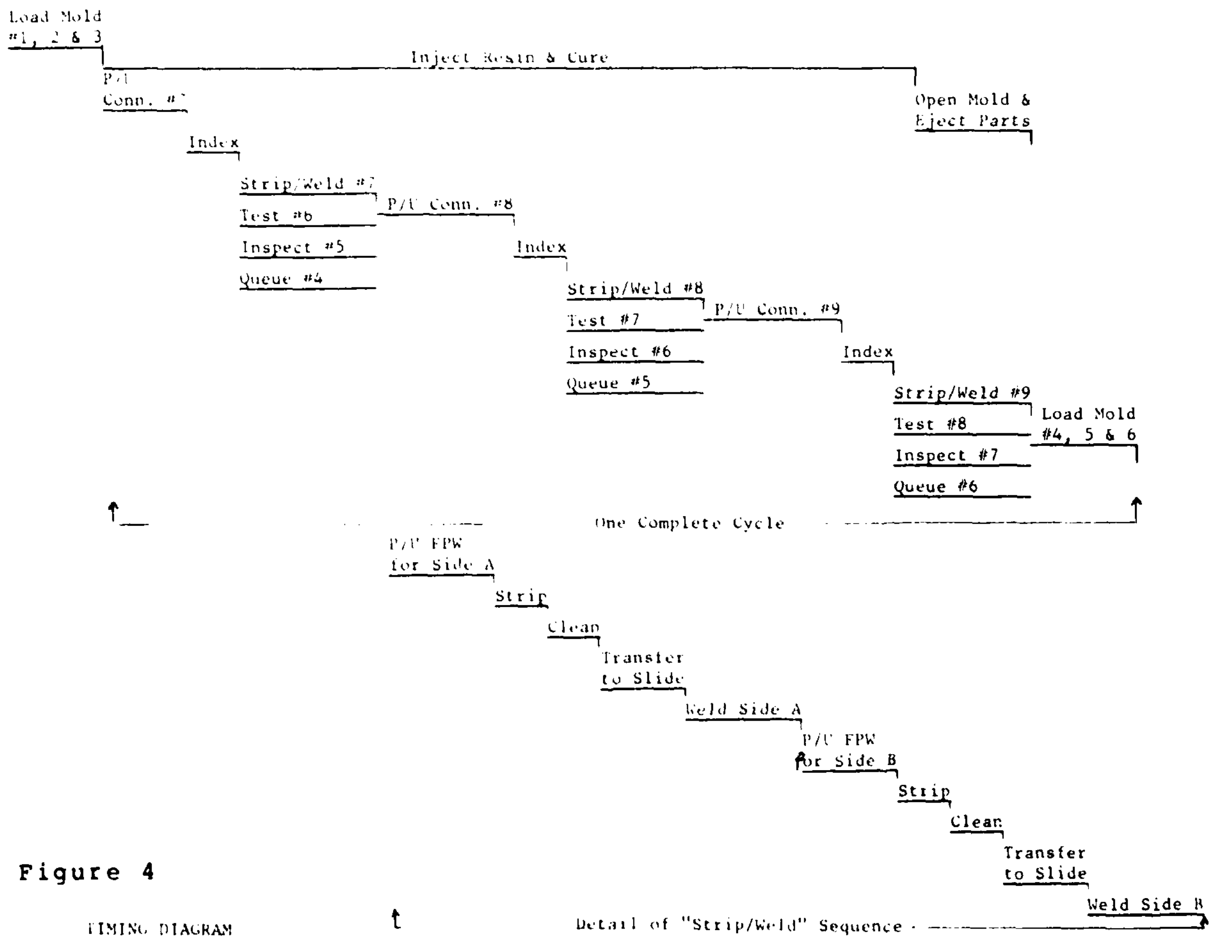



Figure 4

TIMING DIAGRAM

that the system cycle spans the time required to produce three Flexicon assemblies. Because the encapsulation curing cycle requires a longer time than the other Flexicon assembly cycle times, it is necessary to queue the welded assemblies until three at one time can be inserted into the matching three cavity mold. Also note, the electrical test and electro-optical inspection take place concurrently with the FPW stripping and welding. This is made possible by having the hardware for these functions mounted on the positioning tables.

The first event in the automatic process occurs when the vacuum pick-up platen on the radial arm is brought into contact with the preoriented stack of FPW located in the foreground. The table backs away from the stack with the FPW held to the radial arm by pressure differential. This event is illustrated in Figure 3 which was cited earlier in this paper. The radial arm then rotates counter-clockwise 90 degrees in the horizontal plane and commences a series of back and forth passes in the $CO_2$ laser beam. This causes the cover coat to be ablated exposing the copper circuits. This action is illustrated in Figure 5. The stripped circuit is then mechanically cleaned and washed by advancing the circuit into the brushes positioned in line with the laser focal plane.

The table then moves to withdraw the radial arm and FPW from the stripping station. The arm then rotates counter-clockwise an additional 90 degrees. At this point the slide mounted comb is caused to rotate 90 degrees clockwise in

Figure 5

the horizontal plane and advance the comb on the end of the slide to engage the FPW. This is illustrated in Figure 6.

Control of the FPW is transferred to the comb by inhibiting vacuum on the stripping platen and enabling vacuum on the face of the comb. The slide then retracts with the FPW attached, rotates 90° clockwise to return to its start position. The slide advances toward the rail and engages the previously positioned connector, aligning and clamping the FPW leads to the connector pins. This is illustrated in Figure 7. The table then moves the assembly

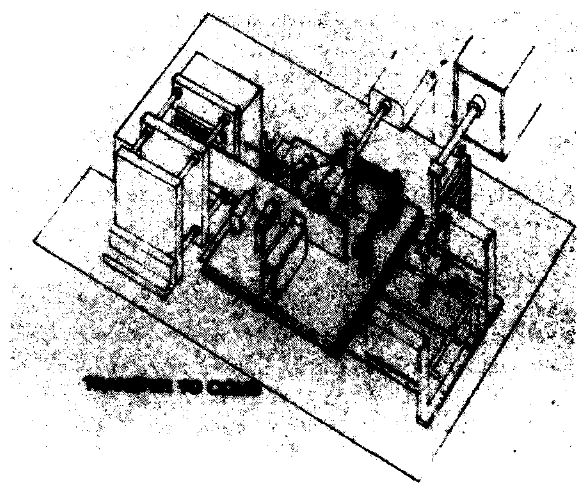


Figure 6


Figure 7

into the focal plane of the YAG laser and commences the spot welding routine. At the completion of the weld cycle the vacuum is inhibited and the slide retracted to start position leaving the FPW behind. This stripping and welding sequence is repeated again, in mirror image, for the second side of the connector.

*During the period when* stripping and welding are taking place, previously welded assemblies are being tested and inspected automatically. The slide mounted probes are caused to advance and contact in the weld area to electronically verify continuity and acceptable conductivity of the weld joint. Cameras for the (optional) optical inspection are positioned next in line on the table.

At this point in the process the table moves to bring the shorter radial arm in line with the connector input station positioned next to the $CO_2$ laser housing. Through an escapement mechanism, one connector is pushed onto the arm. The arm rotates 90 degrees counterclockwise to align with the rail.

With the new connector in this position the indexing cycle starts. The entrained connectors are each simultaneously moved to the next station on the supporting rail. This includes moving the connector on the arm to the first position on the rail. Indexing is accomplished by the rod with radial spokes supported by the YAG laser column, as illustrated in Figure 8. This rod, on command,

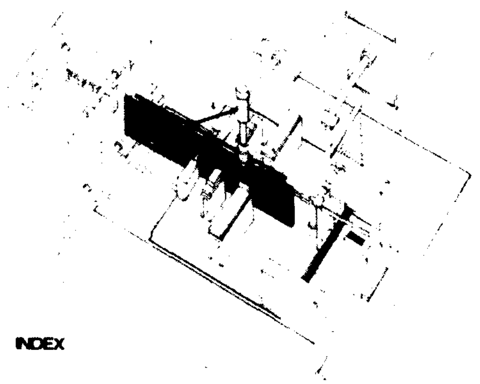



Figure 8

is rotated 180 degrees about its major axis which brings the radial spokes into position between the connectors. The table is then caused to move from left to right, whereupon the connectors, initially moving with the rail, each encounter a spoke on the rod. The spoke acts as a stop to the connectors, holding each stationary while the rail continues to move until the next station on the rail is precisely registed with the next assembly. The rod is then rotated back to its start position and the table, with Flexicon assemblies advanced to their next stations on the rail, moves back to start position.

The next step depends on the status of the Flexicon assembly queue waiting for transfer to the molding press at the far end of the rail. If the queue is not full, that is, there are not yet three Flexicon assemblies in the queue, then the sequence beginning with FPW stripping will occur again. If, however, the queue is full, then the contents of the queue will be transferred to the mold cavities. In this event, the table moves from right to left to bring the Flexicon assemblies in the mold queue into the space between the mold halves. This is illustrated in Figure 9. The mold then closes partially, nesting the connector bodies in

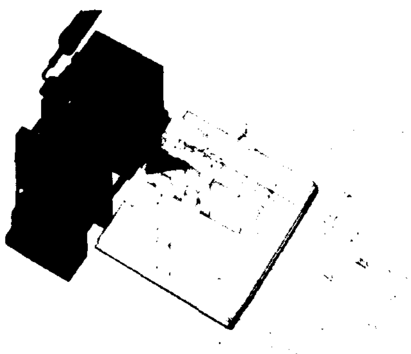



Figure 9

the mold cavities. The rail is then withdrawn, leaving the assemblies in the mold. The mold then closes completely and the molding cycle commences. When the cure is complete, the mold opens and completed Flexicon assemblies are ejected.

SYSTEM CONTROL

As stated in the section on Design Strategy, the Flexicon System is designed for programmable automation in which hardware tooling is minimized and the advantages of control by software are exploited. A microprocessor based C.N.C. system is used for the following functions:

- Positioning commands for the two axis positioning table
- Firing commands for both lasers timed by the position of the FPW and Flexicon assembly
- Control of all other system events through external porting of program commands to interfacing hardware.

All system events which are of a routine nature are controlled by programmed sub-routines. They are cued through external ports of the microprocessor control. Some of the subroutines which are sequential in character are:

- Indexing
- Connector pick up and transfer to rail
- Flex pick-up and radial arm motion
- Flex transfer from radial arm to slide
- Flex Cleaning Cycle
- Load Mold Cycle
- Laser Cover Gas control
- Resin injection and cure cycle
- Continuity Test sequence
- Inspection Sequence (Optional)

## CONCLUSION

The application of microprocessor control to the design of the automated Flexicon assembly system makes possible control of the position of the workpiece through all process steps, control of the process variables and coordination of all system events. In addition, the use of a microprocessor allows changes in process variables and, with some limitations, Flexicon style changes to be accomodated by incorporating appropriate software changes to the program.

The complexity of the automation type tooling required for this system has been greatly simplified by the microprocessor control. The precision motions required for guiding the FPW and assembly through stripping, welding, test/inspection, and mold loading are derived from the capability of the microprocessor to control the position of the x-y table and not from mechanical mechanisms intrinsic to the hardware itself.

## BIOGRAPHY

Richard Hall is a graduate of The Johns Hopkins University and holds a Bachelor of Science degree in Industrial Engineering. His working career has been devoted to manufacturing development in the military electronics environment. His last 15 years have been with Westinghouse where his work has been in the design and development of specialized tooling and automated machining processes.

# APPENDIX J

## LASER WELDING PROGRAM FOR SEMI-AUTOMATED FLEXICON DEMONSTRATION

## APPENDIX J
## COMPUTER PROGRAM FOR LASER WELDING FLEXICON ASSEMBLIES ON SEMI-AUTOMATIC EQUIPMENT

The Aerotech Smart I computer numeric control system governs position and traverse speed of the X-Y table, and firing of the Raytheon SS-500 laser. Laser pulse energy is the only weld parameter not controlled by Smart I. The Aerotech X-Y table has an incremental resolution of 10 micrometers per step and a table range of 24 inches x 12 inches in the X and Y directions respectively.

Listed below is the position and laser fire program used to weld flex circuitry to an Amp male connector. Brief explanations accompany important steps of the program. With Smart I in automatic mode, pressing START initiates execution of the laser welding process.

Flexicon Position and
Laser Fire Program

1) G7 G5 G10 E

Go to home, Establish zero reference position, Reset LED read outs and servo drives, End of block

2) M11 M12 M13 M26 E

Disable laser fire, Inhibit Y count, Inhibit X count, Laser shutter closed, End of block

3) G4 D1000 G1 G90 X20254 Y500 F800 E

Dwell 1 Sec. (G4 D1000), Linear interpolation, Absolute position mode, Travel in X direction to 20254, Travel in Y direction to 500, Feedrate of 80 inches/minute, End of block

4) Y7269 F250 E

5) Y500 F800 E

6) X4553 E

7) Y5886 E

8) X8664 E

9) Y4966 E

10) X20005 E

11) N-100 E

Go to laser fire subroutine N100

12) M1 E

Prqrammed stop. Press "ENTER" to continue.

13) G90 Y4966 F800 E

Return to Absolute position mode.

14) X9472 E

15) Y5886 E

16) X4553 E

17) Y4966 E

18) X8363 E

19) Y25222 E

20) X36848 E

At far side of sail. Ready to duplicate near side moves.

21) Y500 E

22) X41039 E

23) Y5886 E

24) X36928 E

25) Y4966 E

26) X25701 E

27) N-100 E

Go to laser fire subroutine.

28) G90 Y4966 F800

Return to absolute position mode.

29) X36369 E

30) Y5886 E

31) X41039 E

32) Y500 E

33) X36848 E

34) Y25222 E

35) X8363 E

36) Y500 E

37) X20254 E

38) Y12565 F250 E

39) Y500 E F800E

40) X00 Y00 E

Return to home position. Press "START" to reexecute program.

41) M2 E

Physical end of main program.

42) N100 M14 M24 E

Subroutine block number, M14 M24 command combination actuates a flip-flop required by Raytheon Laser to enable laser fire.

43) N910128 N910200 M21 M22 M16 E

N9101 C D and N9102 A B are the Aerotech commands to establilsh length between laser pulse fire. ABCD represents the thousand, hundred, ten, and one column of the position number respectively., Enable laser fire channel one (M21), Count Y step increments. (M22) Laser pulses on any multiple of ABCD., Open laser shutter (M16), End of block

44) G4 D10 G91 Y6604 F200 E

Dwell for one hundredth of a second to allow time for shutter to open. (G4 D10), Incremental program mode, Total Y travel during laser fire. Laser fires only when multiples of ABCD are reached during the total Y travel.

45) M11 M12 M26 E

Disable laser fire channel one, Inhibit Y count, Close laser shutter.

46) M14 M24 E

Second time Raytheon flip-flop command is encountered. Laser fire is disabled.

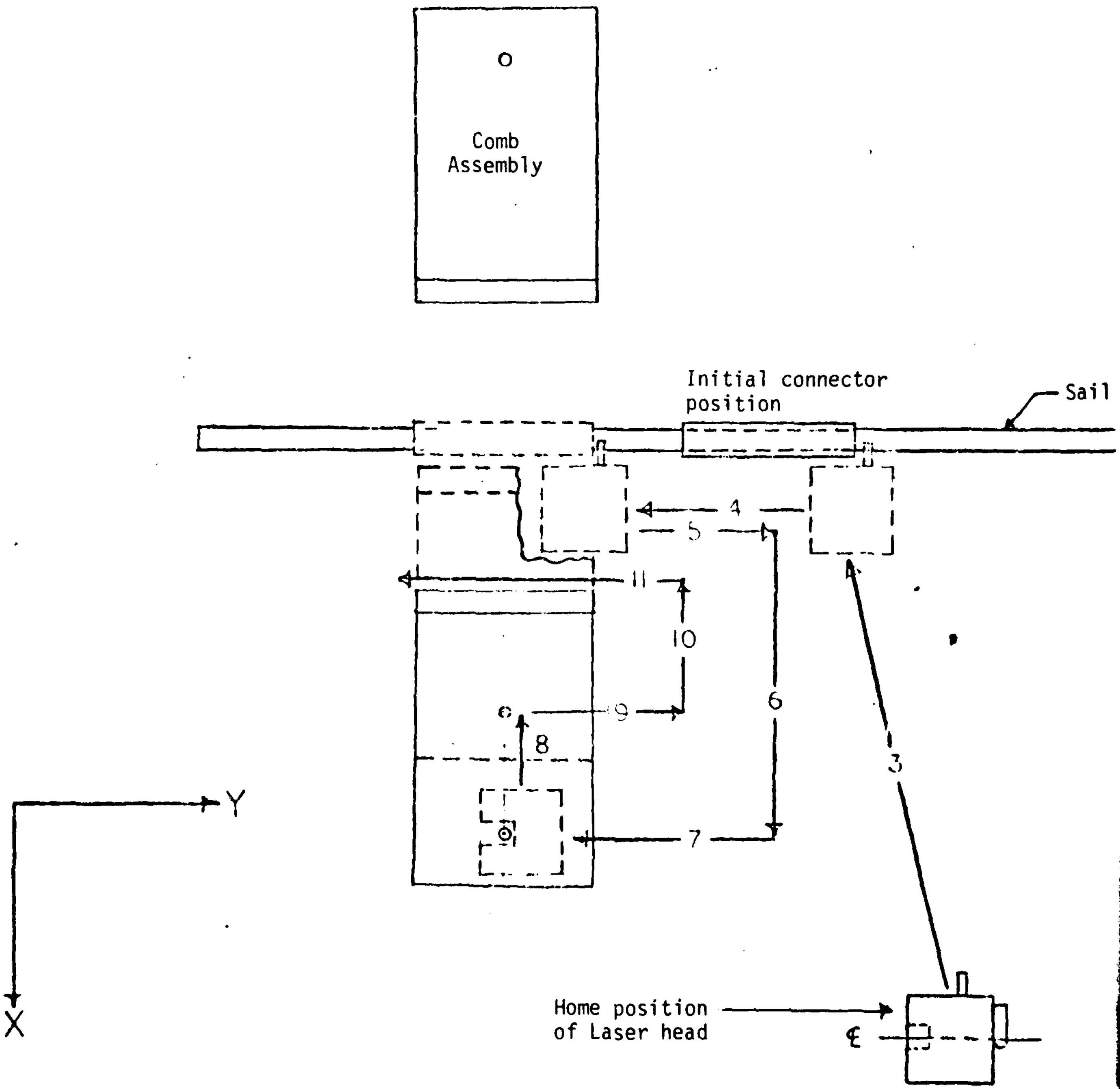
47) M99 E

Return to main program.

48) M30 E

End of program

Note: Numbered arrows correspond to numbered commands of Flexicon Position and Laser Fire Program.




Operational Sequence of X-Y Table

# APPENDIX K

## IMPLEMENTATION, THE KEY TO SUCCESS IN MANUFACTURING TECHNOLOGY

# IMPLEMENTATION, THE KEY TO SUCCESS IN MANUFACTURING TECHNOLOGY

by

James A. Henderson
Westinghouse Electric Corporation
Defense and Electronic Systems Center
Baltimore, Maryland

## ABSTRACT

Through a program sponsored by the U. S. Army Missile Command, Redstone Arsenal, Alabama,[1] a significant advance in technology and automation has been accomplished. The technology improvements involve the use of a $CO_2$ laser for insulation removal, a Nd: YAG laser for welding, and high speed liquid injection molding with hydantoin epoxies. The resulting termination of flexible printed wiring and flat conductor cable to connectors is fully automatable and will meet the military airborne environmental needs. Indeed, the cost reduction is so significant that it is attractive to the commercial as well as military community. Even so, the key to successful implementation and a successful return on investment is timely introduction to industry and a well coordinated implementation plan. This presentation briefly describes the technology advancements and the design of the fully automated facility. It then focuses on the implementation plan, its overall coordination, and its early results.

## PROGRAM NEED

Manufacturing Methods and Technology programs have been established by DoD agencies as a vehicle for improving productivity when R and D has demonstrated feasibility but some funding is necessary to provide a final process set which will benefit many programs. The key to return on investment, therefore, is implementation.

Flexible Printed Wiring (FPW) and Flat Conductor Cable (FCC) are technologies which have been in use for many years. The cable shown in Figure 1 was installed over ten years ago. Its planar shape and low profile enable its use in such assemblies with very little loss of volume. But the practices of individually soldered leads and special molding (for moisture protection) are still commonly found today. Other more rapid techniques, such as crimping through insulation and gang soldering have been used on recent projects with mixed results. The reliability and repeatability of these approaches have been very challenging to maintain.

Yet, FPW has significant possible advantages for military systems. Volume and weight savings over round wire harnesses can be 70 to 80%. Cost savings of 35 to 50%, with the present termination practices, are not uncommon. And, cost benefits of the weight and volume savings can be substantial in new design systems. The basic drawback to the utilization of FPW has been the lack of cost-effective, repeatable termination techniques which meet the environmental and handling requirements of the military

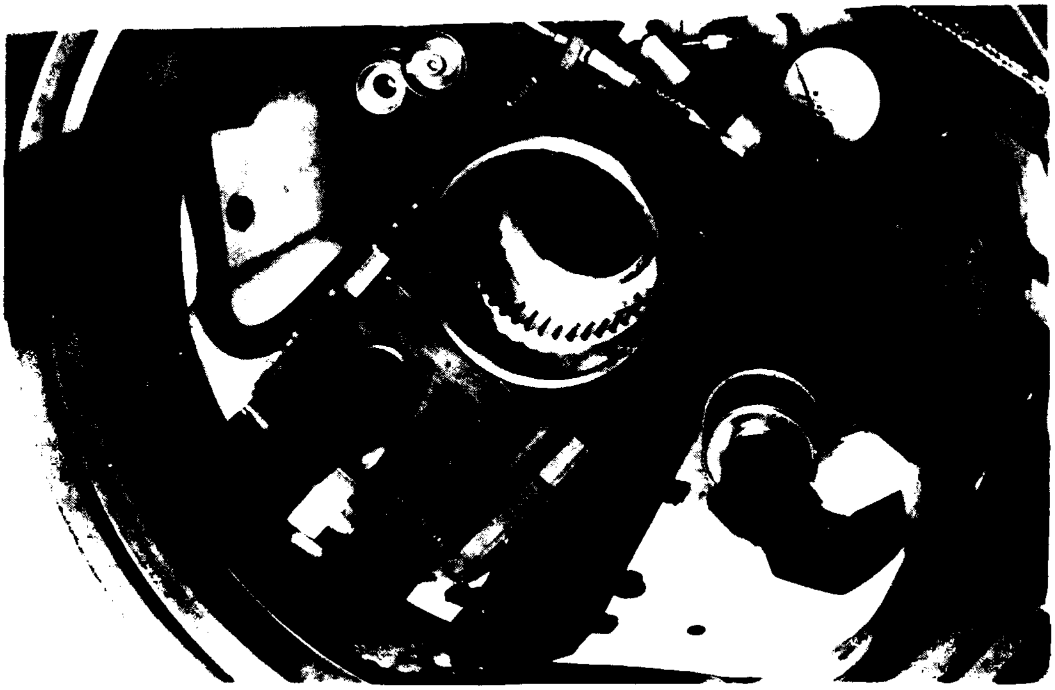


Figure 1: This Flat Cable Required Individually Molded Connector Boots

community. Therefore, this program was established to significantly improve the FPW/connector interface producibility.

PROGRAM APPROACH

Since FPW and FCC are high density interconnection technologies, the use of non-high density approaches and techniques was quickly decided against. The program centered on identifying high density, mil-qualifiable connectors, termination processes, and sealing procedures which would provide terminated FPW assemblies capable of meeting the military airborne environments. Also, since the automation of these processes would significantly impact cost and productivity, an automatability goal of 500 assemblies per 8 hour shift was also established.

The program approach included evaluation of available (possibly modifiable) connectors, evaluation and selection of processes to be used, the demonstration of semi-automated operation of the processes, and the definition of a fully automated facility which would enable cost evaluations of the processes. Environmental evaluation of the resulting product was also required.

Selection of connectors and processes was the most important initial program effort, and was performed through a weighted evaluation technique illustrated in Figure 2 and described below.

Each factor which would be of significant value difference between connectors (or processes), such as cost, inherent reliability, and maintainability, was separately listed. Each connector (or process) was program are being incorporated into four major programs at Westinghouse.

External implementation will be directly related to the intensity of effort of marketing and exposure of the technologies. As an example, that effort for this program is outlined. It is imperative that the timing of information release be carefully orchestrated with the program schedule and industry demonstration, so the continuity of program result dissemination not be lost or key personnel transferred due to a long gap between program end and information presentation. An alert program manager or monitor can ensure this.

Many media are available for dissemination of information. These include industry technical committees, technical journals, symposia, and technology demonstrations. The preparation of a concise technical motion picture can enhance many of these, as can timely discussions with magazine editors. Not to be overlooked are the additional efforts which can be realized from principal suppliers of materials or tooling who can also pass the word.

In the FLEXICON program, discussions of future marketing and possible automated facility set up were initiated in the first month of the program with connector and flexible printed wiring suppliers. Suppliers of the raw materials for the molding operation and FPW have also been briefed on the program and its benefits. In the seventh month, the SAE-A2H Wire and Cable Committee was introduced to developments. At the semi-annual meeting of the IPC in the ninth month, a detailed presentation of the technology innovations was given, along with the approach to station-by-station automation.

Over three hundred industrial representatives were invited to the industry demonstration in the programs thirteenth month. These included military and commercial users, connector and FPW fabricators, raw material suppliers, and key editors of leading technology magazines. The timing between the industry demo and the primary technology introduction (in an open conference), two months, permitted the release of news articles which also advertise the industry introduction. The industry introduction was set as a comprehensive technical session that was integral with a major related conference, in this case the Thirteenth Annual Connector Conference in Philadelphia. Subsequent presentations include this one, and the update to the military community at GOMAC '80.

A further detailed technical paper for future release in a technology magazine has already been invited. There is no doubt that innovation in the application of technology is always newsworthy.[5] Yet, one basic driver to implementation cannot be overlooked. The cost projected with the use of the automated facility is one sixth of that required for the best alternative mil-qualifiable used up to now. And that savings also invites non-military markets for consideration.

1. "Flexible Printed Circuits with Integral Molded Connectors, Contract DAAK40-79-C-0212, sponsored by DRSMI-ET.

2. "Use of Lasers in High Speed Termination of Flexible Printed Wiring", Bosna and Emmel, Proceedings of Thirteenth Annual Connector Symposium, Oct. 1980.

3. "High Speed Liquid Injection Molding of Connectors", Zucker, Proceedings of Thirteenth Annual Connector Symposium, Oct. 1980.

4. "Design of an Automated Termination Process for Flexible Printed Wiring", Hall, Proceedings of Thirteenth Annual Connector Conference, Oct. 1980.

5. "Lasers Help Terminate Flexible Circuits", Electronics Magazine, August 28, 1980.

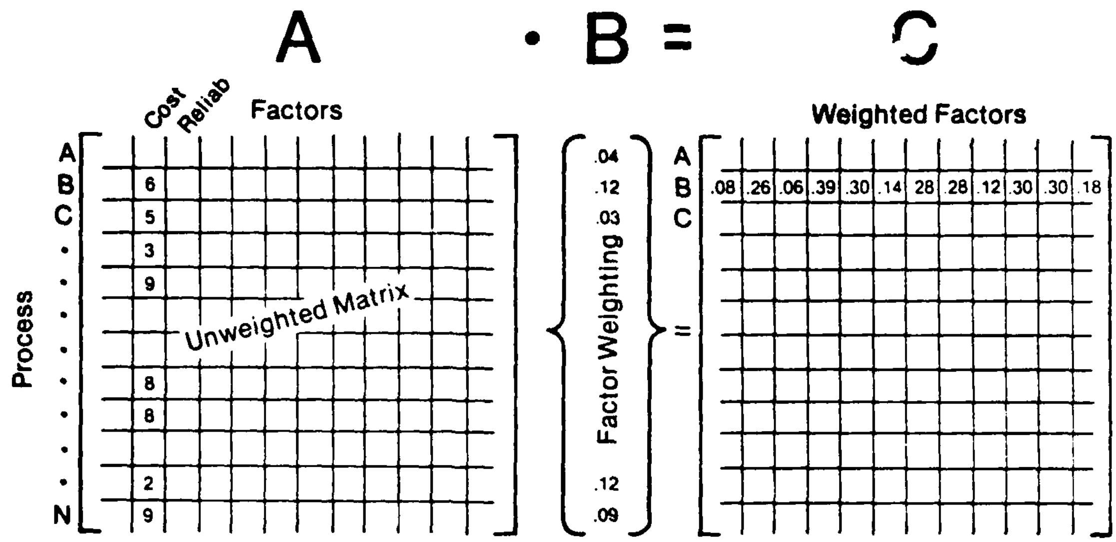



Figure 2: A Matrix Approach to Evaluations Simplified Connector and Process Selections

evaluated for each factor, relative to the other connectors (processes) on a scale of 1 (best) to 9 (worst). These relative values for each factor were listed in columns, as shown in matrix A of Figure 2. The importance of the various factors relative to each other was then determined, ranked, and then normalized to provide the inputs of such things as how important is cost, as opposed to reliability, or aesthetics. This was the B Vector shown. When the A Matrix was post-multiplied by the B Vector, a weighted matrix, C, resulted. This matrix had all of the numbers interrelated so that the sum of the numbers across any given row in the C matrix provided the full weighted value of that connector (or process) relative to the others. Those with the lowest total were the ones selected.

Connectors selected were both high density, planar connectors. They are shown in Figure 3. These were also deemed the most difficult to

Figure 3: These Connectors Are Inexpensive and Compatible with the 50-mil Spacing of FPW

terminate because of the small contact tails (.010 x .012 inch) and close spacing. Many other connectors of planar configuration have also been worked, demonstrating the versatility of the process selected.

## PROGRAM RESULTS

All of the basic processes of termination were evaluated, from the highest reliability weld with-a-braze, through weld (alone), braze (alone), crimp, and solder reflow, to hand solder. The processes selected evolved to a three-process set:

a. Insulation Removal by Laser Ablation
b. Termination by Laser Welding
c. Sealing and Strain Relief by Liquid Injection Molding

## Laser Ablation

All of the termination techniques with the exception of crimping through the insulation require that material covering the FPW leads be removed so that a direct metal-to-metal interface can be attained. All of the present techniques are either specialized (pre-punched base coats or cover coats), or individual and expensive. The use of a $CO_2$ laser at 10.6 micron wave length has been found to thoroughly remove the organic insulation materials commonly used leaving only a fine ash trace which is easily removed by a light brushing. As shown in Figure 4, the non-contact technique leaves no marks or scoring on the conductors. Also, there is no metallurgical effect caused by the laser energy on the metallic conductor. Conductors as small as .005 inch have already been exposed using this technique. Under x-y numerical controls, only a few seconds are required to expose a .250 x 2.0 inch window.

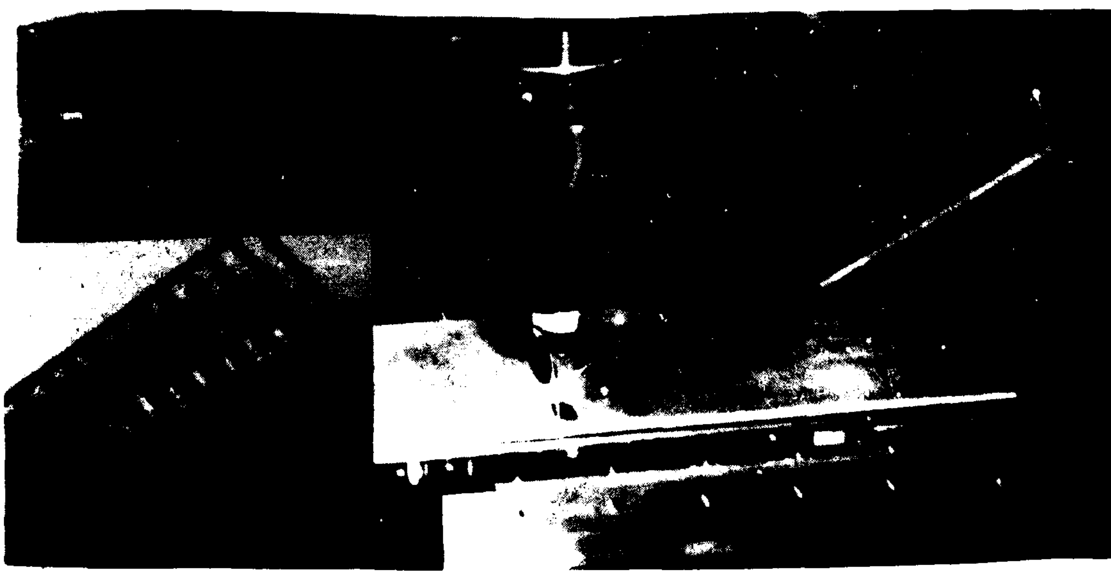


Figure 4: Removal of Organic Insulation by $CO_2$ Laser Ablation is a Rapid Process

## Laser Welding

The use of a Neodymium: YAG laser at 1.06 micron wavelength has been found to be very effective in the welding of flexible printed wiring to contact tails. Intimate contact of the FPW to the connector is required for good heat transfer and fusion. The equipment used in the semi-automated operation is shown in Figure 5, and typical welds in Figure 6. The weld results are also directly dependent on the surface condition

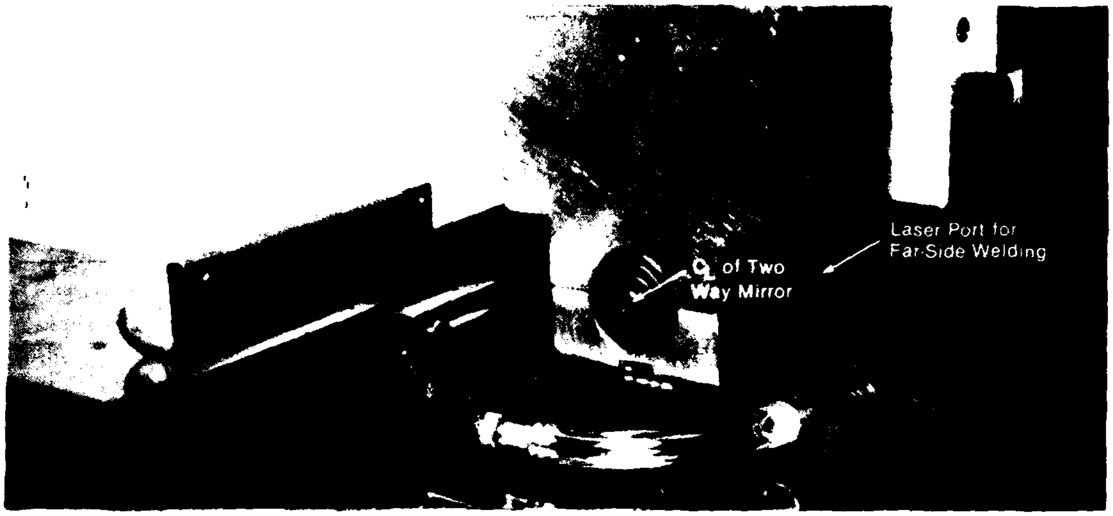



Figure 5: Laser Welding on the Fly

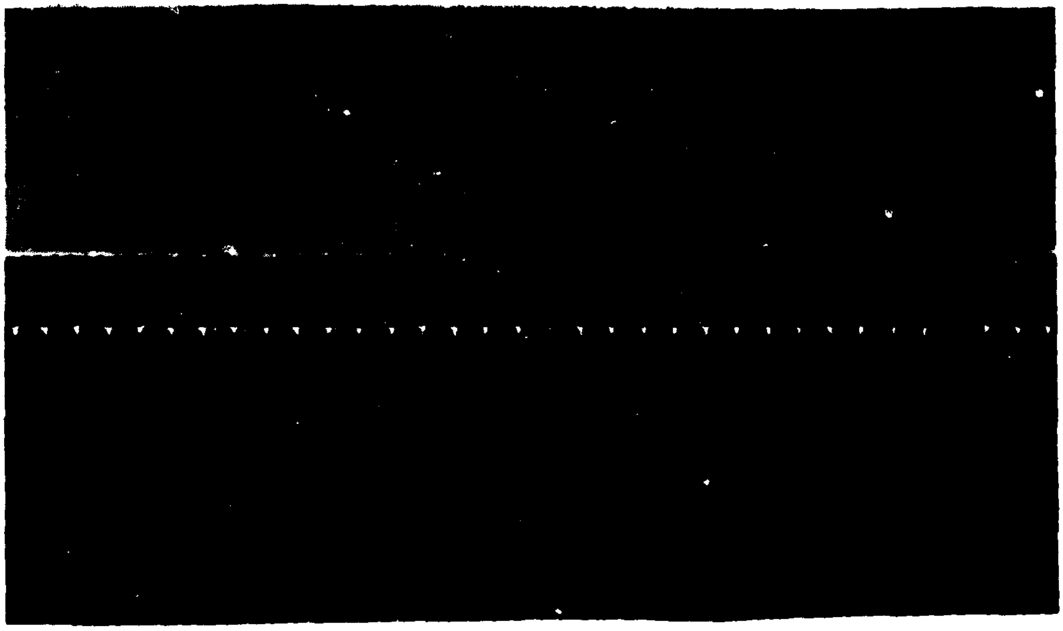


Figure 6: The Uniformity of Laser Welds is Very Evident

of the circuit. Energy is absorbed more by oxided circuits such as normally occurs after copper foil has been treated for better adhesion to the FPW insulation. Even more uniform results with a wider process tolerance have been obtained when the insulation has been removed on one side only (that in contact with the tail of the connector), and the Nd:YAG laser strike is through the polyimide insulation that covers the other side. Inspectability has been found to be extremely simple, with two visually obvious extremes occurring if no weld (copper balling) or excessive weld (material blow-out) are present. Setting and monitoring of pulse shapes on a CRT have also been found to be quite helpful.

More details on both the laser ablation and laser welding processes are available.[2]

## Liquid Injection Molding

The selection of molding materials and techniques proved to be the most challenging aspect of this program. Materials had to be semi-flexible, strong enough to support the weld joints, but capable of providing a gradual strain relief at FPW egress to prevent circuit damage. Many materials which met these requirements would not bond well to the polyimide insulation of the FPW or to the connector body, which had traces of mold release in that material. The materials also needed to be excellent barriers to moisture penetration. The other major challenge was to find materials and process which, having met the above requirements, were compatible with the assembly rate of 500 units per 8 hour shift, that is, one assembly per minute. Two basic materials were finally selected.

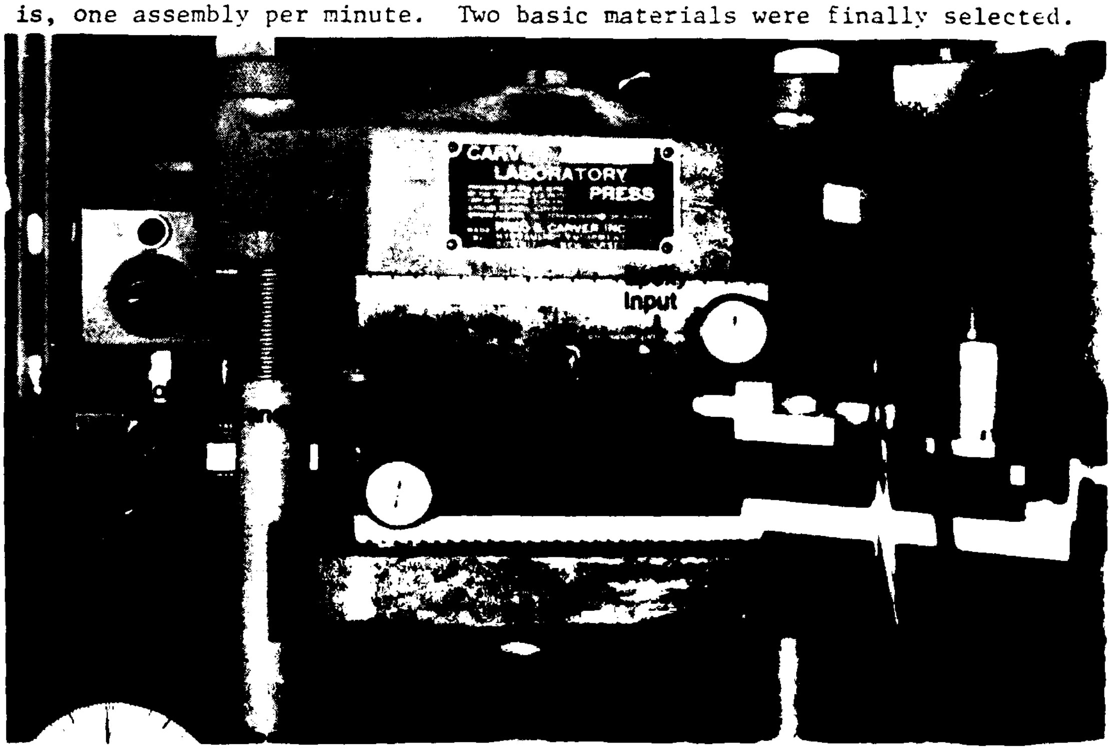



Figure 7: Liquid Injection Molding is Performed at 150°C and Low Pressure with this Equipment

For connectors made with a thermoset material which could withstand the 150° C temperature of a 5 minute mold cycle (such as Diallyl Phthalate), a Hydantoin epoxy using liquid injection molding techniques was selected. Other connectors using thermoplastic materials (such as VALOX) required a lower temperature material (100°C), and a bisphenol epoxy was selected for them. The mold set-up is shown in Figure 7. Typical results are shown in Figure 8 for both materials.

To prevent material flow through on connectors which had contacts inserted into a mold block (rather than being soldered around the contacts) a pin sealing technique was developed as a batch process. This enabled the use of the pressure gelation process (15 psig) with its faster gelation rate. For an automated facility, a five-cavity mold would be appropriate.

Further details of these materials and processes are available.[3]

## Fully Automated Facility

One of the most important requirements for implementation of the results of any program is the reduction of cost and consistency of product output which are attainable only through the use of a fully automated

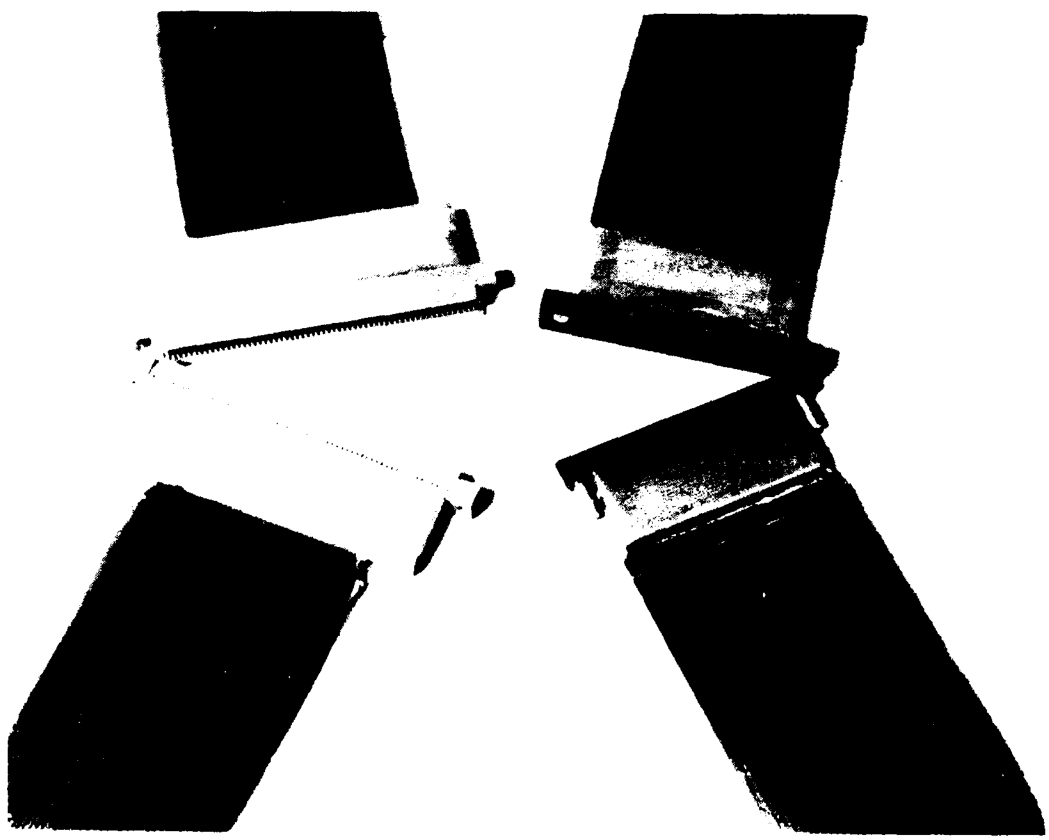


Figure 8: Molded FLEXICON Assemblies for Two Connector Families

facility. Therefore, the materials and processes selected have been carefully integrated with the automated facility requirements and concept. The complete set of processes for the FLEXICON program has been configured as shown in Figure 9. The maximum use of microprocessor control and programming has been made, so that changes to connector and FPW styles require only a few tool insert changes, with all other parameters con-

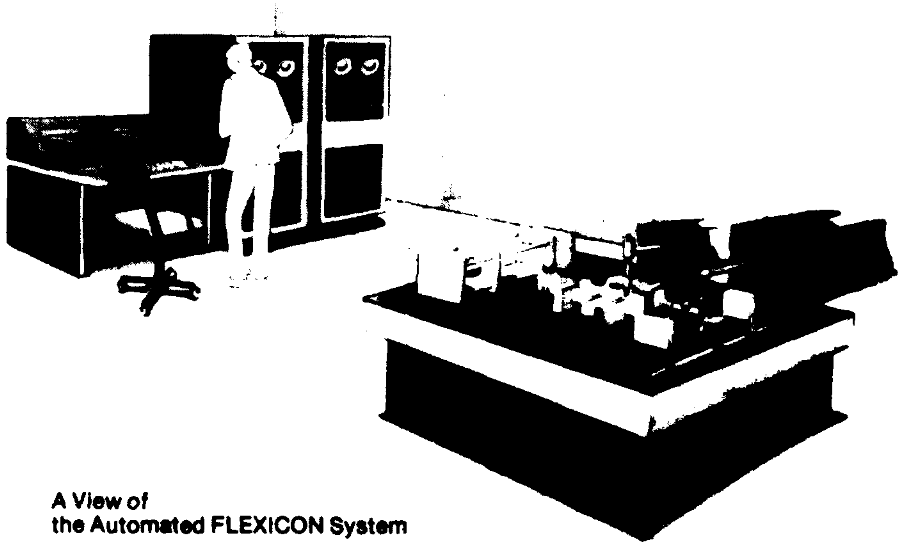



Figure 9: Design of an Automated Termination Process for Flexible Printed Wiring

trolled by software. Referring to Figure 9, the stations of the facility are in the lower right-hand section. From right to left they are insulation ablation (including brush and clean), laser welding, electrical test, automated visual inspection (option) and molding. The facility defined here has had each of these processes demonstrated in a semi-automated set-up. A facility designed with this configuration would require about $300,000 capital investment, and provide assemblies at about $120.00 per mated pair (typical). Further details including the timing and kinematics have been described in reference 4.

IMPLEMENTATION, THE HEART OF ROI

The results of any manufacturing technology program, in order to provide any return on investment, must be incorporated into the design and production of many programs. Obviously there are two basic prerequisites; first, the effort selected for the program must have been appropriate and worthwhile, second, the program must have reached a satisfactory conclusion. Assuming that these have been met, the implementation can be accomplished in two directions, internal to the company performing the program and external through dynamic technology transfer. Usually internal utilization can be realized before out-of-house transfer, and initial results can provide a good basis for initial ROI (return on investment) as well as enhance credibility. Already the results of this

# APPENDIX L

## INDUSTRY DEMONSTRATION ATTENDEES

APPENDIX L

## Industry Demonstration Attendees

AMP Inc.

Bakerman, Jan
Hawk, Gary
McQuaid, Ron
Schrey, Leo
Siwald, Don
Trump, Bob

Battelle Columbus, Lab

Robinson, Dr. Alfred
Soltesz, Carl R.

Bell Labs

Parker, J. L.

Berg Elec.

Mueller, Hans
Mulligan, James
Sands, R. A.

Bob Dean, Inc.

Grimes, Gerry

Boeing

Benezra, David

Continental Connector

Mihelic, Albert

Brautigam Assoc. Inc.

Brautigam, R. H.

DuPont

Bakerman, Frank
Chatfield, Dale
DeHart, Jack

Electronics Magazine

Lyman, Jerry

Flexible Circuits

Farina, George

General Dynamics

Charters, Dr. M. L.
Serpa, John R.

Hughes Aircraft
Shechet, Morris
Weber, Mark
Wheaton, Jarel

Jefferson Chemical

Klein, D.

Kraft Electronic Sales

Gonzalez, Ernie
Kraft, Earl

Martin Marietta

Rigling, Walter S.

McDonnell Douglas

Gonzales, W. L.
Mansini, John

Methode Electronics

Triner, Irv

NAC

Pond, David

NESC

Rigdon, C.

## Industry Demonstration Attendees

Oak Laminates

Fisher, Harold

Parlex

MacDougall, L.
Stewart, T.

RCA

Amato, A.
Asmussen, R.

Robinson Nugent, Inc.

Gribbins, Jim

Rockwell Int'l

Young, John

Santa Barbara Res. Ctr.

Cobb, Larry E.

T & B Ansley

Farnum, R.
Shiells, J.

Teledyne Electro Mech

Boyer, Ivon
Dixon, Herb
Formica, R.
Morris, Gil
Winkler, Jack

U. S. Army

Little, Gordon
McCann, Joseph P.

ED

8