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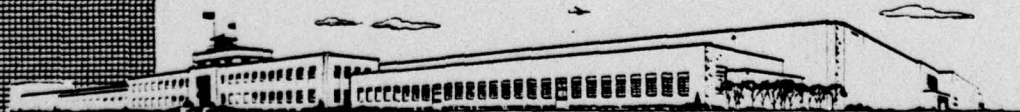
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**EVALUATION OF ZERO
INSERTION FORCE
CONNECTOR FOR STANDARD
ELECTRONIC MODULE XN-1**

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PREFACE

The purpose of this report is to give the results of an evaluation of a zero insertion force (ZIF) connector suitable for use with the standard electronic module (SEM) Model XN-1. This evaluation was made under the sponsorship of the Naval Air Systems Command (AIR-52022) and authorized by N0001977WR73432 BCN AKA5B AA 1771506.47C6 TT 2D CC 740000000010.

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ABSTRACT

This technical report defines and describes the tests performed and the results obtained on a 152-pin zero insertion force (ZIF) connector suitable for the standard electronic module (SEM) program XN-1 module. An Arrhenius plot is generated.

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I. CONCLUSIONS

A. The ZIF connector will perform satisfactorily in MIL-E-5400 (Electronic Equipment, Airborne, General Specification for) Class 2X environments.

B. No additional development work is required for this connector, but further effort is required such as a manufacturing technology program to insure that quality connectors are available in sufficient quantity to support large projects.

C. The present plastic cam ends are not strong enough to operate the connector. This problem can be overcome by substitution of stainless steel cam ends.

D. The connector should be molded in one piece. This would be a cost reduction or manufacturing technology action rather than development work.

E. The connector termination does not permit the use of wire wrap terminators.

F. Location of the mounting holes as required by NAVAVIONICCEN should be changed to more conventional locations.

G. Long-term reliability appears to be satisfactory as indicated by preliminary creep test results, but present test results were obtained from a small data base of three connector samples.

II. RECOMMENDATIONS

The following items are recommended:

A. Prepare procurement specifications for this connector for use in the event of continued need.

B. If the zero insertion force (ZIF) connector is determined to be an advanced standard electronic module (SEM) requirement, generate a manufacturing technology (MT) program to:

- Substitute stainless steel cam ends for the plastic cam ends.
- Have the connector molded in one piece.
- Make the input/output (I/O) terminations compatible with wire wrap.
- Consider relocation of mounting holes.
- Tool for production quantities.
- Provide design documentation to the connector industry.

C. Perform creep tests on a sufficient number of connectors to determine the long-term reliability.

III. INTRODUCTION

This report describes the technical evaluation of a zero insertion force (ZIF) connector, Figure 1, developed by the Kearfott Division of the Singer Co., Little Falls, New Jersey; with the sponsorship of Mr. C. D. Caposell of the Naval Air Systems Command (AIR-52022F). It forms a part of the Standard Electronic Module (SEM) Model XN-1 Higher Level Package (HLP) built by the Naval Avionics Center (NAVAVIONICEN), see Figure 2. This HLP is a modification of an earlier packaging system developed by the Singer Co. as reported in NAFI TR-2099, "An Evaluation of an AADC Higher Level Package." The modification incorporates the recommendations of that report and some additional design/structural modifications introduced by Mr. James Hobson of NAVAVIONICEN.

Two of the dual 76-pin cam-closing ZIF connectors are used at the top and the bottom for each electronics module. The SEM XN-1 modules have a total of 300 contacts on 50-mil centers distributed along opposite sides of the top and bottom edges of the module. There are two more contacts on the circuit side than on the back side; and because of this, contacts number 1 and 76 are not used on the connector for one edge, and contacts number 77 and 152 are not used on the opposite edge.

Materials used in the past on this connector had exhibited excessive cold flow, and were replaced by Singer materials with better temperature characteristics.

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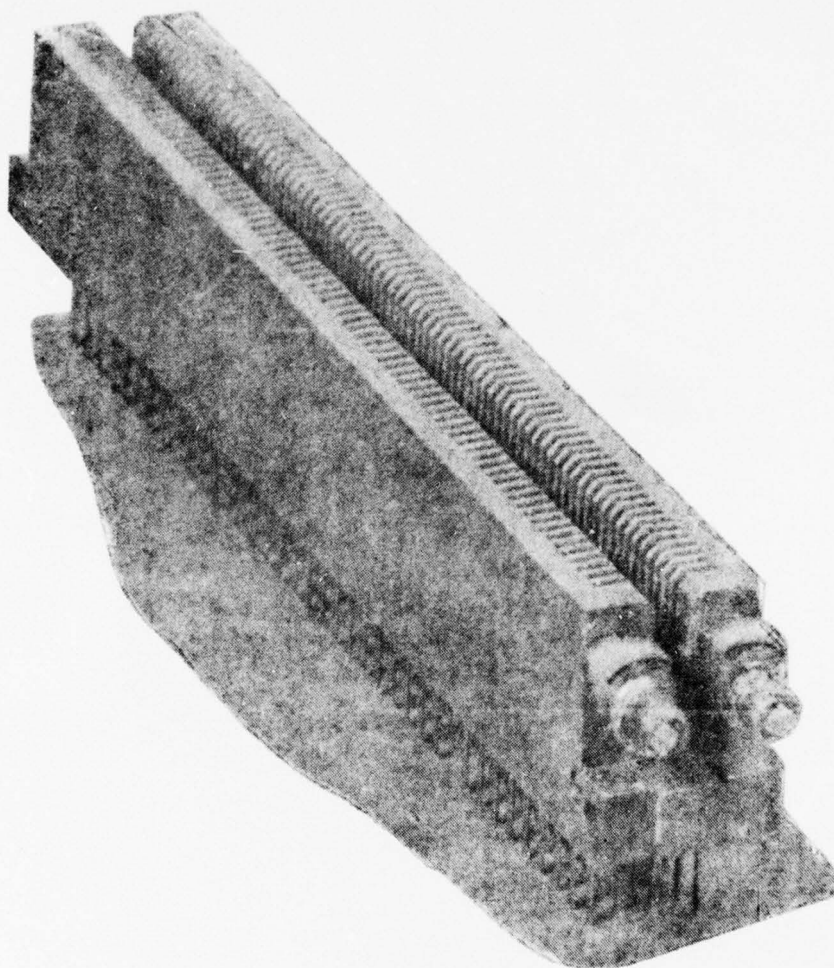


FIGURE 1. SINGER/KEARFOTT ZERO
INSERTION FORCE CONNECTOR

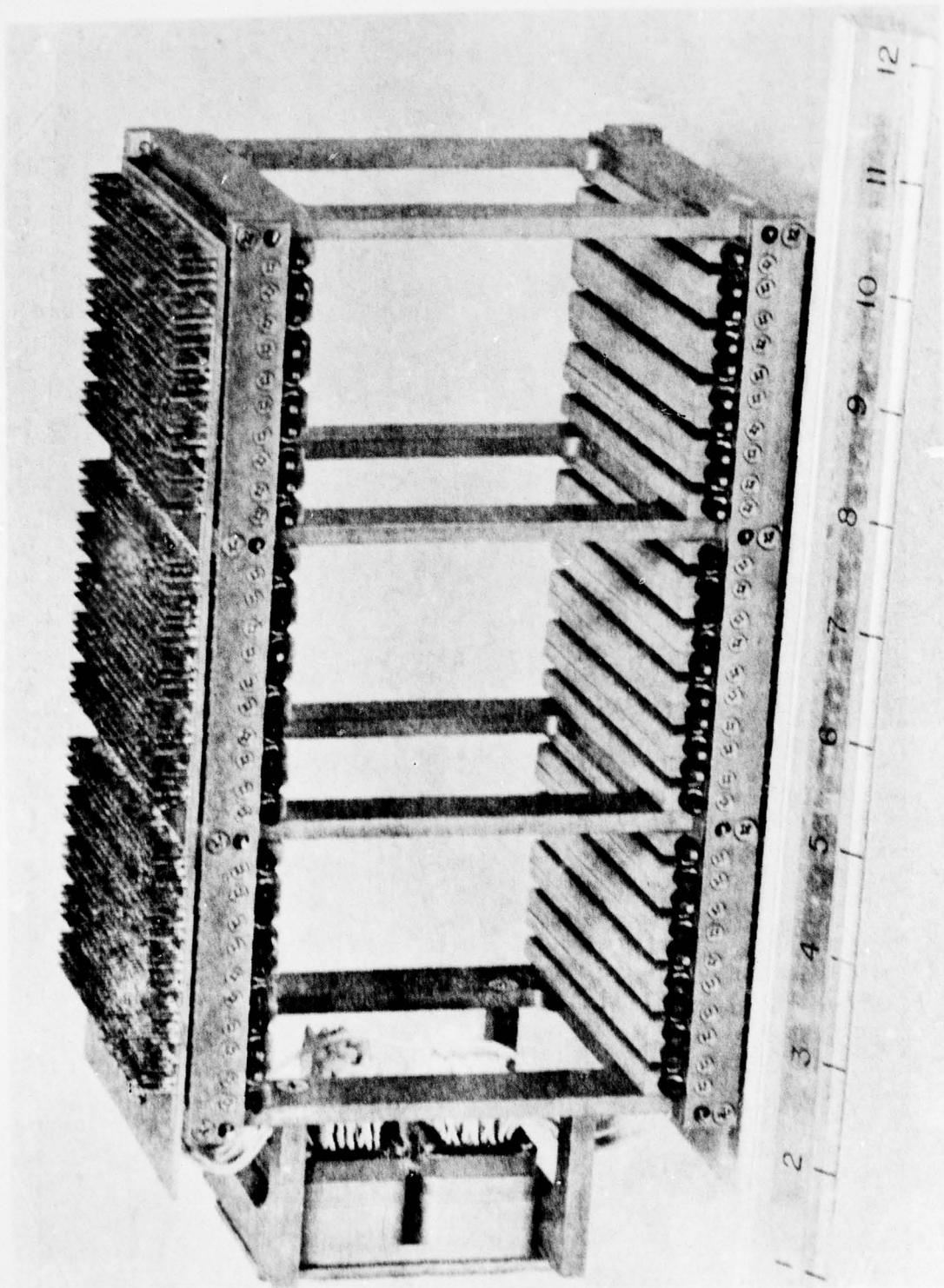


FIGURE 2. INTERCONNECTIONS IN SEM XN-1 HIGHER LEVEL PACKAGE

IV. THEORY OF OPERATION

A minimum requirement of 5 ounces (1.39 newtons) insertion force per contact is currently required for military connectors. This appears to be a very moderate force until it is multiplied by the number of contacts employed in very large connectors, e.g., 100 contacts. The total force would then be in excess of 30 pounds (133 newtons), and since this is the low limit of insertion force, it becomes apparent that large modules with high numbers of termination pins become very difficult to insert or withdraw. There is also the danger of damaging either the module or the connector before the person inserting the module recognizes that there is a keying or insertion problem.

One solution to this dilemma is to use a connector in which the contact surfaces do not mechanically touch until both halves are completely mated (zero insertion force). After this contact point is reached, the contacts are actuated in some manner such that intimate electrical contact is made. If the contacts are actuated by forcing them together, the connector is known as a cam closing zero insertion force connector. If the contacts are actuated by allowing them to come together, the connector is known as a cam opening zero insertion force connector. The latter type is preferred by some designers on the basis of past experience with conventional connectors; while others prefer the former type for reasons of obtaining higher than normal forces on the connector terminations. One manufacturer of ZIF connectors, Hypertronics Corporation, lives in both worlds with their ZIFTACTM connector, Figure 3, which has cam control throughout both operations. The cam closing zero insertion force connector is the type now employed for SEM XN-1 modules. One cam for each row of contacts is rotated 90° to force the contacts together.

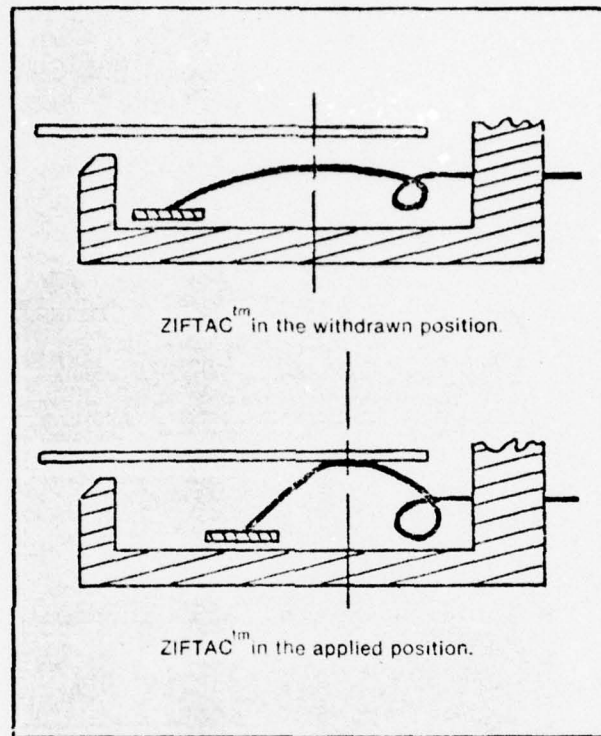


FIGURE 3. ZIFTACTM CONNECTOR

With zero insertion force connectors, it is also possible to use side entry and thus make contact with two edges of a module rather than one. This feature is employed for SEM XN-1 modules in the NAVAVIONICCEN HLP design.

V. DISCUSSION

The connector was tested to its design environment in the HLP through the environmental tests of MIL-T-5422F (Testing, Environmental, Airborne Electronic and Associated Equipment) to test suitability for MIL-E-5400P Class 2X use. This environment is basically an air-cooled service at 71°C ambient at sea level, and has short-term temperature cycles to 95°C at sea level. Additional testing was performed to determine the connector's ability to withstand high temperatures for extended periods of time.

Connectors were installed on 0.5-inch centers in the HLP as they were received from the Singer Co. Back panel connections to the HLP were made by soldering terminations to a two-sided printed circuit board. The back panel pins on this connector are wire wrap posts on staggered 100-mil centers with the two inside and the two outside rows together, as shown in Figures 1 and 13. This arrangement makes automatic wire wrap operations impossible because of the lack of clear channels necessary for routing wires. The assembly of connectors into the inner frame of the HLP is shown in Figure 4.

Nine SEM XN-1 modules manufactured by Plessey/Frenchtown under contract N00163-75-C-0300 were installed in the HLP and two arrays of flat packs on hollow aluminum heat sinks equipped with male connector pins made by Pribble Plastics under contract N00163-75-M-4218 were also installed. These are shown in Figure 4. A third type of electronics module, consisting of a hollow ceramic substrate, is also shown in this same figure.

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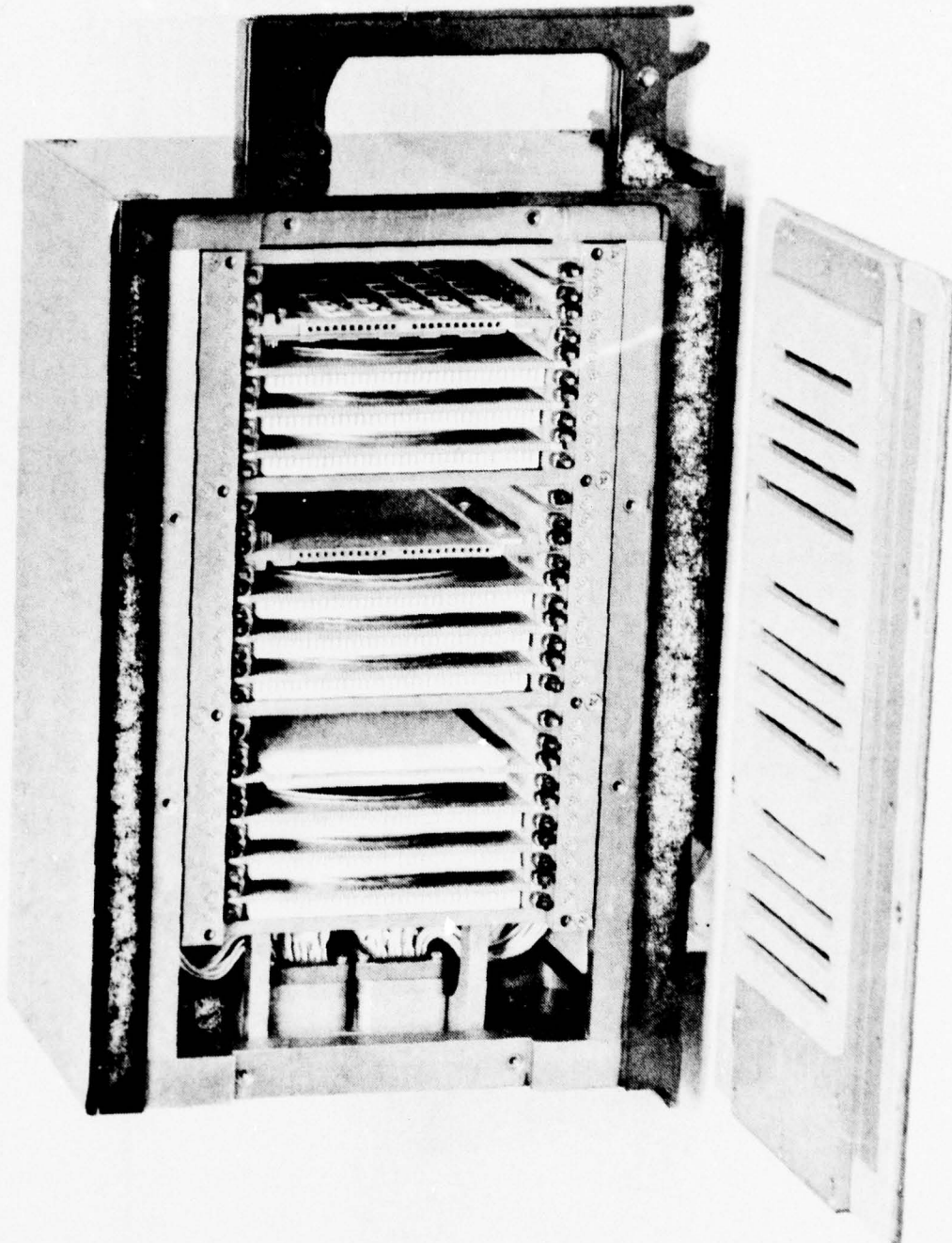


FIGURE 4. MODULES ASSEMBLED INTO HLP

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The completed HLP with modules removed, Figure 5, is a short-half air transport racking (ATR) box (ARINC-404A) which is 4.88 inches wide by 7.22 inches high by 12.52 inches long. A MIL-C-81659 dual 106-pin connector visible in Figure 5 is used; in this case the connector was populated with low insertion force (LIF) contacts developed by ITT/Cannon for new installations in commercial aircraft. Mounting of the HLP was by means of clamps acting on the front and rear of the box. The lever latch handle and connector shells were not used for mounting.

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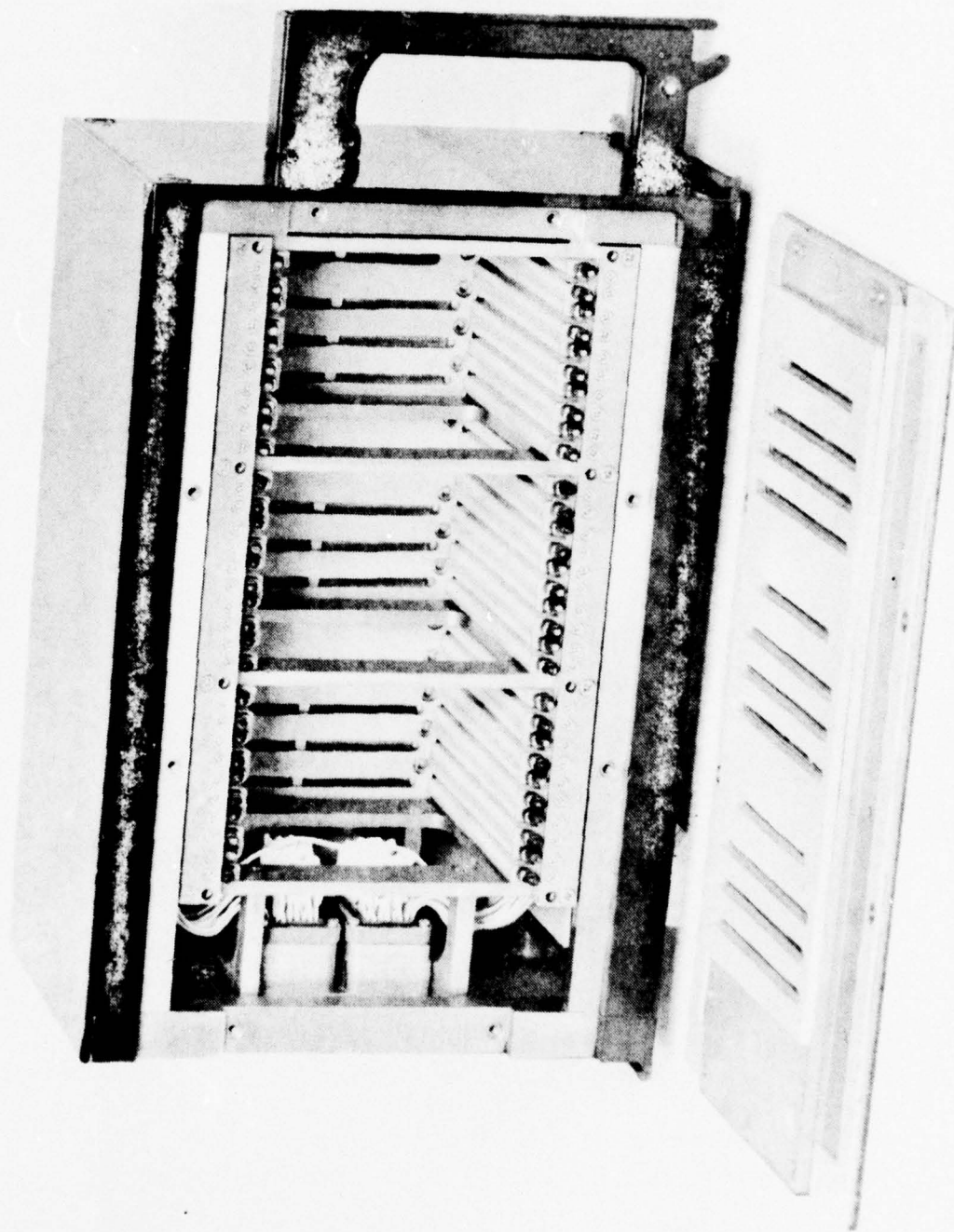


FIGURE 5. HLP WITH MODULES REMOVED

VI. TEST RESULTS

Testing of equipment to MIL-E-5400 is governed by MIL-T-5422 for the Navy. These tests are listed in Table 1.

TABLE 1. TEST PROCEDURES

Temperature-Altitude Test
Vibration Test
Shock Test
Humidity Test
Salt Fog Test
* Explosion Test
* Sand and Dust Test
* Fungus Test
* Temperature Shock Test
* Bench Handling Test
* Drip-Proof Test
* Watertight Test
* Drop Test
* Acoustical Noise Test

Tests marked with an asterisk (*) were omitted since they were not applicable to a racking configuration which did not contain actual operating equipment, or since they were required only when specified for an operating equipment.

Temperature-altitude testing was limited to the storage temperature test of 95°C for 16 hours and -62°C for 2 hours. Termination continuity was maintained through all ZIF connectors and there was no change in the total resistance.

Vibration levels at various locations on the HLP are shown in Appendix A. During vibration, 360 LIF contacts were monitored for openings in excess of one millisecond duration. During resonance at 395 Hz in the Z axis, numerous openings were encountered. These were traced to an external connection. There were 84 openings during resonance at 252 Hz in the same axis, and these were also traced to an external connector. No openings occurred at any other time. No openings traceable to the ZIF connectors ever occurred. Resonance occurred in the X axis at 406 Hz, drifting to 350 Hz, and at 720 Hz and 840 Hz. In the Y axis, resonance occurred at 340 Hz, drifting to 293 Hz. The Z axis had resonances at 395 Hz, 490 Hz, and 552 Hz. Vibration consisted of 30 minutes dwell at each resonance followed by 20-minute logarithmic sweeps from 5 to 2000 Hz with 0.1-inch displacement from 5 to 20 Hz; 2 G's acceleration from 20 to 33 Hz; 0.036-inch displacement from 33 to 74 Hz; and 10 G's acceleration from 74 to 2000 Hz. Maximum accelerations encountered are shown in Table 2.

Cross-coupling was severe only in the Z axis. The input to the case was more severe with this mounting than it was to the Singer HLP with the connectors and a lever latch handle supplying the mounting. After X axis vibration, contact pads were found with wear spots, as given in Table 3. Since the connector was not intended to supply support, movement indicated by the wear spots is not an indication of a flaw in the connector, but rather a sign that the mounting system needs improvement.

The SEM XN-1 modules weigh 225 grams, the hollow ceramic modules weigh 165 grams, and the flat pack modules weigh 105 grams. The higher level package is shown mounted for vibration testing in Figure 6. Three shocks of 15 G's peak amplitude of eleven milliseconds duration were performed for each direction on each axis (a total of 18 shocks) without damage and with no noted ZIF connector openings occurring during the shock tests. The form of the shock impulse is shown in Figure 7 and the mounting fixture for shock testing is shown in Figure 8.

TABLE 2. MAXIMUM ACCELERATIONS ON
HLP IN X, Y, AND Z AXES

AXIS LOCATION	ACCELERATION IN G			CROSS-COUPLING FROM Z AXIS
	X	Y	Z	
Outer Case (Connector End)	46	100	17	(48 in Y axis)
Inner Frame (Connector End)	59	60	46	(62 in X axis)
SEM XN-1 Module (Connector End)	72	68	42	(30 in X & Y axes)
Inner Frame (Handle End)	75	75	34	(30 in X & Y axes)
Flat Pack Module (Handle End)	150	60	60	(125 in X axis)

TABLE 3. WEAR ON MODULE CONNECTORS

MODULES NUMBERED FROM CONNECTOR END	CONTACT PADS SHOWING WEAR
1 (SEM XN-1)	2.3% of pads
2 (SEM XN-1)	2.3% of pads
3 (SEM XN-1)	95% of pads
4 (Flat Packs)	None
5 (SEM XN-1)	50% of pads
6 (SEM XN-1)	95% of pads
7 (SEM XN-1)	75% of pads
8 (Hollow Ceramic)	25% of pads
9 (SEM XN-1)	2.7% of pads
10 (SEM XN-1)	6.3% of pads
11 (SEM XN-1)	50% of pads
12 (Flat Packs)	None

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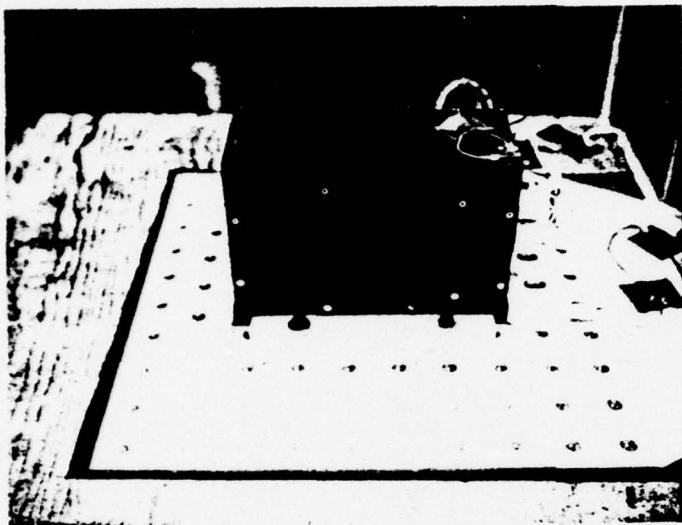
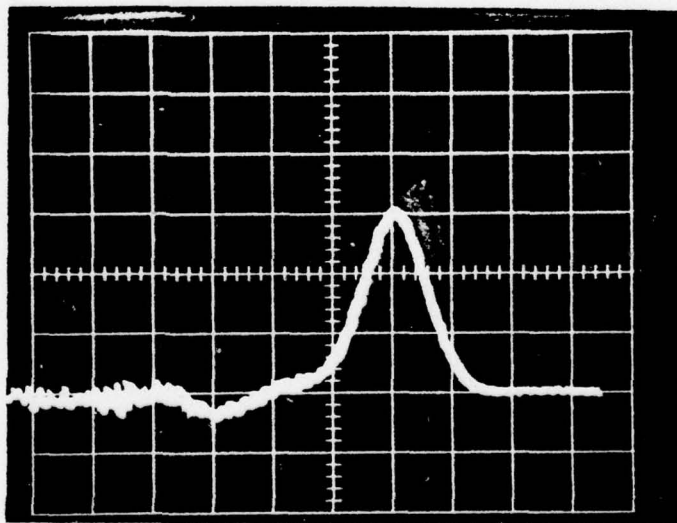


FIGURE 6.
HLP MOUNTED FOR
VIBRATION TESTING

FIGURE 7.
SHOCK IMPULSE



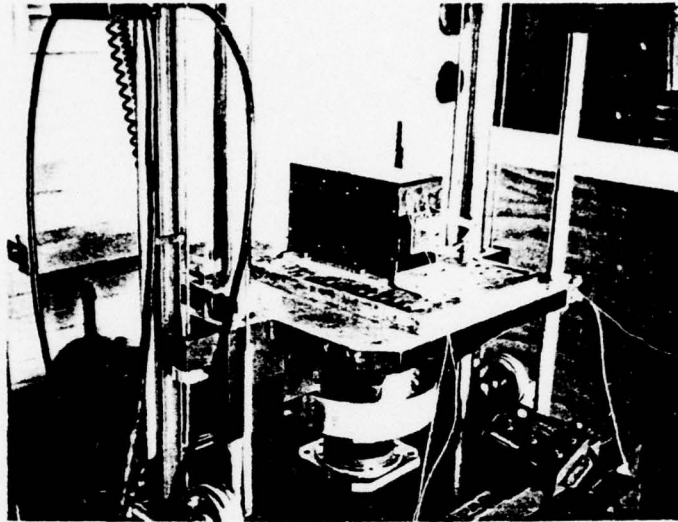


FIGURE 8. MOUNTING FIXTURE FOR SHOCK TEST

The ZIF connectors and assembly were then subjected to humidity cycling from 28°C to 71°C at 85% to 95% relative humidity in cycles outlined in Figure 9. A drain was provided in the HLP to prevent the trapping of water if leakage were to occur. This resulted in all parts being exposed to humidity.

There were five pairs of adjacent lines used for insulation resistance measurement tests included in the package; 500 volts and 100 volts were applied to these lines during the first cycle of testing. Excessive leakage was detected (probably in the two-sided printed circuit board) and bias was discontinued. The initial insulation resistance reading was 1×10^9 ohms for the entire assembly, and the reading taken two hours after the last cycle was 5×10^7 ohms. These values indicate minimum average values of 1.2×10^{10} (before) and 6.8×10^8 (after), respectively, for the ZIF connectors (12 connectors in parallel). This resistance is over 100 times the minimum value required in MIL-C-55302 for printed circuit board connectors.

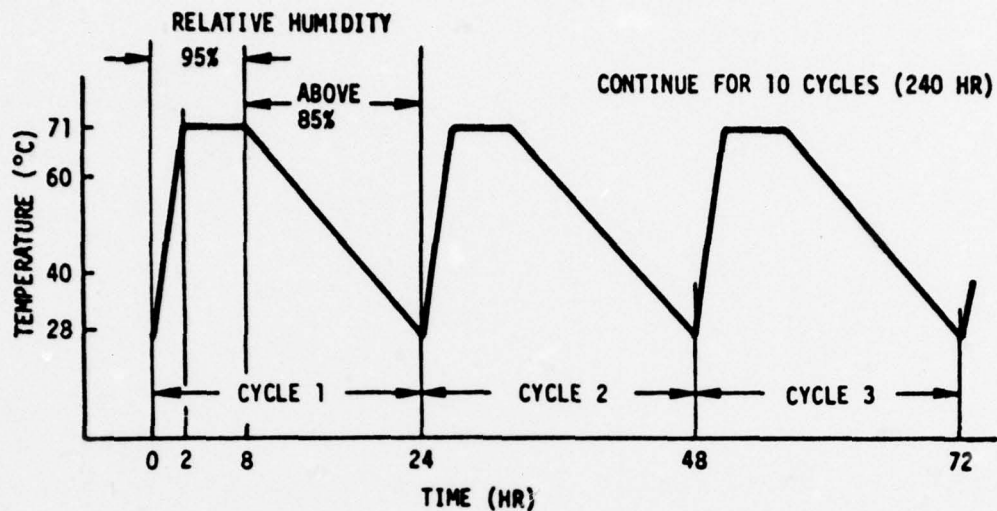


FIGURE 9. HUMIDITY CYCLE FORMAT

The assembly was then placed in salt fog at 35°C for 48 hours. After a 72-hour drying period in an ambient atmosphere, the insulation resistance of the assembly was 1.5×10^7 ohms at 500 volts. The minimum average resistance of the ZIF connector was 1.8×10^8 ohms (12 connectors in parallel). This value is over 100 times the minimum value required by MIL-C-55302.

Tested with the connector plugs made by Pribble Plastics for this connector, the average contact resistance for 136 contacts in series was 23 milliohms per contact. The low level circuit contact resistance measured at 0.02 volts was 31 milliohms per contact after salt spray tests were completed. Although there is no specific MIL-requirement for contact resistance after salt atmosphere testing, these values are only 15% higher than some initial requirements.

This combination had 5×10^{11} ohms insulation resistance (every other contact) at 500 volts initially. After humidity cycling, the insulation resistance was 1×10^{11} ohms, and after salt spray it was 1.4×10^9 ohms.

The first five connectors received, out of the total of fifty, were out of tolerance in width, but this problem was corrected and subsequent deliveries were in tolerance.

The coefficient of friction of the cam material was very high such that the operating torque required to close the contacts was 3.75 in-lbs. (.042 N·m). This high level of torque resulted in shearing the plastic from the cam ends and making it necessary to use a square steel insert running the full length of the cam to operate it. Figure 10 shows a cam with its plastic operating legs intact and one with the plastic sheared off, thereby exposing the square steel insert.

All connectors are subject to creep and stress relaxation. Creep is the gradual flow or yielding of a material under constant load. Stress relaxation is the reduction in the contact force caused by a constant deformation. These factors are interacting in connectors, and dual contact connectors are generally affected to a greater degree than connectors in which all parts producing the contact force are metal, such as pin and socket or blade and tuning fork connectors. In the case of this ZIF connector, the contact force results from a plastic cam acting against a plastic body to force the spring contacts against the mating member.

Creep and stress relaxation can be estimated by storing the closed connector with a module in place at an elevated temperature. Contact force measurements are then made at specific intervals. When materials are loaded, there is initial short time creep at a high rate.

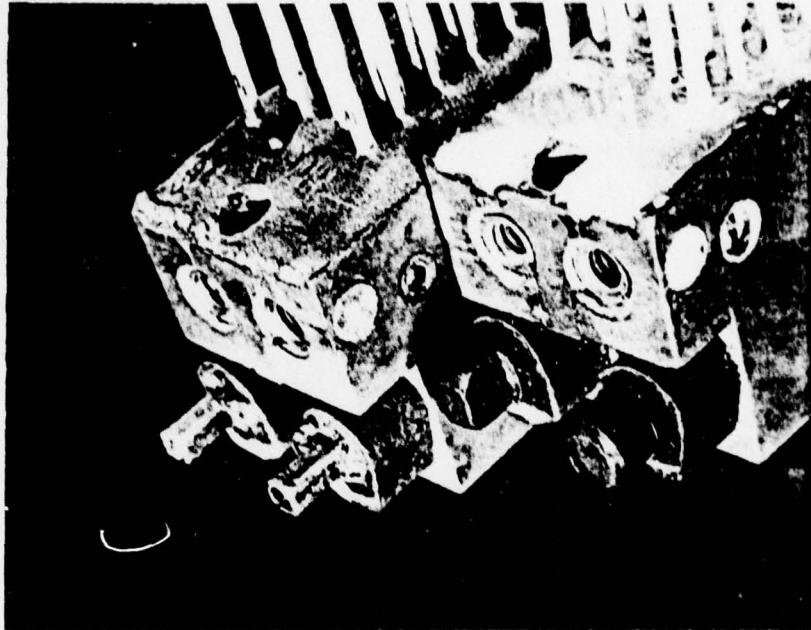


FIGURE 10. OPERATING CAMS SHOWING PLASTIC INSERTS SHEARED OFF (LEFT)

This initial period is followed by an extended period of slower, logarithmic creep. Finally, a third period with a very high creep rate is witnessed as failure occurs. The central portion of the curve for any given operating temperature can be represented by $F_t = F_1 t^B$ where:

- F_t = contact force at time t
- F_1 = contact force after one hour
- t = time in hours
- B = creep factor

Results of these measurements on the ZIF XN-1 connector are presented in Table 4.

TABLE 4. CREEP AND STRESS RELAXATION DATA

		150°C		125°C		100°C	
		INITIAL	1 HR	INITIAL	1 HR	INITIAL	1 HR
Average	Oz. N	11.11 (3.09)	8.39 (2.33)	10.83 (3.01)	10.56 (2.93)	10.36 (2.88)	8.45 (2.35)
Std. Deviation	Oz. N	.82 (.23)	1.21 (.34)	1.89 (.53)	2.22 (.62)	2.39 (.66)	1.85 (.51)
Avg-3S	Oz. N	8.64 (2.40)	4.76 (1.32)	5.15 (1.43)	3.90 (1.08)	3.19 (.89)	2.90 (.80)
Minimum	Oz. N	7.50 (2.08)	6.25 (1.74)	8.50 (2.36)	7.50 (2.08)	6.75 (1.88)	5.25 (1.46)
B		-9.72×10^{-2}		-5.41×10^{-2}		-2.93×10^{-2}	

Time to reach
.75 (Avg-3S)
after initial
drop

19 hours

204 hours

18,100 hours

Such an estimate of creep and stress relaxation indicates adequate life for this connector in Class 2 service, as is further shown in an Arrhenius plot constructed from the data given in Table 4. The period of time required to lose 25% of the contact force at the average value minus three standard deviations was taken as the endpoint for the Arrhenius plot. The resulting curve is shown in Figure 11.

The data for all points in the preceding graph are drawn from only one connector for each temperature tested, and only two data points from each connector are used. A connector was destroyed at each temperature and several connectors were destroyed in earlier attempts to arrive at a meaningful test. Additional testing would be in order to confirm the data, but sufficient connectors were not available to perform this confirmation at the time of this report.

The ZIF connector now has its principal material problem resolved, and the other changes to be made in design are either minor or in the realm of manufacturing technology or producibility enhancement, rather than in additional research and/or development projects. The changes which need to be made are:

- Shift the position of the back panel pins from the present arrangement, as shown in Figure 12; to true staggered 0.100-mil centers, represented by Figure 13; or preferably to 0.100-mil centers, as shown in Figure 14.
- Retain the exposed square steel cam reinforcement rod as the cam operating stud.

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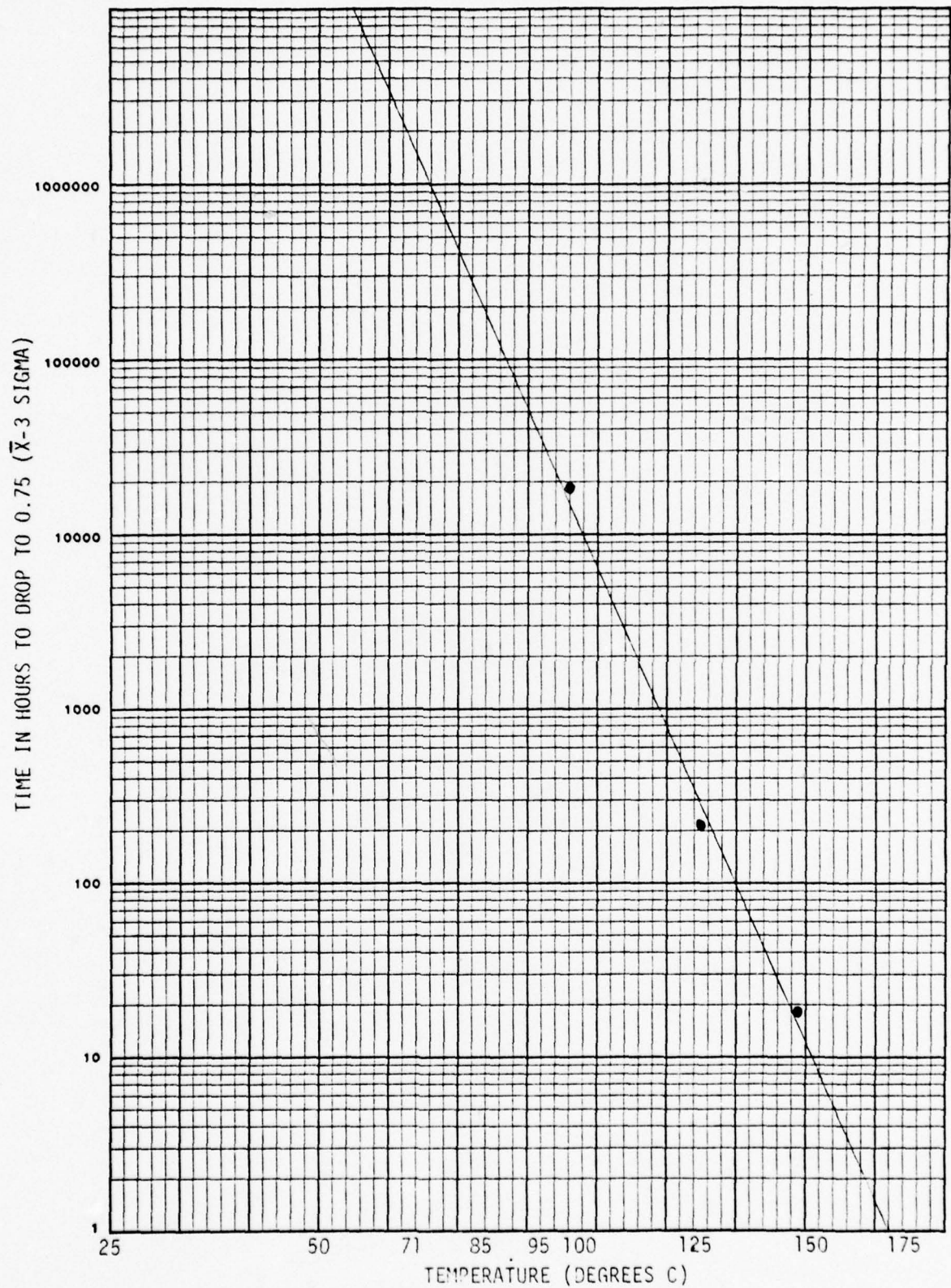
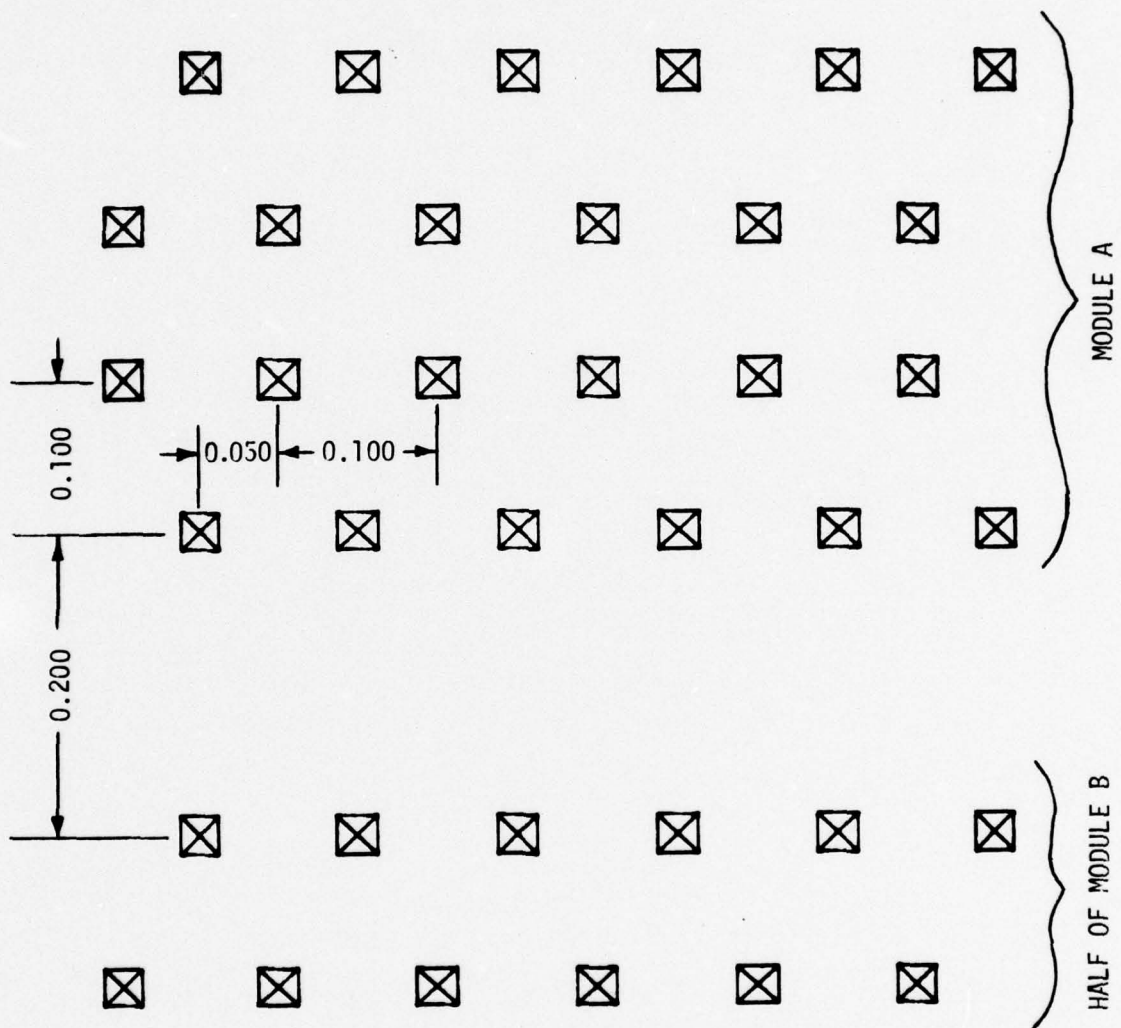
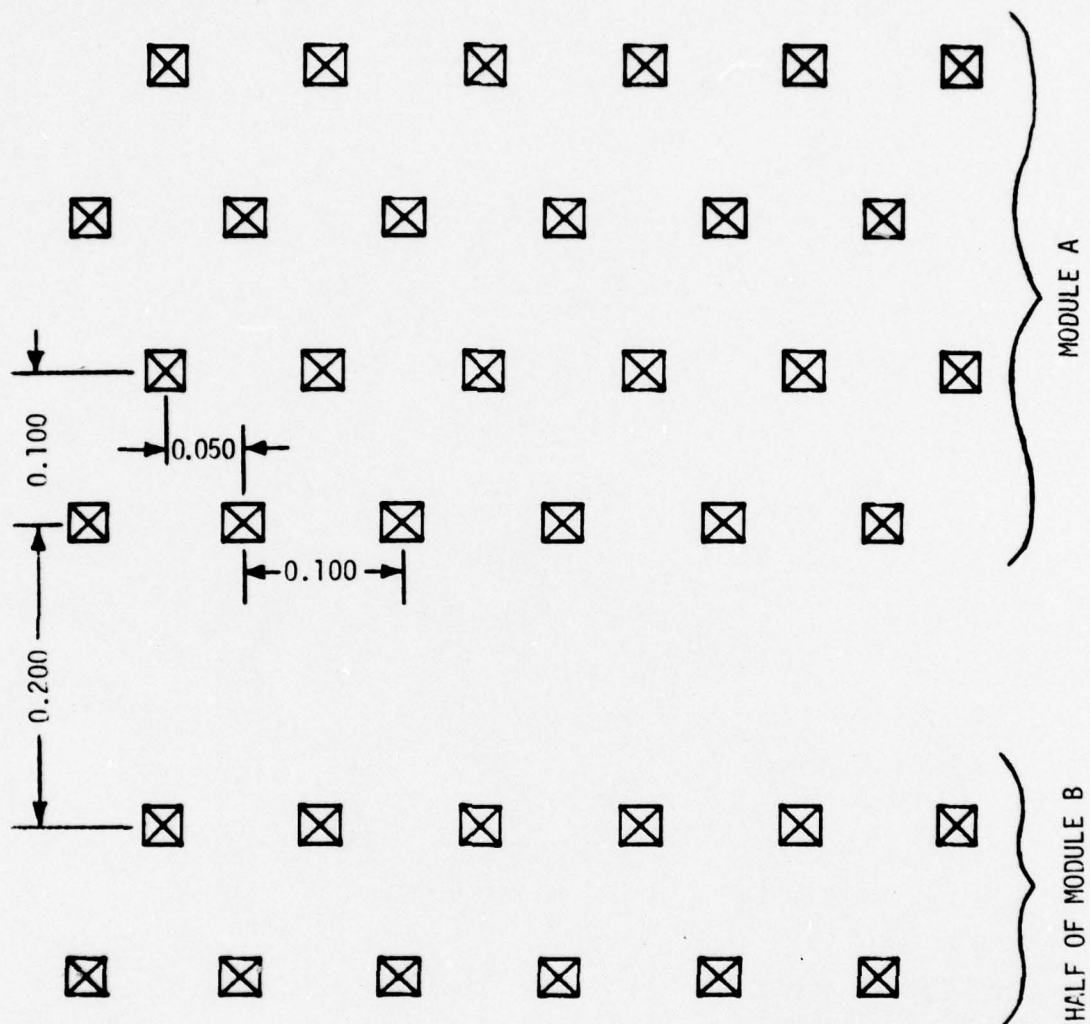


FIGURE 11. ARRHENIUS PLOT OF ESTIMATED LIFE
BASED ON CREEP AND STRESS RELAXATION DATA



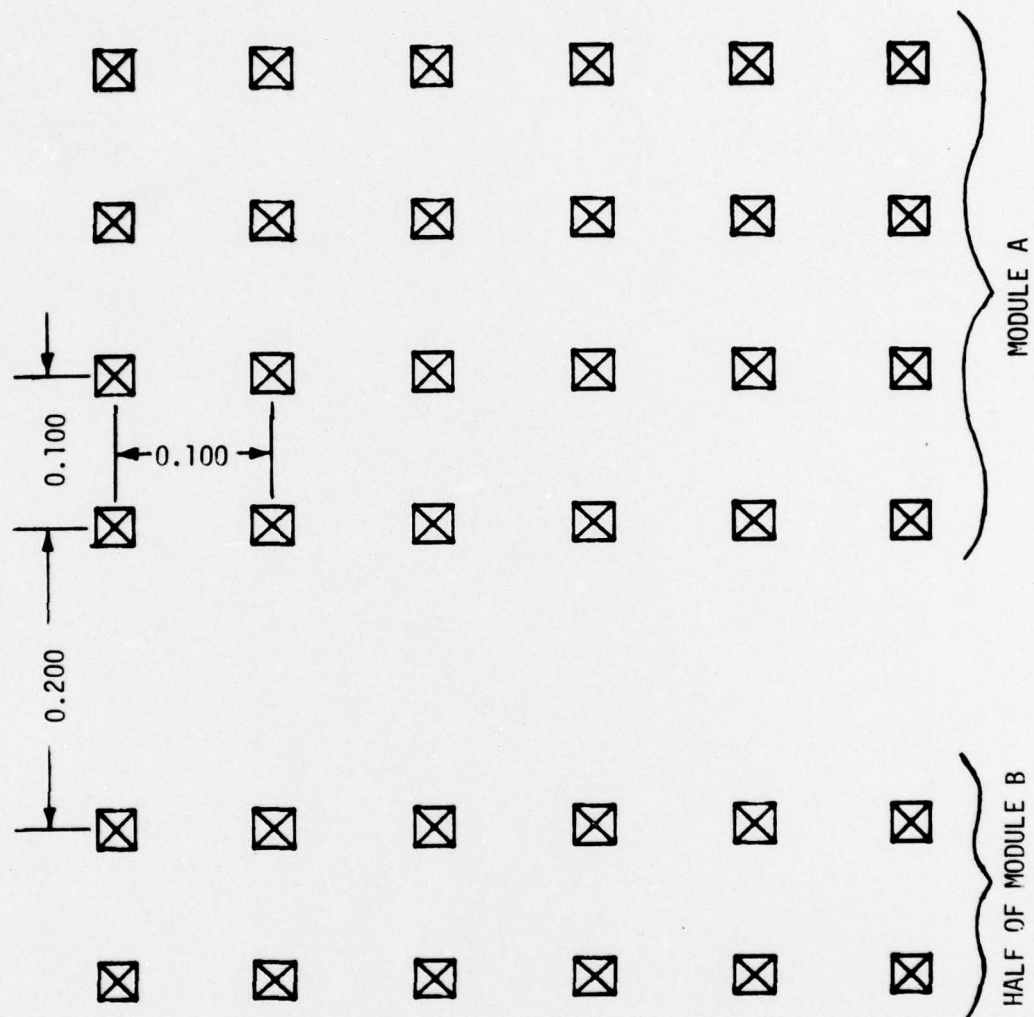
(Dimensions are in inches)

FIGURE 12. PRESENT ARRANGEMENT OF BACK PANEL PINS



(Dimensions are in inches)

FIGURE 13. PINS ARRANGED ON TRUE STAGGERED 0.100-MIL CENTERS



(Dimensions are in inches)

FIGURE 14. PINS ARRANGED ON 0.100-MIL CENTERS

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- Mold the connector body in one piece. (The body opens like a book under continued stress when glued from three separate pieces with epoxy. There is danger of getting epoxy into the contact areas, and assembling multiple piece connectors is more expensive than molding them.)
- Change the mounting holes to permit axes parallel to the contacts rather than to the cams. This would be a conventional connector mounting and would ease tolerance problems in the HLP (see Figure 15).

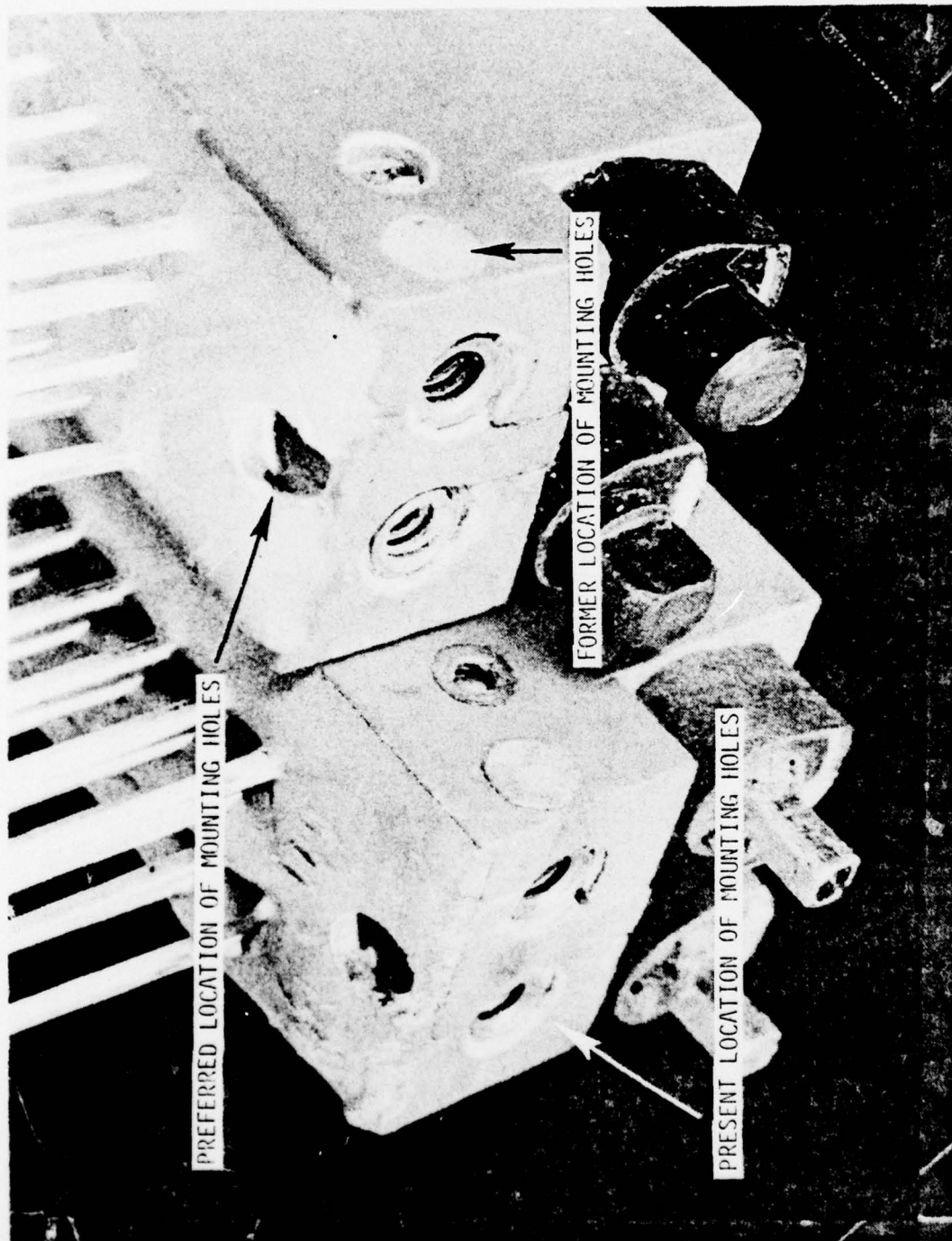


FIGURE 15. MOUNTING HOLE LOCATIONS

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