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ANACAPA ISLAND SPLIT PIPE INSPECTION OF JUNE 1977 AND APRIL 197--ETC(U)  
SEP 78 W R TAUSIG, R L BRACKETT  
CEL-TN-1525

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# Note

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**author:** W. R. Tausig and R. L. Brackett

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## CIVIL ENGINEERING LABORATORY

NAVAL CONSTRUCTION BATTALION CENTER  
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The U. S. Navy currently maintains and operates numerous underwater power and signal cables. Most of these cables utilize split pipe systems to protect the cable from damage in the surf zone and when crossing exposed rocky seafloors. Past experience has shown that the hardware used to install the split pipe system lacks the reliability and maintenance-free operation required for the life of the cables. Based on previous experience with cable failures, the areas determined to be in greatest need of investigation are (continued)		

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CONT fasteners for holding the split pipe halves together, immobilization of the pipe, and cathodic protection for the entire system. As a result, CEL tested prototype and commercially available hardware components which appeared to be suitable replacements for the existing split pipe hardware. The candidate hardware was then used in a 300-ft-long test section of split pipe installed March 1976 at Anacapa Island, to be inspected during a five-year period. Results of the CEL hardware tests, Anacapa pipe installation, and first inspection are documented in TN-1498. This report is a follow-up to TN-1498 and presents the results of the test installation inspections for June 1977 and April 1978; the second and third inspections to be made since the March 1976 installation was completed.

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1. Split-pipe systems 2. Underwater cables I. YF52.556.999.01.301

The U. S. Navy currently maintains and operates numerous underwater power and signal cables. Most of these cables utilize split pipe systems to protect the cable from damage in the surf zone and when crossing exposed rocky seafloors. Past experience has shown that the hardware used to install the split pipe system lacks the reliability and maintenance-free operation required for the life of the cables. Based on previous experience with cable failures, the areas determined to be in greatest need of investigation are fasteners for holding the split pipe halves together, immobilization of the pipe, and cathodic protection for the entire system. As a result, CEL tested prototype and commercially available hardware components which appeared to be suitable replacements for the existing split pipe hardware. The candidate hardware was then used in a 300-ft-long test section of split pipe installed March 1976 at Anacapa Island, to be inspected during a five-year period. Results of the CEL hardware tests, Anacapa pipe installation, and first inspection are documented in TN-1498. This report is a follow-up to TN-1498 and presents the results of the test installation inspections for June 1977 and April 1978; the second and third inspections to be made since the March 1976 installation was completed.

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## 1.0 INTRODUCTION

Underwater power and signal cables are of great importance to the Navy. In most cases, split pipe systems are used to protect these cables from damage in the nearshore and surfzone regions. However, experience has shown that hardware used in installing these split pipe systems is often unreliable. Previous attempts to improve the hardware have been confined to in-the-field trial-and-error procedures using off-the-shelf hardware.

Under the sponsorship of the Naval Facilities Engineering Command (NAVFACENGCOM), a project was undertaken in July 1974 by the Civil Engineering Laboratory (CEL) to develop improved hardware and methods for the maintenance and repair of existing split pipe protected cables. To meet this objective, CEL investigated: different types of fasteners for holding the split pipe together, methods for immobilization of the cable, and methods for cathodically protecting the entire system. The hardware components that showed promise during laboratory tests were then used in a 300-foot-long open ocean test installation on the south side of Anacapa Island, California. These components are being inspected and monitored approximately semi-annually for a five-year period.

This report presents the results of the test installation inspections for June 1977 and April 1978; the second and third inspections to be made since the March 1976 installation was completed. (Due to adverse winter weather conditions, the inspection scheduled for November 1977 was not accomplished). Installation procedures and results of the first inspection are reported in reference 1.

## 2.0 BACKGROUND

To determine the suitability for long-term installations, the candidate hardware components were installed on 98 sections of split pipe located on the south side of Anacapa Island. Details of the pipe installation and hardware description are given in Appendix A, taken from reference 1.

During each of the semi-annual inspections, the following items are monitored:

- (a) effects of cathodic protection on the entire system
- (b) amount of marine growth on the fasteners\*

\* The amount of marine growth observed indicates the amount of abrasion present. The abrasive effects of the sand driven by the local surge keeps the marine growth to a minimum. In addition, large amounts of marine growth will increase the hydrodynamic drag on a cable installation, and thus affect the design of the immobilization system.

- (c) effects of hydrodynamic forces on the pipe and long-term performance of the rock bolt immobilization, and
- (d) serviceability and corrosion resistance of the 3 types of fasteners.

In November 1976, the first of ten planned inspections was accomplished. The results of this inspection revealed numerous broken jumper cables, resulting in the loss of cathodic protection for all pipe sections except sections 45 through 78. All other components were found to be in good condition. Details of the first inspection are discussed in Appendix B, also taken from reference 1.

### 3.0 EFFECTS OF CATHODIC PROTECTION

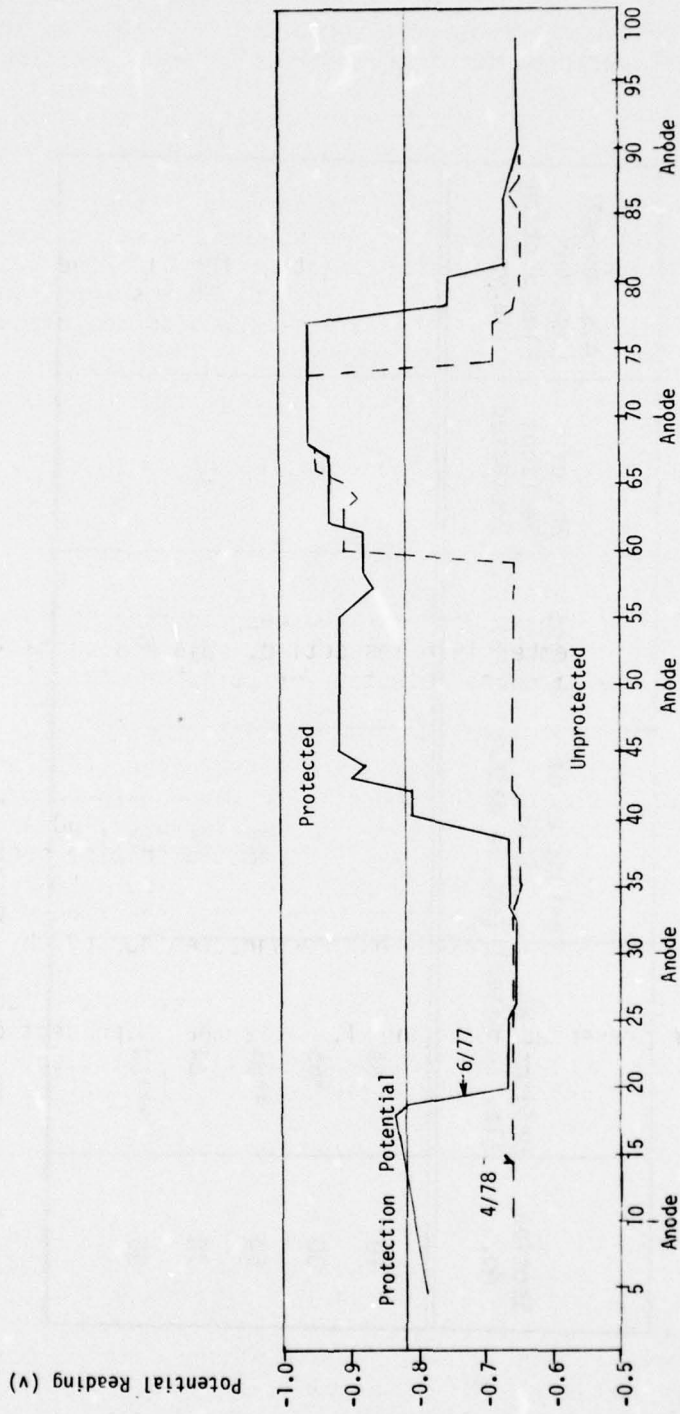
#### 3.1 June 1977

Visual inspection of the pipe installation in June 1977 revealed that numerous jumper cables were missing despite repairs to the jumpers during the November 1976 inspection. This was primarily due to the fact that the hardware selected for attaching the zinc anodes and jumper cables to the split pipe installation was mechanically inadequate to withstand the wave action of the open ocean environment. All jumper cables were broken or missing between pipe sections 1 through 12. Additional broken jumpers were found between pipe sections 29 and 30, 34 and 35, 39 and 40, 41 and 42, 44 and 45, 60 and 61, 86 and 87, 87 and 88. Anodes normally connected to pipe sections 10 and 30 were missing. The anode connected to pipe section 30 was replaced during this inspection. The wire connecting pipe section 90 to its anode was found broken, but reconnected during this inspection.

Galvanic potential readings were taken with an underwater voltmeter. The results are presented in Figure 1. Note that pipe sections 43 through 77 are the only sections cathodically protected. The remaining pipe sections are unprotected due to the numerous broken jumper and anode cables.

#### 3.2 April 1978

In addition to the jumper cables reported broken or missing during the prior inspection, broken jumpers were found between pipe sections 12 through 31, and 33 through 45. The anode cables connected to pipe sections 10, 50 and 90 were also found broken. The anode connected to pipe section 30, which was replaced during the June 1977 inspection, was again missing. The only remaining working anode was located at pipe section 70. This anode was weighed in water to determine the amount of anode consumption. These data are presented in Table 1.



Split Pipe Section Number

Figure 1. Cathodic Protection Potential

Table 1. Anode Consumption Rate (For a 25-Month Period)

Section No.	Original Wt. (lb, in water)	Weight as of 4/78 (lb, in water)	Weight Loss (lb)	No. of Sections Protected	Avg. Annual Loss Per Pipe Section (lb/yr)
10	64	-	-	-	-
30	*65	-	-	-	-
50	**64	53	11	-	-
70	64	42	22	13	0.81
90	***64	58	6	-	-

\* replaced 6/77, missing 4/78

\*\* broken 4/78

\*\*\* reconnected 6/77, broken 4/78

Galvanic potential readings were again obtained over the entire pipe installation. Results of these data are included in Figure 1. Note that due to further jumper cable and anode failures, only pipe sections 60 through 73 are cathodically protected.

Figure 2a shows an example of a cathodically protected, BOM fastener from the June 1977 inspection. Figure 2b shows an example of a cathodically protected BOM fastener from the April 1978 inspection, after 25 months of submersion. Note in comparing these figures that there is little or no sign of corrosion on the fasteners.

#### 4.0 EFFECTS OF MARINE GROWTH

##### 4.1 June 1977

Visual inspection and photographic documentation of the fasteners in June 1977 revealed only moderate amounts of marine growth. All fasteners could be readily identified without removing any growth. In areas where the pipe sections crossed predominately sandy bottom, the fasteners showed very little or no marine growth. This is probably due to "abrasive" effects of the sand driven by the local surge.

##### 4.2 April 1978

Visual and photographic inspection of the fasteners in April 1978 revealed heavy marine growth. In many cases, the type of fastener could not be readily identified without first brushing away the growth.

Figure 3a shows typical marine growth encountered in June 1977. The fastener is a Hi-Shear bolt located on pipe section 53. In comparison, Figure 3b shows the heavy marine growth encountered in April 1978. This fastener is also a Hi-Shear bolt.

#### 5.0 EFFECTS OF HYDRODYNAMIC FORCES AND IMMOBILIZATION

##### 5.1 June 1977

Inspection of the installation revealed that from the period March 1976 to June 1977, no pipe damage was suffered from hydrodynamic forces. In addition, all rockbolts were found intact.

##### 5.2 April 1978

Inspection of the installation revealed that from the period June 1977 through April 1978, the pipe installation suffered heavy damage to its shore end. This was due to extremely heavy storm



Figure 2a. Cathodically protected fastener from pipe section 57, June 1977.



Figure 2b. Cathodically protected fastener from pipe section 71, April 1978.



Figure 3a. Moderate marine growth on Hi-Shear fastener from pipe section 53, June 1977.

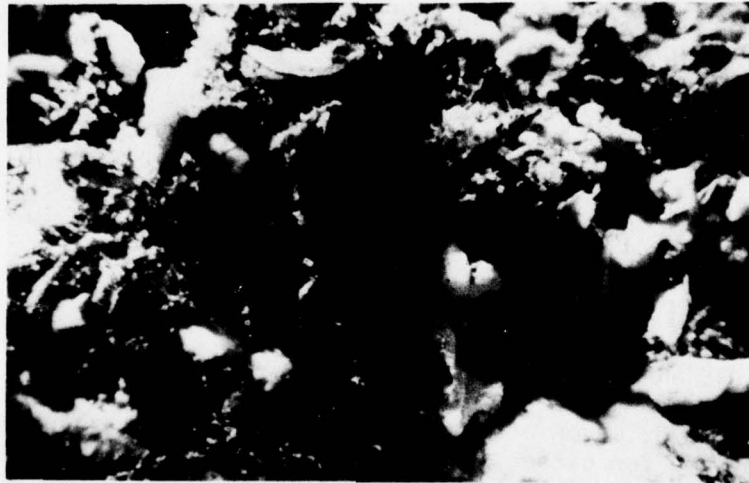


Figure 3b. Heavy marine growth on Hi-Shear fastener from pipe section 80, April 1978.

wave forces. Figure 4 shows the maximum significant wave heights in the pipe installation area for the winter of 1978. Pipe sections 2 through 10 were dislodged and separated from the rest of the installation. Only pipe section 1 remained rockbolted to the shore. All pipe sections beyond section 10 (at a water depth of 10 feet out to 42 feet) remained intact. The four rockbolts located on pipe sections 2 and 3 failed to hold during the storm. In addition, the Hi-Shear fasteners on sections 2 through 10 failed to hold these pipe halves securely together. A failure analysis of the pipe damage is discussed in section 7.

## 6.0 EFFECTS OF CORROSION

### 6.1 June 1977

Visual inspection of each pipe fastener in June 1977 revealed no failures due to excessive corrosion. Fasteners that were not cathodically protected showed signs of corrosion. However, there were no signs of loose pipe halves due to corrosive failures.

### 6.2 April 1978

Visual inspections of April 1978 of the pipe fasteners for the undamaged sections 11 through 98 revealed no evidence of failure due to corrosion. Close inspection of the damaged pipe sections 2 through 10 revealed that the primary cause of failure was due to corrosion of the mild steel Hi-Shear fasteners. Section 7 gives the failure analysis. Figure 5a shows a photograph taken in June 1977 of a BOM fastener which is not cathodically protected. Figure 5b shows an unprotected BOM fastener taken in April 1978. The corrosion products were significantly increased during the 10-month period between inspections.

## 7.0 FAILURE ANALYSIS

In May 1978, seven of the damaged pipe sections 2 through 10 were recovered for closer inspection and failure analysis. Figure 6 shows four views of the damaged installation and broken pipe. Note the large amount of tangled wire and armor from the exposed multi-conductor cable. Pipe sections 2 through 5 were found intact but severed completely from the rest of the installation. These sections were installed with stainless steel Hi-Shear fasteners. Close examination of these fasteners revealed that the pipe flange holes had enlarged around the fastener due to the galvanic interaction between the cast iron pipe and stainless steel fastener. Although none of the stainless fasteners were missing, the pipe halves were loose enough to allow the bell end of section 2 to open and slip off pipe section 1. Figure 7 shows the gap created between pipe

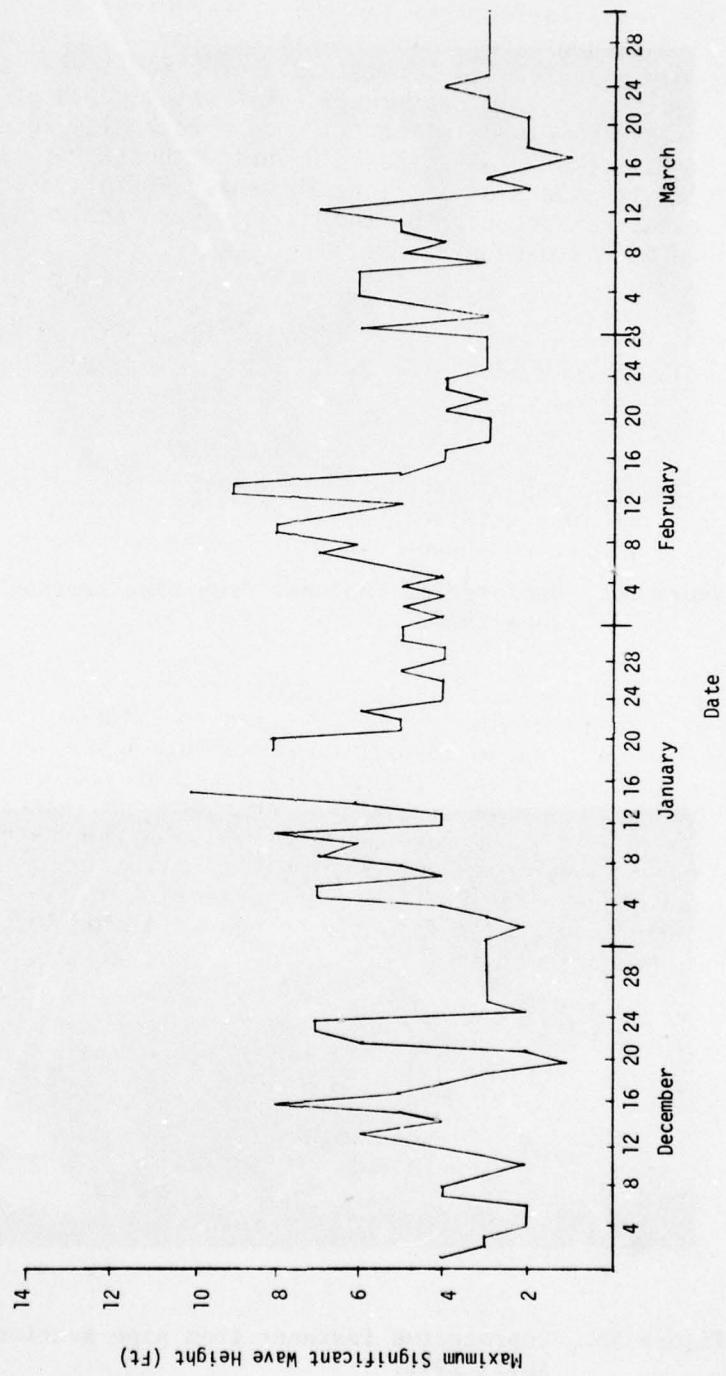


Figure 4. Significant Wave Heights

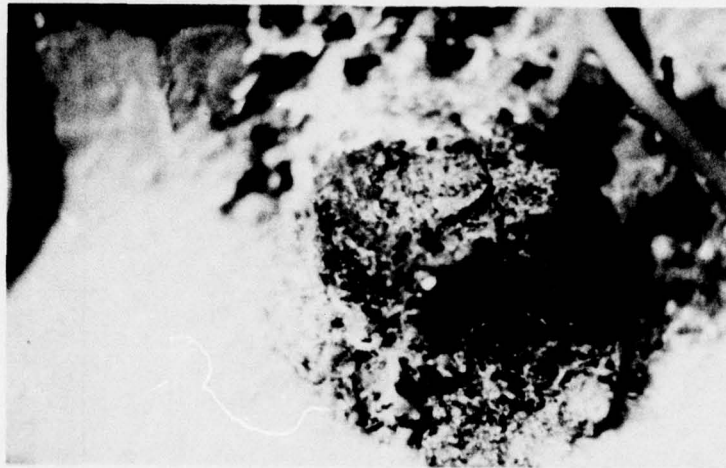


Figure 5a. Unprotected fastener from pipe section 87,  
June 1977.



Figure 5b. Unprotected fastener from pipe section 86,  
April 1978.



Figure 6a. Damaged pipe showing tangled multiconductive cable.



Figure 6b. Damaged pipe separated from installation.



Figure 6c. Cable end extending from pipe section 11.

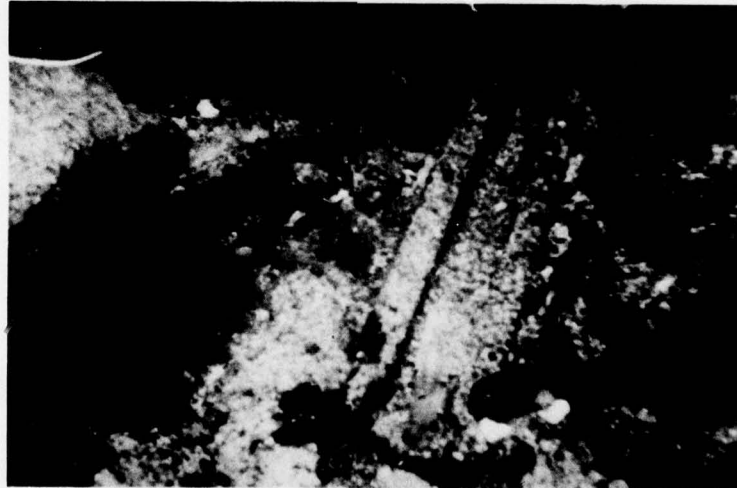


Figure 6d. Disassembled pipe half on the seafloor.

halves due to the fasteners slipping through the enlarged flange halves. The combination of corrosion and high winter wave loads was enough to cause the rockbolts to fail on pipe sections 2 and 3. Figure 8 shows the remains of two recovered rockbolts in which one had severed and one had pulled out.

Pipe sections 6 through 10, which were installed with mild steel Hi-Shear fasteners, were found to be completely disassembled (refer to Figure 6d). The majority of these fasteners were missing from the pipe halves. Close examination of the recovered fasteners revealed that corrosion between the steel pipe and steel fastener decreased the diameter of the flared end of the fastener by about 0.1 inches. Failure occurred when these fasteners corroded enough to slip through the pipe flange holes. Figure 9 shows the mode of failure for the mild steel Hi-Shear fasteners.

In addition, it was noted that all of the mild steel nuts and bolts in pipe sections 2 through 10 were completely missing. They apparently corroded and vibrated loose.

The only fasteners that remained intact were the BOM fasteners which were installed beginning with Section 11. These fasteners have enlarged swaged ends, which resist slippage due to corrosion. Figure 10 shows a comparison of the enlarged swaged end of a BOM fastener with the swaged end of a Hi-Shear fastener.

Table 2 lists the experimental fasteners (in order of mechanical integrity) along with their failure modes after 25 months of testing.

## 8.0 CONCLUSIONS

1. Results to date indicate that the cathodic protection system, where it remained intact, provides sufficient protection for the pipe sections and fasteners. The average anode consumption rate was found to be 0.81 pound per year per pipe section.

2. Failure analysis has shown that both split pipe and fastener (whether mild steel or stainless steel) must be cathodically protected.

3. The exposed jumper and anode cables are identified as the system components most susceptible to damage. Once the cables are broken, the cathodic protection is lost, and corrosive failure follows.

4. Due to its enlarged locking swaged head, the BOM fastener was found to be mechanically superior to the Hi-Shear fastener in resisting corrosive loosening.

5. Without cathodic protection, the BOM fastener appears to maintain its mechanical integrity longer than any other type fastener used to date - including stainless steel nuts and bolts.



Figure 7. Gap in pipe halves due to slippage of Hi-Shear stainless steel fasteners.

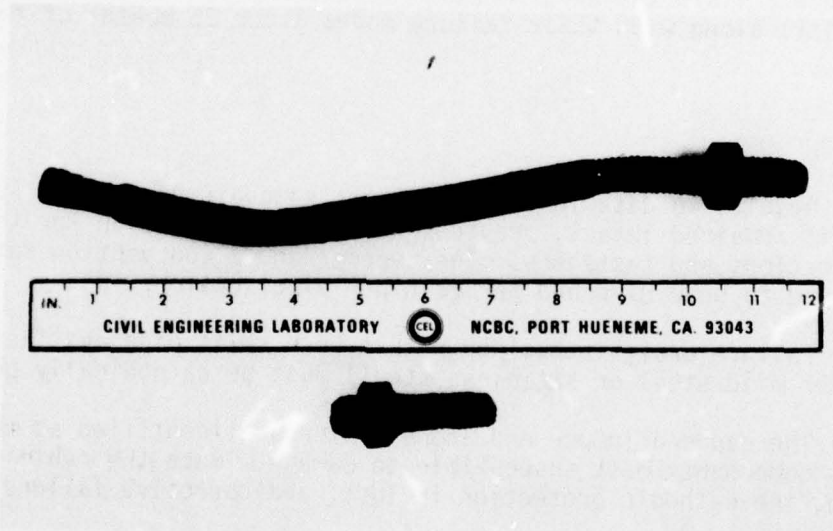


Figure 8. Recovered rockbolts.

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Figure 9. Corroded Hi-Shear steel fasteners slipping through the pipe flange.

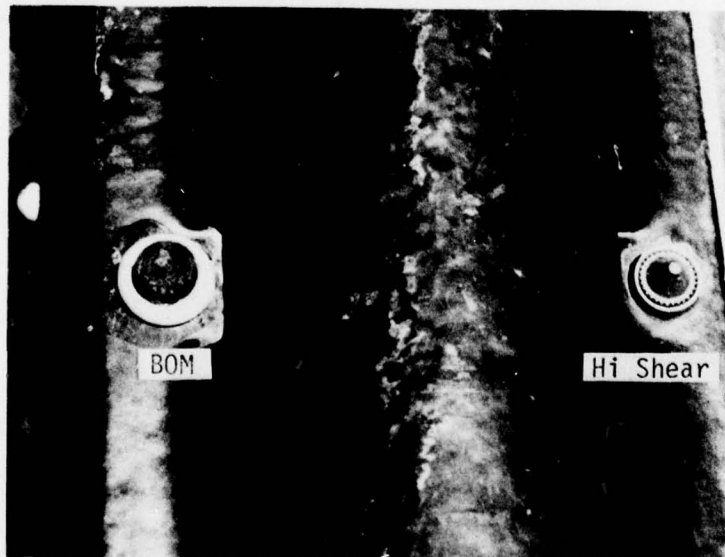


Figure 10. Comparison of the swaged end of a BOM and Hi-Shear fastener.

Table 2.

Fastener	Failure Mode
1. BOM	No failures
2. Hi-Shear Stainless Steel	Corrosion of pipe around fasteners causing pipe halves to loosen.
3. Hi-Shear Mild Steel	Decrease in fastener diameter due to corrosion, allowing fastener to pull out of pipe flange.
4. Nuts and Bolts - Mild Steel	Corrosion and vibration loosening, allowing fastener to fall out of pipe halves.

#### 9.0 REFERENCE

1. Brackett, R. L. and Tausig, W.R. (1977). Improved Hardware and Techniques for Maintenance and Repair of Split-Pipe Protected Cables, Civil Engineering Laboratory. Technical Note 1498, Port Hueneme, CA, August 1977.

## APPENDIX A

### LONG-TERM TEST INSTALLATION (MARCH 1976)

Based on the results of the Laboratory and harbor tests, the following hardware components were selected for long-term testing:

- Fasteners. . . . . Huck BOM
  - Hi Shear Stainless Steel
  - Hi Shear Mild Steel
- Immobilization. . . . . Philips Wedge Masonry Anchor,  
5/8-in. diam. x 12 in. long.
- Cathodic  
protection. . . . . Sacrificial anode consisting of:
  - five 75-lb zinc anodes
  - 99 jumper cables
  - Coal tar epoxy coating on split pipe

To determine the suitability of these candidate system components to perform effectively in an actual split pipe installation, a 300-ft-long test section was installed that will be inspected semiannually for a 5-yr period. This installation serves two purposes. First, it provides an opportunity for military divers to install split pipe using the new hardware and tools, and second, it provides an opportunity to observe the condition of the candidate hardware over a long period when subjected to the open ocean environment.

#### Site Selection

The test site selection was based on the following criteria.

- (1) The site should be close enough to Port Hueneme to allow semiannual inspections without high deployment costs.
- (2) Because of the short length of the test section (300 ft), a steep depth gradient is desirable.
- (3) The area should be predominantly rock to allow full evaluation of the immobilization system.

- (4) The site should be protected to allow for installation and inspection by divers, but it should be subject to the effects of winter storm conditions.
- (5) Underwater visibility should be at least 30 ft to allow for photographic documentation.

The selected site is located on the south side of Anacapa Island at coordinates 34°0'15"N latitude, 119°23'30"W longitude. After preliminary selection, the site was surveyed, and the following conditions were found:

- Bottom material . . . . . Vesicular Basalt, 80%; Sand, 20%
- Depth gradient . . . . . 14% Slope (0 to -42 ft)
- Visibility . . . . . 30 to 90 ft
- Swell . . . . . Minimum, 1/2 ft  
Maximum, 8 to 10 ft  
(late summer and fall)

Installation

The actual installation was accomplished in six phases: (1) mooring installation, (2) assembly of 75 ft of split pipe on warping tug, (3) deployment of cable and first 75 ft of split pipe, (4) deployment and assembly of remaining 225 ft of split pipe by divers, (5) installation of rock bolts and anodes, and (6) inspection and documentation.

Because of the heavy surge conditions that exist near shore, the first 75 ft (25 sections) of pipe were assembled around the cable on board the CEL warping tug. A 12-in. H-beam was first tack-welded to the deck, and the pipe and cable were assembled in the upper channel.

This served to stabilize the pipe during transit to the test site, and it also acted as a guide during deployment of the pipe and cable.

The bolting sequence for the first 25 sections was:

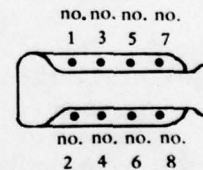
<u>Section No.</u>	<u>Type of Bolt</u>	<u>No. of Rock Bolts</u>
1	Mild Steel	2
2-5	Hi Shear Stainless	4
6-10	Hi Shear Mild Steel	0
11-15	Huck BOM	2
16-20	Hi Shear Stainless	0
21-25	Hi Shear Mild Steel	0

This phase of the installation also allowed all of the tools and power sources to be checked out prior to deployment and the divers to familiarize themselves with the tools and their operation prior to using them in the open ocean.

After the split pipe and cable had been deployed at the test site, the remaining 225 ft of split pipe were assembled on the seafloor by divers.

The procedures used for assembling the test installation were:

- (1) One type of fastener was to be used for five consecutive split pipe sections.
- (2) Sequence of fasteners: Huck BOM, Hi Shear Stainless Steel, and then Hi Shear Mild Steel.
- (3) Bolt holes no. 5 and no. 6 would not contain fasteners (Rock bolts would be installed during the immobilization phase of the installation)
- (4) Jumper cables were to be connected between sections of pipe using bolt holes no. 1 and no. 7.



The rock bolts were always installed in pairs in holes no. 5 and no. 6 in the split pipe flange. This prevented the pipe from twisting and applying a bending load to the bolt. The bolt pairs were to be installed in every sixth section of pipe; however, the presence of sand and loose rocks in some areas precluded absolute adherence to this spacing.

Five anodes were attached, one each to sections 10, 30, 50, 70, and 90. A 20-ft-long cable connected each 75-lb zinc anode to the pipe. The anodes were placed as far from the pipe as possible and in a rocky area where they wouldn't be covered with sand. After the rock bolts and anodes were installed, all of the remaining flange holes were filled with mild steel nuts and bolts and Hi Shear fasteners. Table A-1 lists the position of the fasteners in each pipe section.

Table A-1. Position of Fasteners.

Section	Flange Holes			Section	Flange Holes		
	1-4,7,8	5	6		1-4,7,8	5	6
1	MB	RB	RB	31	HB(1,4L), 3MB,7MB	RB	RB
2	HB	RB	RB	32	HB(7L)	SB	MB
3	HB	RB	RB(L)	33	HB	MB	MB
4	HB	MB	MB	34	HB(3L)	MB	MB
5	HB	MB	MB	35	HB(2L)	MB	MB
6	HG	MB	MB	36	HG(2L)	SB	MB
7	HG	MB	MB	37	HG	MB	MB
8	HG	MB	MB	38	HG	MB	MB
9	HG(2L)	MB	MB	39	HG(1,2L)	MB	MB
10	HG	MB	AN	40	HG(1L)	MB	MB
11	BOM	BOM	BOM	41	BOM	MB	MB
12	BOM	MB	MB	42	BOM	MB	MB
13	BOM	MB	MB	43	BOM	RB	RB(L)
14	BOM	MB	MB	44	BOM	HB	HB
15	BOM	RB	RB	45	BOM	HB	HG
16	HB	MB	MB	46	HB(1L)	RB	RB
17	HB	MB	MB	47	HB(2,7L)	HB	HB
18	HB	MB	MB	48	HB(4L)	HB	HB
19	HB	MB	MB	49	HB(7L)	HB	HB(L)
20	HB	HB	MB	50	HB	HG	AN
21	HG	MB	MB	51	HG	—	—
22	HG	MB	MB	52	HG	HB	HB
23	HG	MB	MB	53	HG	HB	HB
24	HG	MB	MB	54	HG	—	—
25	HG	MB	MB	55	HG	HG	HB
26	BOM	MB	MB	56	BOM	HB	HG
27	BOM	MB	MB	57	BOM	HB	HG
28	BOM	RB(L)	RB	58	BOM	HB	HB
29	BOM	MB	MB	59	BOM	HB	HB
30	BOM	MB	AN				

continued

Table A-1. Continued

Section	Flange Holes			Section	Flange Holes		
	1-4,7,8	5	6		1-4,7,8	5	6
60	BOM	HGL	HB	79	HB(4L)	RB	RB
61	HB	RB	RB	80	HB	HB	HB
62	HB(2,3,7L)	HB	HG	81	HG	HB	HB
63	HG	HG	HG	82	HG	—	—
64	HB(7L)	—	—	83	HG	HB	HB
65	HB(8L)	HG	HB	84	HG,1SB	—	—
66	HG	HG	HB(L)	85	BOM	HB	HB
67	HG	HG	HB	86	BOM	HB	HB
68	HG	HG	HG	87	BOM	RB	RB
69	HG,1MB(L)	HG	HG	88	BOM	HB	RB
70	HG,1MB(L)	—	AN	89	1,2,3,7,BOM	HB	—
71	BOM	HG	HG	90	HB	HB	AN
72	BOM	HB	HG	91	HB(1L)	HB	HB
73	BOM	HB	HG	92	HB	—	—
74	BOM	—	HG	93	HB(1L)	—	—
75	BOM	RB	HG	94	HG	—	HB
76	HB	—	HB	95	HG	HB	HB
77	HB,1MB	—	—	96	HB	HB	HB
78	HB(4,7,L)	HB	HB(L)	97	HG	MB	HB
				98	HG	RB	RB

BOM — Huck fastener

SB — Stainless steel nut and bolt

HB — Hi Shear stainless steel

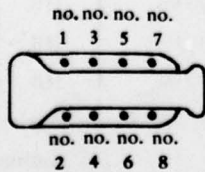
HG — Hi Shear mild steel

MB — Mild steel nut and bolt

(L) — Fastener loose

RB — Rock bolt

AN — Anode attached with stainless nut and bolt



## APPENDIX B

### SEMIANNUAL INSPECTIONS

In November 1976, the first of ten semiannual inspections was conducted. Visual inspection of the installation revealed that numerous jumper cables had been broken. All the jumpers were broken or missing between sections 1 and 35. Additional broken jumpers were found between sections 44 and 45, 60 and 61, and 77 and 78. The wires connecting the anodes to the pipe at sections 10, 30, and 90 were broken, and the anodes connected to sections 10 and 30 could not be located. The three anodes that were found were weighed in the water to determine the amount of anode consumption. These data are presented in Table B-1.

Galvanic potential readings were obtained with an underwater voltmeter; the results are presented in Figure B-1. Because of the numerous broken jumpers and disconnected anodes, only sections 45 through 78 are being protected.

Table B-1. Anode Consumption Rate

Section No.	Original Weight (lb, in water)	Weight After Six Months (lb, in water)	Weight Loss (lb)	No. of Sections Protected	Average Annual Loss Per Pipe Section (lb/yr)
10	64	—	—	—	—
30	64	—	—	—	—
50	64	57	7	15	1
70	64	53	9	19	1
90	64	62	2	—	—

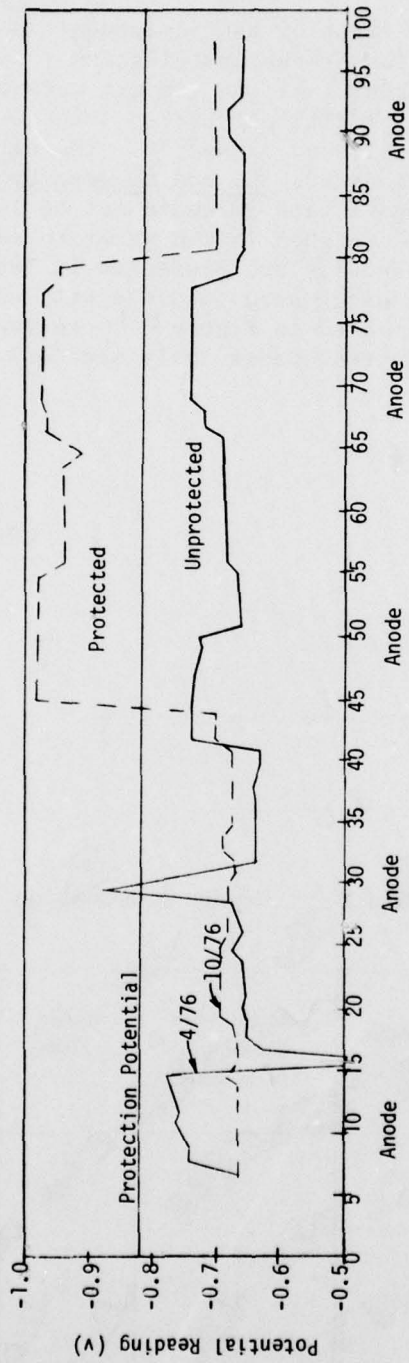


Figure B-1. Cathodic Protection Potential  
Split Pipe Section No.

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