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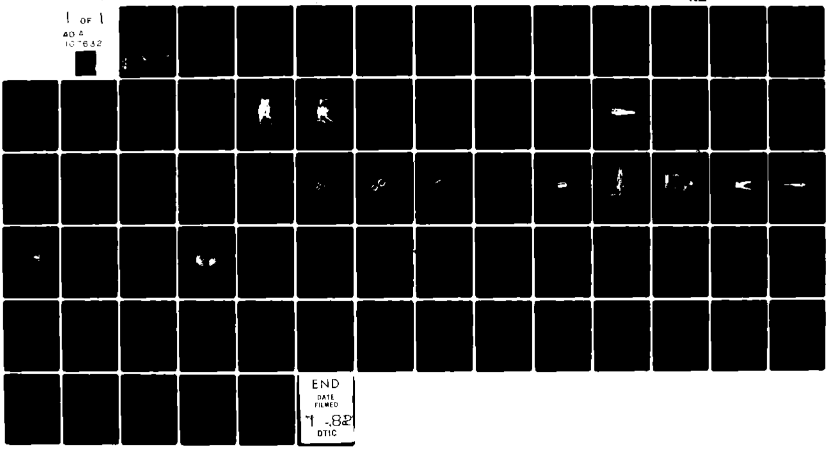

LEVEL # 2

NRL Memorandum Report 4602

The Application of Mechanical Clamps to Portsmouth Connectors

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

The efficiency of mechanical clamps applied to the molded boot of the MIL-C-24231 (Portsmouth) underwater connector was investigated. A mission profile for underwater connectors was prepared and used to design laboratory test sequences to evaluate connector leakage. A test connector was designed that incorporated the important features of the Portsmouth connector with the addition of leakage monitors in the construction so that leakage paths in the connector could be identified during test. Construction variables
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20 ABSTRACT (Continued)

of polyurethane or neoprene boot, both bonded and unbonded, clamp design and shielded or unshielded cable were investigated using factorial experimental design and analysis. A preferred clamped connector configuration was determined. Preferred test connectors were manufactured using bonded neoprene boots, shielded cable and Band-It Preform clamps and compared to a standard non-clamped polyurethane connector in accelerated life testing.

It was determined that a mechanical clamp inhibits leakage in a connector. Although applying a clamp to a connector does not insure water-tight integrity, it was found that after 32 weeks of accelerated life testing, 78% fewer clamped connectors leaked than the control unclamped connectors. The data also indicated that neoprene and polyurethane bonds degrade with time but connectors made with neoprene molded boots were less likely to leak through a bond interface than those made with polyurethane molded boots. It was also found that the pressure qualification tests specified in MIL-C-24231 do not necessarily identify unbonded connectors, and that construction variables other than bond quality may greatly influence the leakage characteristics of connectors.

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THE APPLICATION OF MECHANICAL CLAMPS TO PORTSMOUTH CONNECTORS

BACKGROUND

This report covers the work performed on Phase II of Contract No. N00173-79-C-0129, "Research, Development, Test and Evaluation of Cables and Connectors." This contract was awarded to Texas Research Institute, Inc. (TRI) in May 1979 as part of the FY79 Sonar Transducer Reliability Improvement Program (STRIP).

The STRIP Program investigates problems of current interest to the fleet. An objective of STRIP is to provide engineering solutions to problems that improve the life and reliability of sonar hardware. Many submarine transducers and hydrophones rely on the MIL-C-24231 (Portsmouth) connector to provide electrical transmission through the pressure hull. This connector, however, has had a history of premature and sporatic failure due to water intrusion. One factor contributing to water leakage is the deterioration or absence of the rubber-to-metal bond between the molded connector boot and metal sleeve.

It has been suggested that a mechanical clamp applied over the molded boot at the metal bond interface would aid in preserving the watertight integrity of the connector and would be a rapid, inexpensive quality improvement to connectors. The objective of this laboratory program was to evaluate that suggestion by applying mechanical clamps to Portsmouth connectors and measuring the effect of clamps on connector leakage.

APPROACH

A six-task program was designed to meet the objectives at this investigation and is shown schematically in FIGURE 1. The first task required that a test plan be developed to statistically evaluate the efficiency of clamps. To do this, potential clamping systems were identified and clamp samples obtained. A hypothetical mission profile was assembled which detailed the expected use stresses that submarine and surface ship connectors experience in service, and the data were used to define testing parameters.

The MIL-C-24231 (Portsmouth) connector is shown in FIGURE 2. Three water leakage paths are identified:

1. Between the cable and molded boot.
2. Between the metal sleeve and molded boot.
3. Through the "O" ring seal.

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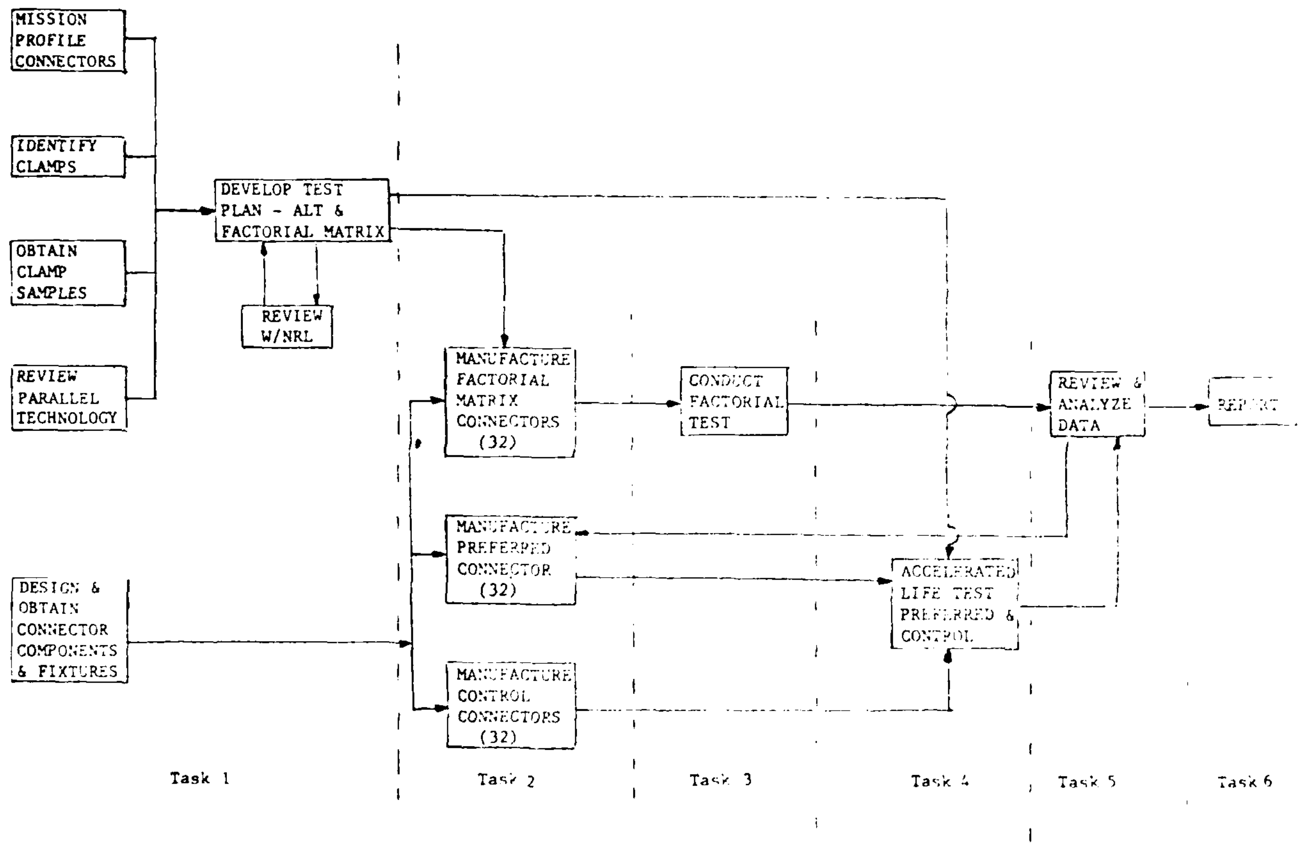

FIGURE 1 — Flow chart: connector clamp evaluation

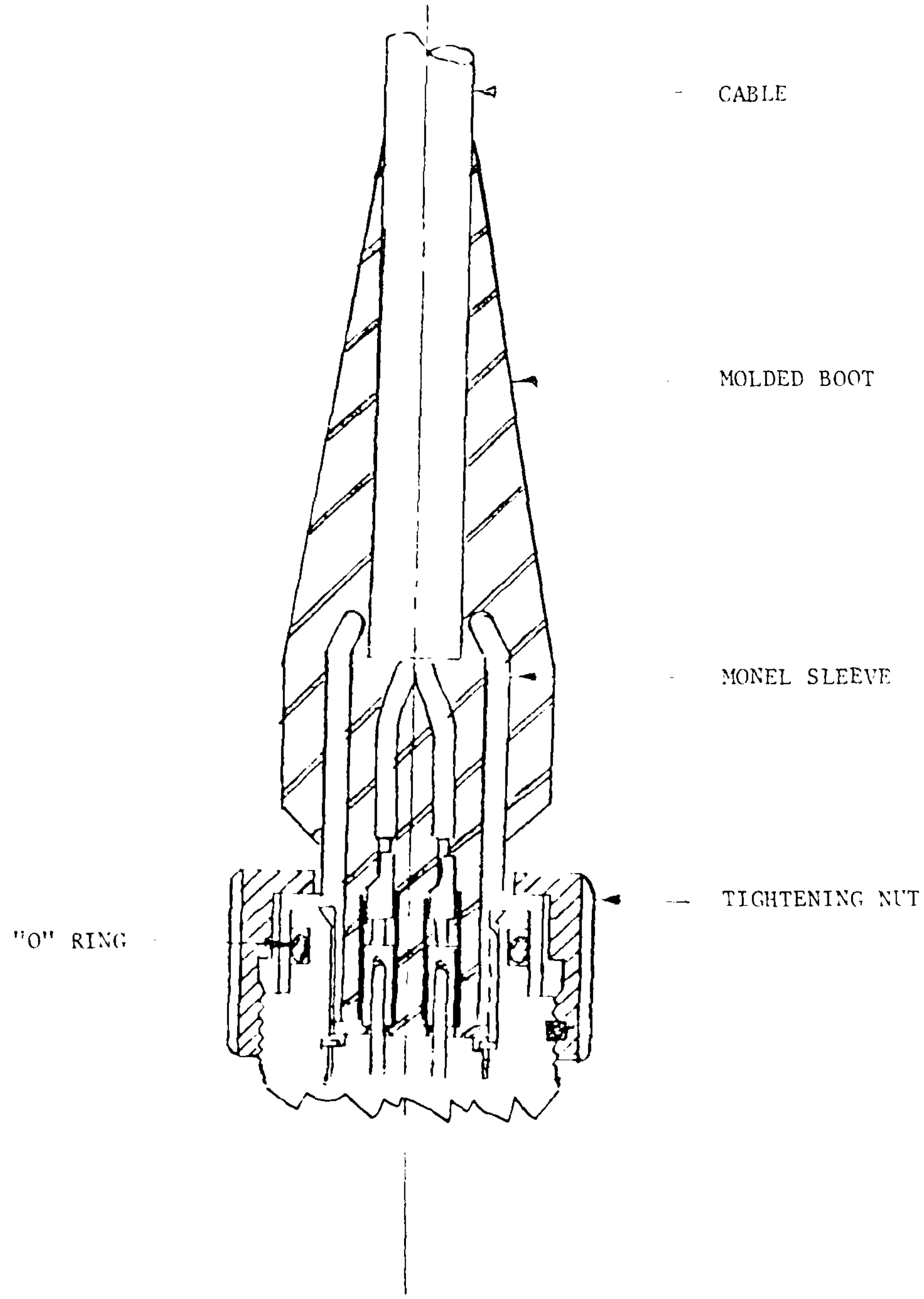

FIGURE 2 – Portsmouth connector, MIL-C-24231

Since the objective of this investigation was to determine the efficiency of clamps applied to the molded boot, it was necessary to design a test connector that would incorporate the physical and materials parameters of the Portsmouth connector and provide a means to monitor leakage at each of the three possible leakage paths.

The test connector shown in FIGURE 3 was designed to monitor leakage. This connector incorporated three electrical probes to indicate the presence of water in the connector and to identify the leakage path. A failed connector was defined as one showing continuity between water outside of the connector and either of the resistance probes located in the connector body, when the resistance was measured with a megohmmeter. Each connector failure identified by resistance measurements was confirmed by applying dye penetrant, sectioning and visually inspecting the leakage path to assure that "failure" in each case meant "leakage".

Also in the initial task, a two-part connector test plan was developed. The first part addressed the manufacturing variables of connectors and the second addressed clamp efficiency. Several polyurethane and neoprene compounds are used in manufacturing MIL-C-24231 connectors, and it was anticipated that a minimum of three clamp designs would be evaluated in the program. In addition, it was desired to evaluate shielded and nonshielded MIL-C-915/8E cable. It became clear that it was not possible to manufacture a statistically significant number of connectors incorporating all possible variables and still obtain meaningful test data.

To narrow these variables to a manageable number, the two boot molding elastomers most commonly used by Navy facilities, the presence or absence of an elastomer-to-metal bond, three clamp designs and both shielded and nonshielded MIL-C-915/8E cable were evaluated in a screening test. Connectors incorporating the variables to be screened were assembled in the 32-unit factorial matrix shown in TABLE 1. The desired result of screening was to select a single connector design of boot material, clamp design and cable type most likely to result in low leakage rates. The connector of the identified design and a control connector made to the design used most by Navy facilities could then be made in statistically significant numbers to allow evaluation of mechanical clamp efficiency.

A screening test sequence was designed to qualify the connectors in the matrix following the production acceptance procedures of MIL-C-24231. After qualification, stress levels were gradually increased until sufficient connector failures were produced to allow evaluation of the construction variables.

The object of second test sequence was to evaluate clamps on the connector identified as most likely to succeed by accelerating the aging process of the test and control connectors. The resulting Accelerated Life Test (ALT) considered the stress limits of the Mission Profile and data obtained from the screening test so that aging stresses were accelerated without exceeding design limits of the connector construction materials.

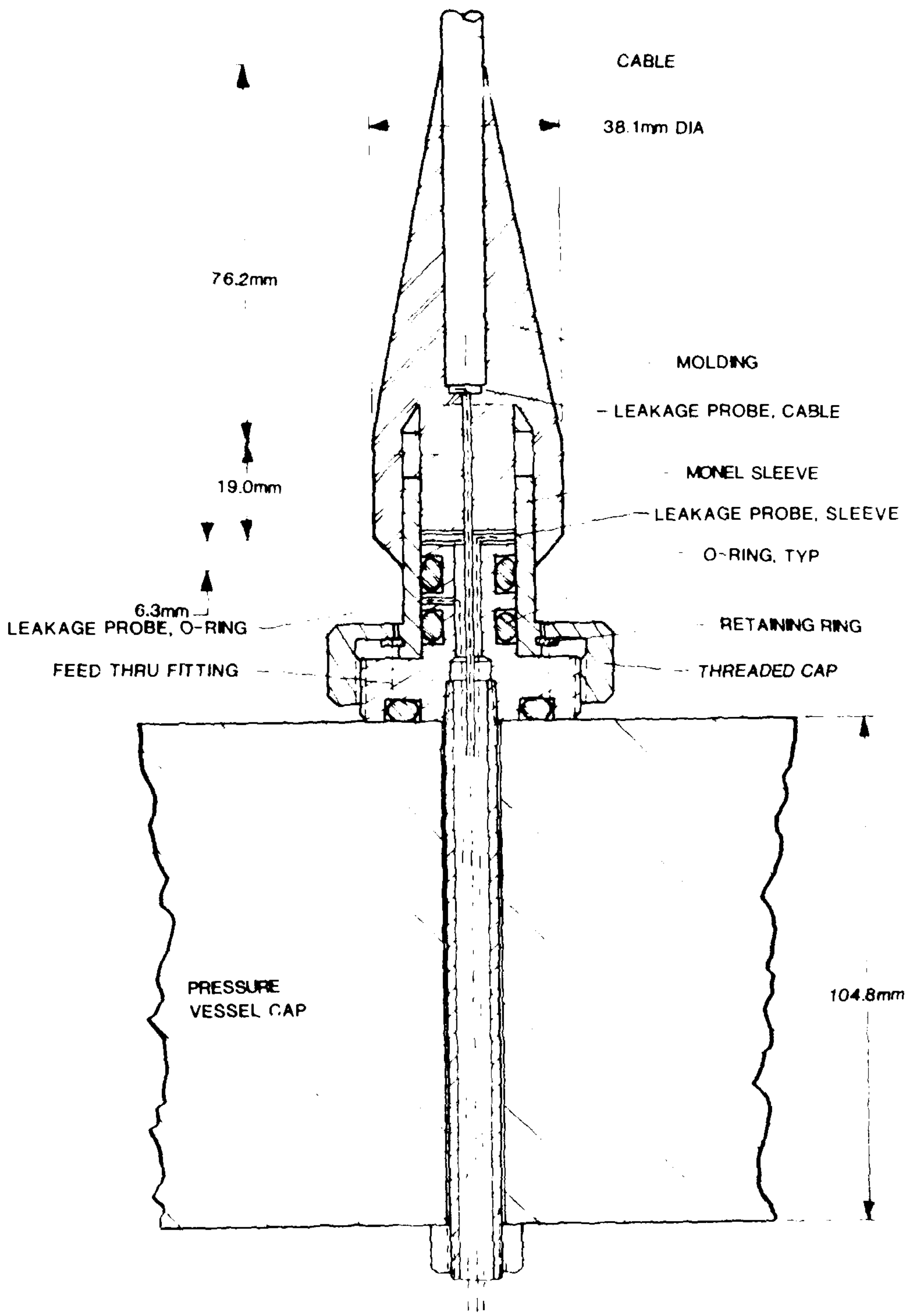

FIGURE 3 – Test connector

In the second task, 96 test connectors were manufactured. The first 32 units followed the matrix described in TABLE 1. The second 32 were manufactured to the preferred design as determined by the results of the factorial matrix, and the last 32 were control connectors. The control units were made without clamps using shielded MIL-C-915/8E, DSS-3 cable, and polyurethane PR-1547 with PR-420 primer on the metal sleeve and PR-1523M on the neoprene cable. Molding of the connectors followed procedures set forth in Molding & Inspection Procedures for Fabricating Connector Plugs for Submarine Outboard Cables, NAVSHIPS 0902-022-2010.

The third task exercised the test sequence developed for the factorial matrix, and Task 4 consisted of the accelerated exposure and testing of 32 connectors with clamps and 32 control connectors following the ALT sequence. Task 5 reviewed and analyzed the data, and the analysis was included in the published reports of Task 6.

TABLE 1

FACTORIAL MATRIX

		POLYURETHANE (PR-1547)		NEOPRENE (JOY 319,735-8)	
		BONDED	NOT BONDED	BONDED	NOT BONDED
NO CLAMP	SHIELDED	X	X	X	X
	UNSHIELDED	X	X	X	X
OETIKER	SHIELDED	X	X	X	X
	UNSHIELDED	X	X	X	X
BAND-IT PREFORMED	SHIELDED	X	X	X	X
	UNSHIELDED	X	X	X	X
BAND-IT SCRU-LOKT	SHIELDED	X	X	X	X
	UNSHIELDED	X	X	X	X

TOTAL MATRIX -- 32 UNITS

DISCUSSION OF RESULTS AND CONCLUSIONS

This investigation addressed the efficiency of mechanical clamps applied to the molded boot of Portsmouth Connectors. The specific questions that were pursued were:

1. Does a clamp prevent leakage in unbonded connectors?
2. Does a clamp lose effectiveness with time in service?
3. Can a "best" clamp design be identified?
4. Does a clamp decrease bond degradation rate?
5. Can the lifetime of a connector be determined?
6. What is the efficiency of clamps applied to connectors?
7. What cost trade-offs are associated with connectors?

The following discussions address these questions.

Unbonded Connectors

It was determined that clamps improve the water tight integrity of non-bonded connectors. Test connectors were made with both polyurethane and neoprene molded boots without bonds between the boot and metal sleeve, and between the boot and cable jacket. To insure lack of bond, no adhesives were used in manufacturing the connectors, and a mold release agent was applied to the metal sleeve and to the cable jacket. The completed connectors were examined and the boot was easily separated from both the cable and sleeve.

Of eight polyurethane non-bonded connectors tested in the factorial matrix, one of six clamped connectors and none of two unclamped connectors survived the total test cycle. Of the neoprene molded connectors, six of six non-bonded clamped units survived along with one of two non-bonded not clamped connector. The data do suggest that clamps do not increase leakage, do decrease leakage of unbonded neoprene connectors, and may improve unbonded polyurethane connectors. It should be noted, however, that the statistical significance of these results indicates that the performance difference between the polyurethane boot and the neoprene boot may override clamp performance with the neoprene material performing better than the polyurethane.

Service Influence on Clamps

Thirty-two clamped connectors were subjected to accelerated life testing (ALT) for a total of 32 weeks. The ALT exposures were within exposures of the Mission Profile and the connectors were not stressed above levels experienced in service. At the conclusion of the test sequence, four clamped connectors had failed (12.5%), one of which was identified as a manufacturing defect failing during the first weekly cycle. The other three failed within weeks 21 and 23. The test was terminated before the failure rate of clamped connectors was sufficient to predict wearout or detrimental effects of service life on clamp efficiency. From the available data and estimates of acceleration factors shown in Appendix C, it may be concluded that clamps can remain effective for a minimum of eight years in service.

Clamp Design

Preliminary analysis of the Portsmouth connector system led to guidelines for selecting a clamp. Included in the guidelines were:

1. Clamp material must be of relatively high strength and modulus and show low stress relaxation. Most metal clamps have these properties.

2. Clamp material must be non-corrosive in sea water or if corrosive, must have a satisfactory service history. Type K-Monel is relatively inert in sea water and type 316 stainless steel, although subject to crevice corrosion, has had a satisfactory service record on transducers and hydrophones.

3. The clamp must be designed to be tightened to a consistent pressure. Three general types of clamps are commercially available: a continuous band tightened by crimping or swaging, an open band closed and tightened by means of a self-contained screw, and an open band closed and tightened using an external tensioning device and closure clip.

4. For installation on existing connectors, the clamp must be an open type or be able to open sufficiently to fit over the connector tightening nut.

5. The clamp must be securely closed after tightening.

Three clamps were identified that met the above guidelines. These were the Oetiker One Ear clamp, Band-It Jr. Preform and Band-It Scru-Lokt. The factorial matrix test results showed a possible but not statistically significant advantage of the Band-It Preform over the other two clamps. However, ease of installation made the Preform clamp preferable over the others and it was selected for further evaluation.

Bond Degradation Rate

Analysis of the test connectors at the conclusion of 32 weeks of ALT showed that all the polyurethane and neoprene molded connectors had marginal or nonexistent bonds at the sleeve-to-boot interface. Typical connectors analyzed at the conclusion of the ALT are shown in FIGURES 4 and 5. Both boot types exhibited adhesive failure when the boot was pulled from the sleeve with failure occurring between the adhesive and elastomer.

The bond at the boot-to-cable interface also appeared deteriorated. Polyurethane units were sporatic in bond tenacity; some units showed a combination of adhesive and cohesive failure. All units with neoprene

FIGURE 1   Polyurethane control connector ALT bond analysis

FIGURE 5   Neoprene clamped connector ALT bond analysis

boots showed only cohesive failure. Examination of the bonds under clamps at the cable and sleeve did not appear to be of better quality than the bond away from the clamps.

To obtain an indication of cable bond deterioration, samples of cable jacket bonded to polyurethane and to neoprene were aged in the ALT sequence with test connectors. After four weeks of ALT the polyurethane-to-cable bond strength decreased by approximately 26% and the neoprene-to-cable bond strength by approximately 21%. After a total of eight weeks of aging the polyurethane remained at the same level of 26% decrease and the neoprene decreased by a total of 83%. While the neoprene bonds lost far more of their strength, they were still showing cohesive failure. The polyurethane-to-cable interface failed adhesively.

It can be concluded that both neoprene and polyurethane bonds degrade in service, and the application of clamps does not inhibit this degradation.

Connector Lifetime Prediction

The results of the factorial matrix experiment and the ALT testing show that the lifetime of a connector is dependent on construction. When subjected to the extreme stress of the factorial matrix screening test 58% of the clamped connectors survived compared with 37% of unclamped connectors. Considering mean cycles to leakage failure, clamped connectors ranged from 14 for Oetiker clamped connectors to 47 for Band-It Preform clamped connectors and 28 for Band-It Scru-Lokt connectors. This compares with 16 for unclamped connectors. In the less severe ALT sequence, unclamped control connectors failed at a rate suggesting wear-out failure as shown in the histogram of FIGURE 6.

Equivalent service life exposures estimated from acceleration factors for water permeation in neoprene and polyurethane are derived in Appendix C. The acceleration factors used are shown in TABLE 2 and show that 32 weeks of ALT exposure is approximately equivalent to 14 service years for neoprene connectors and 10 years for polyurethane. Using the factors in TABLE 2, it may be seen in FIGURE 6 that ten percent of the clamped neoprene connectors failed in 21 weeks (equivalent to approximately 8.8 years) and ten percent of the unclamped polyurethane connectors failed in eight weeks (equivalent to approximately 2.5 years).

It can be concluded that the lifetime of connectors is dependent on construction parameters such as elastomer selection and the presence of clamps.

Clamp Efficiency

A total of 64 connectors was made for determining clamp efficiency. Thirty-two of these were control connectors constructed with a polyurethane (PR-1547) molded boot and bonded with recommended bonding agents. DSS-3 shielded cable was used and no clamp was applied.

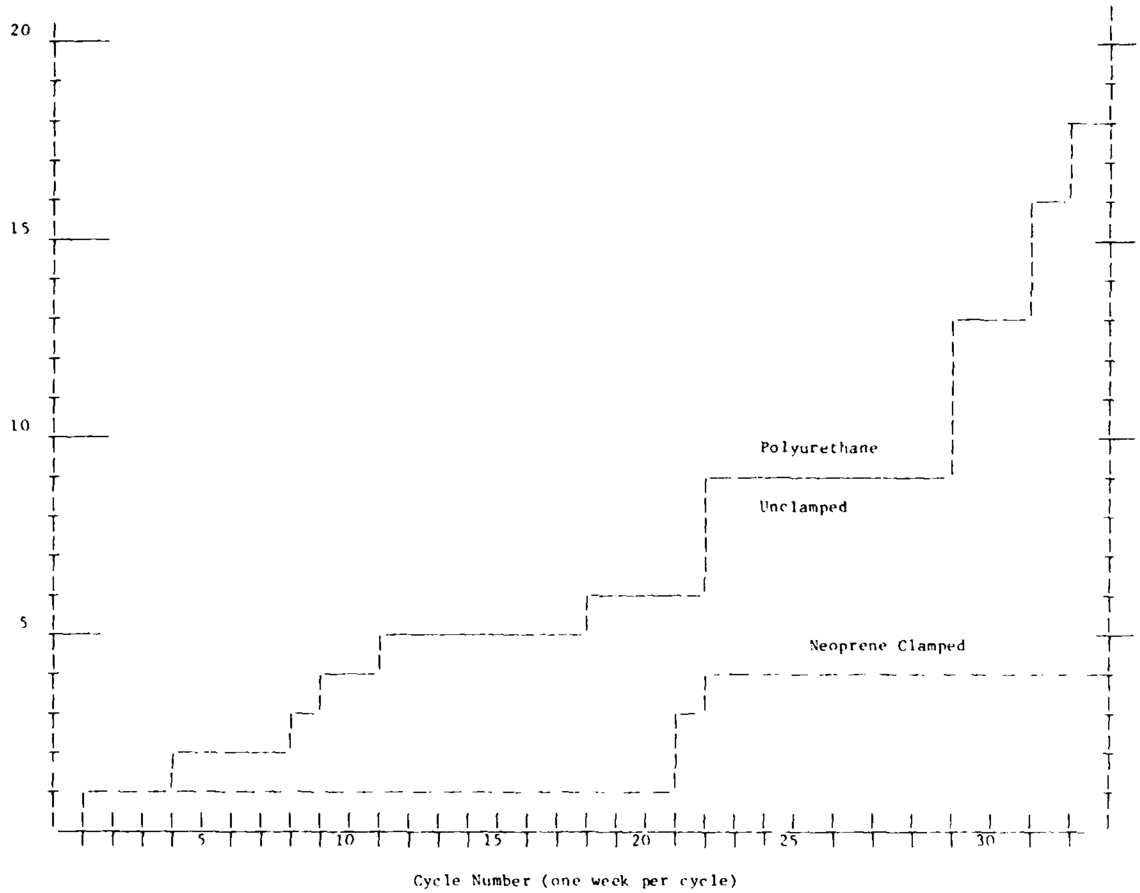

FIGURE 6 — ALT failure histogram for neoprene and polyurethane connectors

TABLE 2

ONE-WEEK ALT EXPOSURE SUMMARY

	EXPOSURE		NEOPRENE		POLYURETHANE	
	Hours	Temp, °C	Accel. Factor	Equiv. Hours	Accel. Factor	Equiv. Hours
	2	-78	0	0	0	0
	8	25	1	8	1	8
	158	70	23	3634	17	2686
TOTAL	168			3642 (0.42 yr)		2694 (0.31 yr)

The remaining thirty-two connectors were molded of neoprene (Joy No. 319,735-8) and bonded with recommended bonding agents. DSS-3 shielded cable was also used in assembly. Each of these connectors was fitted with a Band-It Preform clamp over the boot at the metal sleeve interface. Sixteen of these test connectors were also fitted with a Band-It Preform clamp over the boot-to-cable interface. FIGURE 7 shows the configuration of a test connector fitted with a clamp at both bond interfaces.

At the conclusion of the test sequence eighteen of the thirty-two (56%) control connectors failed and a total of four of thirty-two (13%) clamped connectors failed. Of the clamped connectors that failed, all were clamped only at the sleeve. None of the connectors clamped at both sleeve and cable failed.

Analysis of the failures was made and of the eighteen failed polyurethane control connectors, ten were analyzed as sleeve bond failures and two as cable bond failures. An additional three showed failure at both bond areas. One control connector failed on the first cycle and showed a manufacturing defect. The remaining two control failures cracked because of handling during cold shock.

Of the clamped connectors, one showed a manufacturing defect after failing the first cycle, two failed at the sleeve bond interface and one at the cable bond interface.

It can be concluded that the clamped connectors show less tendency to leak than do the control non-clamped connectors, and that clamp application does not increase the incidence of leakage in connectors.

Clamp Economics

The cost of all the clamps identified was minimal compared to the manufacturing and materials cost of the Portsmouth connector. In the test connector manufacturing operation, approximately five minutes additional time was required to apply a clamp to a connector. Compared with a total manufacturing time of 1 to 2 man hours for parts preparation for molding, clamp addition would add 3-7% to the labor cost of a connector. By applying clamps, a positive change in connector lifetime can be expected which would effectively reduce connector costs.

It can be concluded that clamp application to Portsmouth connectors will result in a slight overall cost increase but will appreciably prolong the average service life of connectors.

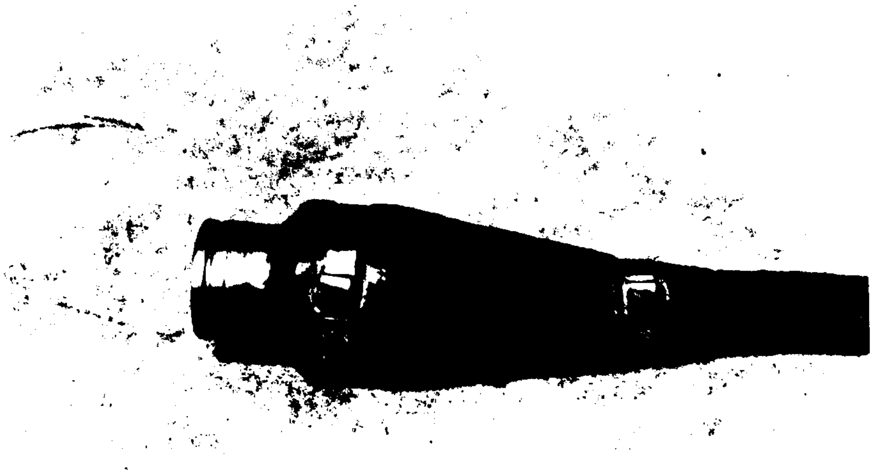

FIGURE 7 Test connector with Band It Preform clamps

DISCUSSION OF TASKS

The detailed data measurements and procedures associated with the test program are presented in the following sections.

Mission Profile

A mission profile is a description of environmental and mechanical stresses to which hardware is exposed during the lifetime of that hardware. Environmental stresses include temperature extremes, thermal shock, moisture exposure, ultraviolet radiation, pressure excursions and other exposures that contribute to materials degradation or change in properties.

The information developed in a mission profile is essential for product design and for verification test design. The maximum and minimum stress exposures called out in a mission profile are used as guidelines to design and test products. As such, the mission profile is a tool for ensuring product reliability and life expectancy.

For this program, a hypothetical mission profile for connectors was developed to provide maximum and minimum stress limits. Three categories of mission profile were established, Transportation and Storage (TABLE 3), Installation and Maintenance (TABLE 4) and Service: SSN (TABLE 5), SSBN (TABLE 6) and Surface Ship (TABLE 7).

The general format used for describing the mission profile is as follows:

Column 1 - Exposure number for identification.
Column 2 - Exposure description.
Column 3 - Range of exposure, maximum and minimum values that can be experienced. This includes the entire environmental range the item may be expected to encounter.
Column 4 - Circumstances under which the exposure occurs.
Column 5 - Time weighted description of extreme exposure normalized to one year's estimated stress, based on maximum or minimum exposure values.
Column 6 - Time equivalent of extreme exposure.
Column 7 - Time weighted description of a typical or average exposure normalized to one year's estimated stress.
Column 8 - Time equivalent of typical exposure.
Column 9 - Companion exposures that may contribute synergistically to material changes in service.

Information contained in the mission profile was collected from various sources. Among these are product specifications, steaming data or estimates thereof, consensus opinion of Naval personnel associated with maintenance and fleet operation, published literature and manufacturers' opinions. In many instances hard numerical data for an exposure were not available and the data presented were therefore estimated.

TABLE 3: MISSION PROFILE - TRANSPORTATION AND STORAGE

NO.	EXPOSURE	EXPOSURE RANGE	OCCURANCE	DURATION (time or cycles) EXTREME	PER 1 YR.	CONTINUING LONG TERM	PER 1 YR.	COMPANION EXPOSURES
1	Temperature in air	-30° to +70°C	Storage Outside	70°C for 5 hrs day x 180 days	900 hrs			
2				-30°C 12 hrs day x 30 days	360 hrs			Humidity Ultraviolet Air Pollution
3			Covered Storage			-6° to +38°C	8640 hrs	
4	Pressure in Air	12 to 100 kPa	Air Transportation	12 kPa 2 flights x 8 hrs	16 hrs			
5			Storage			100 kPa	8640 hrs	Humidity Temperature Air Pollution
6	Humidity	-30° to +38°C Dew Point	Storage	-30°C Dew Point 30 days	720 hrs			
7				+38°C Dew Point 120 days	2880 hrs			Temperature Ultraviolet Air Pollution
8						+10° to 32°C Dew Point	8640 hrs	
9	Ultraviolet *Radiation*	0-2625 w/*cm*$^{-2}$ 290-400 nm	Storage Outside Uncovered	2625 w cm^{-2} 1.5 hrs day 270 days	410 hrs			
10						770 w cm^{-2} 8 hrs day x 360 days	2880 hrs	Temperature Humidity Air Pollution
11	Air Pollution	0-500 PSI[a]	Storage	500 PSI 8 hrs day for 3 days[b]	24 hrs			
12						200 to 50 PSI 8 hrs day for 180 days	1440 hrs	Temperature Humidity Ultraviolet
13	Rough Handling	Per MIL-STD-167-1[c]	Transportation	Per MIL-STD-167-1	1 series			

a - PSI - Pollution Standard Index per Fed. Reg. Vol 44 #219
b - Based on Los Angeles Experience, 1975.
Ozone is major contaminant.
c - Rough handling as defined by specification due to lack of service data.

TABLE 4
MISSION PROFILE - INSTALLATION AND MAINTENANCE

NO	EXPOSURE	EXPOSURE RANGE	OCCURANCE	DURATION (Time or Cycles) EXTREME	PER 1 YR.	CONTINUING LONG TERM	PER 1 YR.	COMPANION EXPOSURES
1	Temperature in Air	-30° to +60°C	Dry Dock[c] Winter	-30°C for 30 Days	720 Hrs			Humidity Air Pollution
2						-11°to +11°C for 180 Days	4320 Hrs	
3			Dry Dock[c] Summer	+60°C for 8 Hrs/Day 90 Days	720 Hrs			
4						+11°to +39°C for 180 Days	4320 Hrs	
5	Temperature in Water	-2° to +32°C	Dockside Winter	-2°C for 90 Days	2160 Hrs			
6						-1° to +15°C for 180 Day	4320 Hrs	
7			Dockside Summer	+32°C for 90 Days	2160 Hrs			
8						+10°to +32°C for 180 Day	4320 Hrs	
9	Thermal Cycling	T≤50°C	Dry Dock[c]	T = 50°C 1 Cycle/Day 90 Days	90 Cycles			Humidity Air Pollution
10						T = 30°C 1 Cycle/Day for 180 Days	180 Cycle	
11	Humidity	-30° to +38°C Dew Point	Dry Dock[c] Dockside	-30°C Dew Point 30 Days	720 Hrs			Temperature Air Pollution
12				+38° Dew Point 120 Days	2880 Hrs			
13						+10°to +32°C Dew Point	8640 Hrs	
14	Air Pollution	0 -500 PSI[a]	Dockside and Dry Dock[c]	500 PSI 8 hrs/day for 3 days[b]	24 Hrs			Temperature Humidity
15						200 to 50PSI 8 hrs/day for 180 days	1440 Hrs	

a - PSI - Pollution Standard Index per Federal Regulations Vol. 44 #219.
b - Based on Los Angeles experience, 1975. Ozone is the major contaminant.
c - Drydock frequency varies with ship type.

TABLE [illegible]
MISSION PROFILE [illegible]

No.	EXPOSURE	RANGE OF EXPOSURE	[illegible] RANGE	EXTREME	FEW YR.	CONTINUING LONG TERM	PER YR.	COMPANION EXPOSURE
				DURATION OF EXPOSURE (Hrs or Cycles)				
1	Temperature in Air	[illegible]	[illegible]	[illegible]	[illegible]			Humidity, Air Pollution
2				[illegible]	[illegible]			
3						[illegible]	[illegible]	
4			[illegible]	[illegible]	[illegible]			
5	Temperature in Seawater	[illegible]	[illegible]	[illegible] 90 days	[illegible]			[illegible]
6			[illegible]	[illegible] days	[illegible]			
7						[illegible] days	[illegible]	
8	Thermal Cycling	[illegible]	Dockside	[illegible]	[illegible] cycles			Humidity, Air Pollution
9						[illegible]	[illegible] cycles	
10	Thermal Shock	[illegible]	Diving-Tropic	[illegible]	[illegible] cycles			
11			Diving-Arctic	[illegible]	3 cycles			
12	Pressure	[illegible] to [illegible] kPa	At Sea	[illegible] kPa [illegible] day; 90 days	180 [illegible]			Temperature, Vibration
13						[illegible] 210 kPa for 90 days	210 hrs	
14	Pressure Cycling	100kPa-4100 kPa	At Sea	100 to 4100kPa [illegible] 2 day; 90 days	180 cycles			
15						[illegible] to 2100kPa 90days	180 cycles	
16	Humidity	+55° to +38 C Dew	Surface	38 C D.P. 24 hr/day;	648 hr			Temperature, Air
17						10° to 32 C D.P.; 270 days	6480 hrs	
18	Air Pollution	0-500 PSI[a]	Dockside	500 PSI 8 hrs/day for 3 days[c]	24 hr			Temperature, Humidity
19						200 to [illegible] PSI 8 hrs day; 180 days	1440 hrs	
20	Vibration	Per MIL-STD-167-1[b]	At Sea	Per MIL-STD-167-1	1 series			Temperature, Pressure
21	Explosive Shock	Per CIPS[b]		Per CIPS	1 series			Pressure
22	Tensile Load, Static	Note d	All Service			Continuous load per Note d	8640 hrs	Humidity, Temperature, Vibration, Air Pollution

NOTES:

a PSI - Pollution Standard Index per Fed. Reg. Vol 44 #219.

b Vibration and explosive shock as defined by specification due to lack of service data.

c Based on Los Angeles experience, 1975. Ozone is the major contaminant.

d Static stress based on 10 meters of unsupported cable. DSS-2 = 6 kg, DSS-3 = 10 kg, DSS-4 = 12 kg, FSS-2 = 12 kg.

TABLE [illegible]
MISSION PROFILE - SSBN SERVICE

NO.	EXPOSURE	RANGE OF EXPOSURE	OCCURANCE	EXTREME (DURATION OF EXPOSURE (hrs or cycles))	PER 1 YR.	CONTINUING LONG TERM	PER 1 YR.	COMPANION EXPOSURE
1	Temperature Air	-55° to +65°C	Dockside	+6[illegible]°C, 1[illegible] hr day; [illegible] days	[illegible] hrs			Humidity Pollution
2				-30°C 12 hr day; 2 days	24 hrs			Air Pollution
3						+3[illegible] to 32°C for [illegible] days	1440 hr	
4			Arctic Surface	[illegible] for 21 days	[illegible] hrs			
5	Temperature Sea Water	-2° to +3[illegible]°C	Tropical Service	+32°C for 27 days	648 hrs			Pressure
6			Artic Service	-2°C for 270 days	648 hrs			
7						[illegible] to 11°C for 270 days	6480 hr	
8	Thermal Cycling	T < 50°C	Dockside	T = 50°C	60 cycles			Humidity Air Pollution
9						T < 30°C	60 cycles	
10	Thermal Shock	T < 33°C	Diving-Tropic	T< 28°C	300 cycles			
11			Diving-Arctic	T< 3°C	300 cycles			
12	Pressure	100 to 4100 kPa	At Sea	4100 kPa for 300 days	7200 hrs			Temperature Vibration
13						200 to 2100kPa for 300 days	7200 hrs	
14	Pressure Cycling	100<P<4100 kPa	At Sea	100 to 4100kPa 2/day, 300days	600 cycles			
15						200 to 2100kPa	600 cycles	
16	Humidity	-55° to +38°C Dew Point	Surface	38°C D.P. 24 hr/day; 60 days	1440 hr			Temperature Air Pollution
17						+10° to +32°C D.P.; 60 days	1440 hr	
18	Air Pollution	0-500 PSI[a]	Dockside	500 PSI 8 hrs/day for 3 days[c]	24 hr			Temperature Humidity
19						200 to 50 PSI 8 hrs/day for 60 days	48[illegible] hr	
20	Vibration	Per MIL-STD-167-1[b]	At Sea	Per MIL-STD-167-1	1 series			Temperature Pressure
21	Explosive Shock	Per CIPS[b]		Per CIPS	1 series			Pressure
22	Tensile Load, Static	Note d	All Service			Continuous Load per Note d	8640 hr	Humidity Temperature Vibration Air Pollution

NOTES:
a PSI - Pollution Standard Index per Fed. Reg. Vol. 44, #219
b Vibration and explosive shock as defined by specification due to lack of service data.
c Based on Los Angeles experience, 1975. Ozone is the major contaminant.
d Static stress based on 10 meters of unsupported cable. DSS-2 = 6 Kg, DSS-3 = 10 Kg, DSS-4 = 12 Kg, FSS-2 = 12 Kg.

TABLE 7

MISSION PROFILE - SURFACE SHIP SERVICE

NO.	EXPOSURE	RANGE OF EXPOSURE	OCCURANCE	DURATION OF EXPOSURE (hrs or cycles): EXTREME	PER 1 YR.	CONTINUING LONG TERM	PER 1 YR.	COMPANION EXPOSURE
1	Temperature in Air	0° to +38°C	Dockside	0° C; 180 days	4320 hr			Humidity Pollution
2				+38°C	8640 hr			
3						+3° to +37°C for 360 days	8640 hr	
4	Temperature In Sea Water	-2° to 32°C	Artic	-2° C for 180 days	4320 hr			
5			Tropical	+32°C for 360 days	8640 hr			Pressure Vibration
6						0° to +30°C for 360 days	8640 hr	
7	Pressure	100 to 250 kPa	Service	250 kPa for 360 days	8640 hr			Temperature Vibration
8						100 to 250 kPa for 360 days	8640 hrs	
9	Humidity	0° to +38°C Dew Point	Service	38°C D.P. 360 days	8640 hr			Temperature Pollution
10						10° to +32°C D.P.; 360 days	8640 hr	
11	Air Pollution	0-500 PSI[a]	Dockside	500 PSI, 8 hrs/day for 3 days	24 hr			Temperature Humidity
12						200 to 50 PSI 360 days	8640 hr	
13	Vibration	Per MIL-STD-167-1[b]	At Sea	Per MIL-STD - 167-1	1 series			Temperature Pressure
14	Explosive Shock	Per CIPS[b]	At Sea	Per CIPS	1 series			Pressure
15	Tensile Load, Static	Note d	All Service			Continuous Load per Note d	8640 hr	Humidity

NOTES:

a PSI - Pollution Standard Index per Fed. Reg. Vol. 44 #219.

b Vibration and explosive shock as defined by specification due to lack of service data.

c Based on Los Angeles experience, 1975. Ozone is the major contaminant.

d Static stress based on 10 meters of unsupported cable. DSS-2 = 6 Kg, DSS-3 = 10 Kg, DSS-4 = 12 Kg, FSS-2 = 12 Kg.

The importance of Mission Profile data becomes obvious when considering that the environmental stresses to which a connector is exposed throughout its lifetime influence the rate at which the watertight bond of molded boot-to-cable or -to-metal sleeve deteriorates. Bond deterioration, the primary cause of non-"O" ring related connector failures, is a diffusion dependent chemical reaction and is related to temperature, pressure, moisture and time. The Mission Profile for connectors defines these exposures in detail and TABLE 8 summarizes the extremes of the exposures and therefore defines the minimum stress levels connectors must be designed to endure. Definition of these levels is necessary to ensure that materials considered for connector construction can meet the minimum stress requirements and to design laboratory qualification tests for connectors within the stress limits for the intended use.

Clamps

The literature was surveyed to identify clamps suitable for connector application. Selection guidelines were set forth as discussed in the section on Clamp Design and three clamps were identified as probable successful candidates for this evaluation. These were:

1. Oetiker One Ear clamp, manufactured by Oetiker, Inc. This clamp is available in various diameters and made of Type 316 stainless steel. An internal shield is available to minimize pinching under the ear. Closure is accomplished by crimping the ear closed with a crimping tool. The advantages of this clamp are quick and positive closure. Disadvantages are that the clamp does not adjust to a wide range of diameters, is not available in other non-corrosive materials and can non-uniformly compress the connector boot because of the gap at the ear. FIGURE 8 shows examples of this clamp.

2. Band-It Jr. Preformed Clamp manufactured by the Band-It Company. This clamp is available in various diameters and made of type 316 stainless steel. Closure is made by an external tensioning tool. The advantages are that the band can be expanded to accommodate many diameters, closure is easily accomplished (but takes longer than the Oetiker clamp) and this clamp is available in type 316 stainless steel. Disadvantages are that the clamp is not available in other non-corrosive materials and a small non-uniform compression area exists under the closure buckle. FIGURE 9 shows some examples of this clamp.

3. Band-It Scru-Lokt clamp manufactured by the Band-It Co. This clamp is cut from a continuous roll of banding and fitted with a closure requiring a screw crimping device. Advantages are that the band and closure are available in Monel and silicon bronze as well as type 316 stainless steel and the band can be cut to size. Disadvantages are that closure takes a longer time than with the previous two clamps and a small non-uniform compression area exists under the buckle. FIGURE 10 shows an example of this clamp.

TABLE 8
CONNECTOR STRESS EXTREMES

Exposure	Occurrence	Maximum	Duration/Yr
Heat, Dry	Storage	+70°C	900 Hrs.
Heat, Wet	Tropical Service	+32°C	8640 Hrs.
Cold, Dry	Arctic Service	-55°C	504 Hrs.
Pressure, Water	Submarine Service	4100 kPa	7200 Hrs.

[illegible]

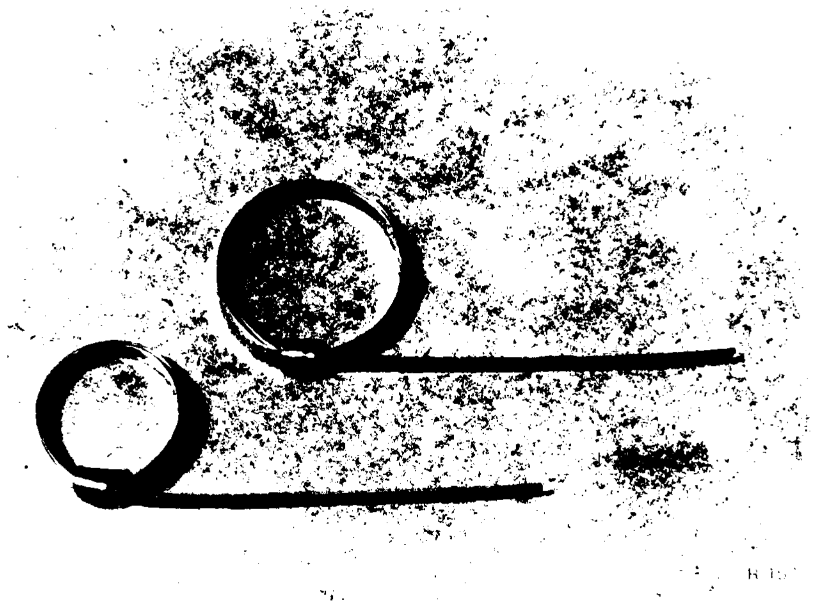

FIGURE 9 — Band-It preform clamps

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FIGURE 10 – Band-It Scru-Lokt clamp

Parallel Technology

Mechanical clamps have been successfully used for several underwater applications. Several sonar transducers use metal banding to seal an elastomer boot enclosing the unit as in the rubber boot on the TR-203A, TR-193B, TR-205, TR225, and DT-168A. For these applications, bands made of type 316 stainless steel have been successfully used.

In the area of connectors, a connector made by Souriau in France is marketed for high pressure underwater applications. This connector uses a stainless steel strip to secure and seal an elastomer boot encapsulating the connector. Service data are not available on this connector.

Test Connector Design and Fabrication

The test connector was designed to simulate the wetted components of the Portsmouth connector. The metal sleeve was machined to the MIL-C-24231 specifications from K-Monel stock. However, the reduced radius present on the cable end of the Portsmouth sleeve was omitted from the test hardware to simplify manufacturing. The sleeve design is shown in FIGURE 11.

The test connector was designed to incorporate leakage probes to detect leakage at the boot-to-cable interface, boot-to-sleeve interface and through the "O" ring seal. The leakage probes were insulated from the metal component of the connector but provided an electrical path from the point of measurement to the test tank if leakage occurred.

A double "O" ring system was designed to seal the interior of the connector sleeve during pressure testing. FIGURE 12 shows a cross section of the test connector mounted on a receptacle plug. The "O" ring leakage detector is located between the two "O" rings. The cable-to-boot detector is located at the end of the cable within the molded boot and the boot-to-sleeve leakage detector is at base of the elastomer inside of the sleeve.

The connector boots were fabricated in a mold designed to fit the test sleeve. This mold was constructed to be used both for casting the polyurethane PR-1547 and for compression/transfer molding the neoprene. FIGURE 13 shows the mold used for manufacturing the test connectors.

A portion of the completed connectors were fitted with the identified clamps. The Oetiker clamp was tensioned by crimping with a supplied tool as shown in FIGURE 14. FIGURE 15 shows a test connector with closed Oetiker clamps at both bond interfaces. Compression of this clamp was not adjustable and was set by the diameter of clamp and connector.

Both Band-It clamps were installed and tensioned using a tool fitted with a torque wrench. A torque value of 30 in-lbs. was determined by measuring torque required to compress the boot by the thickness of the clamp which was 0.022 inches, and this value was used to control installation. FIGURE 16 shows a Band-It clamp with the tensioning tool, and a connector with Band-It clamps installed was shown in FIGURE 7.

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FIGURE 11 — Test connector sleeve

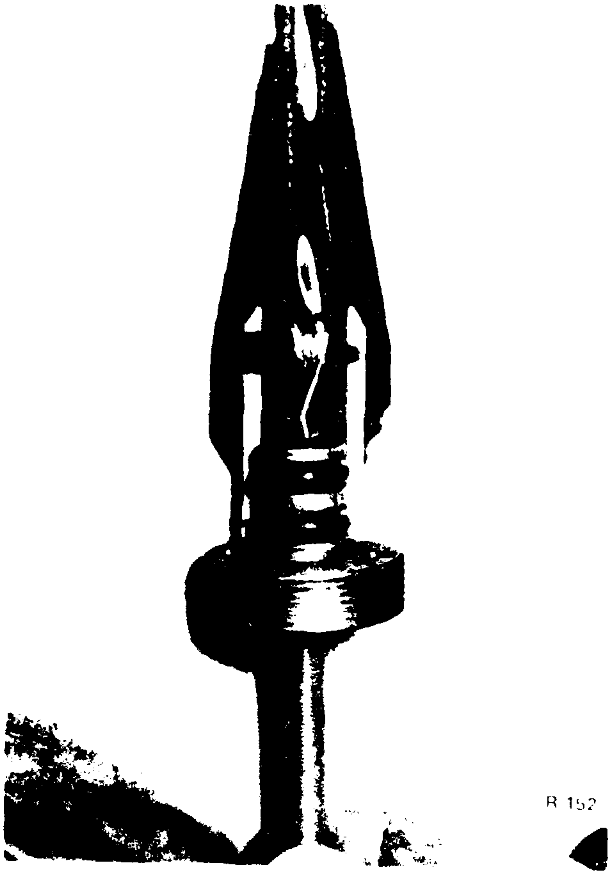

FIGURE 12 — Sectioned test connector with receptacle plug

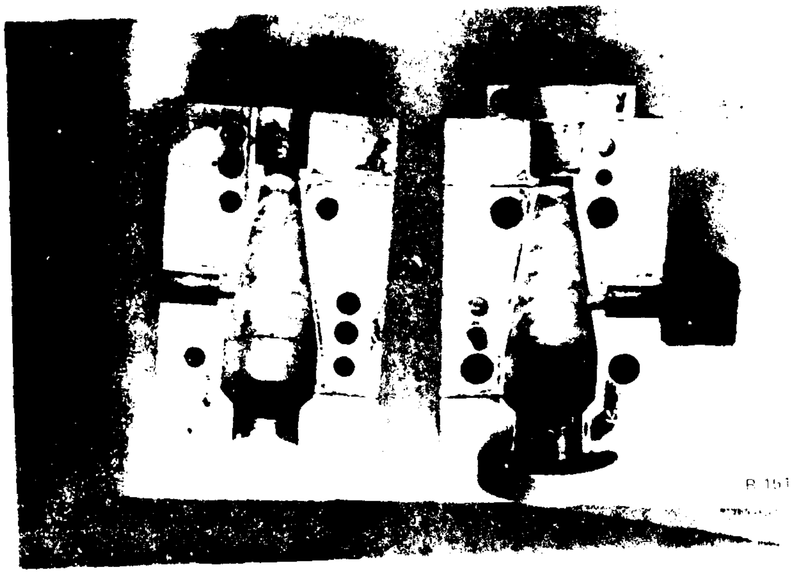

FIGURE 13 Connector mold

FIGURE 14 – Oetiker clamp with crimping tool

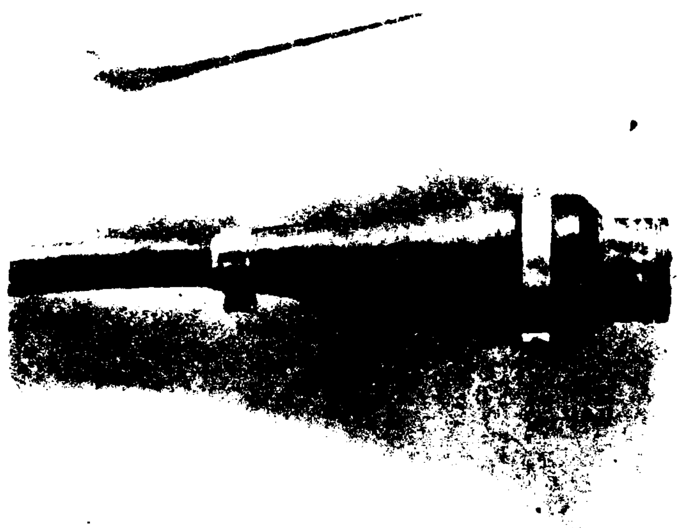

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FIGURE 15 Factorial matrix connector with Oetiker clamps

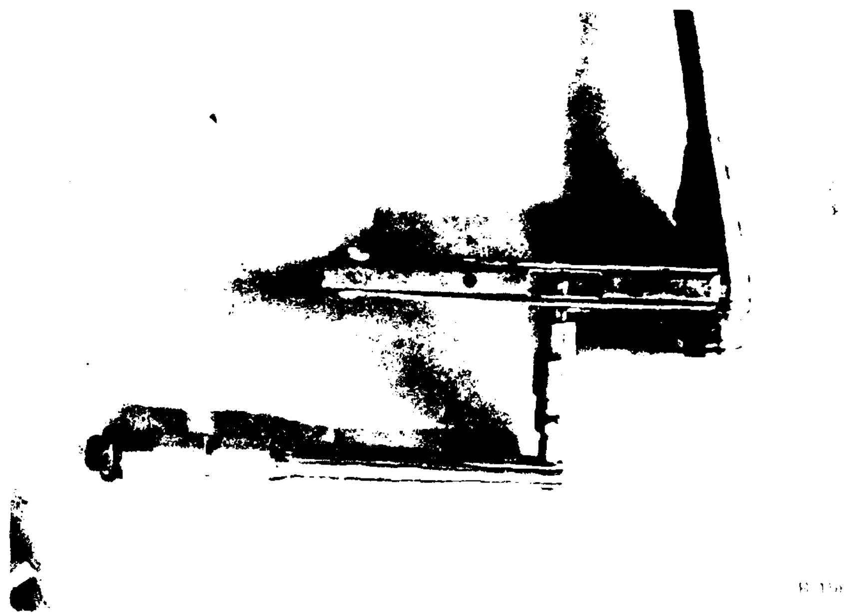

FIGURE 16 Band It preform with tensioning tool

Connector Testing

Test connectors were manufactured to the parameters of the factorial matrix as described in TABLE 1. A test plan was developed as shown in TABLE 9. The first part of the plan followed the acceptance tests in MIL-C-24231 and was used to qualify the connectors. After Cycle 3, the stress was increased each cycle to accelerate the failure rate.

For pressure testing a tank with a removable top was used. The top was fitted with sixteen sleeve plugs to allow for pressure testing of half of the matrix at one time. This configuration is shown in FIGURE 17.

Leakage measurements were made on each connector at the conclusion of each pressure cycle. The measurements were made using a General Radio Model 1863 Megohmmeter and the resistance readings from each probe recorded. The data obtained during the matrix testing are shown in Appendix A.

Hot saltwater aging was done in a temperature controlled tank fixturing the connectors so that the elastomer boot and cable were submerged. The connectors were placed in a dry ice chest at -78°C for cold shock and in a recirculating air oven at +70°C for dry heat aging.

For the ALT, the plan shown in TABLE 10 was used. This plan was less severe than the matrix screening test plan and was designed to be repeated on weekly cycles. The pressure tank, saltwater aging tank, cold shock chest and dry heat oven were the same ones used for the factorial matrix. Data obtained from the ALT are shown in APPENDIX B.

Resistance readings were made on the connectors in test until flooding of the connector occurred. Resistance readings were found to decrease before flooding occurred and the leakage probe showing the lowest resistance was used to identify the failed bond. Leakage was confirmed by visual bond inspection and in some cases by dissecting the connector after a penetrant dye was applied.

TABLE 9

SCREENING TEST PLAN

CYCLE*	DESCRIPTION	CYCLE	DESCRIPTION
1	Pressure cycle**	11	Saltwater, 70°C, 64 Hrs.
2	Fresh water, 25°C, 7 days Pressure cycle		Dry cold, -78°C, 1 Hr. Dry heat, 70°C, 7 Hrs.
3	Fresh water, 25°C, 7 days Pressure cycle		Saltwater, 70°C, 16 Hrs. Fresh water, 25°C, 8 Hrs.
4	Saltwater, 60°C, 60 Hrs. Pressure cycle		Pressure cycle
5	Dry cold, -78°C, 160 Hrs. Pressure cycle		Saltwater, 70°C, 64
6	Saltwater, 70°C, 60 Hrs. Pressure cycle		Dry cold, -78°C, 1 Hr. Dry heat, 70°C, 7 Hrs.
7	Saltwater, 88°C, 24 Hrs. Pressure cycle	12	Saltwater, 70°C, 64 Hrs.
8	Saltwater, 88°C, 168 Hrs. Pressure cycle		Dry cold, -78°C, 1 Hr. Dry heat, 70°C, 7 Hrs.
9	Saltwater, 70°C, 168 Hrs. Pressure cycle		Saltwater, 70°C, 16 Hrs.
10	Saltwater, 70°C, 168 Hrs. Pressure cycle		Fresh water, 25°C, 8 Hrs. Pressure cycle

* Each test cycle is terminated by a set of insulation resistance measurements.

** Pressure Cycle = 0-690 kPa and Hold for 5 Min.
0-690 kPa and Hold for 5 Min.
0-690 kPa and Hold for 5 Min.
0-13.8 MPa and Hold for 2 Hrs.

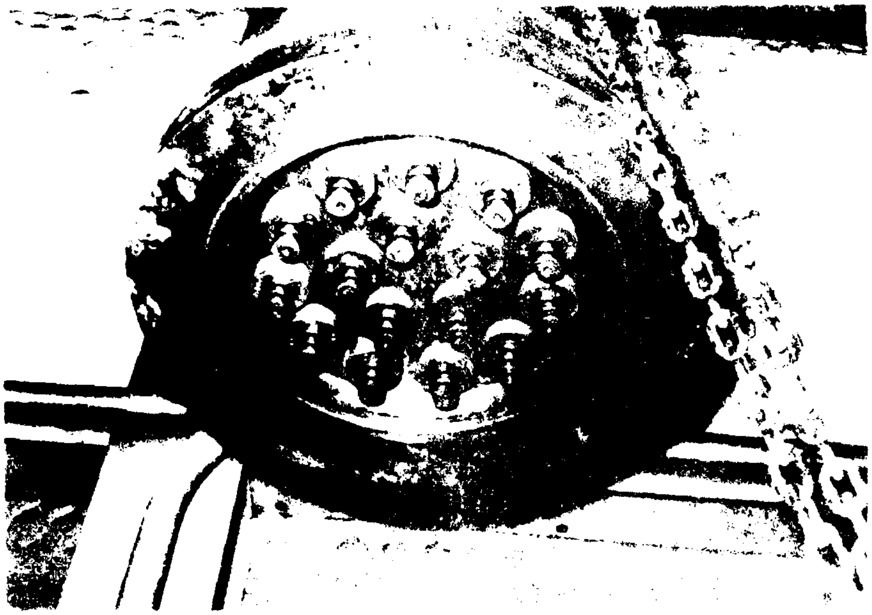

FIGURE 1[illegible]. Pressure case connector fittings

TABLE 10
ACCELERATED LIFE TEST PLAN

Exposure	Time, Hrs.	Temp, °C	Conditions
1	64	70	sea water soak
2	1	-78	dry cold
3	7	70	dry heat
4	16	70	sea water soak
5A*	8	25	fresh water and pressure cycle
5B*		70	sea water soak
6	16	70	sea water soak
7A*	8	70	sea water soak
7B*		25	fresh water and pressure cycle
8	40	70	sea water soak
9	1	-78	dry cold
10	7	70	dry heat
TOTAL	168		

Repeat cycle.

*Order reversed for one half of the connectors.

TEST RESULTS

Factorial Matrix

The factorial matrix containing 32 connectors, as shown in TABLE 1, was tested for the 12 cycles listed in TABLE 9, and the connectors surviving at the conclusion of the test are summarized in TABLE 11.

Fifty-three percent of the connectors had leaked by the test conclusion. In TABLE 12 the number of test cycles to failure for each connector is listed and a comparison is made between variables by summing the total survival time of each variable and calculating the mean number of cycles to failure. This weighted performance is tabulated in TABLE 13.

Inspection of TABLE 13 suggests that neoprene is superior to polyurethane in this application. Also the Band-It Preform and Scru-Lokt type clamps seem to offer some advantage. The reader is cautioned to avoid trying to draw more subtle conclusions from TABLE 13. One must remember that the figures of merit (mean cycles-to-failure estimators) displayed in the table are distributed random variables, i.e., repetition of the entire experiment would yield different results. Ideally, appropriate dispersion measures should be associated with the TABLE 13 entries. Calculating dispersion data for the cable and connector factorial experiment is complicated because not all the loading cycles are of the same severity and the raw cycles-to-failure data have not been cataloged by specific distributional type. To roughly fill this gap we might imagine that the cycles to failure in a particular category are normally distributed. In this case (wearout model) the fractional uncertainties of the mean-cycleto-failure entries of TABLE 6 would equal $r^{-1/2}$ where r is the observed number of failures in the categories of interest. If the random hazard or exponential model is actually more appropriate, these dispersion measures would be somewhat different and based on the ^{2} distribution.

As a result of the factorial analysis the following became the preferred construction.

- BAND-IT Preform or Scru-Lokt
- Unshielded or shielded cable
- Neoprene elastomer
- Bonded interface

For a final selection of clamp, Band-It Preform was picked because preassembly was not required. Since shielded cable is used in fleet service to a much greater extent than unshielded cable, the shielded type was selected. Band-It Preform clamp and MIL-C-915/8E, DSS-3 cable were used for manufacturing the remaining test connectors.

Reviewing the results of the matrix test, it is noted that seven of eight neoprene connectors made without adhesive survived the test sequence, and only one of the eight similarly made polyurethane connectors survived.

TABLE 11
FACTORIAL MATRIX
TEST RESULTS

NUMBER OF CONNECTORS SURVIVING

	NEOPRENE (16)	POLYURETHANE (16)	TOTAL (32)
CLAMPED (24)	11 (92%)	3 (25%)	14 (58%)
NOT CLAMPED (8)	2 (50%)	1 (25%)	3 (37%)
SHIELDED (16)	5 (62%)	2 (25%)	7 (44%)
UNSHIELDED (16)	8 (100%)	2 (25%)	10 (62%)
BONDED (16)	6 (75%)	3 (37%)	9 (56%)
NOT BONDED (16)	7 (87%)	1 (12%)	8 (50%)
OVERALL SURVIVING	31 (81%)	4 (25%)	17 (53%)

TABLE 12

FACTORIAL MATRIX, NUMBER OF CYCLES TO FAILURE

		POLYURETHANE		NEOPRENE	
		BONDED	NOT BONDED	BONDED	NOT BONDED
NOT CLAMPED	SHIELDED	+	4	12	12
	NOT SHIELDED	8	7	+	+
OETIKER	SHIELDED	8	6	3	+
	NOT SHIELDED	11	4	+	+
BAND-IT PREFORM	SHIELDED	+	7	+	+
	NOT SHIELDED	+	8	+	+
BAND-IT SCRU-LOKT	SHIELDED	11	1	+	+
	NOT SHIELDED	7	+	+	+

NOTE: + = Did Not Fail in 13 cycles

TABLE 13

NUMERICAL COMPARISON OF FACTORIAL EXPERIMENT RESULTS

ATTRIBUTE	TYPE	CUMULATIVE EXPOSURE (CYCLES)*	NUMBER OF FAILURES	MEAN CYCLES TO FAILURE**
CLAMPING MODE	NONE	82	5	16
	OETIKER	71	5	14
	PREFORM	93	2	47
	SCRU-LOKT	84	3	28
CABLE TYPE	SHIELDED	155	9	17
	UNSHIELDED	175	6	29
BOOT ELASTOMER	POLYURETHANE	137	12	11
	NEOPRENE	196	3	65
BONDING	BONDED	177	7	25
	NOT BONDED	153	8	19

*Total Number of cycles experienced up until failure of each of the connectors having that attribute.

**"Cumulative Exposure" divided by "Number of Failures."

These data indicate that the pressure qualification tests required by MIL-C-24231 do not assure bond quality in a connector and that factors other than bond quality may greatly influence the leakage characteristics of connectors.

Analysis of the failed connectors was made by visual inspection followed by dye penetrant inspection after which each unit was dissected to confirm leakage paths. The failure analyses are tabulated in TABLES 14A and 14B. It should be noted that a high number of cable bond failures were observed and failures at the cable/boot interface are not generally reported from the fleet. Apparently, the high stress levels used in the screening test activated this failure mode and accelerated the observation leakage at the cable much more rapidly than observed leakage in normal service.

Clamp Efficiency

The ALT of TABLE 10 was used to test 32 control connectors and 32 test connectors. The construction as determined was:

Preferred Connector: Bonded Neoprene, Joy No. 319,735-8
Band-It Preform Clamp
MIL-C-915/8E, DSS-3 shielded cable

Control Connector: Bonded Polyurethane, PR-1547
No Clamp
MIL-C-915/8E, DSS-3 shielded cable

The ALT was terminated after 32 weeks of testing and after four clamped neoprene connectors and eighteen polyurethane control connectors had failed by flooding. All failed connectors were analyzed visually and leakage was confirmed using a dye penetrant. The results of failure analyses are shown in TABLE 15A and 15B and the data summarized into categorizes of identified failures in TABLE 16.

Resistance measurements were made on each connector during the pressure cycles, exposures 5A and 7B on TABLE 10, and the data obtained are shown in APPENDIX B.

TABLE 14A

FAILURE ANALYSIS, FACTORIAL MATRIX

CONNECTOR NO.	CONSTRUCTION	CYCLE FAILED	ANALYSIS
11	Bonded Neoprene Shielded Oetiker	3	"O" Ring leakage. Bonds intact.
2	Not Bonded Polyurethane Shielded No Clamp	4	Leakage at cable/boot interface.
14	Not Bonded Polyurethane Unshielded Oetiker	4	Leakage at cable/boot interface.
10	Not Bonded Polyurethane Shielded Oetiker	5	Boot crimped by the clamp at cable interface. Leakage at cable/boot interface.
26	Not Bonded Polyurethane Shielded Scru-Lokt	5	Leakage at cable/boot interface
6	Not Bonded Polyurethane Unshielded No Clamp	7	Leakage at cable/boot interface.
18	Not Bonded Polyurethane Unshielded Preform	7	Crack developed in boot starting at the cable Leakage at cable/boot interface.
29	Bonded Polyurethane Unshielded Scru-Lokt	7	Leakage at cable/boot interface.
5	Not Bonded Polyurethane Unshielded No Clamp	8	Crack developed in boot. Leakage at cable/boot interface.

TABLE 14B

FAILURE ANALYSIS, FACTORIAL MATRIX

CONNECTOR NO.	CONSTRUCTION	CYCLE FAILED	ANALYSIS
9	Bonded Polyurethane Shielded Oetiker	8	Crack developed in boot. Leakage at cable/boot interface.
22	Not Bonded Polyurethane Unshielded Preform	8	Leakage at cable/boot interface.
25	Bonded Polyurethane Shielded Scru-Lokt	11	Leakage at cable/boot interface.
13	Bonded Polyurethane Unshielded Oetiker	11	Leakage at cable/boot interface.
3	Bonded Neoprene Shielded No Clamp	12	Cable failed, leakage through jacket. No bond failure.
4	Not Bonded Neoprene Shielded No Clamp	12	Leakage at cable/boot interface.

TABLE 15A

ALT CONNECTOR FAILURE ANALYSIS

CONNECTOR NO.	CONSTRUCTION	CYCLE FAILED	ANALYSIS
2	Neoprene one clamp	1	Manufacturing defect
29	Polyurethane control	1	Manufacturing defect
14	Polyurethane control	4	Bond failure at sleeve
24	Polyurethane control	8	Mechanical failure cracked during cold cycle due to handling
13	Polyurethane control	9	Bond failure at cable
32	Polyurethane control	11	Bond failure at sleeve
26	Polyurethane control	18	Bond failure at cable
9	Neoprene one clamp	21	Bond failure at cable
13	Neoprene one clamp	21	Bond failure at sleeve
3	Polyurethane control	22	Bond failure at sleeve
5	Polyurethane control	22	Mechanical failure, boot cracked
19	Polyurethane control	22	Bond failure at sleeve
8	Neoprene one clamp	23	Bond failure at sleeve

TABLE 15B

ALT CONNECTOR FAILURE ANALYSIS

CONNECTOR NO.	CONSTRUCTION	CYCLE FAILED	ANALYSIS
7	Polyurethane control	28	Bond failure at sleeve
18	Polyurethane control	29	Bond failure at cable and sleeve
28	Polyurethane control	29	Bond failure at cable and sleeve
20	Polyurethane control	29	Bond failure at cable and sleeve
2	Polyurethane control	31	Bond failure at sleeve
4	Polyurethane control	31	Bond failure at sleeve
10	Polyurethane control	31	Bond failure at sleeve
8	Polyurethane control	32	Bond failure at sleeve
17	Polyurethane control	32	Bond failure at sleeve

TABLE 16

ALT FAILURE ANALYSIS SUMMARY

ANALYSIS OF FAILU[illegible]	NUMBER OF FAILURES	
	UNCLAMPED POLYURETHANE	CLAMPED NEOPRENE
Manufacturing Defect	1	1
Mechanical Failure	2	0
Bond Failure, Sleeve Only	10	2
Bond Failure, Cable Only	2	1
Bond Failure, Both Cable and Sleeve	3	0
TOTAL	18	4

APPENDIX A

TEST DATA FACTORIAL MATRIX

TABLE 1
APPENDIX A
FACTORIAL MATRIX RESISTANCE DATA

Resistance Reading*

NO.		TYPE		PATH	CYC 1	CYC 2	CYC 3	CYC 4	CYC 5	CYC 6	CYC 7	CYC 8	CYC 9	CYC 10	CYC 11	PATH	CYC 12
1	No	DSS-3	PU-G	C	---	---	---	1G	---	6G	2G	2M	3M	4M	5M	C	2M
	Clamp			B	---	---	---	1.5G	---	---	---	---	---	---	---	B	---
2			PU-U	C	2G	2.5M	(Flooded	2M	X							C	
				B	---	---	"O" ring)	Cont								B	
3			N-G	C	---	---	---	1G	---	9G	1.5G	70M	70M	70M	60M	C	X
				B	---	---	---	1.5G	---	---	---	---	---	---	---	B	
4			N-U	C	100M	800M	1G	500M	2G	2G	1G	100M	100M	50M	50M	C	X
				B	---	---	---	1.5G	---	8G	---	---	---	8G	---	B	
5		DSU-3	PU-G	C	---	---	---	1.5G	---	---	---	1M	X			C	
				B	---	2G	---	1.5G	---	---	---	Cont				B	
6			PU-U	C	---	---	600K	---	800M	300M	X	X				C	
				B	1G	---	Cont	---	---	300M						B	
7			N-G	C	1G	600M	---	600M	2G	2G	1.5G	2G	2.5G	2G	2G	C	2G
				B	---	300M	---	1.5G	---	---	---	8G	---	---	---	B	6G
8			N-U	C	2M	500M	1G	600M	2G	2G	1.5G	1M	200K	200K	10M	C	10M
				B	---	1G	---	1.5G	---	---	---	---	---	---	---	B	---
9	OETIKER	DSS-3	PU-G	C	3G	2G	N/T	300M	---	2G	200M	Cont	X			C	
				B	---	1.5G	N/T	1.5G	---	---	---	Cont				B	
10			PU-U	C	---	1.7G	3G	1M	Cont	X						C	
				B	---	2G	---	Cont	Cont							B	
11			N-G	C	---	7G	Cont	X								C	
				B	---	1G	Cont									B	
12			N-U	C	300M	500M	500M	300M	2G	1.5G	900M	2M	3M	2M	5M	C	5M
				B	---	400M	---	1.5G	---	---	---	6G	---	300M	---	B	---
13		DSU-3	PU-G	C	---	---	---	1.5G	---	---	1.5G	5G	---	---	C	C	X
				B	---	---	---	1G	---	---	---	---	---	9G	C	B	
14			PU-U	C	---	600K	2M	150K	X							C	
				B	---	Cont	Cont	Cont								B	
15			N-G	C	700M	600M	500M	400M	1G	1G	1G	1G	1.5G	1.5G	1.5G	C	2G
				B	---	---	20M	1G	---	---	---	---	---	---	---	B	---
16			N-U	C	4G	5G	5G	600M	5G	3G	3G	2G	2.5G	600M	500M	C	300M
				B	---	---	---	1.5G	---	---	---	---	---	---	---	B	---

* --- = Resistance Greater than 10 Gigohm
G = Gigohm
M = Megohm
K = Kilohm

C = Cable
B = Back shell
X = Removed from test
Cont = Continuity measured

PU = Polyurethane
N = Neoprene
G = Bonded
U = Unbonded
N/T = Not tested

TABLE 2

APPENDIX A

FACTORIAL MATRIX RESISTANCE DATA

Resistance Reading*

NO.	TYPE			PATH	CYC 1	CYC 2	CYC 3	CYC 4	CYC 5	CYC 6	CYC 7	CYC 8	CYC 9	CYC 10	CYC 11	PATH	CYC 12
[illegible]	Band-It	DSS-3	PU-G	C	5G	500M		1G	5G		30M	10M	1M	1M	3M	C	3M
	Preform			B	---	1.5G		---	---		---	---	---	---	---	B	---
18			PU-U	C	9G	1.5G		2.5G	---		200K	X				C	
				B	---	1.5G		---	---		Cont					B	
19			N-G	C	800M	500M		1G	8G		80M	20M	30M	30M	20M	C	10M
				B	---	2G		---	---		---	---	---	---	---	B	---
20			N-U	C	---	1.5G		N/T	N/T		N/T	N/T	N/T	N/T	N/T	C	N/T
				B	---	2G		---	---		N/T	N/T	N/T	---	---	B	---
21		DSU-3	PU-G	C	9G	2G		6G	---		3G	500M	500M	400M	400M	C	500M
				B	---	2G		---	---		---	---	---	---	5M	B	---
22			PU-U	C	6G	2G		500M	---		8M	150K	X			C	
				B	---	2G		---	---		---	Cont				B	
23			N-G	C	1.5G	700M		1G	---		1G	2G	2G	2G	1.5G	C	500M
				B	---	2G		---	1G		---	---	---	---	---	B	---
24			N-U	C	6G	1G		3G	3G		3G	3G	2G	500M	200M	C	50M
				B	---	2G		---	---		---	---	--	---	---	B	---
25	Band-It	DSS-3	PU-G	C	Cont	Cont		Cont	N/T		N/T	300M	50M	2M	[illegible]	C	X
	SCPU-LOCT			B	---	---		---	N/T		N/T	---	Cont	10M	1G	B	
26			PU-U	C	Cont	Cont		Cont	Cont		X					C	
				B	Cont	Cont		Cont	Cont							B	
27			N-G	C	7G	2G		8G	---		1G	100M	400M	300M	200M	C	200M
				B	---	2G		---	---		---	---	---	---	150M	B	---
28			N-U	C	1.5	1G		5G	1G		1.5G	80M	40M	20M	20M	C	50M
				B	---	2G		---	---		---	---	---	---		B	---
29		DSU-3	PU-G	C	2G	1G		1.5G	3G		3M	X				C	
				B	9G	1G		---	---		Cont					B	
30			PU-U	C	3G	3M		1.5G	5G		5M	10M	50M	5M	60M	C	60M
				B	---	2G		---	1G		---	---	---	1M	5M	B	---
31			N-G	C	1G	500M		1G	1G		1G	500M	300M	4M	---	C	---
				B	7G	30M		---	---		---	---	---	Cont	---	B	---
32			N-U	C	2G	800M		1G	2G		N/T	3G	3G	2G	2M	C	7G
				B	7G	1.5G		---	---		---	---	---	8G	---	B	---

* --- = Resistance Greater than 10 Gigohm
G = Gigohm
M = Megohm
K = Kilohm

C = Cable
B = Back Shell
X = Removed from test
Cont = Continuous reading

PU = Polyurethane
N = Neoprene
G = Bonded
U = Unbonded
N/T = Not tested

APPENDIX B

TEST DATA ACCELERATED LIFE TEST

Legend for the Following Tables

Resistance in Gigohms except:

-- = Resistance greater than 10 Gigohms
M = Megohms
K = Kilohms
C = Continuity measured
X = Removed from test
N/R = Not read

Path Notation:

C = Cable bond
B = Backshell bond

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TABLE 1

ALT SUMMARY - NEOPRENE CONNECTORS

Resistance Readings

No.	Path	CYC 1	2	3	4	5	6	7	8	9	10	11	12
1	C	6	700M	400M	600M	300M	300M	200M	200M	100M	100M	90M	70M
	B	N/R	5	10M	500M	1	--	--	--	--	--	--	4
2	C	X											
	B	X											
3	C	3	150M	500M	400M	60M	--	N/R	15M	10M	10M	10M	8M
	B	--	5	600M	1	--	--	--	--	--	--	--	3
4	C	3	1 M	1	1	200M	50M	30M	20M	6M	5M	4M	3M
	B	--	6	6	--	--	--	--	4	--	--	--	4
5	C	3	150M	1	800M	500M	300M	250M	300M	200M	250M	30M	30M
	B	--	5	15M	--	--	--	--	--	--	1.5	--	5
6	C	20M	3M	800M	800M	200M	150M	100M	100M	70M	65M	60M	N/R
	B	--	5	2M	2	--	--	--	--	--	--	--	6
7	C	3	3M	150M	70M	30M	20M	15M	15M	10M	9M	5M	7M
	B	--	5	100M	--	--	--	--	--	--	N/R	--	5
8	C	3	1	1	1	600M	500M	500M	400M	300M	300M	300M	200M
	B	--	6	700M	--	N/R	--	--	--	150M	N/R	N/R	3
9	C	1	1	1	1	300M	30M	10M	10M	9M	8M	8M	10M
	B	--	4	--	--	--	--	--	7	1	--	--	5
10	C	3	5M	800M	1	200M	150M	150M	100M	90M	80M	75M	60M
	B	--	4	200M	--	--	--	--	--	--	--	--	5
11	C	3	2	700M	--	800M	1	1	1	700M	500M	250M	150M
	B	--	3	70M	--	--	--	--	--	--	--	--	--
12	C	3	3M	30M	1	800M	700M	700M	700M	600M	700M	1	500M
	B	--	4	150M	--	--	--	--	--	--	--	--	--
13	C	3	2M	200M	1	800M	700M	500M	300M	150M	100M	60M	60K
	B	--	3	N/R	--	--	N/R	--	--	--	--	N/R	C
14	C	3	1	1	600M	200M	100M	80M	70M	50M	40M	30M	20M
	B	--	5	--	--	--	--	--	--	--	--	--	--
15	C	3	1	800M	1	700M	700M	700M	600M	500M	400M	300M	300M
	B	--	6	100M	--	--	3	--	--	--	--	--	--
16	C	N/R	600M	700M	1	600M	500M	800M	1	700M	600M	1	500M
	B	N/R	3	500M	--	--	--	--	--	--	--	--	1M

TABLE 2

ALT SUMMARY - NEOPRENE CONNECTORS

Resistance Readings

No.	Path	CYC 1	2	3	4	5	6	7	8	9	10	11	12
17	C	2	1	600M	700M	400M	400M	500M	500M	500M	500M	400M	500M
	B	--	4	800M	5M	C	1M	--	2	8M	100M	--	--
18	C	2	1	1	1	--	300M	200M	60M	400M	100M	20M	250M
	B	--	5	5	N/R	10M	--	--	100M	--	10M	--	--
19	C	5	1	1	1	600M	400M	200M	300M	400M	200M	200M	200M
	B	--	5	--	--	--	--	--	500M	5M	--	1	--
20	C	5	600M	600M	400K	300M	150M	100M	60M	600M	50M	30M	30M
	B	--	5	2	10M	200M	300M	--	--	3M	15M	1.5	20M
21	C	--	--	--	300M	150M	150M	150M	150M	50M	1M	1M	30M
	B	--	7	3	7M	--	--	--	3M	400M	2M	--	1M
22	C	--	800M	800M	300M	700M	700M	300M	300M	250M	100M	80M	70M
	B	--	6	200M	N/R	--	2M	--	--	200M	60M	--	70M
23	C	--	1	500M	20M	5M	4M	10M	1.5M	1M	5M	600K	1M
	B	--	4	--	15M	10M	10M	--	300M	3M	1	C	700M
24	C	5	900M	1	1	1	200M	100M	500M	500M	300M	200M	90M
	B	N/R	3	--	20M	--	200M	--	1.5M	20M	1	--	80M
25	C	2	500M	400M	500M	300M	150M	150M	100M	90M	65M	50M	40M
	B	--	3	--	100M	10M	1.5	--	300M	1	100M	2	--
26	C	2	400M	500M	600M	200M	90M	100M	80M	100M	60M	50M	50M
	B	--	3	--	--	6M	--	--	1	--	40M	--	5
27	C	2	500M	700M	800M	200M	100M	40M	60M	65M	70M	50M	40M
	B	5	4	--	5	--	--	--	--	--	--	200M	1
28	C	--	2	1	1	800M	1	800M	1	1.5	1.5	1.5	1.5
	B	--	5	100M	--	C	--	--	--	2	1	500M	500M
29	C	--	1	800M	1	700M	400M	300m	150M	100M	80M	70M	10M
	B	--	3	5M	20M	30M	2	1	3	--	--	700M	800M
30	C	--	600M	700M	800M	100M	70M	80M	40M	30M	20M	20m	20M
	B	--	4	50M	300M	--	2	N/R	50M	20M	10M	--	--
31	C	--	1	700M	20M	300M	100M	200M	70M	70M	50M	40M	5M
	B	--	4	--	5	1M	N/R	--	200M	--	4	--	--
32	C	--	50M	10M	3	2	1.5	2	2	2	2	1.5	20M
	B	7	5	N/R	150M	400M	1	--	--	--	--	--	2

TABLE 3

ALT SUMMARY - NEOPRENE CONNECTORS

Resistance Readings

No.	Path	CYC 13	14	15	16	17	18	19	20	21	22	23
1	C	30M	50M	5	30M	30M	20M	15M	15M	20M	40M	30M
	B	--	700M	40M	--	--	--	700M	--	--	1	--
2	C											
	B											
3	C	7M	7M	6M	4M	7M	6M	N/R	N/R	N/R	7M	1
	B	--	1	3	2	4	--	100K	80M	--	30M	1M
4	C	3M	5M	5M	10M	4M	N/R	N/R	N/R	5M	5M	5M
	B	--	1	1.5	--	3	--	C	100K	--	1.5	5
5	C	4M	5M	5M	150M	5M	5M	500K	400K	5M	5M	5M
	B	--	700M	1.5	--	--	C	C	1M	--	3	400M
6	C	15M	50M	50M	50M	40M	30M	1M	1M	25M	30M	N/R
	B	--	1	500M	--	2	--	C	10K	--	500M	5
7	C	10M	9M	9M	70M	9M	10M	100K	1M	10M	10M	60K
	B	--	1	1.5	1M	N/R	100M	C	1M	300M	15M	C
8	C	200M	150M	100M	150M	100M	100M	80M	100M	500M	400M	80M
	B	--	1	2	500M	N/R	--	C	100K	4M	5M	8
9	C	N/R	9M	C	C	1M	8M	200K	1M	C	X	
	B	N/R	750M	2	--	--	--	100K	70M	--	X	
10	C	60M	70M	65M	70M	70M	6M	1	1M	60M	7M	60M
	B	--	800M	5M	700M	--	7	C	200M	--	10M	--
11	C	150M	75M	75M	100M	80M	50M	1M	1M	50M	50M	50M
	B	--	850M	3M	2	--	--	C	300M	--	1	--
12	C	1	500M	550M	1	1	1	2M	50M	1.5	600M	1.5
	B	--	1	1.5	1	3	--	70K	2M	--	2	--
13	C	200K	10M	40M	15M	200K	20M	100K	100K	80K	X	
	B	N/R	C	C	--	C	4	100K	1.5M	C	X	
14	C	15M	25M	25M	20M	25M	5M	500K	1M	10M	25M	25M
	B	--	900M	20M	--	--	10M	80K	1	--	1	--
15	C	500M	200M	350M	40M	400M	200M	300M	500M	300M	200M	300M
	B	--	800M	500M	--	1	--	N/R	--	--	3	--
16	C	700M	500M	300M	1	1	800M	C	C	1	150M	--
	B	--	1	1.5	-	10M	--	C	10M	50M	2M	5

TABLE 4

ALT SUMMARY - NEOPRENE CONNECTORS

Resistance Readings

No.	Path	CYC 13	14	15	16	17	18	19	20	21	22	23
17	C	400M	400M		100M	700M	200M	100M	50M	10M	400M	5M
	B	--	20M	S	2	50M	5	10M	--	100M	C	--
18	C	500M	125M	Y	50M	150M	50M	N/R	N/R	N/R	100M	70M
	B	--	150M	S	--	20M	7	4M	5M	20M	6M	--
19	C	100M	125M	T	70M	200M	50M	10M	1.5M	10M	150M	1M
	B	--	1	E	--	20M	--	C	1M	30M	9M	10M
20	C	20M	25M	M	10M	25M	1M	20M	1M	1M	20M	1M
	B	2	2		70M	70M	5	15M	2M	--	800M	--
21	C	10M	1M	M	10M	1.5M	1M	1M	100K	1M	1M	1M
	B	200M	2	A	700M	500M	800M	70M	800M	2	30M	700M
22	C	50M	60M	I	50M	50M	70M	50M	30M	10M	40M	10M
	B	150M	5M	N	100M	40M	300M	20M	200M	1.5M	5M	3
23	C	1M	1M	T	1M	1.5M	2M	1.5M	1.5M	1M	1.5M	1M
	B	100M	2	A	500M	C	30M	C	100K	1M	C	2
24	C	100M	100M	I	70M	200M	30M	150M	40M	50M	150M	100M
	B	10M	2	N	3	400M	20M	100M	C	10M	150M	--
25	C	1M	--	A	50M	30M	10M	20M	1M	1M	20M	5M
	B	N/R	1	N	--	10M	20M	500M	C	--	10M	--
26	C	50M	500M	C	20M	50M	1.5M	50M	30M	30M	80M	1M
	B	--	40M	E	--	100M	100K	3M	800M	700M	700M	1
27	C	20M	60M		100M	60M	100M	60M	40M	50M	1	30M
	B	1	10M	N	--	50M	2M	80M	300M	1	30M	10M
28	C	1	800M	O	1	2	1	1.5	1	800M	600M	500M
	B	--	500M		2	300M	100M	50M	C	100K	50M	1M
29	C	20M	350K	R	1M	60M	40M	40M	20M	1M	40M	10M
	B	N/R	C	E	--	500M	70M	25M	500M	80M	150M	--
30	C	20M	50M	A	20M	50M	20M	15M	20M	25M	50M	5M
	B	--	2	D	1.5M	150M	--	10M	--	500M	50K	4M
31	C	30M	50M	I	15M	50M	10M	60M	10M	30M	40M	10M
	B	--	150M	N	--	60M	30M	70M	1	2	40M	N/R
32	C	100M	900M	G	70M	N/R	N/R	N/R	N/R	N/R	600M	1
	B	--	2	S	30M	100K	--	C	100K	--	1M	100K

TABLE 5

ALT SUMMARY - NEOPRENE CONNECTORS

No.	Path	24	25	26	27	28	29	30	31	32
		Resistance Readings								
1	C	40M	50M	100M	30MM	10MM	5M	30M	100M	35M
	B	--	5	--	--	--	--	1M	--	--
2	C									
	B									
3	C	--	8M	50M	8M	5M	1M	6M	20M	--
	B	--	--	--	--	--	--	--	2	--
4	C	N/R	N/R	10M	5	10M	100M	70M	100M	--
	B	--	70M	--	--	70M	100M	5	--	6
5	C	--	N/R	1M	7M	3M	1M	2M	1M	3M
	B	--	500K	--	400K	--	--	20M	--	--
6	C	50M	40M	100M	40M	40M	40M	80M	100M	150M
	B	--	100M	1	--	--	--	800M	25M	--
7	C	10M	100K	1M	50M	30M	20M	20M	20M	N/R
	B	C	C	800M	--	--	--	2	--	50M
8	C	100M	10M	10M	5	5M	3M	1M	200K	C
	B	--	50M	--	700M	1M	40M	--	1M	C
9	C									
	B									
10	C	55M	50M	5M	50M	1M	2M	100M	300M	40M
	B	30M	500M	30M	--	30M	5	--	800M	--
11	C	3	N/R	20M	100M	20M	N/R	10M	500M	70M
	B	--	4M	--	--	--	3	10M	--	--
12	C	1.5	1.5	70M	2	800M	1	1	10M	2
	B	--	--	N/R	--	--	--	70M	30M	--
13	C									
	B									
14	C	25M	30M	1M	25M	10M	5M	500M	1	3
	B	--	--	700M	--	80M	--	100K	--	--
15	C	200M	200M	200M	150M	150M	70M	50M	80M	150M
	B	--	8	--	--	7M	N/R	C	--	--
16	C	N/R	N/R	700M	3	700M	500M	1	1.5	6
	B	--	1M	--	--	100M	1	30M	--	500M

TABLE 6

ALT SUMMARY - NEOPRENE CONNECTORS

Resistance Readings

No.	Path	24	25	26	27	28	29	30	31	32
17	C	10M	600M	100M	70M	100M	90M	100M	80M	600M
	B	--	10M	--	3M	--	2M	--	C	1
18	C	30M	150M	30M	50M	100K	50K	50M	30M	100M
	B	--	30M	--	1M	2M	--	--	--	500M
19	C	2M	200M	5M	2M	1M	1M	1M	2M	3M
	B	--	N/R	80M	10M	--	5M	--	--	60M
20	C	5M	20M	3M	1.5M	5M	5M	10M	5M	60M
	B	--	15M	100M	1M	--	--	2M	1	--
21	C	1M	1.5M	1M	3M	1M	1M	2M	1M	1M
	B	--	300K	100M	2M	2	5	20M	30M	8
22	C	20M	50M	50M	100M	100M	70M	50M	40M	40M
	B	--	3M	10M	--	--	--	--	--	--
23	C	1M	1.5M	3M	1M	1M	1M	1M	1M	2M
	B	--	80M	2	1	5	10M	100M	--	2
24	C	30M	100M	50M	5M	1M	100K	1M	2M	3M
	B	1M	20M	--	5	10M	1M	--	5	15M
25	C	1M	20M	1M	1M	1M	5M	20M	10M	20M
	B	200M	1.5	5	--	--	--	--	1M	7-
26	C	5M	100M	1M	10M	3M	5M	10M	150M	90M
	B	5	--	300M	10M	--	300K	200M	80M	50M
27	C	30M	70M	1M	8M	2M	1M	2M	5M	15M
	B	--	10M	C	C	80M	C	700M	--	100M
28	C	700M	800M	500M	40M	50M	70M	100M	5M	500M
	B	30M	5	700M	30M	100K	--	1	30M	200M
29	C	3M	500M	50M	50M	70M	10M	2	50M	70M
	B	100K	C	1	100K	--	--	800M	1	--
30	C	20M	50M	50M	50M	15M	3M	20M	100M	40M
	B	2M	10M	--	2	700M	1M	50M	--	--
31	C	20M	--	100M	80M	1M	1M	50M	20M	30M
	B	--	15M	50M	700M	--	--	--	--	--
32	C	800M	--	1.5	400M	200M	100M	300M	2M	100K
	B	50M	--	150M	600M	--	3	--	100M	--

TABLE 7

ALT SUMMARY - POLYURETHANE CONNECTORS

Resistance Readings

No.	Path	CYC 1	2	3	4	5	6	7	8	9	10	11	12
1	C	--	5	2	800M	1	1	1	1	600M	300M	15M	500M
	B	--	5	--	6	--	200M	5	--	4	6	C	--
2	C	--	300M	500M	400M	300M	200M	200M	150M	150M	100M	70M	N/R
	B	--	6	700M	1	--	--	4	2	5	200M	40M	--
3	C	--	4	400M	600M	700M	700M	600M	600M	500M	600M	600M	500M
	B	--	8	--	1	--	--	--	--	2	--	C	--
4	C	--	4	1.5	800M	1.5	1	800M	1	700M	800M	1.5M	500M
	B	--	3	--	1	--	2	--	5	3	--	6M	--
5	C	--	3	2	800M	1.5	1	800M	1	600M	700M	600M	400M
	B	--	2	10M	1	--	3	--	--	5	--	600M	--
6	C	--	4	2	600M	700M	200M	700M	700M	400M	500M	200M	500M
	B	--	6	2M	1	--	N/R	--	--	3	--	--	--
7	C	--	5	3	800M	2	300M	1.5	2	1	1	40M	700M
	B	--	5	--	1	--	10M	--	--	4	N/R	C	--
8	C	--	4	2	700M	1	1	1	1.5	700M	1	200M	100M
	B	--	3	--	1	--	--	--	--	1.5	--	C	--
9	C	--	4	2	800M	80M	1.5	1.5	1	700M	1	3M	400M
	B	--	4	--	1	--	300M	--	--	C	--	C	--
10	C	--	5	200M	800M	1.5	1	1	1.5	700M	400M	200M	40M
	B	--	4	--	1	--	2	1.5	--	30M	2	--	--
11	C	--	5	2	800M	1.5	1.5	1	1.5	700M	1	800M	700M
	B	--	4	--	1	--	--	--	--	4	--	--	--
12	C	--	4	2	800M	1.5	1.5	1	1	800M	1	800M	800M
	B	--	3	1	1	--	N/R	--	--	300M	--	5M	--
13	C	--	4	2	800M	1.5	1	1	1.5	C	X		
	B	--	2	15M	1	--	10M	--	--	C	X		
14	C	--	4	1.5	600M	20M	X						
	B	--	6	--	C	C	X						
15	C	--	3	300M	200M	300M	200M	150M	200M	150M	150M	5M	4M
	B	--	C	300M	1	600M	N/R	--	600M	2	--	C	C
16	C	--	4	1	800M	2	300M	500M	600M	250M	400M	300M	200M
	B	--	3	--	1	200M	100M	--	5	1	--	--	--

TABLE 8

ALT SUMMARY - POLYURETHANE CONNECTORS

Resistance Readings

No.	Path	CYC 1	2	3	4	5	6	7	8	9	10	11	12
17	C	--	4	300M	100M	600M	10M	150M	50M	10M	40M	20M	30M
	B	--	4	--	1	15M	10M	--	200M	100k	3	3M	5
18	C	3	1	100M	90M	600M	40M	40M	30M	25M	N/R	15M	2M
	B	--	5	4	1	--	--	--	--	2	--	--	80k
19	C	--	2.5	1	800M	500M	400M	400M	400M	300M	300M	300M	400M
	B	--	5	--	1	--	--	--	--	C	5	300M	--
20	C	--	4	2	700M	1	1	1	600M	400M	500M	400M	500M
	B	--	6	--	1	200M	50M	1	1	30M	N/R	500M	--
21	C	--	4	2.5	800M	1.5	1	1.5	1	500M	1	N/R	N/R
	B	--	--	100M	1	--	--	--	1M	1.5	4	N/R	--
22	C	--	4	2	800M	7	1	1	1	600M	800M	600M	700M
	B	--	4	1M	1	5	1	--	6	1M	--	1	--
23	C	--	8	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	B	--	3	--	1	50M	10M	--	15M	20M	N/R	10M	--
24	C	--	3	1	600M	1	1	800M	X				
	B	--	3	--	1	C	700M	--	X				
25	C	--	2	1.5	600M	600M	50M	100M	800M	50M	N/R	4M	200M
	B	--	3	6	1	--	30M	--	1M	1M	--	C	--
26	C	--	2.5	2.5	700M	1	1	2	50M	500M	1	5M	600M
	B	--	4	--	1	--	--	2	7M	30M	--	C	4
27	C	--	4	4	700M	1.5	1.5	2	1	600M	1	500M	N/R
	B	--	3	--	1	--	100M	--	500M	10M	5	C	C
28	C	--	3	1.5	1	3	2	1	2	1	2	800M	1.5
	B	--	7	100M	1	3	--	--	--	200M	20M	10M	N/R
29	C	C	C	X									
	B	--	C	X									
30	C	--	1.5	1.5	600M	600M	1	800M	600M	500M	N/R	500M	600M
	B	--	2	--	1	1.5	--	--	C	500M	N/R	20M	--
31	C	--	3	2	700M	1	20M	20M	700M	N/R	N/R	--	N/R
	B	--	3	200M	1	C	--	--	10M	20M	N/R	--	C
32	C	N/R	2	2	700M	1	800M	500M	10M	70M	700M	C	X
	B	N/R	3	2	1	500M	1	--	2M	100M	1	C	X

TABLE 9

ALT SUMMARY - POLYURETHANE CONNECTORS

Resistance Readings

No.	Path	CYC 13	14	15	16	17	18	19	20	21	22	23	24
1	C	500M	800M	675M	600M	600M	500M	N/R	800M	N/R	N/R	1	
	B	--	1	2	C	500M	--	4	600M	C	7	--	
2	C	N/R	N/R	N/R	N/R	100M	70M	C	100M	150M	400M	--	
	B	--	N/R	C	100M	150M	--	2	300M	--	--	2	
3	C	600M	700M	500M	600M	300M	10M	400M	400M	700M	C	X	
	B	--	800M	2	--	500M	--	1	600M	2	C	X	
4	C	600M	700M	750M	4M	300M	50M	700M	400M	30M	1	N/R	
	B	--	700M	3	50M	1	--	--	700M	500M	--	--	
5	C	600M	500M	625M	500M	400M	200M	800M	300M	1	X		
	B	--	900M	1.5	--	700M	5	C	600M	--	X		
6	C	500M	500M	500M	--	300M	300M	500M	250M	1	700M	1	
	B	--	800M	3	50M	500M	--	5	300M	7	5	--	
7	C	600M	500M	675M	10M	300M	100M	500M	200M	400M	500M	6	
	B	--	800M	3	C	400M	C	C	100M	3	--	--	
8	C	150M	300M	300M	100M	150M	100M	100M	90M	60M	150M	200M	
	B	--	25M	3	C	600M	--	3	400M	150M	--	--	
9	C	300M	500M	N/R	N/R	500M	400M	2	300M	100K	5	--	
	B	--	700M	3	C	500M	100M	2	300M	150K	--	300M	
10	C	500M	700M	600M	700M	300M	200M	10M	N/R	N/R	N/R	1	
	B	--	800M	1.5	--	200M	50M	100M	300M	--	--	--	
11	C	700M	900M	3	--	400M	400M	5M	50M	1	N/R	1.5	
	B	7M	850M	2	50M	700M	10M	300M	40M	2M	6	--	
12	C	800M	500M	1	15M	600M	700M	--	N/R	N/R	N/R	--	
	B	--	850M	2	1	50M	--	300M	300M	--	--	--	
13	C												
	B												
14	C												
	B												
15	C	6M	600M	2	N/R	30M	20M	N/R	N/R	N/R	N/R	50M	
	B	60M	700M	1	N/R	300M	--	2	300M	60M	5	--	
16	C	--	850M	2	200M	25M	100M	30M	400M	30M	N/R	N/R	
	B	--	800M	3	4	400M	70M	C	500M	N/R	N/R	--	

TABLE 10

ALT SUMMARY - POLYURETHANE CONNECTORS

Resistance Readings

No.	Patn	CYC 13	14	15	16	17	18	19	20	21	22	23	24
17	C	N/R	N/R	40M	N/R	N/R	100M	N/R	40M	30M	30M	40M	
	B	3	1	3	500M	5M	--	1.5	700M	--	15M	20M	
18	C	15M	8M	10M	2M	2M	5M	2M	N/R	N/R	N/R	15M	
	B	5	C	70M	2M	3M	--	1M	C	C	100M	150M	
19	C	300M	500M	300M	300M	300M	300M	300M	C	600M	600M	600M	
	B	100K	800M	1	8	2M	70M	40M	2	1	C	C	
20	C	500M	700M	550M	N/R	N/R	500M	N/R	N/R	N/R	N/R	N/R	
	B	B	500M	3	--	N/R	70M	50M	50M	100M	N/R	10M	
21	C	N/R	N/R	N/R	N/R	N/R	10M	50M	50M	8M	50M	N/R	
	B	--	1	2	30M	2M	--	600M	600M	1M	10M	30M	
22	C	600M	600M	725M	600M	90M	50M	800M	500M	1	1	1.5	
	B	2	500M	2	500M	100K	5	2M	400K	2M	60M	3M	
23	C	N/R	N/R	N/R	N/R	50M	30M	50M	60M	20M	30M	40M	
	B	--	1	3	1M	N/R	--	C	5M	N/R	C	100K	
24	C												
	B												
25	C	100M	250M	N/R	N/R	200M	70M	5M	500M	N/R	N/R	2	
	B	2	300M	4	--	1	--	7M	600M	10M	--	60M	
26	C	400M	250M	600M	1.5M	100M	C	X					
	B	C	5M	500M	100M	100M	C	X					
27	C	500M	600M	500M	500M	C	100K	100M	400M	700M	150M	700M	
	B	10M	C	2	80M	C	C	70M	15M	C	7M	6M	
28	C	1	900M	4	N/R	N/R	N/R	80M	600M	N/R	N/R	N/R	
	B	--	30M	4	N/R	3M	--	4M	600M	--	800M	--	
29	C												
	B												
30	C	N/R	N/R	N/R	N/R	N/R	N/R	15M	20M	1M	20M	N/R	
	B	--	50M	1	N/R	100K	--	400M	500M	C	300M	7M	
31	C	600M	600M	550M	N/R	100M	50M	20M	15M	15M	20M	15M	
	B	150M	1	1.5	1	C	20M	15M	800M	300M	600M	600M	
32	C												
	B												

TABLE 11

ALT SUMMARY - POLYURETHANE CONNECTORS

Resistance Readings

No.	Path	24	25	26	27	28	29	30	31	32
1	C	N/R	N/R	700M	1.5	600M	3	400M	100M	1
	B	--	--	--	--	--	--	--	--	8
2	C	--	--	--	--	N/R	N/R	N/R	C	X
	B	--	--	--	--	--	C	8	C	X
3	C									
	B									
4	C	N/R	N/R	50M	60M	50M	30M	40M	C	X
	B	--	--	--	--	--	--	200M	20M	X
5	C									
	B									
6	C	1	700M	650M	1.5	60M	--	N/R	5	5
	B	--	--	--	--	20M	--	--	--	40M
7	C	--	N/R	10M	C	X				
	B	C	--	--	C	X				
8	C	200M	100M	100M	--	--	N/R	N/R	300M	X
	B	--	--	--	--	--	--	--	--	X
9	C	N/R	N/R	15M	5M	20M	5M	15M	8M	15M
	B	--	--	--	5M	--	50M	--	7M	--
10	C	--	N/R	3	--	4	600M	250M	1M	X
	B	--	--	--	--	--	--	5	C	X
11	C	4	1	1	2	900M	N/R	N/R	20M	20M
	B	--	--	--	--	--	--	--	C	7
12	C	--	--	N/R	N/R	N/R	N/R	N/R	10M	7M
	B	--	--	--	--	C	C	--	--	10M
13	C									
	B									
14	C									
	B									
15	C	5	300M	400M	--	N/R	N/R	N/R	30M	20M
	B	15M	--	--	--	--	--	--	--	15M
16	C	--	N/R	2.5	6	3	N/R	7M	4	60M
	B	C	--	--	--	--	N/R	50M	--	250M

TABLE 12

ALT SUMMARY - POLYURETHANE CONNECTORS

Resistance Readings

No.	Path	24	25	26	27	28	29	30	31	32
17	C	30M	30M	50M	30M	30M	20M	25M	25M	X
	B	C	200M	--	--	1M	7M	300M	1.5	X
18	C	20M	15M	15M	15M	5M	C	X		
	B	7M	200M	--	200M	3M	C	X		
19	C	--	N/R	400M	1	50M	25M	150M	100M	300M
	B	C	70M	2	100K	--	5	500M	2	1
20	C	N/R	N/R	30M	3	2	C	X		
	B	300M	50M	--	300M	3	C	X		
21	C	N/R	N/R	5M	3	1	500K	10M	40M	600M
	B	C	C	1.5	200M	10M	20M	60M	2	200M
22	C	1.5	200M	100M	70M	10M	40M	50M	60M	30M
	B	10M	20M	80M	100K	500M	500M	C	100M	100K
23	C	50M	2	30M	50M	30M	15M	--	--	--
	B	C	3	3M	300M	C	70M	1	70M	--
24	C									
	B									
25	C	30M	200M	70M	5	50M	10M	10M	6M	8M
	B	70M	--	1.5M	2	80M	30M	2	50M	3M
26	C									
	B									
27	C	1	700M	1	N/R	N/R	N/R	N/R	15M	15M
	B	200M	3M	C	6	--	10M	--	100M	30M
28	C	N/R	N/R	40M	C	100K	C	N/R	X	
	B	4	--	--	500M	1M	150M	C	X	
29	C									
	B									
30	C	N/R	N/R	1M	20M	5M	1M	5M	5M	9M
	B	8M	300M	--	30M	800M	5M	30M	8M	4M
31	C	--	2	5M	20M	5M	15M	10M	20M	1M
	B	700M	200M	30M	600M	--	6	--	3	5M
32	C									
	B									

APPENDIX C

ESTIMATION OF ACCELERATION FACTORS

We are assuming that the bond failures are controlled by water permeation through the elastomer to the bondline. One convenient measurement related to water permeation is the weight change of samples in water.

Few data are available to date on the degradation rate of elastomers and bonds in water at various temperatures. References [1] and [2] were analyzed to estimate the acceleration factors used in this report. The references report on measurements of weight change of various elastomers in deionized water, artificial sea water and 3.5 percent saltwater at several temperatures.

The specific polyurethane (PR-1547) and neoprene (Joy 319,735-8) used in manufacturing connectors in this program are not included among the materials reported. However, we are using the published data to generate the acceleration factors since they discuss the same generic materials and are likely to contain the same families of constituents. We do understand, however, that differences in the additives can substantially affect the aging characteristics of these elastomers. As shown in Table C-I, the acceleration factor between 25°C and 70°C may vary considerably depending upon the formulation and the amount of water absorbed.

TABLE C-I

Measured Acceleration Factors for Weight Gain at 70°-vs-25°C

Material	Water	Weight Gain %	Acc. Factor
(Baker and Thompson)			
Polyurethane	DI	1	x11.0
		2	x10.0
	Sea	1	x11.3
		2	x16.9
Neoprene W	DI	1	x16.8
		2	x20.8
	Sea	1	x 9.2
		2	x14.9
Neoprene 5112	Sea	1	x31.5
		2	x37.5
(Glowe and Thornton)			
Neoprene (Straza	Salt	1	x 9.4
		2	x15.2

Since the purpose of the program was to compare polyurethane with neoprene assemblies it was felt important to have acceleration factors for the two materials that were comparable. Two phenomena in weight change experiments appear to be eligible references for comparing the performance of materials: the weight change at saturation, and the weight change at disintegration. The records in reference [2] showed no saturation or disintegration. In reference [1] the polyurethane saturated and disintegrated at the same weight increase in sea water while neoprene W saturated at 25°C at one weight increase and disintegrated at 80°C at a higher weight increase. While the data are confusing, the weight gain for neoprene saturation at 25°C was about the same as for polyurethane saturation at all temperatures, so the two materials are presumed to be subject to failure at about the same weight gain.

The weight gain at failure measures about 2.5 percent, so the acceleration factors used in this program are estimated from the measured acceleration factors for sea water at 2 percent weight gain. Having only one such datum for polyurethane makes that choice simple, while the three such data for neoprene makes the selection of a value more difficult. In absence of any better methodology the three numbers were averaged.

TABLE C-II

Estimated Acceleration Factors for 70°-vs-25°C Exposures

Polyurethane	x 17
Neoprene	x 23

REFERENCES

1. "The Effect of Seawater on Polymers", G. R. Baker and C. M. Thompson, Naval Research Laboratory Memorandum Report 4097, dated 14 Nov. 79.

2. "Reliability Improvement Investigations of DT-308 Hydrophones and TR-125 Transducers, second Report: Preliminary Aging Results", D. E. Glowe and J. Scott Thornton, Texas Research Institute Report 7631-2, Dated 20 May 77.

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