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EXAMINATION OF WAVERIDER MOORING FROM COME-BY-CHANCE, NEWFOUNDLAND

by

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PHYSICAL METALLURGY DIVISION

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G. J. Biefer* and R. D. McDonald**

ABSTRACT

Components of a Waverider mooring which had undergone 3 months of sea-water service near Come-by-Chance, Newfoundland, were examined in order to assess the extent of corrosion and other types of damage. It was found that the stranded rope of Type 302 stainless steel was, in general, in good shape, though it had suffered a loss in strength of about 10%. Type 316 stainless steel parts in the end fittings were virtually uncorroded, but the Type 302 rope associated with the fittings showed a few broken wires. Some of this damage had occurred where the rope was sharply bent and appeared to be due to crevice corrosion. At one thimble, abrasion of the rope appeared to have brought about a breakage of wires.

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INTRODUCTION

A letter from Mr. S. L. Holland, Head, Wave Climate Study, Marine Sciences Division, Environment Canada(1) requested assistance with problems arising from corrosion and other types of service damage in "Waverider" moorings. As a result of this request, the upper and lower strops of a Waverider mooring, which had been in sea-water service at Come-by-Chance, Newfoundland, for four months (June 9 to Oct. 7, 1971) were sent to the Physical Metallurgy Division (PMD) for examination. Details regarding this mooring were supplied by Mr. B. Kelly of Oceanographic Research (see Appendix).

EXAMINATION

1. Upper Strop

Each of the rope ends was fitted with terminals of the type shown in Figure 1. The rope was stated to be Type 302* stainless steel and the metal fittings Type 316 stainless steel. The Type 316 steel showed no significant corrosion attack. One of the terminals was made up in a non-standard way in that the loop over the shaft (at right in Figure 1) was omitted, but, rather a tight bend was made over the right-hand bolt under the screwed-on lid. Rust was observed to be bleeding from under the lid and was found to originate at the region of sharpest bend around the bolt. Here, several wires had broken through and others were thinned by corrosion, some to the point of breaking. Typical corrosion damage is shown in Figures 2 and 3.

The entire length of the $\frac{1}{4}$-in. rope was slightly rusty in appearance, and it seemed that the rust was emanating from the more central wires. Unravelling the rope at several different points confirmed this, but examination under a low-power microscope did not reveal either pitting or other localized attack.

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*Type 316 in the required rope size was said to be unavailable. A check at PMD showed the rope submitted to have 0.2% Mo, consistent with the Type 302 composition.

At least at the points examined, corrosion had been quite uniform.

2. Lower Strop

Figure 4 shows the lower strop, including terminals and beading of rubber hose. The latter was designed to protect the rope against possible abrasion damage caused by intermittent contact with the ocean bottom.

The lower end of the strop was connected to a chain anchor which was electrically separated from the rest of the system by a "Celeron" insulator. This is shown in Figure 5. At the right are seen two galvanized shackles and a third ordinary steel one, the latter being fastened directly to the insulator. Visual observation indicated little or no corrosion damage to the galvanized shackles, though they seemed to have lost most of their zinc. The ordinary steel showed many large shallow pits and loosely adherent corrosion product.

The rope terminal fastened to the other side of the insulator with a Type 316 shackle was similar to the ones, used on the upper strop, shown in Figure 1. All the Type 316 parts of the terminals were virtually uncorroded. As with one of the upper strop terminals, rust was observed to be bleeding from the enclosed area of the fastener, under the screwed-on lid. However, when the lid was removed and the rope examined, corrosion damage was found to be minimal. Only a small amount of etching was visible and no wires had corroded through.

In the teardrop-shaped "thimble" area of both lower strop terminals, broken wires ("stranding") could be seen on the most severely bent portion.

Under examination by low-power stereomicroscope, the outermost parts of the rope at the thimble of the upper terminal seemed flattened, and the six broken ends were flattened. Metallographic sections were made in the vicinity of the main concentration of broken ends (Figure 6). It is seen that there are flattened wires at the surface of the rope but no evidence of corrosion attack. Apparently, abrasion was the principal cause of stranding in this case.

Under examination by low-power stereomicroscope, the stranding seen at the thimble of the lower terminal appeared to result from crevice corrosion which was proceeding within a strand. Some individual wires were seen to be so thinned by corrosion that they were on the point of breaking. Whereas attack was quite severe at the area where the stranding had occurred, it was not as severe at adjacent areas, nominally subject to similar conditions. Metallographic sections were made in the vicinity of the stranding and an illustrative photomicrograph is shown in Figure 7. This shows individual wires to be severely corroded.

MECHANICAL TESTING

Portions of unused rope and of rope from the upper and lower strops were submitted to the Mechanical Testing Section for determination of their breaking load. This was obtained using a Baldwin Universal Testing Machine, 20,000 pound capacity, and the results appear in Table 1.

TABLE 1

Breaking Load of $\frac{1}{4}$-In. Cable, Lb

(Unused rope)	7860 7840
(Upper strop, exposed at Come-by-Chance)	6920 7080
(Lower strop, exposed at Come-by-Chance)	7120 6900

DISCUSSION

Structures of austenitic stainless steels such as Types 304 or 302, when exposed to sea water, are subject to accelerated corrosion attack at parts where the bulk corrodent has limited access, for example, under bolt heads or under adherent marine growths. This form of attack is referred to as crevice corrosion. In a stranded rope in sea-water service, it is apparent that access of sea water to the innermost wires will be more or less restricted, resulting in the possibility of crevice corrosion for susceptible materials. It is well-known, in fact, that Type 304 stranded ropes tend to fail more or less rapidly because of crevice corrosion[2,3]. The same references show that Type 316 stainless, which is more resistant to chloride attack, performed better than Type 304 in stranded rope.

In the Come-by-Chance mooring, Type 302 cable appears to have lost approximately 10% of its strength after 3 months of sea-water service. The operative mechanism seems to have been a quite uniform crevice corrosion, occurring chiefly on the innermost wires of the rope to which access of bulk sea water is most restricted. Crevice corrosion has been much more severe, however, on parts of the rope in the end fittings, especially at severe bends. Here, some wires have been observed to corrode completely through, and a continuation of this process would obviously have led to a rope failure, most likely at the thimble. The increased severity of the crevice corrosion at the end fittings is possibly due to the immobilization of the rope, which might restrict the access of bulk sea water to a greater extent than observed in other parts of the rope. It also appears possible that galvanic attack caused by the coupling to Type 316 hastens the process. Type 316 steel is more corrosion resistant than Type 302, and would form the protected cathode in a couple, the Type 302 forming the corroding anode.

It was also observed that the rope was being noticeably abraded at the radius around one of the thimbles on the lower strop. Presumably, this was caused by an intermittent rubbing contact with some harder material.

SUMMARY - RECOMMENDATION

1. After 3 months in a mooring at Come-by-Chance, Type 302 stranded rope has lost approximately 10% of its strength because of crevice corrosion.

2. Rope in the end fittings, especially at the thimbles and in other regions of severe bending, has shown more intense crevice corrosion than at other parts of the strops, leading to breakage of some wires.

3. The outermost wires of the rope on the upper thimble of the lower strop showed definite abrasion damage, leading to broken wires.

4. If practicable, the replacement of Type 302 by Type 316 stranded cable should give improved service in that crevice corrosion should be minimized.

ACKNOWLEDGEMENT

Mr. G. D. Ayers provided assistance with the metallographic studies required in this investigation.

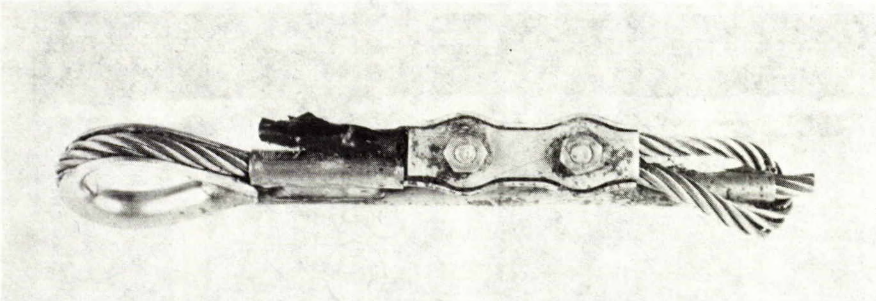
GJB/RDMcD/sg

REFERENCES

1. G. L. Holland, Environment Canada, Letter to S. L. Gertsman, Energy, Mines and Resources, Dec. 23, 1971.

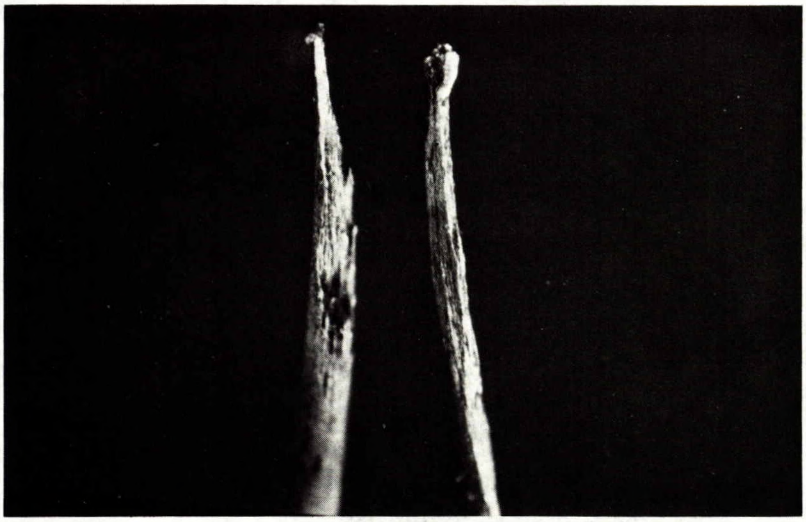
2. V. C. Peterson and D. Tamor, "Tests Show How Sea Water Affects Wire-Strand and Rope", Materials Protection, vol. 7, p.32, May 1968.

3. J. H. Rigo, "Stranded Steel Wire in Sea Water", Materials Protection, vol. 5, p.54, Apr. 1966.



Approx. X 1/2

Figure 1. Standard rope terminal from upper strop.



X15

Figure 2. View of broken wires taken from the end fitting of the upper strop showing evidence of corrosion.

X250

Figure 3. A metallographic section of one of the wires shown in Figure 2 illustrating the appearance of corrosion pits at an early stage of the attack.

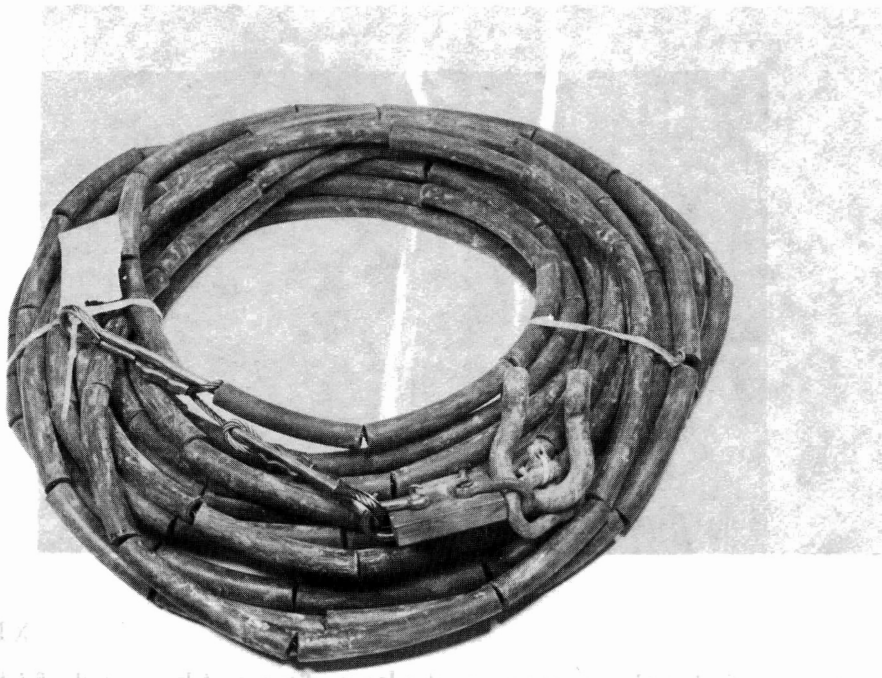


Figure 4. Lower strop, showing rubber beading and rope terminals.

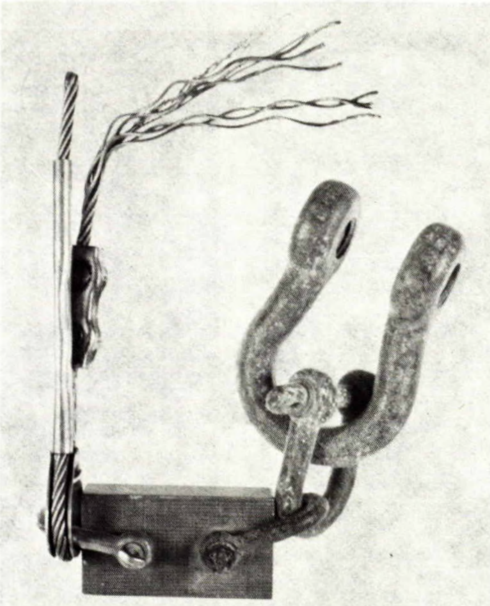
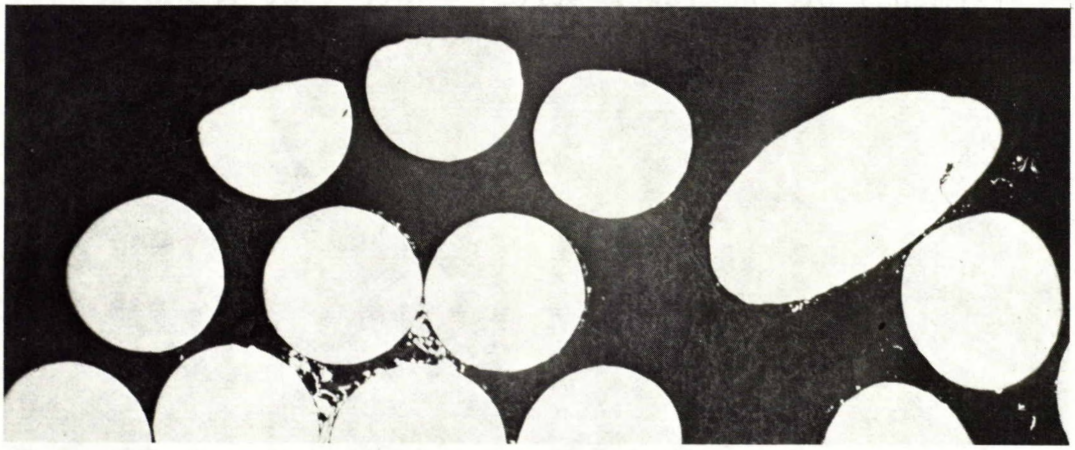
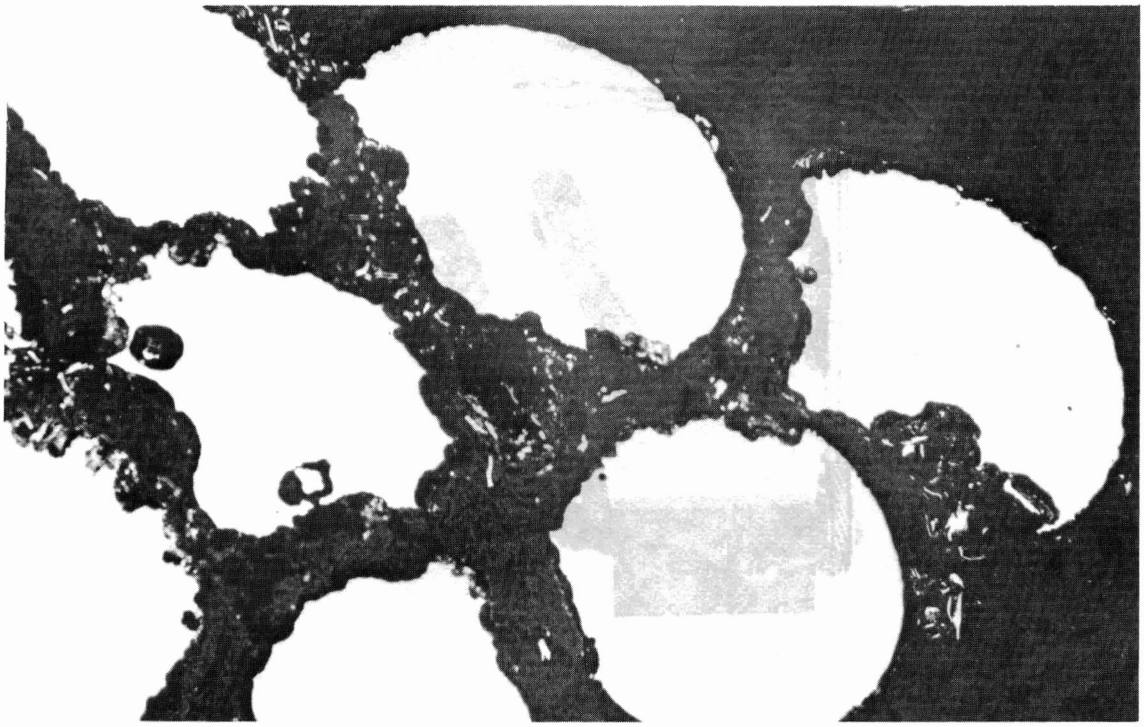


Figure 5. Lower terminal of lower strop.



X50

Figure 6. Wires flattened by abrasion on the upper terminal of the lower strop.



X100

Figure 7. Wires showing severe corrosion attack on the lower terminal of the lower strop. Note that the severest attack is on the inner surfaces of the wires in the strand.

APPENDIX

In conjunction with our proposed investigation of the causes of Waverider mooring failures I am sending you the documentation on the Come-by-Chance mooring which we have already delivered to your establishment. We have also included for comparison purposes, an unused portion of wire rope, end fittings, shackles, etc.

We also have four other recovered moorings which we hope to have available within a week. There will be a symposium on the Waverider, in England, at the end of January. We would hope to include your findings in our contribution.

Wave Climate Study

Waverider Mooring at Come-by-Chance

Type 1/4" - 7X19: 316 stainless steel (MIL-C-5424) breaking strength of 6400 lb.

Chain is 1 1/2" used buoy chain 30' long and supplied by MOT, St. Johns, Newfoundland. Celeron blocking is NC 3 and has absorption of 4% with a high abrasion index.

The bottom at the position of the buoy is gravel, rock, and rock and sand. The maximum wave height is about six feet with sub-surface currents less than one knot.

We would require a metallurgical analysis of the components to determine corrosion on the;

wire rope,
end fittings, and the
galvanized shackles.

The wire rope should be broken to ascertain losses in breaking strength and a possible explanation put forward on these areas that are stranded. We would require the moorings for photographic purposes only and are not concerned with component destruction due to testing.