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Technical Note N-832

CATHODIC PROTECTION OF MOORING BUOYS AND CHAIN

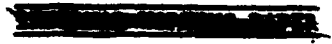
PART II. FURTHER FIELD STUDIES

by  
Richard W. Drisko, Ph. D.



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**PART II. FURTHER FIELD STUDIES**

Technical Note N-832

Y-PC80-03-04-003

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Richard W. Drisko, Ph. D.

**ABSTRACT**

An investigation was conducted into the use of specially cast zinc anodes to cathodically protect the ground tackle of a fleet mooring. While part of the mooring was completely protected by these anodes, a lack of good electrical continuity in parts of the ground legs prevented complete protection there. A cable joined periodically along one of the ground legs provided the necessary continuity and permitted complete protection of the leg.()

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## INTRODUCTION

This is the second in a series of internal working papers on the cathodic protection of fleet moorings. Part I<sup>1</sup> described the initial field testing of cathodic protection as a means of reducing costs for Naval Facilities Engineering Command field activities maintaining moorings. The original system utilizing sacrificial magnesium anodes connected through control heads did not provide the desired level of protection. When the magnesium anodes were replaced with uncontrolled zinc anodes, the latter functioned properly but were present in insufficient number to provide the desired level of protection. The present study utilized much larger zinc anodes cast on special chain links that became an integral part of the ground tackle.

## INSTALLATION AND TESTING OF CATHODIC PROTECTION

The cathodic protection system investigated in the present study utilized specially manufactured zinc anodes (Figure 1). These anodes were prepared by casting SA-3 zinc alloy on a 2½-inch thick steel link 35 inches in length. The zinc casting was of trapezoid cross section, with a length of 1.8 feet and a total surface area of approximately 6.6 square feet. The weight of the entire anode was approximately 485 lbs.

The design of the cathodic protection system is shown in Figure 2. Two of the smaller zinc anodes (approximately 144 lbs.) used in the previous study<sup>1</sup> were located in sea chests on opposite sides of the buoy cone. One of the special anodes was located on the riser-chain approximately three feet above the ground ring. Thus no place on the chain is further than 45 feet from an anode. The anodes were secured into the ground tackle using standard detachable links.

The entire mooring complex was layed out on the deck of a floating crane (Figure 4) and later carefully lowered into service to avoid abrasion or impact damage to the anodes.

Immediately after placement of the mooring, the potential of the buoy was found to be -920 mv (all potentials to be reported will be with reference to a standard silver-silver chloride half-cell). On the following day a potential profile was made of the mooring using a portable field meter and two foot leads. The instrument was read at the surface while a diver made electrical contact with a steel pick to the mooring chain. The standard half-cell was held one foot from the point of contact.

The readings received are listed in Table 1. Another potential profile was made three months later, after the chains had considerable time to erode the recently applied coal tar coating by movement during tidal change. These later readings are listed in Table 2.

The results of Tables 1 and 2 indicated that the zinc anodes were working properly and much of the ground tackle was protected. It also indicated that a lack of electrical continuity on other parts of the ground legs prevented complete protection there.

In order to determine ways to obtain better electrical continuity between chain links two of the ground legs were slightly modified eight months after the readings of Table 2 were made. One was removed from the water and those portions of the chain links that come into contact with each other (Figure 5) were sandblasted using portable sandblast equipment aboard a floating crane. This ground leg was then returned to its normal location underwater, and a second ground leg was lifted and layed out on the deck of the floating crane (Figure 6). Three 3/4-inch diameter galvanized steel cables were woven back and forth through every sixth link. One cable extended from the A-link nearest the anchor to the A-link nearest the zinc anode 45 feet away. The other two cables extended between the zinc anodes 90 and 80 feet apart. The ends of each cable were silver-soldered to the A-link nearest the anode (Figure 7), and the cable was also silver-soldered to each twelfth link (approximately 9 feet). Sufficient slack was placed between fixed positions so that there was no strain on the cable. This ground leg was returned to its normal position with no difficulty.

The anodes on the modified ground legs were examined when removed from the water. There was no sign of passivation, and plenty of zinc remained for further use. Zinc losses occurred in irregular pits (Figure 9) rather than in a uniform manner.

A potential profile was made on the entire mooring one week after the two ground legs had been modified. The readings received are listed in Table 3.

## DISCUSSION

The specially prepared zinc anodes performed satisfactorily and showed no signs of passivation. They were present in sufficient quantity to provide complete protection to the mooring but lack of electrical continuity between chain links limited the amount of protection provided ground legs. Complete protection was provided to the underwater portion of the buoy and to the entire riser chain and the first twenty feet from the ground ring on each leg. These are the areas most corroded and the areas most costly in terms of both original purchase and maintenance. Thus the cathodic protection design in Figure 2, while not providing complete protection to

all areas of the mooring reduced the maintenance requirements appreciably. The relatively greater amount of vertical movement of the fully protected areas of chain with changes in tide probably resulted in better electrical continuity between links. Sandblasting of the contact areas of the chain links failed to increase the conductivity appreciably on ground legs.

The ground legs on the test mooring were very tight. Frequent use of a mooring by ships tends to displace and slacken the ground legs. This would decrease electrical continuity and reduce the degree of cathodic protection. Thus use of wire cables threaded through the ground legs to provide the necessary continuity seems most desirable. The results in Table 3 indicate that Leg 4 is completely protected and the anchor is receiving nearly complete protection. Should this protection continue for a prolonged period of time, cables will be added to the other ground legs. Since the silver-soldering to chain links is time-consuming and may very slightly decrease their strength, consideration will be given to the use of screw-fitting connectors to join the cable to chain links.

The zinc in the anodes is present in sufficient amounts to provide a few additional years protection, if it continues to be consumed at the present rate.

#### FINDINGS

1. The cathodic protection system utilizing specially cast zinc anodes provided complete protection to the underwater portion of the buoy and to the riser chain and first 20 feet of each ground leg. Protection of the remainder of the ground legs was limited by the lack of good electrical continuity between chain links.
2. Sandblasting of the contact areas of the chain links to remove the coating failed to increase the electrical continuity appreciably.
3. A galvanized steel cable threaded through a ground leg and silver-soldered to every twelfth link provided the desired electrical continuity and permitted complete cathodic protection of the leg.
4. There was sufficient zinc present to protect all parts of the mooring. The rate of loss is such that there should be sufficient zinc for a few additional years.

#### CONCLUSIONS

Results to date of cathodically protecting a fleet mooring using a cable to provide the necessary electrical continuity are very promising.

#### REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Note N-726. Cathodic protection of mooring buoys and chain, Part I. Initial field testing, by Richard W. Drisko, Port Hueneme, Calif., June 1965.

Table 1. Potential Profile of Cathodically Protected Mooring

Potential in Millivolts <sup>1/</sup>				
Riser	Leg 1	Leg 2	Leg 3	Leg 4
-935 <sup>2/</sup>	-860 <sup>4/</sup>	-860 <sup>4/</sup>	-860 <sup>4/</sup>	-860 <sup>4/</sup>
-905	-890	-895	-900	-880
-910	-950 <sup>3/</sup>	-990 <sup>3/</sup>	-1,020 <sup>3/</sup>	-990 <sup>3/</sup>
-1,010 <sup>3/</sup>	-850	-915	-670	-670
-860 <sup>4/</sup>	-720	-910	-670	-670
	-720	-910	-680	-670
	-685	-700	-695	-670
	-690	-710	-695	-670
	-680	-710	-705	-740
	-845 <sup>3/</sup>	-715	-710	-755 <sup>3/</sup>
	-1,020 <sup>3/</sup>	-1,035 <sup>3/</sup>	-1,065 <sup>3/</sup>	-1,000 <sup>3/</sup>
	-660	-940	-710	-665
	-665	-925	-705	-660
	-670	-650	-690	-665
	-675	-650	-690	-665
	-675	-650	-690	-670
	-670	-655	-700	-675
	-675	-670	-710	-675
	-675	-710	-720	-690
	-865 <sup>3/</sup>	-680	-750	-840
	-975 <sup>3/</sup>	-1,070 <sup>3/</sup>	-1,055 <sup>3/</sup>	-980 <sup>3/</sup>
	-770	-700	-690	-840
	-645	-700	-700	-835
	-645	-690	-700	-830
	-650	-690	-700	-825
	-645 <sup>5/</sup>	-690 <sup>5/</sup>	-700 <sup>5/</sup>	-770 <sup>5/</sup>
	-635 <sup>5/</sup>	-710 <sup>5/</sup>	-700 <sup>5/</sup>	-610 <sup>5/</sup>

<sup>1/</sup> Potentials recorded approximately every 10 feet.

<sup>2/</sup> At buoy.

<sup>3/</sup> At link on which anode was cast.

<sup>4/</sup> At ground ring.

<sup>5/</sup> At anchor.

Table 2. Potential Profile of Cathodically Protected Mooring

Potential in Millivolts <sup>1/</sup>				
Riser	Leg 1	Leg 2	Leg 3	Leg 4
-960 <sup>2/</sup>	-905 <sup>4/</sup>	-905 <sup>4/</sup>	-905 <sup>4/</sup>	-905 <sup>4/</sup>
-940	-920	-890	-940	-935
-940	-940 <sup>3/</sup>	-950 <sup>2/</sup>	-975 <sup>3/</sup>	-990 <sup>3/</sup>
-980 <sup>3/</sup>	-920	-905	-935	-935
-905 <sup>4/</sup>	-860	-895	-930	-930
	-700	-900	-695	-925
	-690	-900	-690	-915
	-690	-880	-680	-915
	-685	-695	-685	-940
	-935	-735	-750	-950
	-1,030 <sup>3/</sup>	-990 <sup>3/</sup>	-1,050 <sup>3/</sup>	-995 <sup>3/</sup>
	-680	-950	-685	-680
	-680	-950	-680	-660
	-695	-880	-680	-660
	-690	-650	-675	-675
	-685	-650	-670	-680
	-685	-650	-675	-685
	-675	-645	-680	-685
	-735	-645	-690	-700
	-750	-645	-820	-870
	-990 <sup>3/</sup>	-1,015 <sup>3/</sup>	-1,015 <sup>3/</sup>	-950 <sup>3/</sup>
	-910	-850	-675	-880
	-690	-720	-680	-850
	-670	-700	-675	-840
	-670	-680	-670	-860
	-675 <sup>5/</sup>	-645 <sup>5/</sup>	-655 <sup>5/</sup>	-845 <sup>5/</sup>
	-670 <sup>5/</sup>	-645 <sup>5/</sup>	-660 <sup>5/</sup>	-725 <sup>5/</sup>

<sup>1/</sup> Potentials recorded approximately every 10 feet.

<sup>2/</sup> At buoy.

<sup>3/</sup> At link on which anode was cast.

<sup>4/</sup> At ground ring.

<sup>5/</sup> At anchor.



Table 3. Potential Profile of Cathodically Protected Mooring

Potential in Millivolts <sup>1/</sup>				
Riser	Leg 1 <sup>6/</sup>	Leg 2	Leg 3	Leg 4 <sup>7/</sup>
-960 <sup>2/</sup>	-895 <sup>4/</sup>	-895 <sup>4/</sup>	-895 <sup>4/</sup>	-895 <sup>4/</sup>
-920	-960 <sup>3/</sup>	-900 <sup>3/</sup>	-980 <sup>3/</sup>	-950 <sup>3/</sup>
-915 <sup>3/</sup>	-1,000 <sup>3/</sup>	-980 <sup>3/</sup>	-1,020 <sup>3/</sup>	-1,000 <sup>3/</sup>
-960 <sup>3/</sup>	-735	-900	-980	-965
-890	-735	-900	-730	-965
	-735	-850	-690	-955
	-735	-850	-690	-935
	-740	-790	-690	-940
	-740	-695	-690	-935
	-740	-720 <sup>3/</sup>	-970 <sup>3/</sup>	-935 <sup>3/</sup>
	-1,060 <sup>3/</sup>	-1,055 <sup>3/</sup>	-1,050 <sup>3/</sup>	-970 <sup>3/</sup>
	-750	-680	-730	-930
	-745	-660	-690	-915
	-745	-655	-680	-915
	-730	-655	-680	-920
	-725	-660	-680	-935
	-725	-660	-675	-920
	-730	-660	-675	-920
	-735	-655	-675	-920
	-730	-670 <sup>3/</sup>	-700 <sup>3/</sup>	-915 <sup>3/</sup>
	-1,035 <sup>3/</sup>	-1,040 <sup>3/</sup>	-1,050 <sup>3/</sup>	-980 <sup>3/</sup>
	-730	-650	-680	-915
	-730	-650	-675	-900
	-720	-650	-670	-900
	-720	-650	-650	-895
	-720 <sup>5/</sup>	-650 <sup>5/</sup>	650 <sup>5/</sup>	-880 <sup>5/</sup>
	-720 <sup>5/</sup>	-650 <sup>5/</sup>	-650 <sup>5/</sup>	-800 <sup>5/</sup>

<sup>1/</sup> Potentials recorded approximately every 10 feet.

<sup>2/</sup> At buoy.

<sup>3/</sup> At link on which anode was cast.

<sup>4/</sup> At ground ring.

<sup>5/</sup> At anchor

<sup>6/</sup> Sandblasted leg.

<sup>7/</sup> Leg with attached cable.

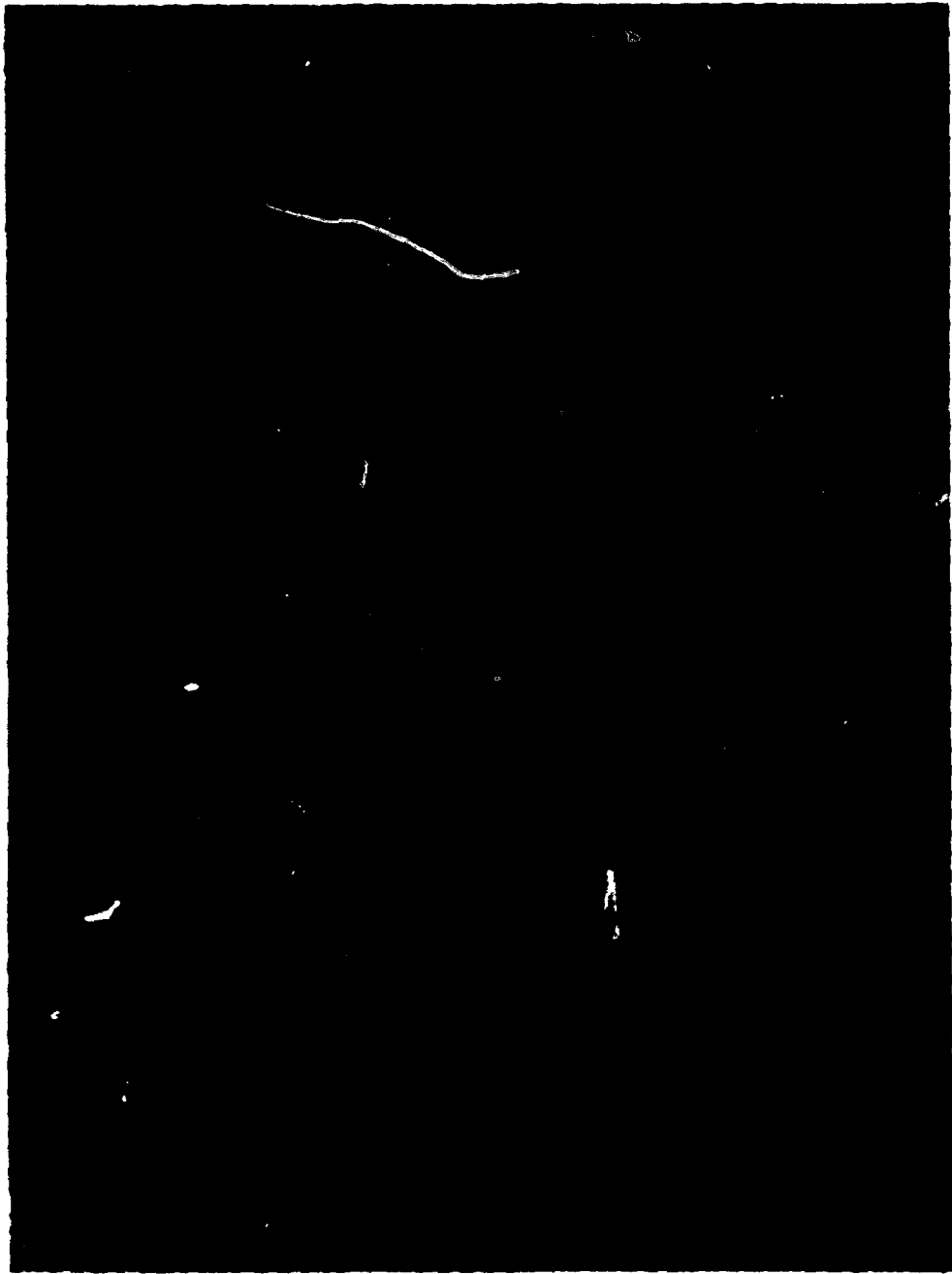


Figure 1. Special zinc anode cast on chain links.

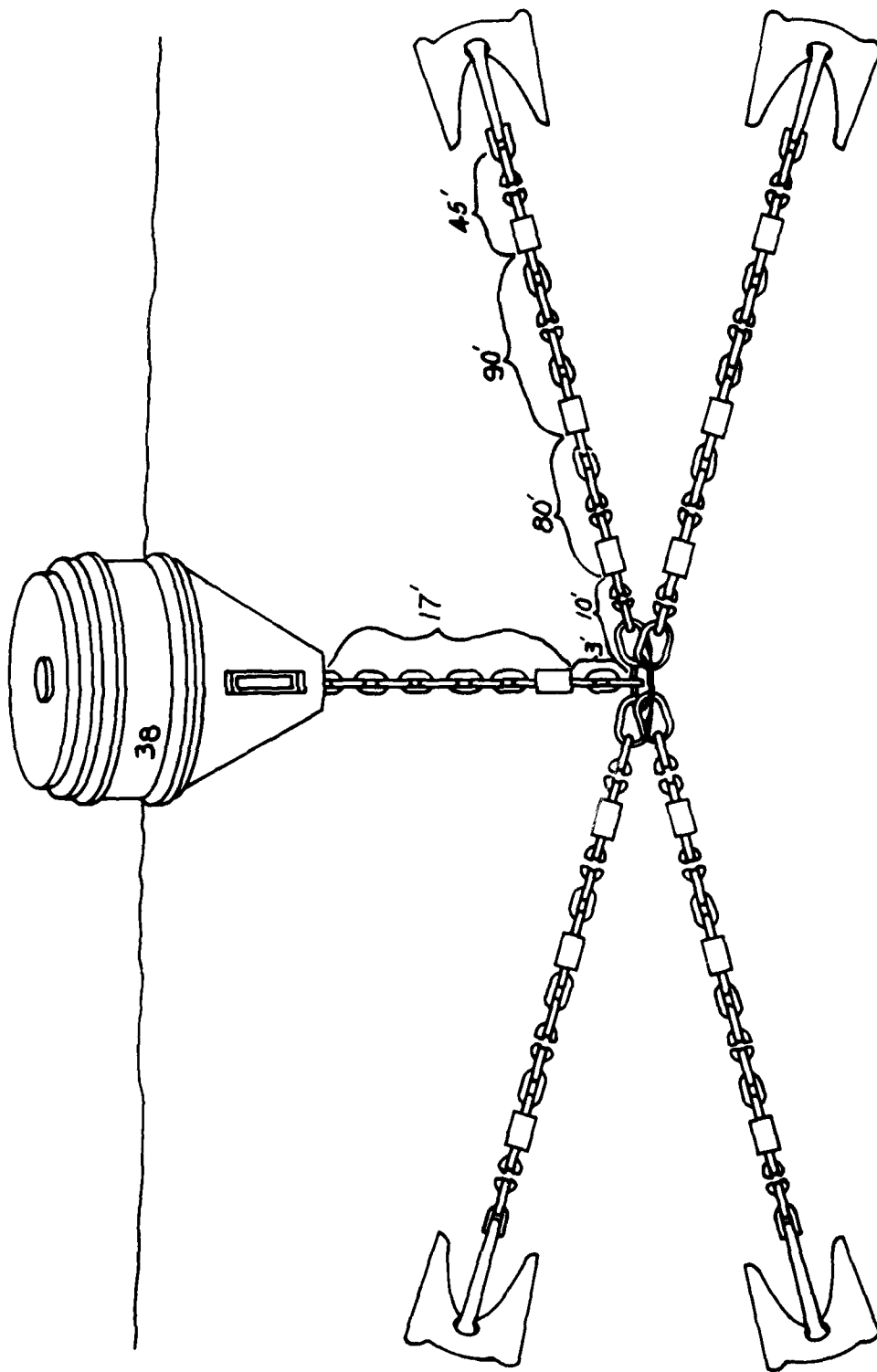


Figure 2. Cathodic Protection Design.



Figure 3. Lifting of mooring from floating crane showing the location of anodes in the area of the ground ring.

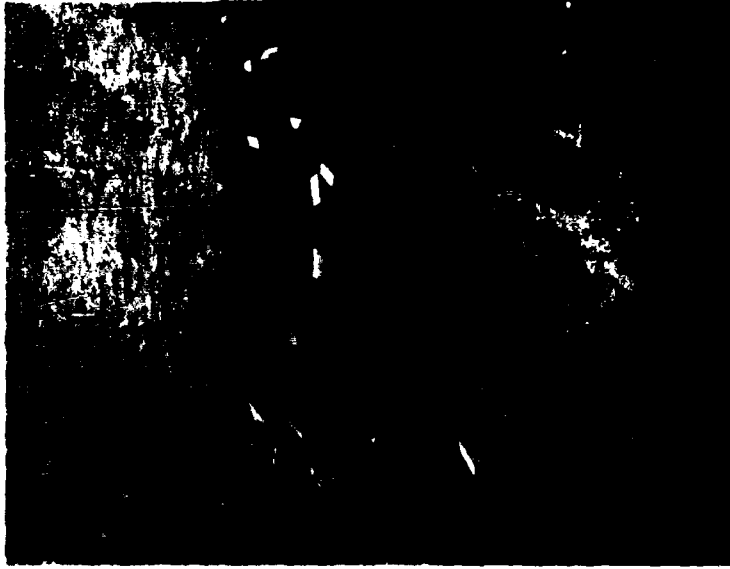


Figure 4. Ground tackle rigged for mooring on the deck of a floating crane.



Figure 5. Chain links sandblasted at contact areas.

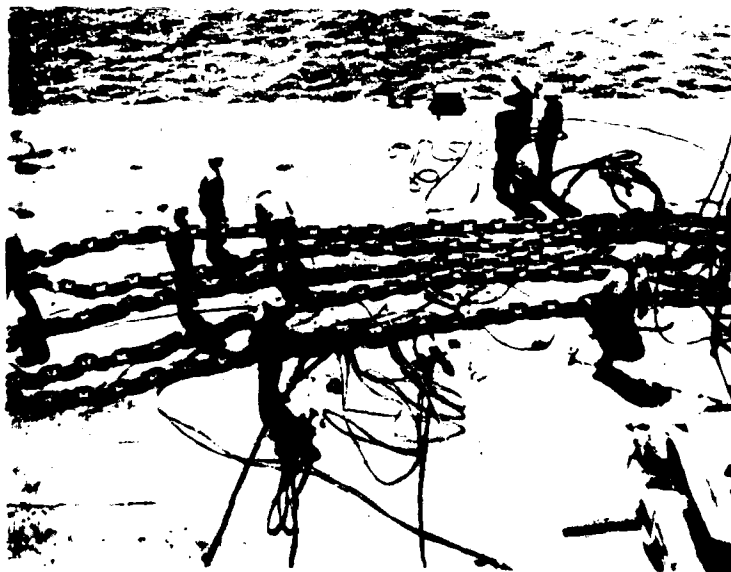


Figure 6. Ground leg on deck of floating crane showing cables threaded through it.



Figure 7. End of galvanized steel cable soldered to chain link.

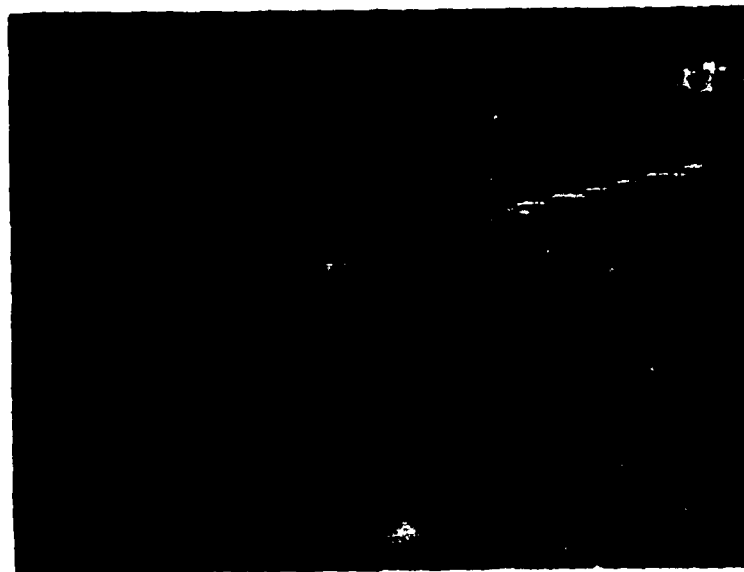


Figure 8. Cable tacked to chain link.



Figure 9. Special zinc anode after 9 months service.