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Technical Report 627

CABLE FAILURES IN THE AN/BQS-15 SONAR SYSTEM

Analysis of failures in the depression/elevation drive-motor power cable and recommendations for their prevention

TL Lewis

June 1980

Final Report for Period September 1979 - February 1980

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Naval Sea Systems Command
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Design and fabrication deficiencies in the MIL-C-24217/1400 connector cause failure of the AN/BQS-15 sonar system depression/elevation drive motor power cable, resulting in damage to the motor. Failures in the 41 cables analyzed were caused primarily by mechanical and electrical breakdown and mishandling. Fabrication materials, methods, and inspections required to correct these problems are described.

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OBJECTIVE

Develop recommendations for preventing failure of the depression/elevation drive-motor power-cable, and all other cables, in the AN/BQS-15 Sonar System. Identify the causative mechanisms. Define specific corrective actions in sufficient detail to permit preparation of an engineering change proposal by the system contractor.

RESULTS

1. The MIL-C-24217/3-001 connector has serious design and fabrication deficiencies.

2. Thirty-five percent of the returned cables had been rejected or had failed because of abrasions, cuts, etc, caused by mishandling.

3. Thirty-five percent had failed because of mechanical and electrical breakdown in the cable.

4. Thirty percent had nothing wrong except that in most of these the connectors, normally supplied by the shipyard, had been cut off. This implied that problems with these cables may have been solely associated with the missing connectors.

RECOMMENDATIONS

1. Modify acceptance criteria for the cables to include a physical inspection of the neoprene-to-metal bond. The inspection should be similar to the inspection of the bond used for MIL-C-24231 connectors.

2. Modify the 24217/3-001 connector to eliminate the cable notch.

3. Modify the mold for the 24217/3-001 connector to include a 45° beveled termination near the connector coupling nut, and to be faired without a step at the cable.

4. Mold the part number and date of fabrication into the connector mold to serve as lot number information.

5. Do not extend the water block in these connectors beyond the metal shell housing.

6. Install a pressure strap near the 45° beveled termination of the mold to aid in preventing long-term bond failure.

7. Machine an O-ring groove into the metal sleeve in the area directly beneath the pressure strap.

8. Direct personnel removing cables that have failed in installation to supply detailed failure scenarios with cables returned to the vendor or other cognizant technical center to aid in incorporating developmental engineering changes in the system.

9. Direct personnel to avoid rough handling of the cables.

10. Fabricate the coupling nut from material that would eliminate galvanic reactions within the connector. This material should be 316 stainless steel. Teflon tape should be used on installation to prevent thread galling.

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BACKGROUND

The AN/BQS-15 sonar system has experienced an inordinate amount of outboard cable failures, particularly with the depression/ elevation (D/E) drive-motor power cable W31 (part 8-60013652). Other AN/BQS-15 outboard cables also have been failing at a very high rate. Failure of the D/E cable, caused by water flooding of the P2 connector, damages the D/E drive motor. This seriously degrades the submarine's forward-look capability, requires major repair, and results in high repair costs. Table 1 lists the cables that have been sent to the fleet as replacement items.

NAVSEASYSCOM 63X143 requested that the cable failure mechanisms be identified and specific corrective action defined. Recommendations were requested that would be sufficiently detailed to permit preparation of an engineering change proposal by the AN/BQS-15 contractor, Ametek, Inc, Straza Division.

DESCRIPTION OF TEST CABLES

The location in the submarine of the cables examined in this analysis is shown in figure 1, and their description in table 2. There were 19 different cable numbers; the total analyzed was 41.

Table 1 lists 47 cables as replaced, but not all of the failed cables were returned to Ametek or NOSC. All of the cables used in this analysis had been returned to Ametek as defective, except one, a W30 (ser 15024), which was received from the Amecom Division of Litton Industries. Its history is unknown; Amecom has no knowledge of the cable.

As can be seen in table 2, all of the cables supplied to NOSC by Ametek have MIL-C-24217 connectors on at least one end. The connectors have from 3 to 14 pins. Two of the cables use 90° connectors; one of these has 3 pins and the other has 14. The bitter ends of the cables have a MIL-C-24231 Portsmouth connector, installed at the shipyard. Some of the cables returned to Ametek had these connectors attached, however, most had been removed. Figure 2 shows the above cables. Note that at least three have only pigtail ends.

Boat		Cable Type*									
Electric Boat	Newport News	40	46	48	49-1	49-2	50-1	50-2	51	52	Total Cables per Boat
685										1	1
	688		1	2					1	2	6
	689		3		1				1	1	6
690			1		1	3	1	3		1	10
	691		1			1		1		1	4
692		3									3
	693									1	1
694		2					1				3
	695							1		1	2
696		1	1						1		3
697							1			1	2
698											
699			1								1
700			3								3
701											
702											
703											
704											
705											
706											
707											
708											
709											
710											
	711		1								1
Landbased evaluation facility									1		1
Total cable types		6	12	2	2	4	3	5	4	9	47

*Cable type part numbers are all preceded by 8 600136

Table 1. AN/BQS-15 replacement cables sent to the fleet (as of December 1979).

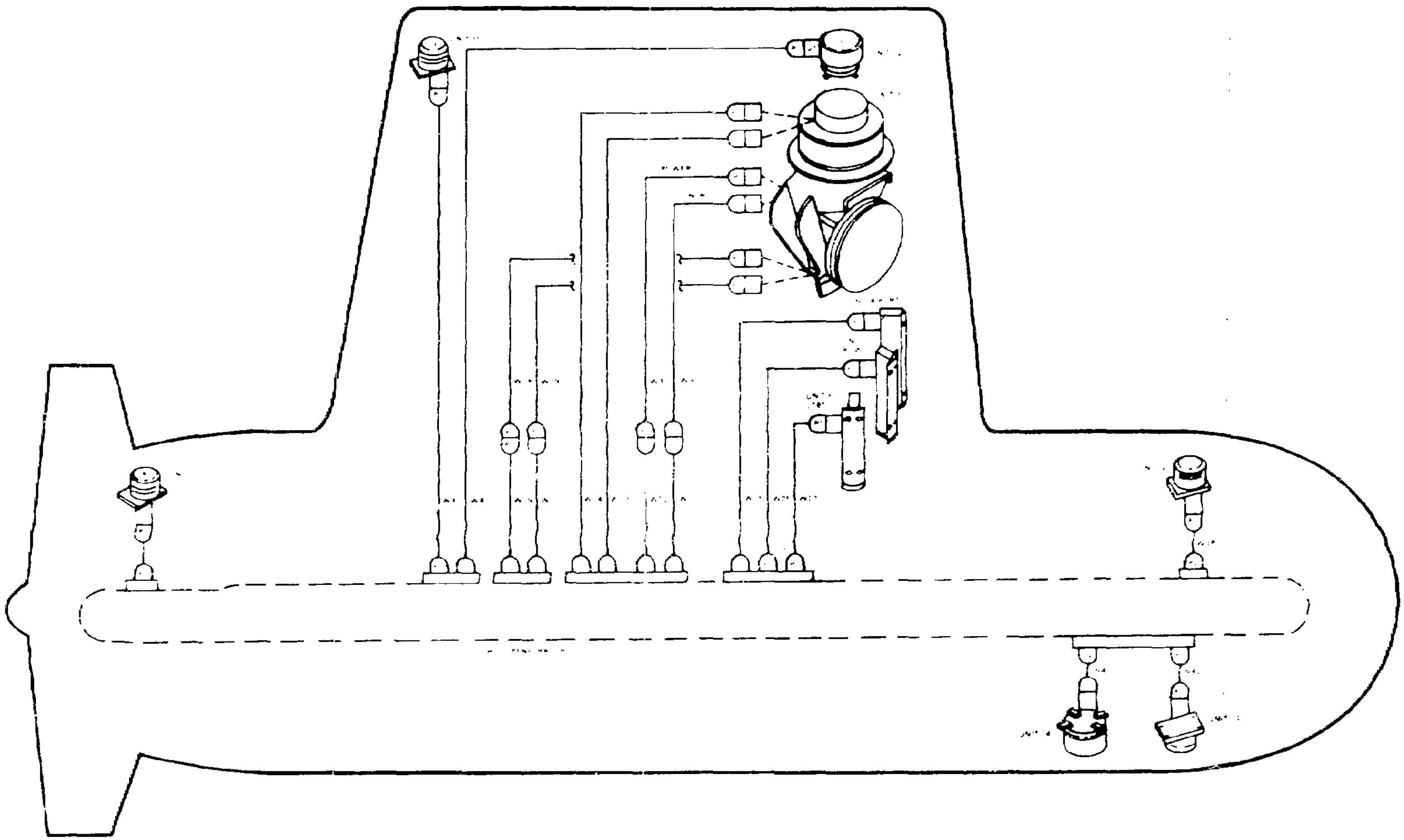
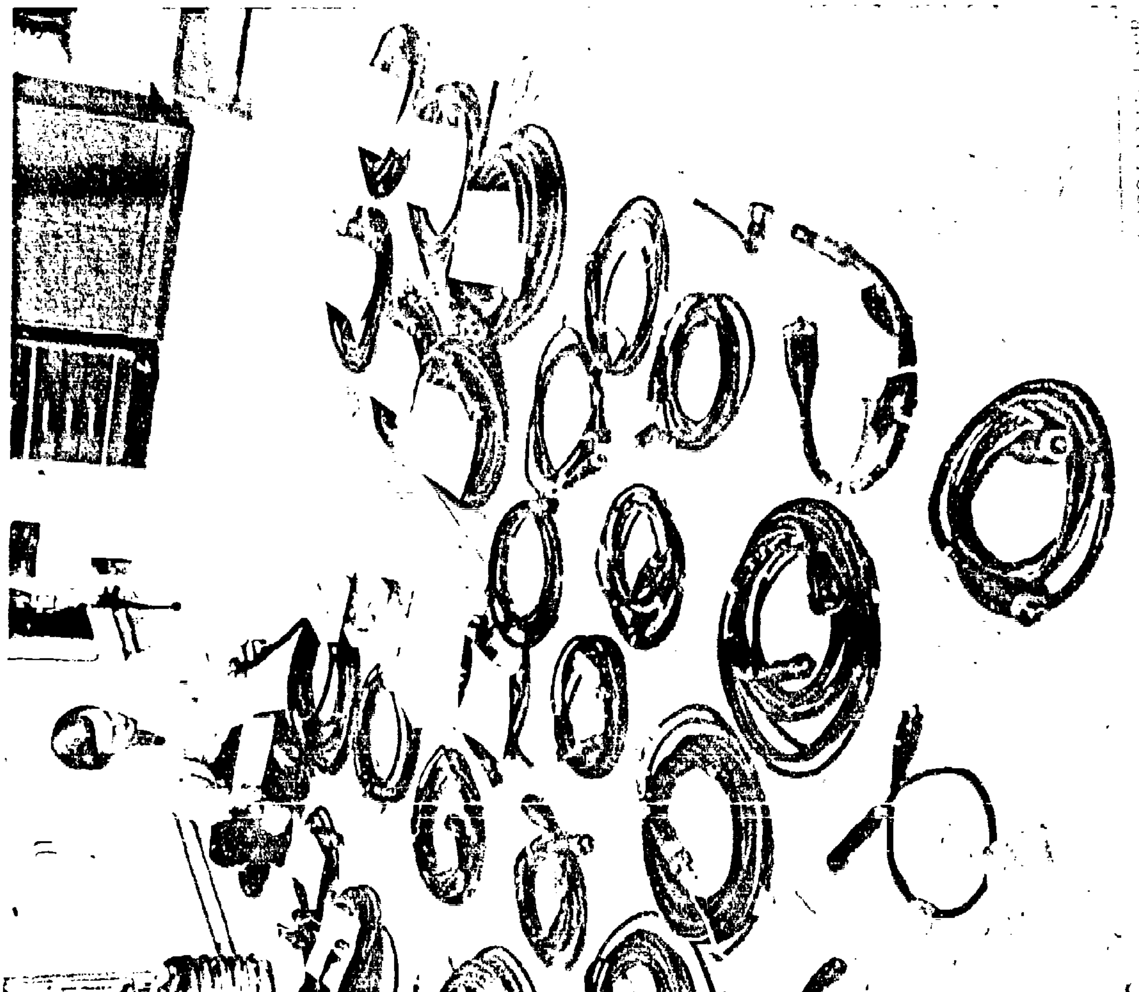


Figure 1. Location of analyzed cables.

Cable	Navy Number	Type	Active Cond	P1 Mates with	P2 Mates with	P1 Type	P2 Type
W19	R SQ19	2SWF 3	4	W28P1	Hull penetrator	M24217 7-005	Supplied at installation
W20	R SQ20	2SWF 3	6	W29P1	Hull penetrator	M24217 7 005	Supplied at installation
W21	R SQ21	2SWF 7	8	W30P1	Hull penetrator	M24217 7 007	Supplied at installation
W22	R SQ22	DSS 4	2	W31P1	Hull penetrator	M24217 7 001	Supplied at installation
W23	R SQ23	2SW 7	11	3A1J2	Hull penetrator	M24217 7 007	Supplied at installation
W24	**R-SQ24**	**DSS-4**	**2**	**3A1J1**	**Hull penetrator**	**M24217/7-001**	**Supplied at installation**
W25	R SQ25	FSS 2	4	4J1	Hull penetrator	M24217/7-003	Supplied at installation
W26	R SQ26	FSS 2	4	5J1	Hull penetrator	M24212 7 003	Supplied at installation
W27	R SQ27	FSS 2	4	6J1	Hull penetrator	M24217 7 003	Supplied at installation
W28	R SQ28	2SWF 3	4	W19P1	3A3J1	M24217 7 005	M24217 3 003
W29	R SQ29	2SWF 3	6	W20P1	3A3J2	M24217 7 005	M24217 3 003
W30	R SQ30	2SWF 7	8	W21P1	3A2J2	M24217 3 004	M24217 8 007
W31	R SQ31	DSS 4	2	W11P1	3A2J1	M24217 3 001	M24217 8 001
W38	R SQ38	DSS 3	2	9J1	Hull penetrator	M24217 7-005	Supplied at installation
W39	R SQ39	DSS 3	2	10J1	Hull penetrator	M24217 7 005	Supplied at installation
W40	R SQ40	DSS 3	2	11J1	Hull penetrator	M24217 7 005	Supplied at installation
W41	R SQ41	DSS 3	2	12J1	Hull penetrator	M24217-7 005	Supplied at installation
W42	R SQ42	DSS 3	2	13J1	Hull penetrator	M24217 7 005	Supplied at installation
W43	R SQ43	DSS 3	2	14J1	Hull penetrator	M24217 7 005	Supplied at installation

Table 2. Cable description.



CONDUCT OF ANALYSIS

OBJECTIVES

The principal objective of this analysis has been to determine the modes of failure of the W31 cable. Additionally, the modes of failure of all other cables were required to be determined.

The specific objectives have been to determine causes and extent of cable failure due to

Flexing of the cable, including the effects of currently used installation techniques, eg, bundling of several pedestal cables, excessive cable bending

Poor adhesion between the connector molding and the cable, including poor cable manufacturing techniques, eg, improperly cleaned molds, presence of mold release, chemical incompatibilities

Poor adhesion of neoprene and epoxy to the connector; analysis of this potential failure mechanism considered manufacturing techniques, procedures, and quality assurance in addition to chemical incompatibilities

Molding imperfections, such as bubbles, in the neoprene and epoxy

Failure of cable-assembly components such as connectors, O rings

Storage and aging

INVESTIGATION METHOD

Initially, 40 failed cables were delivered to NOSC. All were labeled indicating part, cable, and serial numbers. Serial numbers were stamped on the brass coupling nut of the MIL-C-24217 connectors. The analysis consisted of the following successive steps

1. Each cable was physically inspected and the results were recorded

2. Salient characteristics of cable deficiencies were photographed using a close-up lens

3. Continuity tests were made to determine

   Resistance of each line

   Short circuits between lines

4. An insulation resistance test (using 500 V dc and a megohmmeter) was made on each cable

5. Cables were X-rayed to determine

Construction details

Bonding breakdowns

Other internal characteristics

6. A test fixture was fabricated to determine the volume of the cable that had previously been flooded by water; figure 3 illustrates the test setup in which the cable was placed into a water-filled pressure vessel and pressure increased until the water (laced with a red dye, a barium sulfate solution, and a wetting solution) was just visible in the exposed connector

7. After removal from the test chamber, the cables were X-rayed and dissected to determine flood-failure paths, and were photographed using a close-up lens; they were also photographed under ultraviolet light

8. Those cables showing no visible signs of leakage after at least 30 minutes under 1000 psi (6.895 MPa) were again tested for insulation breakdown using 500 V dc and a megohmeter

9. Paul Henderson of NWSC Crane examined the neoprene molded material for improper curing, effects of aging, and other reasons for loss of bond to the steel casing (his report is in appendix A)

10. Installation procedures were reviewed and shipyard installation techniques were monitored to determine possible areas for improvement

11. Failures caused by handling were identified

12. A meeting to review test results and their interpretation was held at NOSC on 5 February 1980; those in attendance were from NAVSEACENPAC, Ametek/Straza, NWSC, NUSC, Mare Island Naval Shipyard, NAVSECNORDIV, and NOSC (a report on this meeting is in appendix B)

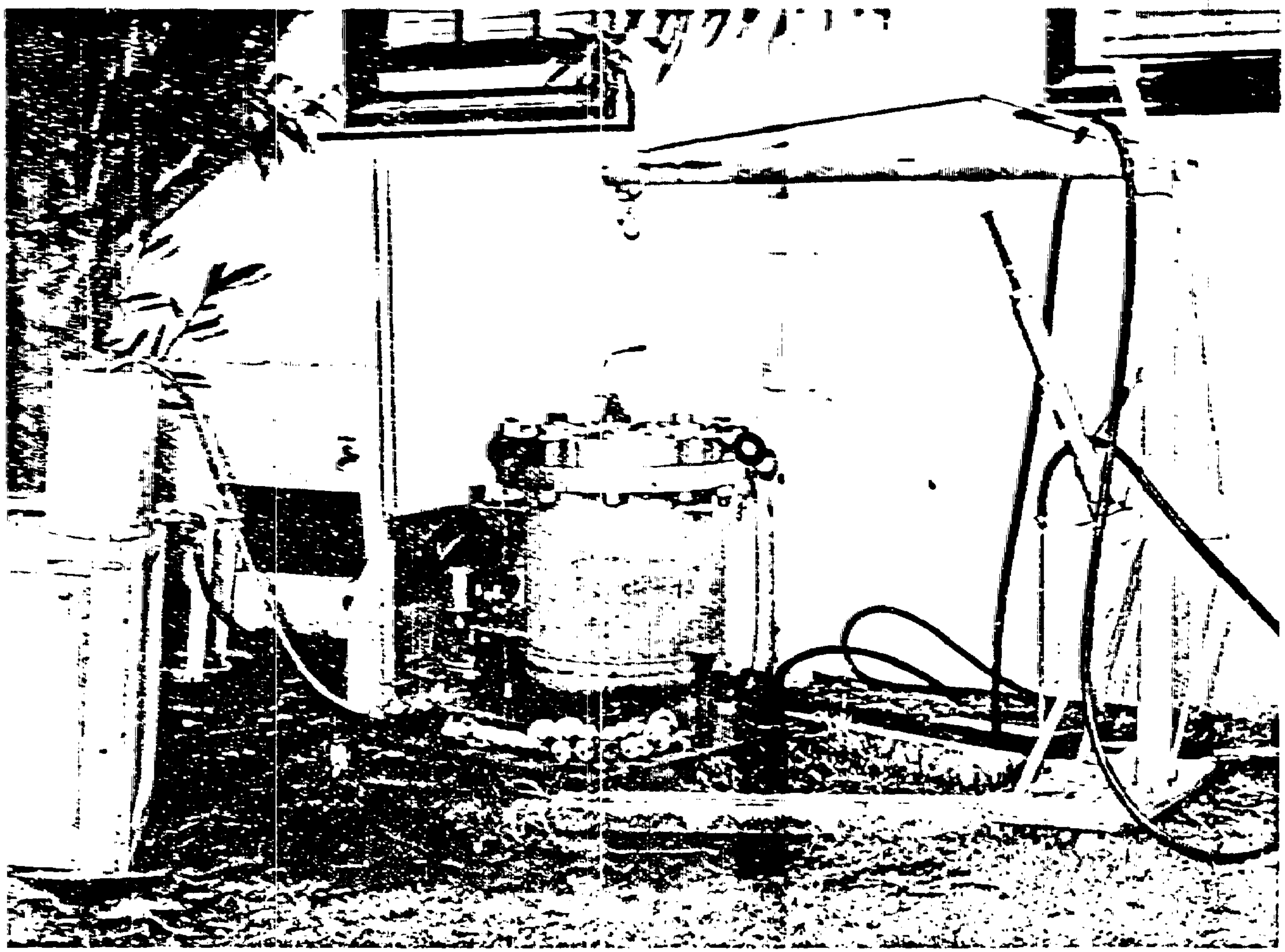


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Figure 5. Pressure test setup.

TEST RESULTS

Table 3 lists all analyzed cables by serial number and type, and classifies the mode of failure. Failures due to handling comprise the largest group and are caused primarily by abrasions and cuts in the cable, not by normal wear as installed.

The next largest failure group consists of cables where causes could not be determined because

Failure cause had not been documented

Failure occurred in a connector which had been cut off and not supplied for analysis

Failure is intermittent and cause could not be determined during analysis

The group listing leakage due to bonding breakdown shows a predominance of the W31 cable, the principal test specimen in this investigation. Only the W31 cable showed visual signs of leakage at the pin interface during pressure testing. The W30 cable showed bond breakdown or leakage inside the connector of one specimen. This was the MIL-C-24217/3-004 (P2 on W30). A W24 cable, which had been involved in a collision with ice, and, therefore, not tested in the water-pressure test, showed flooding and a strong leakage path into the pin area.

The internal shorts group lists connectors whose failure was diagnosed during the physical and electrical inspections. Approximately half of this group was diagnosed after pressure testing the cables. No physical signs of water penetration were observed in these cables, however, X-ray inspection showed that the shielded areas were too close together. It appears that the pressure had caused the lines to touch and that this was partly the reason for the original cable failure diagnosis. Handling of the cables and/or releasing pressure on the shields had opened the contact and had allowed the cables to pass the electrical inspection.

DEPRESSION/ELEVATION POWER CABLE

Figure 4 shows the in situ installation of the W31 and W30 cables at the AN/BQS-15 pedestal. Failure of the smaller 90° connector (left side of the motor) precipitated this analysis. The unrestricted surrounding area and the free motion of the pedestal assembly would allow modifications to both of these connectors without significant constraint in size. Figure 5 shows connectors P1 and P2 of the W31 cable (ser 15014). A partial dissection of the 90° portion of the P2 connector is shown in figure 6; the pink wire (normally white) at the center of the figure indicates dye penetrating to this point in the connector. There is little, if any, bond over a very large area. Possible reasons for bond failure in this connector are discussed in appendix A.

Figure 7 shows an enlargement of the failed-bond area, illustrating the lack of surface preparation for bonding. Linear scratches on the metal sleeve were caused by the dissecting tool. A complete dissection of this type of

Handling Failure		Leakage Due to Bond Breakdown		Internal Shorts		Undetermined	
Type	Serial Number	Type	Serial Number	Type	Serial Number	Type	Serial Number
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]					[illegible]	[illegible]
[illegible]	[illegible]					[illegible]	[illegible]
[illegible]	[illegible]					[illegible]	[illegible]
[illegible]	[illegible]					[illegible]	[illegible]
[illegible]	[illegible]					[illegible]	[illegible]

Table 1 [illegible]

[illegible] transducer pedestal viewed from the [illegible]

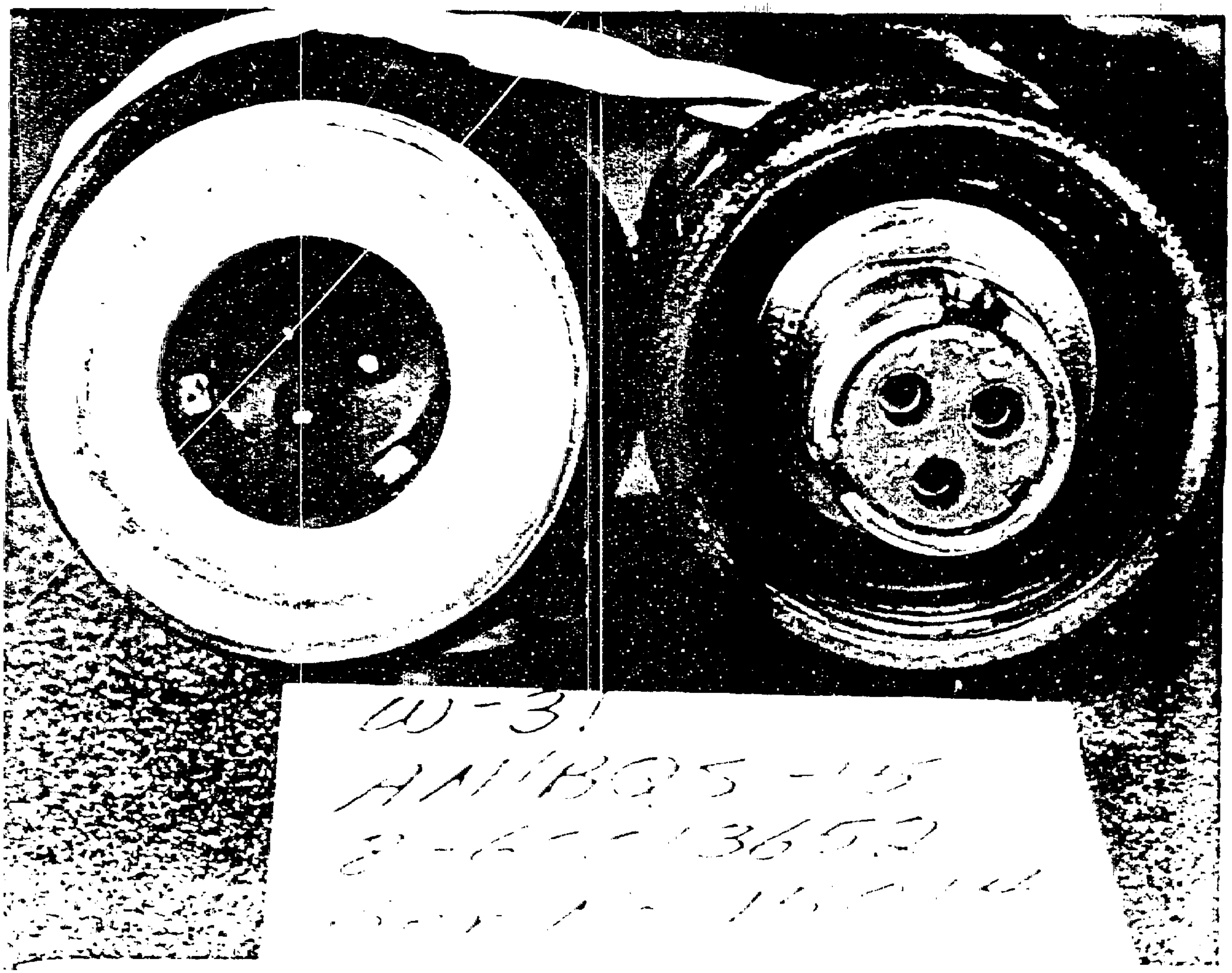
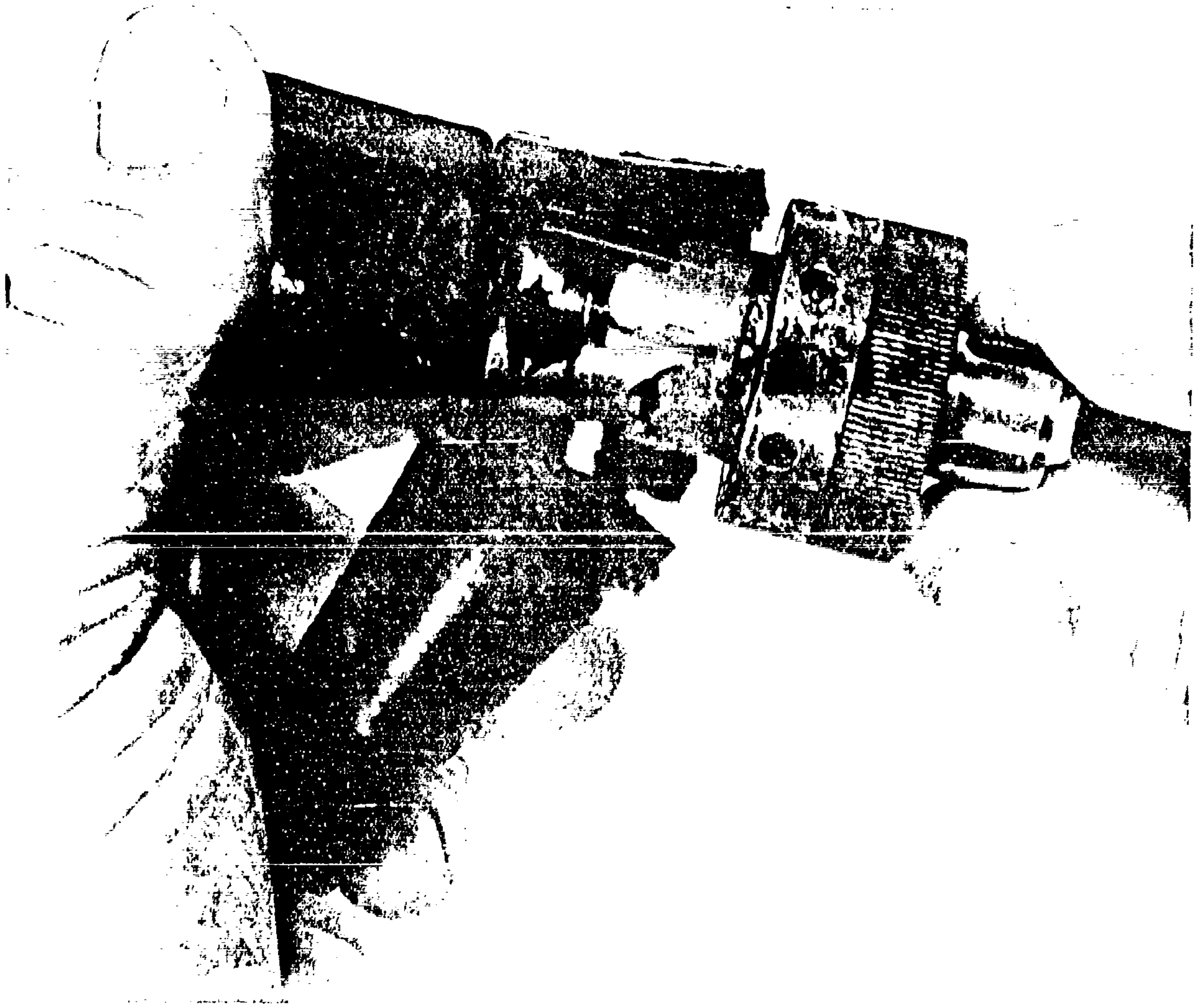


Figure 5. [illegible] of P1 and P2 on cable W31, Serial [illegible]



NWSC CRANE [illegible]

Figure [illegible]. Close-up of some voids [illegible] metal sleeve surface and [illegible]

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connector is shown in figure 8a. Clearly illustrated by pink is the water path that resulted in failure of the connector. A cross section of the rubber molding is shown at the right in the figure; the gray area surrounding the wire is a hard-epoxy compound. The compound can also be seen inside the blue insert at the left in the figure. The minimum water path, approximately 1/4 inch (6.35 mm), can be seen in the center of the rubber molded section below the left edge of the epoxy. The metal sleeve section is in the center; the uppermost left edge is the cutout which is in the main water path. In 8b an ultraviolet exposure illustrates more clearly the flooded areas in this dissection.

Figure 9 shows an additional dissection of the same P2 connector. The rusted area in the center of the metal sleeve indicates the principal water path which caused failure in this connector. Pink areas in the rubber mold (top center) and near the cutout portion of the connector (left) clearly illustrate water leakage; the gray area inside the blue insert is the hard epoxy water block. The hard epoxy shows fracture at the interface of the metal sleeve and the stress relief section which is the tail of the uppermost part in this photograph. A section of the insert is shown at the right.

Figure 10 shows a third dissection of the 90° connector. As can be seen on the right, the bond failure is in the vicinity of the cutout, and the rusted section defines the water path.

These results are considered to show clearly that the failure path was defined as being under the rubber, through a failed, previously bonded, section into the cutout area of the metal sleeve, then through the circumferential area surrounding the blue plastic insert, past a protective O-ring in this insert, and then to the pins. This failure path was observed during the pressure testing, ie, the pink liquid used in the pressure test was seen to emerge from the circumference of the blue insert.

Connector P2 on Cable W30

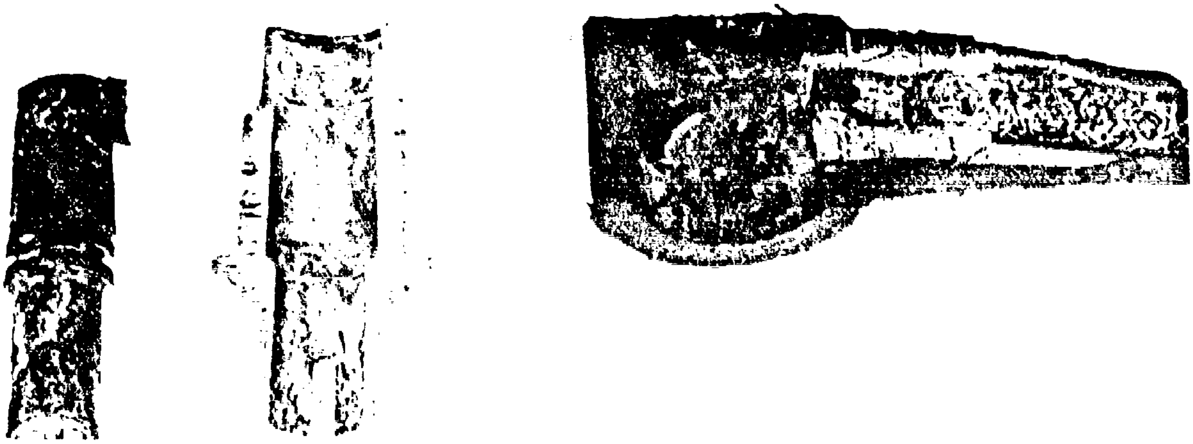
A dissection of P2 of cable W30 is shown in figure 11. This connector is the larger 90° connector shown in figure 4. Its construction is very similar to that of P1 in the previous section and the failure mode is considered to be identical. The right side of figure 11 shows a gray epoxy water block inside the stress-relief section of the mold. The water block is cracked in several places, most noticeably at the interface of the stress-relief section and the metal sleeve, near the cutout (where the wires enter the connector). At the left in this figure, lying on top of the blue insert, is a portion of the O-ring designed to prevent water from entering at the open end of the connector, rather than to keep out high-pressure water which could enter through the flooded back end (as occurred in this connector). Once water reaches the innermost section of this sleeve there is no longer any bonded area to prevent leakage.

Connector P1 on Cable W31

P1 of cable W31 is an inline connector and no failure of this connector has yet been observed, however, a dissection of the connector was made for diagnostic purposes (figure 12). The main pins in the connector are sealed with glass and a polyurethane section, seen in the lower part of the figure as a light yellow area to the right of the bright gold pin. The metal sleeve in the upper section consists of two pieces for ease in connecting the wires to the rear of the connector pins. The rubber molding is forced into the threaded section during vulcanization and aids in reducing the likelihood of the threaded section becoming a water path. The gray area in the center of the lower portion, which extends some distance into the tapered stress relief section of the mold, is a water block epoxy. It is considered not necessary since none of the many connectors supplied by the shipyard use a water block made of material different from that used to mold the rest of the connector (polyurethane). Also, the hard epoxy water block tends to reduce the effectiveness of the stress-relief design of mold itself. If, because the molded portion of the connector is made from neoprene, the innermost portion of the metal connector shell must be filled completely so as to reduce any motion (because of exterior pressure on the cable end connector), then it is suggested that only the area inside the connector shell be filled with either epoxy or polyurethane. This has been done in some instances with these particular connectors. The water block fill should not extend into the stress relief area.

Failed Bonds on Inline Connectors

Figure 13 shows several MIL-C-24217 inline connectors with varying degrees of bond failure. Those on the left side show only slight traces of bond failure, that on the right shows a complete bond failure which resulted in flooding of the connector. The latter connector has been completely dissected and shows (fig 14) a polyurethane water block which extends into the stress relief section of the molded connector; as in several other examples found with these connectors, the neoprene does not bond to the polyurethane. A slippage occurs inside the stress-relief section, and possibly it is a cause for excessive stress on the bond area. The flooding path may be seen on the blue insert on the right and inside the steel shell in the center. The rubber mold appeared to be in good condition throughout, however, the bond failed because of flooding. A pink dye is not seen here because this connector was not included in the pressure tests.



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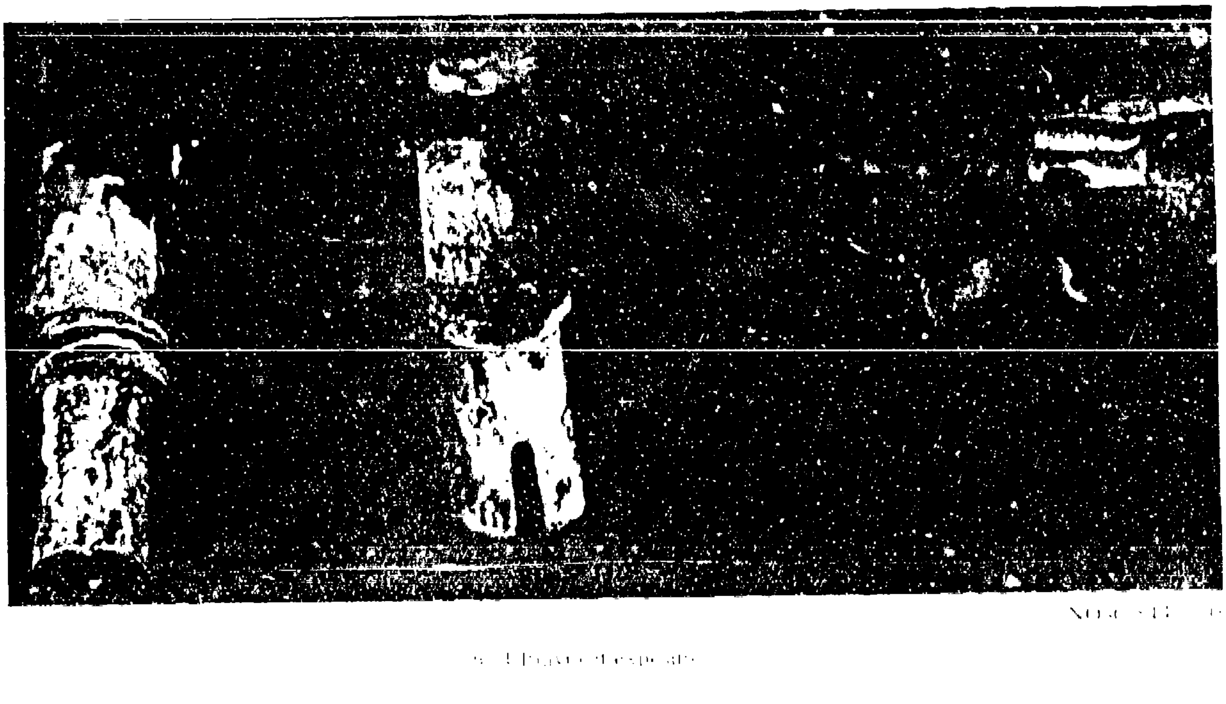
a. Normal exposure



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b. [illegible] exposure

[illegible]

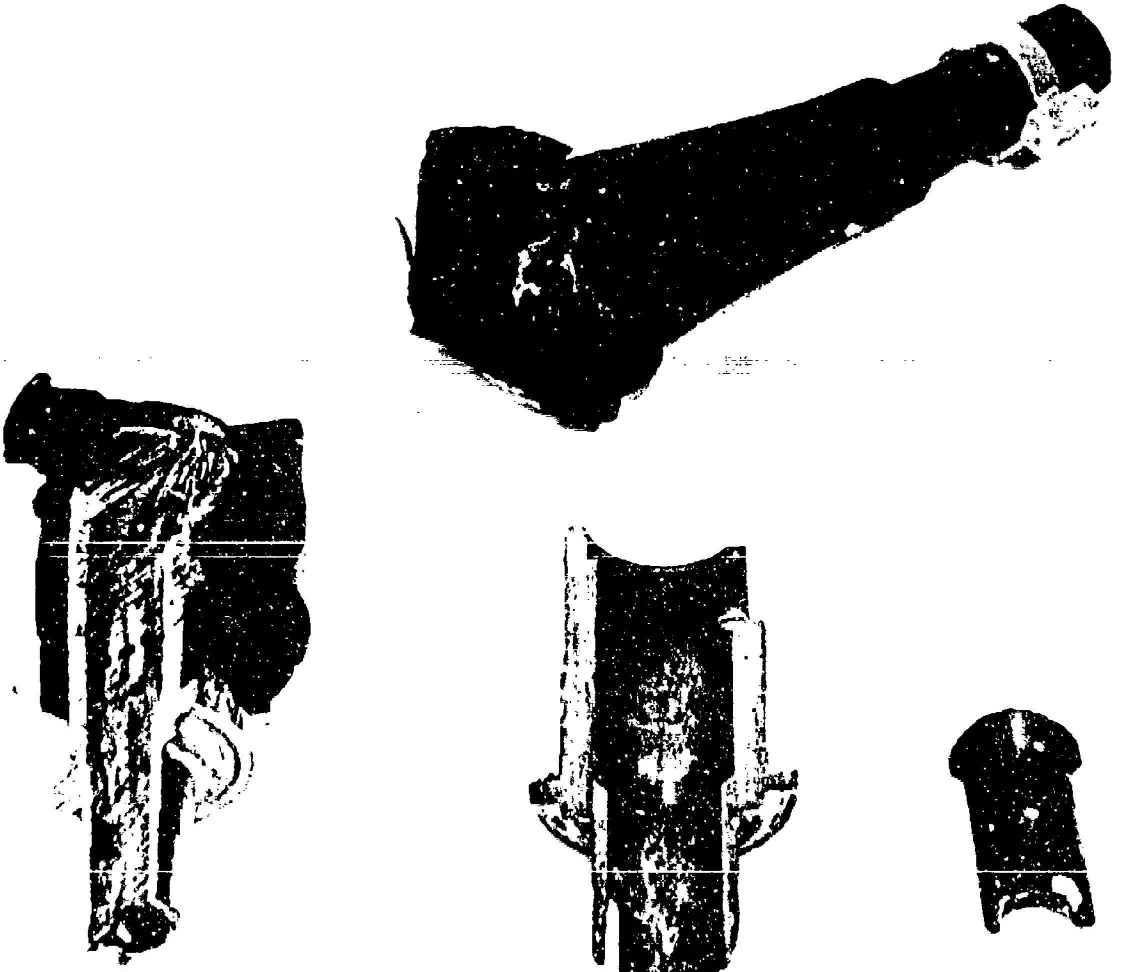

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Figure 9. Additional dissection of P2 connector on cable W31.

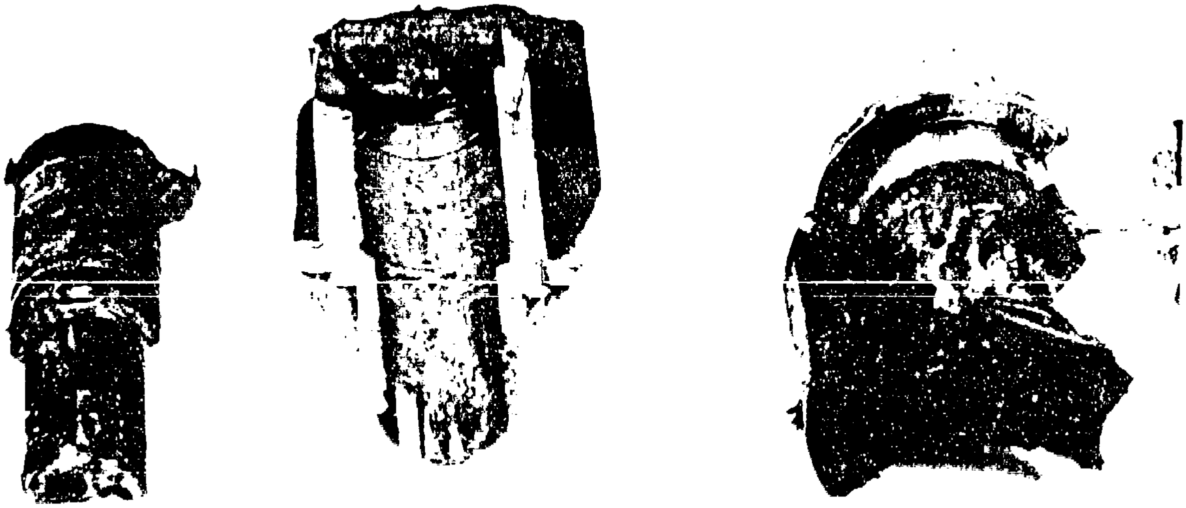

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Figure [illegible]. Dissection of P connector on cable W31.

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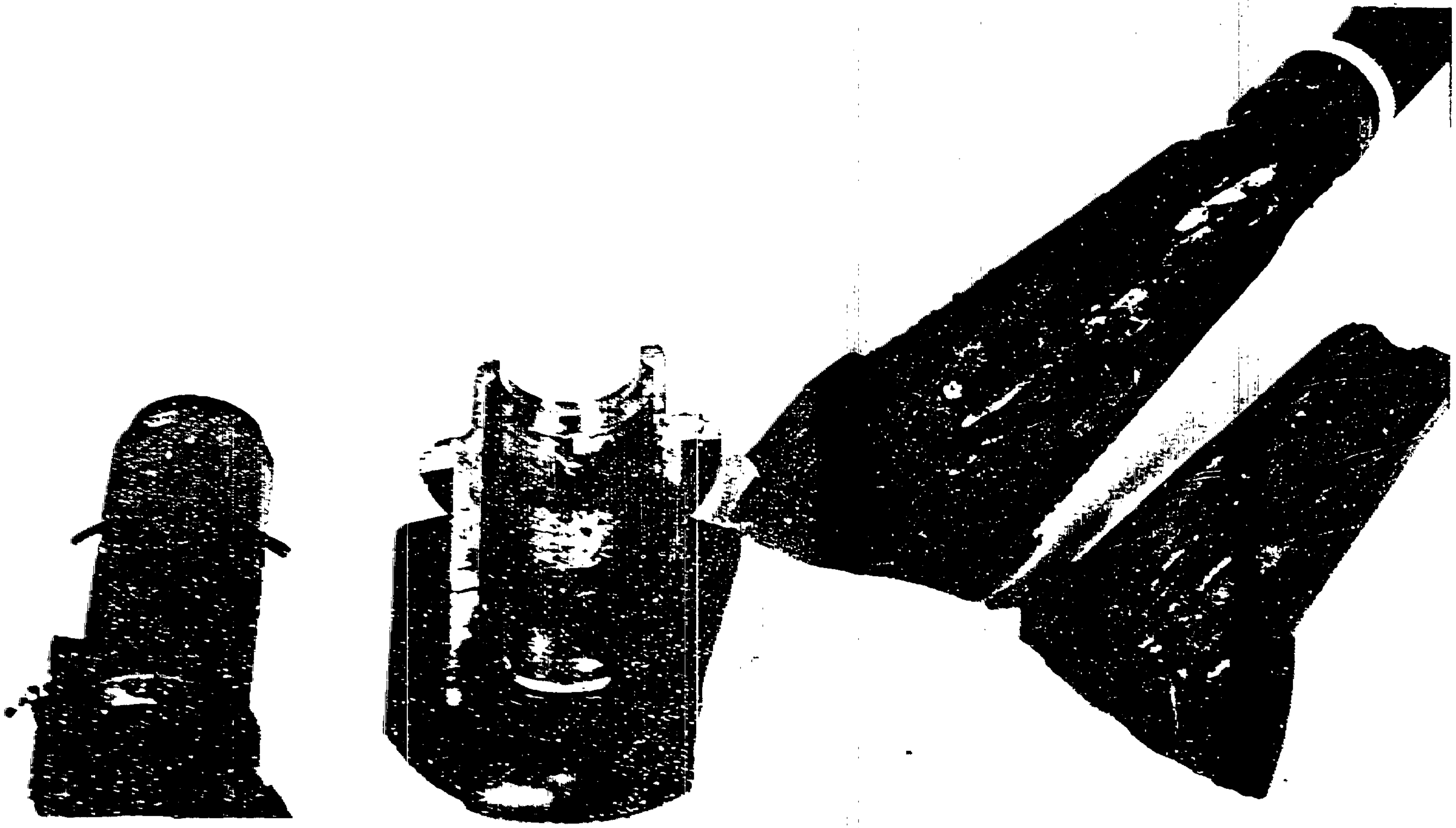

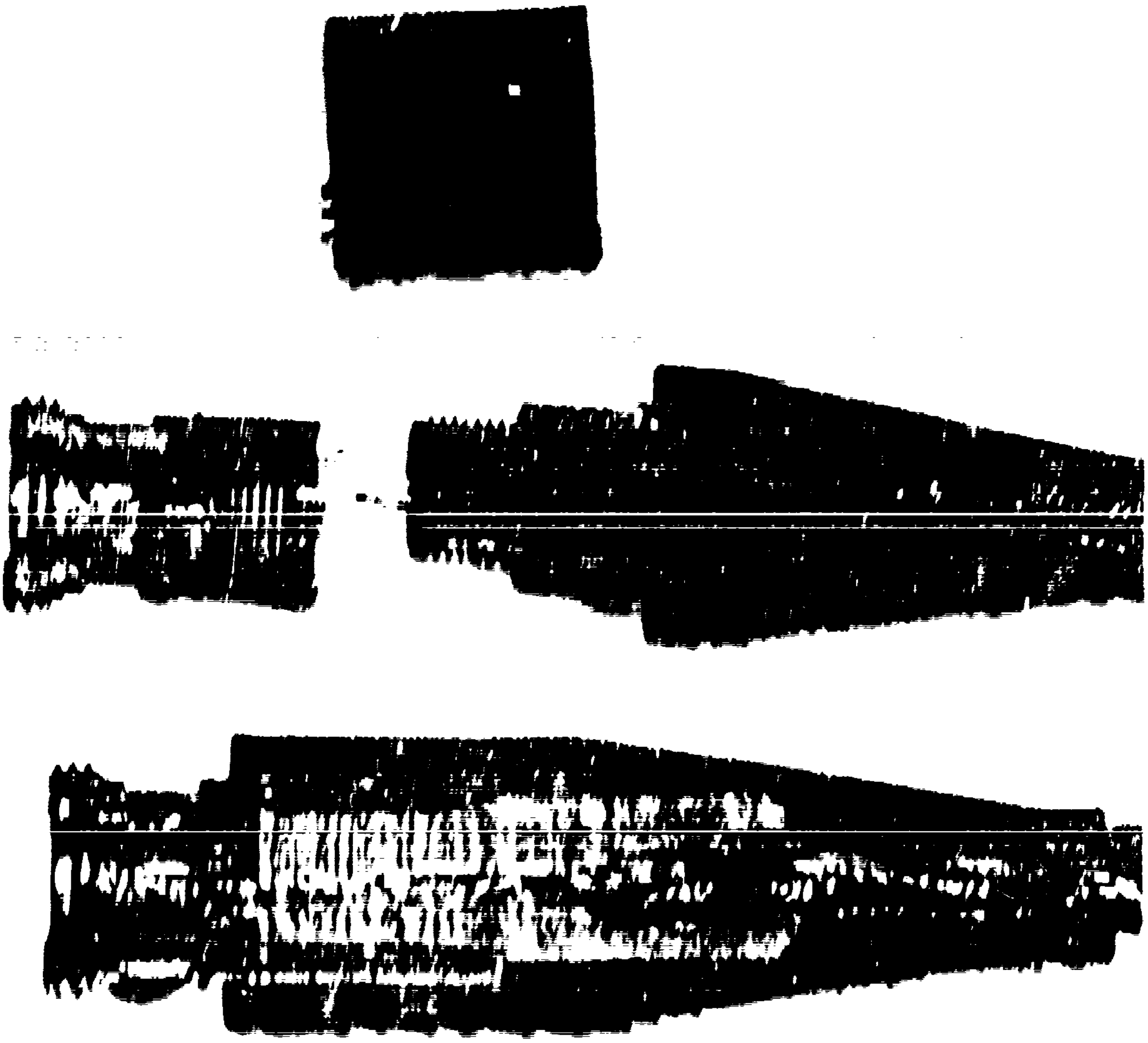

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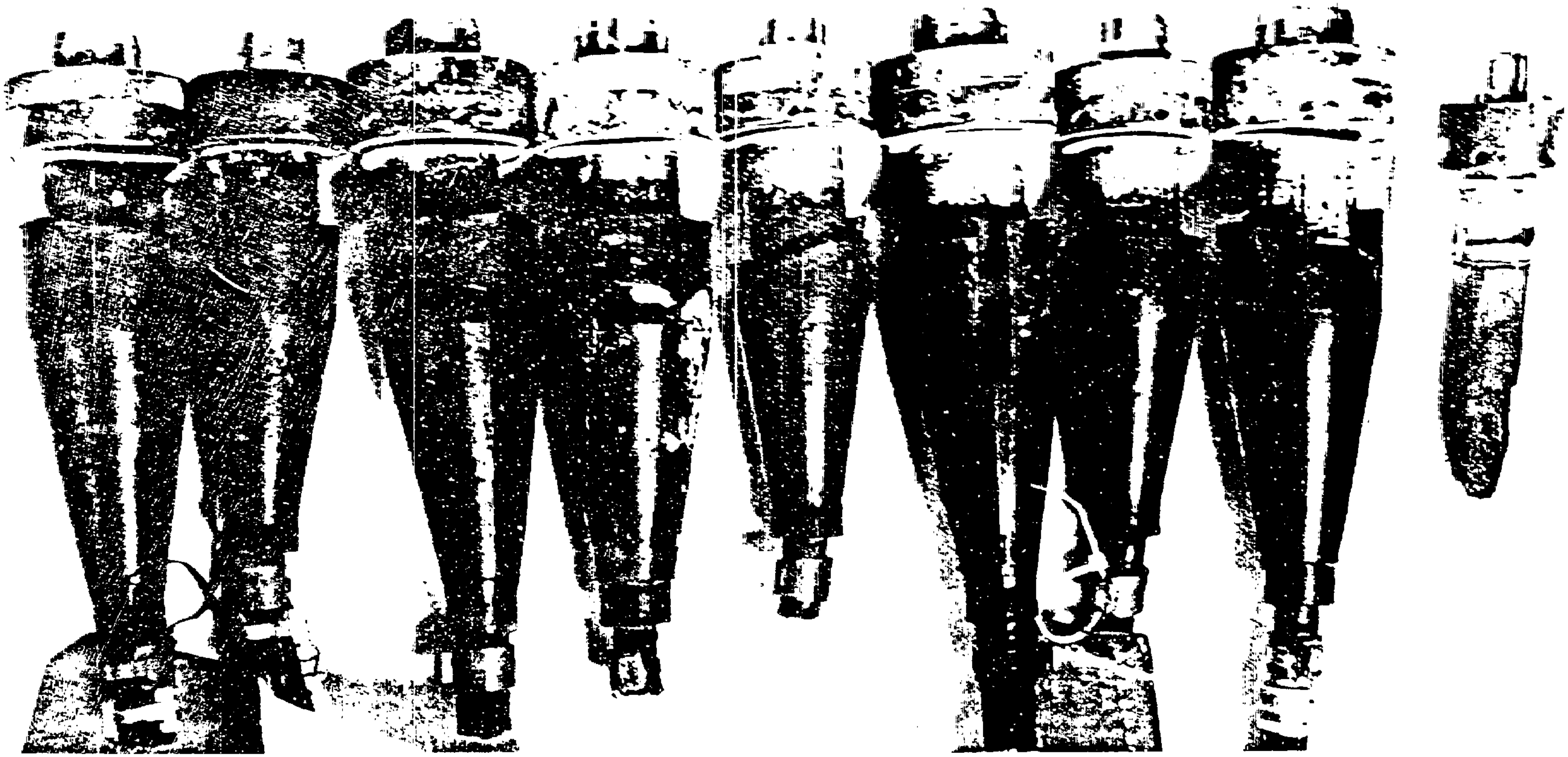

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Figure 13. Inline connectors showing all stages of bond failure from incipient to complete.

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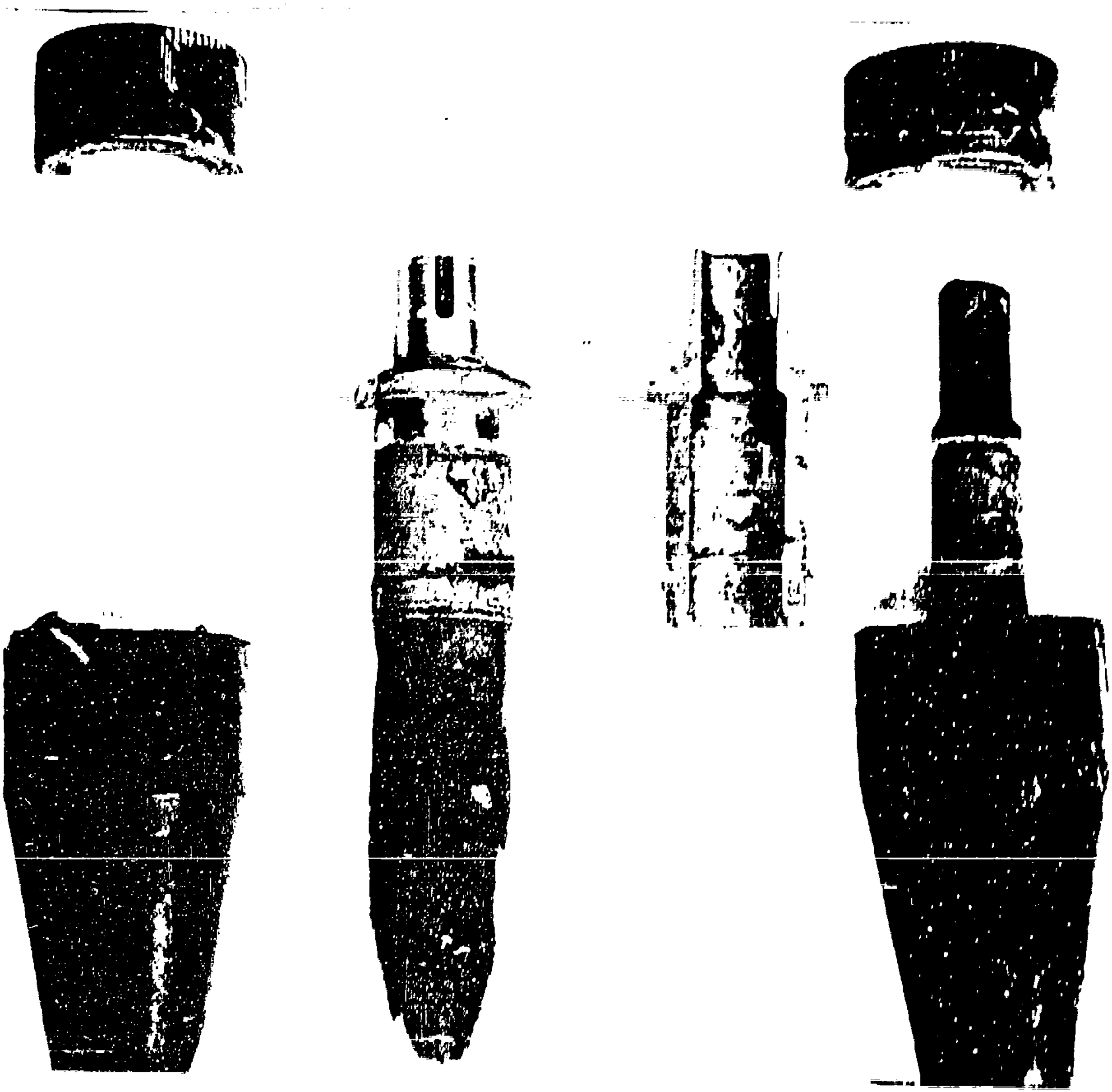


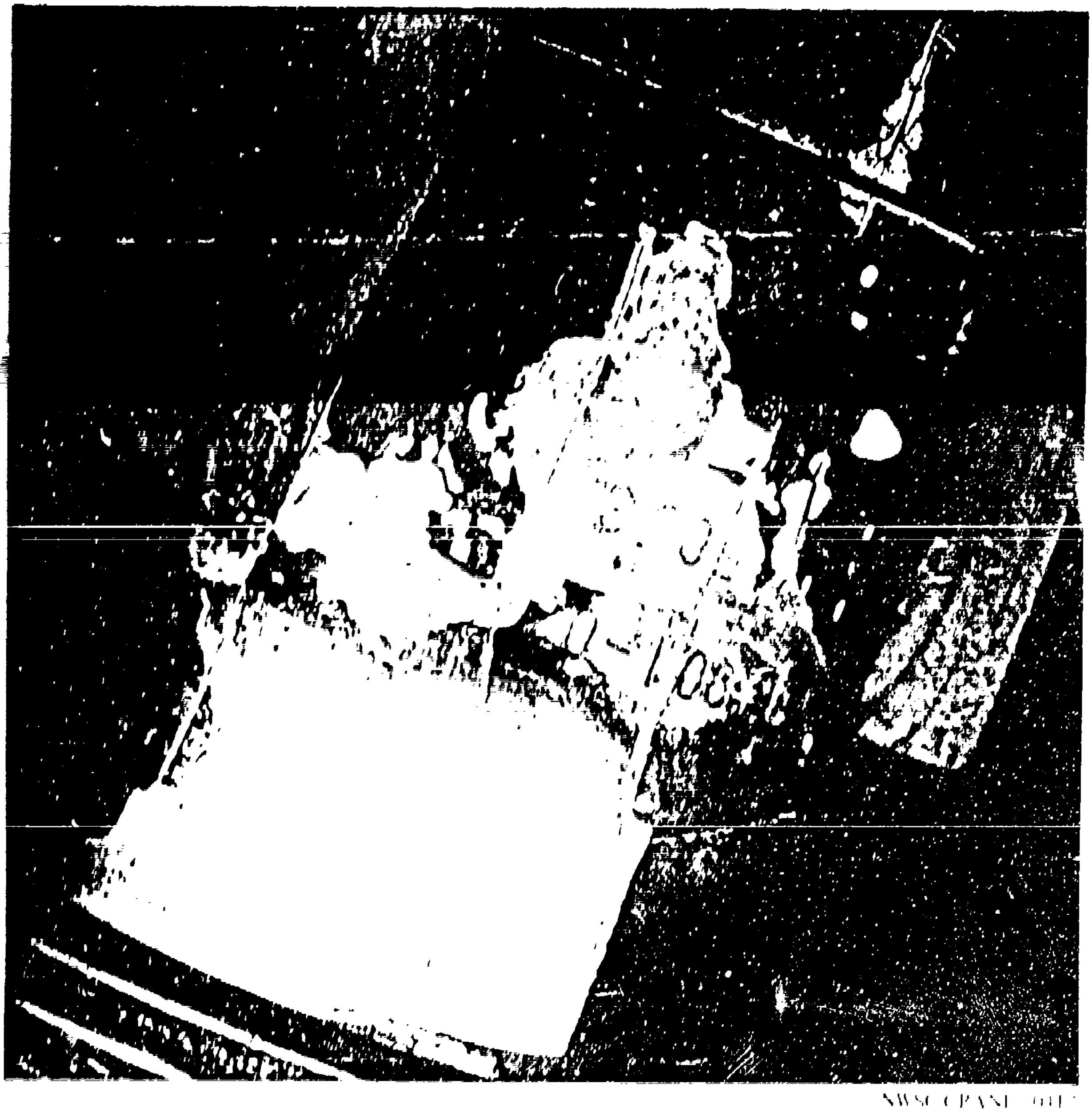
[illegible]

POSSIBLE CAUSE OF BOND FAILURE

It is difficult if not impossible to assess the reasons for bond failure in cables of this type. Several probable causes that have been suggested are discussed in a report by Paul Henderson of NWSC CRANE (appendix A). Of special interest in the analysis of the bond failures is the initial nature of bond breakdown. Specifically, some salient qualities of bond breakdown may be seen in figure 15, a closeup of an inline connector with incipient bond failure. In the center of the figure the neoprene is shown removed from the metal shell of the connector in order to expose the failed bond areas; the semi-circular lines in the lower center indicate several different stages of the bond failure process. The bond is intact farther from the termination of the bond neoprene which is at the center of the figure. This condition appears to be generally representative of all failures seen in these cables. If this type of failure occurs over a relatively long period of time, it may not be due to poor fabrication methods but rather to the basic design of the connector. A possible cause might be the dissimilar metals used in this connector. The metal shell (center section) of the connector is made of a 316 stainless whereas the connecting nut is nickel-aluminum bronze. A test in the laboratory using sea water showed that approximately 0.25 volt of electrical potential exists between these two metals. It is possible that under long term conditions a galvanic process as yet not completely diagnosed might exist in which the basic primer is caused to become increasingly permeated by water. Diffusion of water into the adhesive from the edge of the neoprene mold would then result in a breakdown of the bond. This could also occur if the galvanic process caused the primer to simply dissolve into the water. Details of this type of failure mode are currently being studied at the Texas Research Institute, Inc, in Austin, Texas. Results of the study at this time, however, are inconclusive. Although this phenomenon could be studied in great detail, it is simpler to just change the coupling nut of this connector to 316 stainless, thereby eliminating any dissimilar-metal or galvanic process. Coupling would then require teflon tape or a non-galling lubricant so as to eliminate thread damage.

CONCLUSIONS AND RECOMMENDED SOLUTIONS

When the acceptance criteria for these cables were reviewed during the early phase of this investigation, it was discovered that a large number of cycles at high pressure were used to determine whether or not the connectors leaked. If the cables did not leak during the pressure cycles they were considered to be acceptable. There was no visual or mechanical inspection of the bond in the connector near the termination of the bond on the metal sleeves. There was, however, a mechanical check for the bond on the cable. The lack of a visual mechanical inspection for any initial failure of the bond on a metal sleeve is considered to be the weakest part of the acceptance criteria. It is, therefore, one of the conclusions of this investigation that a mechanical and visual inspection of the bond at its termination on the metal sleeve be incorporated into the inspection criteria. In order that this may be accomplished with relative ease, it is recommended that the bond in this area be terminated with a 45° bevel. Terminating a mold in this manner allows easy visual inspection of the bond. Additionally, others have determined that a better bond results when the mold terminates in this manner (appendix A). Although the reason for this is unknown it may be due to lower heat transfer



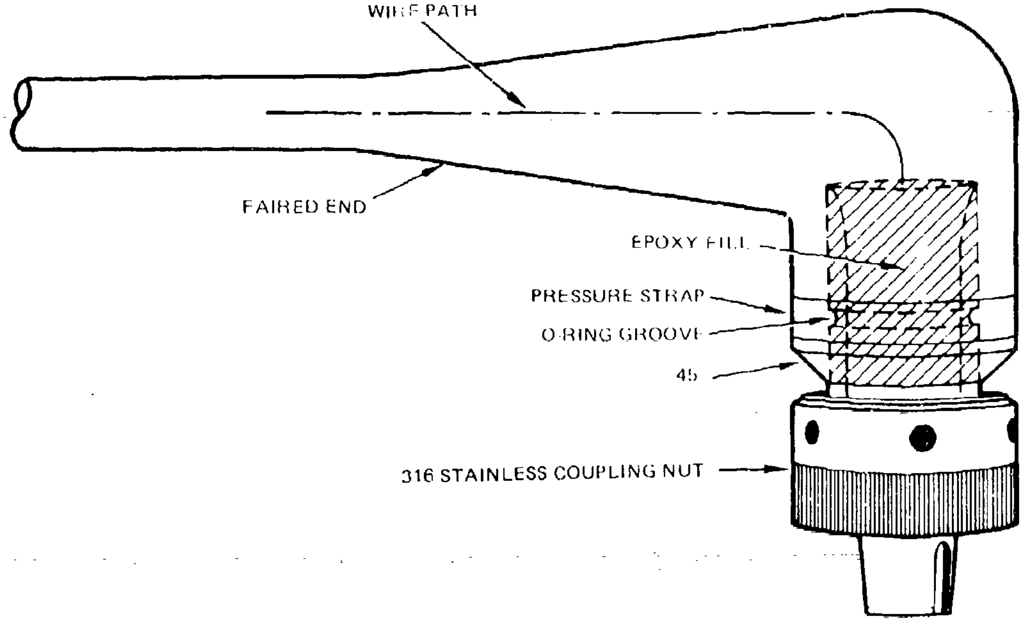
NWSC CRANE [illegible]

Figure [illegible]. Close-up of incipient bond failure.

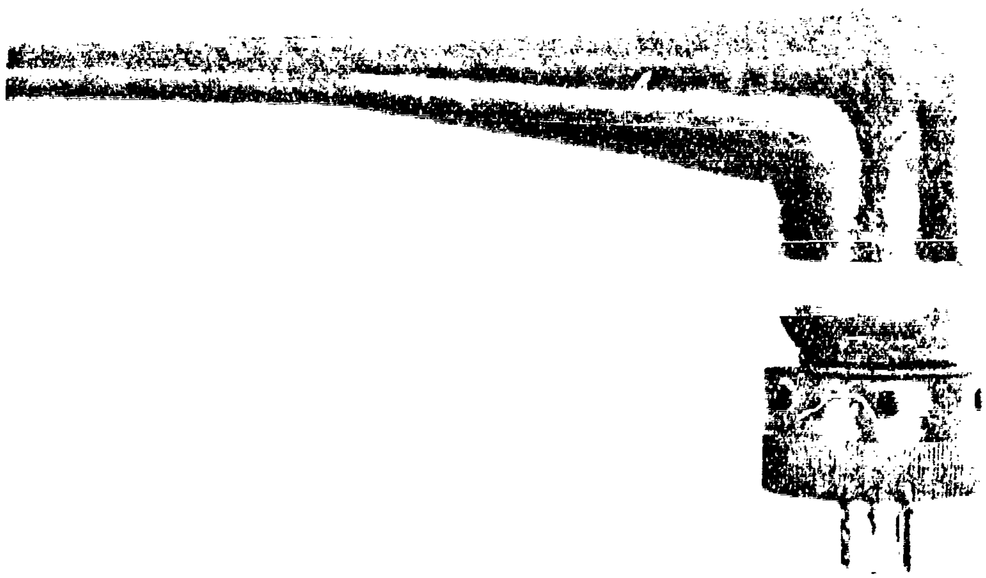
in the area of the 45° bevel during vulcanization. When the mold terminates at 90° there is only a very thin section of the mold in this area, and, therefore, increased heat transfer occurs. The method of inspection can follow that used for MIL-C-24231 connectors when the mold terminates at 45°.

The material used for a water block in the system should not extend into the stress relief portion of the mold but should be terminated at the end of the metal sleeve. Additionally, the stress relief portion of the mold should be faired into the cable rather than terminate as a step at the cable end. The cutout portion of the smaller MIL-C-24217/3-001 connector should be eliminated, the lines routed up and over the metal sleeve, and the mold changed to accommodate this in a manner similar to that of MIL-C-24231/2-001. A sketch showing this can be seen in figure 16. It illustrates the 90° termination, the fairing into the cable, routing of the wires around the rear of the metal sleeve, the epoxy water block, a metal pressure strap, and an O-ring groove in the metal sleeve directly under the metal strap. The metal strap is recommended since there have been laboratory results (at NUSC) showing that its use apparently aids in the tolerance of the bond to a severe pressure environment. Some results using the strap have shown bond failure in all areas except directly below the metal strap. Installation of the metal strap can be simple. One method would be to tighten the strap so that the exposed surface of the strap just becomes flush with the exterior surface of the neoprene. A buckle would be used to tie the strap in a manner presently used on many deep-submersible transducers. A specially designed tool has been fabricated for this purpose; details of the tool are available from NOSC.

Although the results of this investigation have shown no dramatically conclusive single mode of failure for all cables, the results have led to a considerable number of modifications to the system as being desirable if not completely necessary. In addition to the above modifications to the 90° connector, some modifications are also considered necessary for the inline connectors. These include continued use of the 45° termination of the molding in the vicinity of the nut, and the use of both the O-ring groove and the stainless steel pressure strap. In addition, the mold should be tapered into the cable as in the 90° connector. The coupling nut should also be changed from nickel-aluminum bronze to 316 stainless, and teflon tape should be used to prevent thread galling. These are all changes to the present system. An artist's concept of the recommended connector is shown in figure 16. Although there has been only one known failure due to flooding of an inline connector, our results indicate that there is a high probability that in the future, more failures of the same type will occur in the inline connector.



a. Recommended internal modification to the MIL-C-24217/3-001 connector.



b. External modification

Figure 16. Proposed change for connector P2 of cable W 31.

APPENDIX A: CABLE BONDING FAILURE

This appendix consists of a report on some detailed background related to the bonding failures found on these cables. The report contains some discussion of other possible design considerations for improving the present cabling system. It was originally issued as an informal test report and is included here essentially intact.

5 Feb 80
By Paul Henderson
NWSC Crane

PURPOSE: The BQR-15 cable assemblies are exhibiting extremely low service life due to water entering the connector and shorting out the socket contacts. Crane has been tasked to analyze the rubber to metal interface which is the primary rear seal.

BACKGROUND: In December 1979 a cable assembly (P/N 8-600136552, S/N 15032) was received from Naval Ocean Systems Center to be analyzed. It was a reject unit from the suspect manufacturer's lot that was exhibiting this low life failure. This reject was caused by a cut in the strain relief prior to installation, so this cable had not seen sea environment. This cable gave us a real insight into the overall cable problem.

DISCUSSION:

1. A small probe with a 1/16" ball tip was used to lightly lift the bond area to test mechanical integrity of the rubber to metal bond. Photograph (1) showed that the rubber lifted easily from the metal indicating that there is a major rubber problem in this area.

2. One-half inch strips were cut at 90° from each other, parallel to the axis of the connector, starting at the mold parting line. These strips were pulled back revealing almost complete bond failure (see photographs (2) and (3)). This type of failure, 90° from the parting line, is called spotty rubber (SR) and is evidenced by the appearance on the metal surface of splattered rubber. On the 0° (parting line) strip there is a complete absence of bond revealing exposed metal (CM). (See photograph 4.) Both of these failures can be caused by the same basic problems.

a. Oil, dirt, or other foreign matter on the metal surface may have prevented adhesion from taking place.

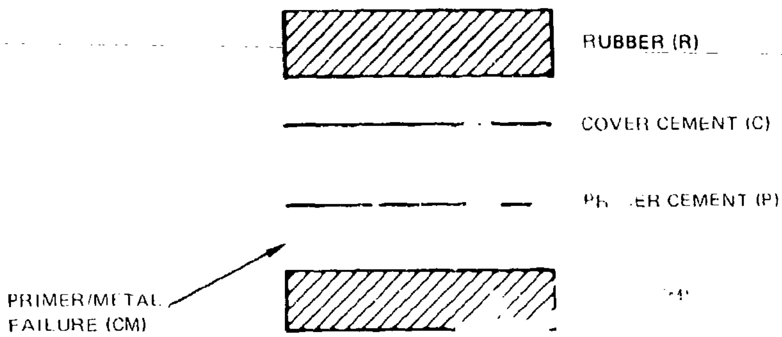
b. Too rapid evaporation of solvents in the adhesive may result in ultrafast drying of the adhesive.

c. Flow of the elastomer stock during bonding may have caused displacement of the adhesive from the metal surface.

3. Since the bond failure was at the metal primer interface, it is assumed that the basic rubber stock (WRI Polychloroprene with 40 to 50% carbon) is adequate for this application. The durometer was homogeneous throughout the elastomer indicating proper mastication and curing. There was no evidence of plasticizer migration.

4. The primer system used by Viking was the two coat method of bonding the elastomer to metal.

This two coat method is used when the assembly will face severe usage and extreme temperature, but the bonding temperature must be high. This is by far the best method for this application.



TWO COAT SYSTEM

5. Probable causes of the CM failure:

a. Problem. Poor metal surface — oil or powdery residue.

Solution. Better chemical or mechanical cleaning. Check operation.

b. Problem. Excess flow of the elastomer stock during the bonding process may cause displacement of the adhesive from the metal.

Solution. Use semipositive molds if compression molding technique is required, or use transfer molding to reduce this excess flow and keep proper pressure in cavity.

c. Problem. Sacrificial metal activity.

Solution. Avoid the dissimilar metals in abrasive cleaning.

d. Problem. Contamination of treated metal parts before adhesive application.

Solution. Cover parts.

6. The most critical area of failure occurs at the 180° mold parting line. (See Photograph (5)). This is due to the small distance between cable entry point and the elastomer cutoff. If the bond fails in this area there is a direct entry path for water into the cable assembly causing, at least, a short in the contacts.

7. Some other changes to improve the product might be considered.

a. Add a test for integrity of the bond, such as a pry test, to the specification for this connector (MIL-C-24217 (SHIPS)). This would be a 100% test requirement.

b. Add a peel test to paragraph 3 on a sample basis to prove out production process.

c. Changes to design.

(1) Bonding of metal to rubber can be greatly improved and life expectancy extended for a much longer period if the leading edges of the bond area are kept in compression. This may be accomplished by placing a strap around strain relief. See Figure 1.

(2) Bond design. The elastomer shape should avoid any sharp radii and abrupt elastomer-metal cutoff. The present design has both discrepancies and the shape could be changed as shown in Figure 1.

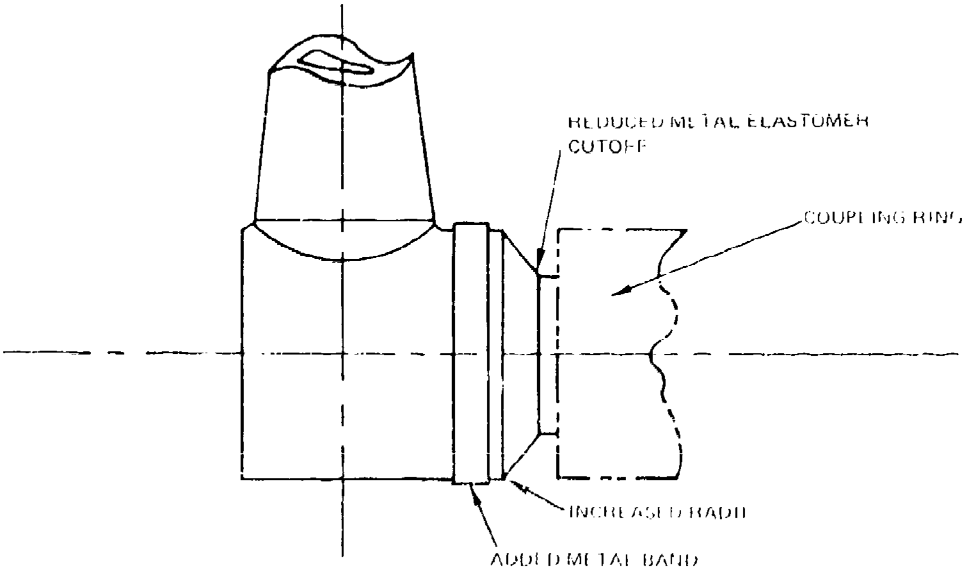


Figure 1.

(3) The effective bond length may be increased and an O-ring type action obtained by cutting grooves on the metal part. (See Figure 2.) This also gives more mechanical strength.

A tube may be added to support the strain relief on the right angle connector giving more bond length. This tube may be welded or soldered in place for ease of replacement. The tube may also have grooves. (See Figure 3.)

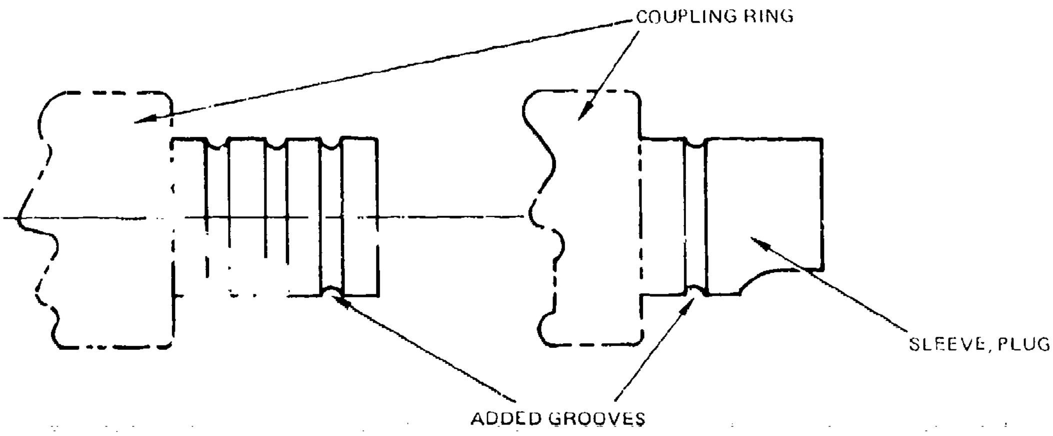


Figure 2.

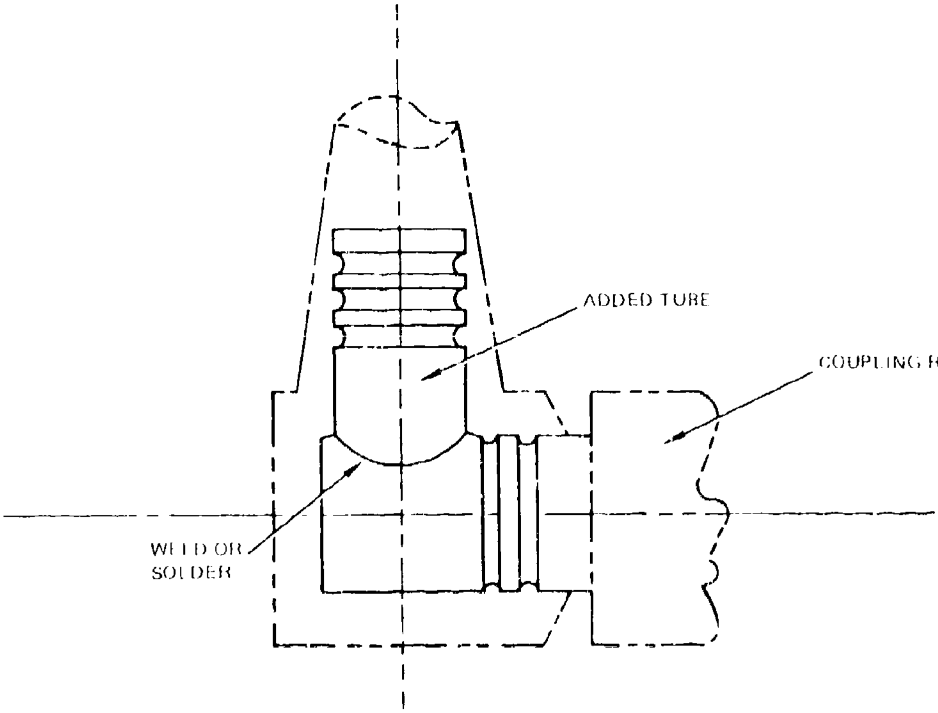
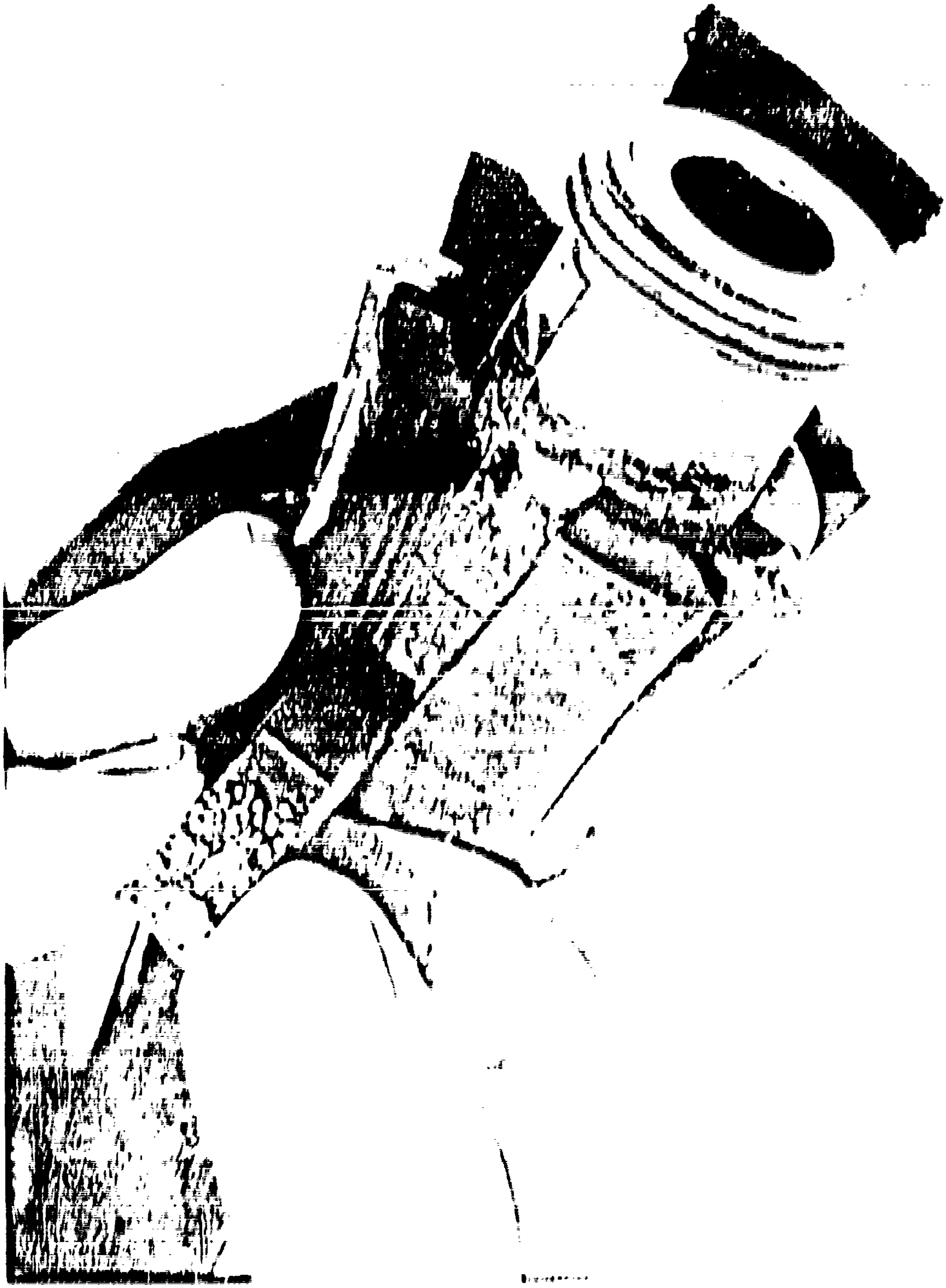


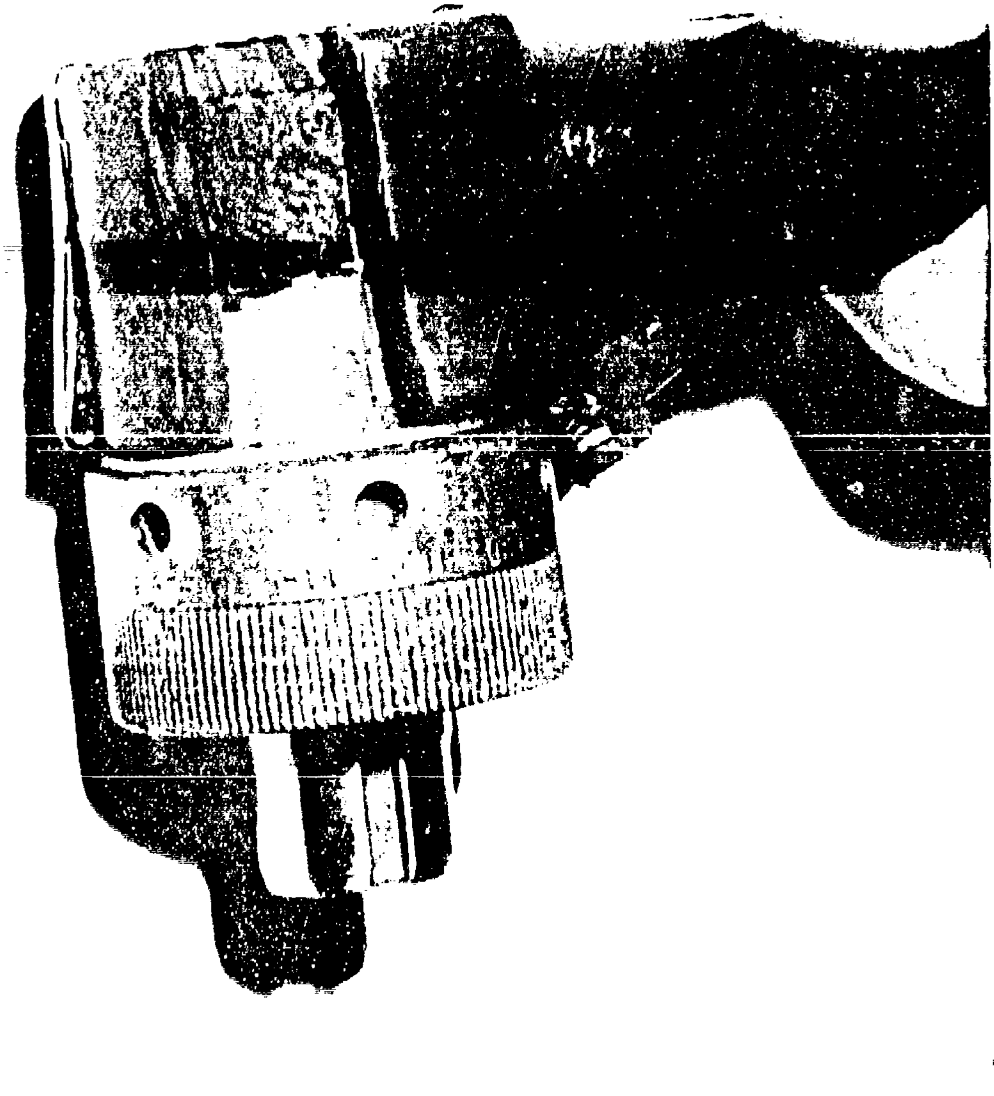
Figure 3.

Part No. 8-60013652 SN 15032

Photo [illegible]



NWSC-PASE



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APPENDIX B. AN/BQS-15 CABLE FAILURE ANALYSIS MEETING REPORT

This appendix consists of a report on a meeting held at NOSC for the purpose of receiving constructive criticism on the method used for the failure analysis and on the recommendations put forth in this report. Included is a memorandum from the Mare Island Naval Shipyard which discusses some of the current uses of these connectors. The report was originally issued as an informal report and is included here intact.

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AN/BQS-15 CABLE FAILURE ANALYSIS MEETING REPORT

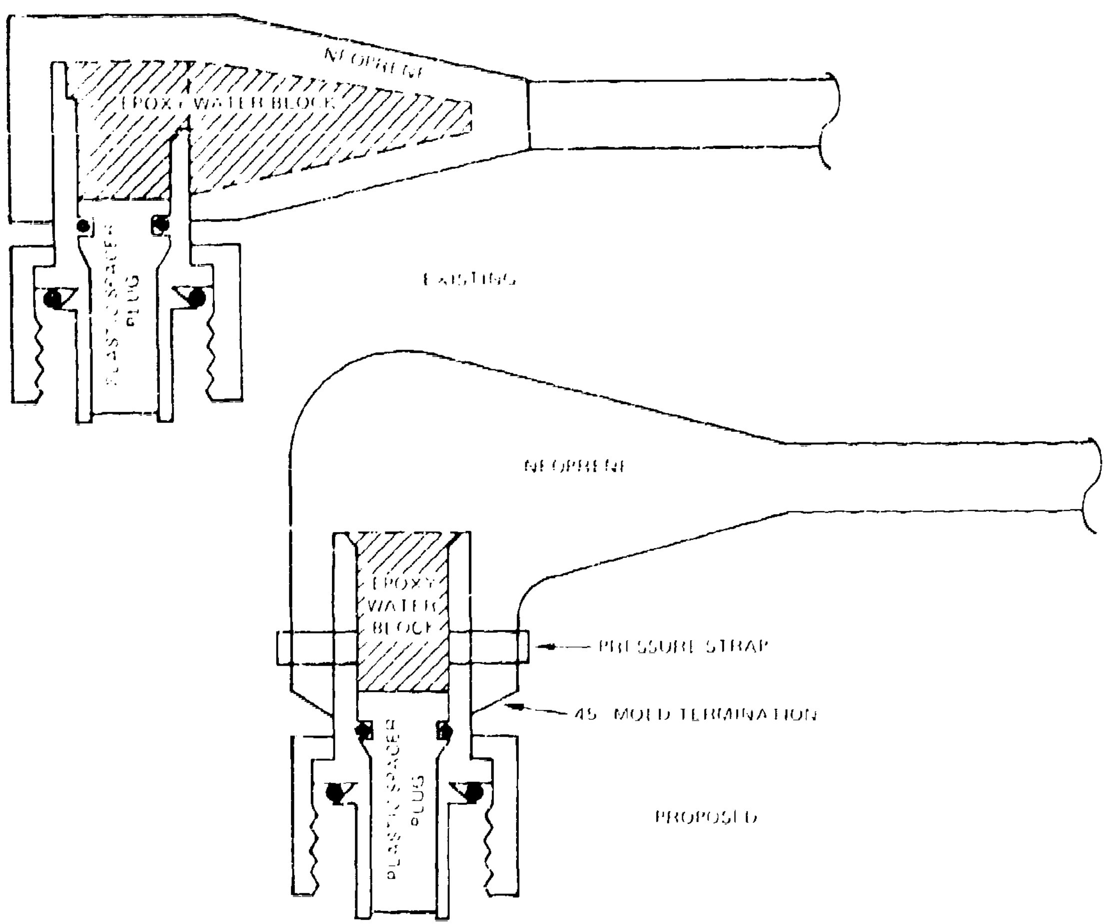
By T. L. Lewis

The test plan for the cable failure program was presented and discussed. Several of the attendees indicated that they would forward written comments.

Several samples of dissected cables were shown to illustrate the failure mode of the W31 (D/F) 3-pin 90° connector. Test results indicate that this connector will require a fundamental change in its design. The leakage path in the 90° connector has been confirmed to be up the outside of the connector metal sleeve thru the side notch and then down the inside of the metal sleeve to the plug-receptacle interface. The connectors did not leak along the wire path.

A dissection of the W30 (D/F) 14-pin 90° connector also showed the same water path failure mode.

A proposed solution to the problem was presented for comments This solution is illustrated below along with the existing connector.



A principal fault with the existing 90° connector emanates from the laying up of the epoxy water block. The volume encapsulated in the conical strain section has several problems related to it:

1. It reduces the minimum neoprene bond water path from an available 3/8 inch to 1/4 inch.

2. It does not allow the strain relief section to function as designed.

3. It is not layed up uniformly.

4. All dissected pieces showed cracking of the water block closest to the connector metal sleeve near the wire entry notch.

Concern was raised at the meeting about the proposed pressure strap. This method is presently under development at NUSC (Charley Olds). Its use will stop leakage even if the neoprene bond failed. Similar straps have been used for years on some transducers. The implementation of the strap here however needs design, material, and installation development.

Enclosure (1) to NOSC ltr Ser 623/24

ATTENDANCE LIST

NAME	ORGANIZATION	TELEPHONE
Tom Lewis	NOSC	A/V 933-7491
Tow Yee	MINSY	A/V 253-2575
Frank McBain	NAVSEACENPAC	A/V 957-5482
Dave Draper	NAVSEACENPAC	A/V 957-5481
James Dillon	NAVSEC NORDIV	A/V 690-9215
Paul W. Henderson	U.S.Navy NWSC CRANE	A/V 982-1832
Eugene A. Hill	AMETEK	(714) 442-3451
Don Huckle	NOSC	A/V 933-6430
John Redding	NUSC	(203) 447-4294

Inclosure (2) to NOSC ltr Ser 623/24

OPNAV 5216/144 (REV. 8-70)
S/N 0107-LF-778-8097
DEPARTMENT OF THE NAVY

Memorandum

270.3-Ser. 318
DATE: 12 March 1980

FROM: Tow Yee, Code 270.301, NAVSHIPYDMARE

TO: Tom Lewis, Code 6231, Naval Ocean Systems Center

SUBJ: AN/BQS-15 Cable Failure Analysis Meeting, Comments of

REF: (a) NUSC Ltr, TLL:cyXA57 Ser. 623/24 of 13 Feb 1980; Subj: AN/BQS-15 Cable Failure Analysis Meeting

Encl: (1) Sketch: a) fig (1); Polyurethane encapsulated MIL-C-24217 Right Angle Connector
b) fig (2); Deep Submergence Right Angle Connector Assembly.

1. As discussed at reference (a), AN/BQS-15 Cable Failure Analysis meeting, the MIL-C-24217 right-angle connections were flooding. The connectors have a hard epoxy backfill and cable strain relief, and are encapsulated in neoprene rubber. Failure analysis identified flooding was caused by rubber to metal bond separation and fracture of the hard epoxy cable relief at the connector shell. Comments on solutions and MIL-C-24217 right angle connector service data were requested.

2. The MIL-C-24217 right angle connector is equipped on the AN/BQN-13 Submarine Distress Pinger transducers, and the deep submergence vehicles (DSV's) NR-1, DSV-3 (TURTLE), DSV-4 (SEACLIFF), and the deep submergence rescue vehicles (DSRV's). The cable connector assemblies installed on the DSV's are reliable and have not experienced the failure mode exhibited by the AN/BQS-15 cable connector assemblies. The DSV connector assemblies are subjected to 6.5k foot depths without significant failures and are inspected and replaced nominally every 5 years. The connectors incorporate a hard epoxy backfill and polyurethane for strain relief and encapsulation.

3. We concur with the failure analysis findings that the AN/BQS-15 cable connector assemblies flooded at the cable connector. Suggest that two alternative methods be considered. The methods are to encapsulate connectors with polyurethane, enclosure (1), fig 1, or to manufacture the proposed right angle connector cable assemblies incorporating a straight inline connector shell, detailed in enclosure (1) of reference (a).

4. Polyurethane encapsulated connectors have proven to be reliable for deep submergence service. The uniformally molded polyurethane encapsulation eliminates the stress fracture failure at the strain relief area and increases the available bond surface from 0.25 inches to 0.375 inches, enclosure (1), fig 1. The polyurethane to metal interface can be visually inspected for bond integrity without the use of prying tools, which could damage bond integrity. The

molds and molding procedures are in service and available for polyurethane encapsulation of the MIL-C-24217 right angle connector.

5. Right angle connector assemblies similar to the proposed method detailed in enclosure (1) of reference (a) has been in service on the DSV's NR-1 and DSRV's with satisfactory results. See fig 2 of enclosure (1). The connector assemblies are repeatedly subjected to 6.5k foot depths without significant failures. The connector assemblies installed on the NR-1 and DSRV's do not incorporate pressure bond straps and in service data is not available. The proposed encapsulation method has more available connector bonding surface than the MIL-C-24217 right angle connector, and eliminates the stress fracture failure at the cable strain relief area. The proposed connector assemblies can be installed in areas where vertical clearance is not critical.

6. Cable failures and reliability can be improved with quality control program and proper material choice. Surface preparation and elimination of the hard epoxy strain relief area would eliminate a majority of problems encountered.

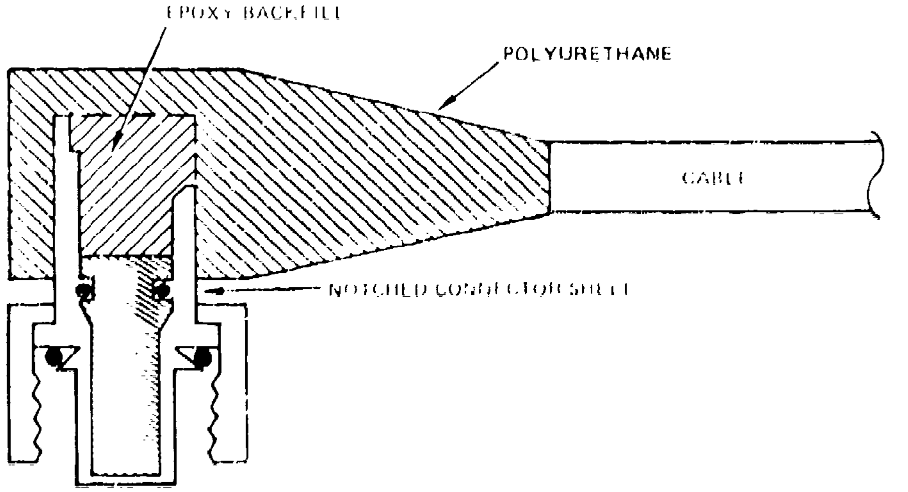


Figure 1. Polyurethane encapsulated MIL-C-24217 right angle connector.

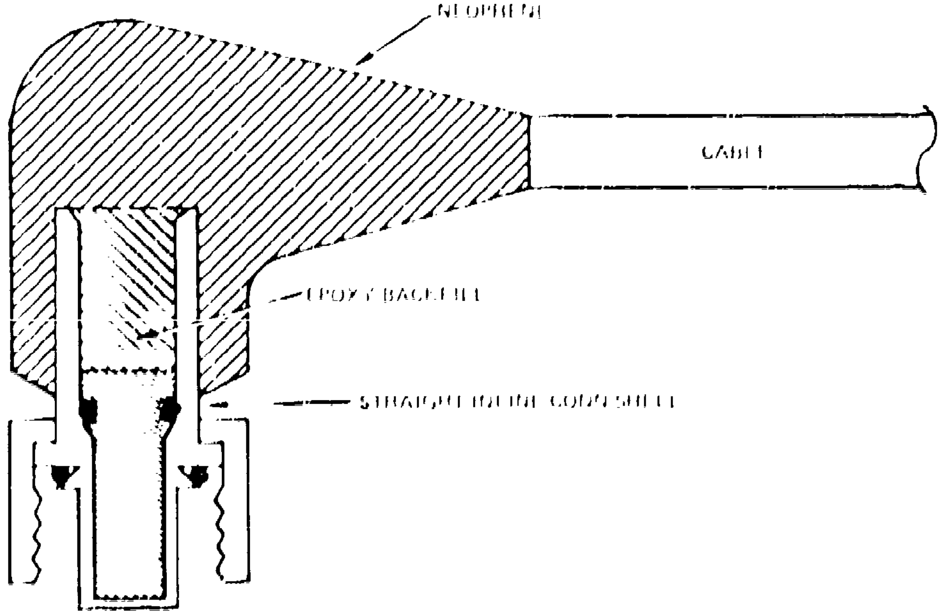


Figure 2. DSN molded right angle connector.