

Report 28-938

Galvanic Corrosion of Coated HY-130 Steel Coupled to 5456 Aluminum

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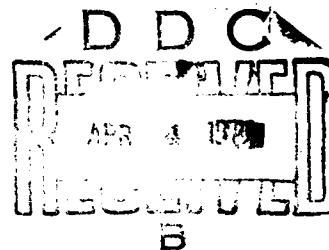
# NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20034



## GALVANIC CORROSION OF COATED HY-130 STEEL COUPLED TO 5456 ALUMINUM

by  
Harvey P. Hack



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RESEARCH AND DEVELOPMENT REPORT

March 1974

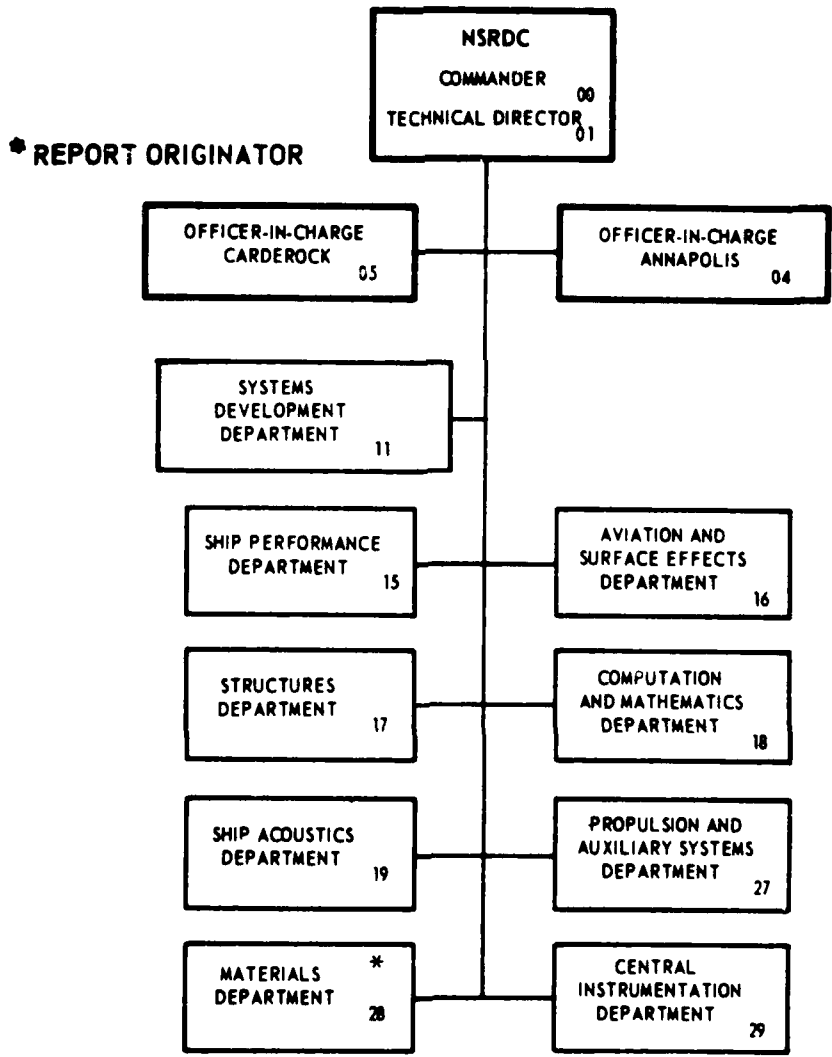
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#### ABSTRACT

Specimens of HY-130 steel were galvanically coupled to 5456-117 aluminum in natural sea water at velocities of 0 to 30 feet per second. The steel was coated with an epoxy primer and topcoat to various degrees: fully coated, coated with defect, partially coated, and uncoated. Corrosion rates of both materials increased with increasing sea-water velocity. Corrosion of the HY-130 was reduced and that of the aluminum was increased when galvanically coupled, with the effect on the aluminum increasing with increasing amount of uncoated steel area.

ADMINISTRATIVE INFORMATION

This report was prepared under Work Unit 1-2813-153, Task Area SF 54 541 702, Task 17256, and constitutes milestone 1a in the November 1973 Program Summary.

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## INTRODUCTION

HY-130, a low-alloy quenched and tempered high strength steel, has been proposed for struts and foils of aluminum-hulled hydrofoil craft. It will require suitable coating for protection against corrosion. Nevertheless, some galvanic corrosion effect between the steel struts and foils and the aluminum hull is likely when the craft is hullborne. The amount of galvanic corrosion will depend on the integrity of coatings on the materials, and also will be a function of speed, which, for hullborne operation, would range from 0 to about 30 ft/s.\* While these general trends can be predicted with reasonable confidence, the relative effect of these factors and severity of corrosion is unknown. Therefore, experiments have been carried out to provide this information. This report presents the results obtained in corrosion tests of coated and galvanically coupled steel and aluminum specimens exposed in sea water at velocities in the range of about 0 to 30 ft/s.

## INVESTIGATION

### MATERIAL

HY-130 steel specimens were machined from 7/32-inch rolled-sheet product while the aluminum specimens were machined from 1/2-inch sheet of 5456-H117 alloy. No subsequent heat treatments were performed. Nominal compositions of these materials follow:

- HY-130 - 5% Ni, 0.5% Cr, 0.5% Mo, 0.1% V, 0.12% C, 0.075% Mn, 0.15% Cu, balance Fe.
- 5456-H117 aluminum - 0.8% Mn, 5.25% Mg, 0.1% Cr, balance Al.

### APPARATUS AND PROCEDURE

Figure 1 illustrates the apparatus used in the tests; figure 2 shows the test specimens. Specimens were affixed to both sides of two micarta disks by means of common nylon or steel screws. The steel screws served as a means for galvanic coupling of the specimens as well as securing them to the disks. The disks were then mounted on a motor-driven rotating shaft

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\*Abbreviations used in this text are from the GPO Style Manual, 1973, unless otherwise noted.



immersed in natural sea water. Specimen velocity was determined by the disk diameter. The angular velocity of the shaft was 425 r/min, with resultant velocities of 18 (~15) and 34 (~30) ft/s for the two disk diameters used in this investigation. A third disk style was made for static tests and was not attached to the shaft, but instead was immersed in the sea-water trough at 2 (~0) ft/s. Test length was 60 days.

All steel specimens except those reserved for adhesion measurements were sandblasted before coating. Coating coverage was varied to obtain specimens that were fully coated, coated with defect (knife-scribed X), 3/4 coated, and uncoated. The coating system used was an epoxy type, MIL-P-24441/1 primer and MIL-P-24441/2 topcoat. No aluminum specimens were sandblasted or coated.

Triplicate tests were run on all steel specimens, both coupled to aluminum and uncoupled for comparison. At the completion of the test, coating adhesion tests were attempted and the degree of corrosion and coating damage on the specimens was determined by weight loss measurements and visual inspection.

#### RESULTS AND DISCUSSION

Table 1 presents results of the exposures. Figures 3 through 6 show the visual evidence of the corrosion of the HY-130 specimens, while figures 7 through 9 show the degradation of the aluminum specimens. Weight-loss data is plotted for HY-130 in figure 10 and for aluminum in figure 11. From visual examination of the specimens and weight-loss data analysis, the following test results can be noted:

- Increasing the sea-water velocity increased the corrosion of the uncoated HY-130 by a factor of two when coupled to aluminum and a factor of five when uncoupled.
- Increasing the exposed area of HY-130 increased the overall weight loss roughly in proportion, indicating little corrosion of coated material.
- Coupling of HY-130 to aluminum decreased the amount of corrosion of the steel by 3-10 times, with the effect being greater at higher velocities.

TABLE 1  
WEIGHT LOSSES OF TEST SPECIMENS, GRAMS

|   | ~0 FT/S |                  |           | ~15 FT/S |        |                  | ~30 FT/S  |        |        |                  |           |
|---|---------|------------------|-----------|----------|--------|------------------|-----------|--------|--------|------------------|-----------|
|   | Coated  | Partially Coated | Un-coated | Coated   | Defect | Partially Coated | Un-coated | Coated | Defect | Partially Coated | Un-coated |
| HY-130 coupled to aluminum                  | -.0030  | .0160            | .1097     | -.0077   | .0009  | .0602            | .2007     | -.0036 | .0051  | .0961            | .2805     |
|   | -.0007  | .0116            | .1254     | -.0056   | -.0002 | .0473            | .1701     | -.0009 | .0131  | .0800            | .2568     |
|   | -.0027  | .0165            | .1277     | -.0063   | .0024  | .0361            | .2229     | -.0056 | .0103  | .0601            | .2836     |
| HY-130 uncoupled                            | -.0114  | -                | .6739     | .0046    | .0799  | -                | 1.9543    | -.0037 | .0801  | -                | 3.1480    |
|   | -.0129  | -                | .6911     | -.0022   | .1172  | -                | 1.7505    | .0548  | .0980  | -                | 3.1928    |
|   | -.0124  | -                | .6121     | .0007    | .0803  | -                | 1.7087    | .0135  | .1344  | -                | 3.1332    |
| HY-130 coupled no sandblast                 | .0287   | -                | -         | .0397    | -      | -                | -         | .6616  | -      | -                | -         |
| HY-130 uncoupled, no sandblast              | -.0131  | -                | -         | .1090    | -      | -                | -         | 1.5217 | -      | -                | -         |
|   | -.0187  | -                | -         | -.0105   | -      | -                | -         | -.0060 | -      | -                | -         |
| Bare aluminum coupled to                    | .1301   | .1818            | .2780     | .6317    | .7478  | 1.7121           | 9.0522    | .9293  | 1.0615 | 1.8775           | 3.5407    |
| HY-130 in condition noted                   | .1115   | .1939            | .2776     | .6474    | .7876  | 1.7300           | 3.8024    | .9059  | 1.0546 | 2.0071           | 3.6851    |
|   | .0958   | .1981            | .2566     | .6808    | .7854  | 1.7613           | 3.3637    | 1.0187 | 1.0623 | 2.0503           | 4.1207    |
| Aluminum coupled to non-sand-blasted HY-130 | .1136   | -                | -         | .6711    | -      | -                | -         | 2.1347 | -      | -                | -         |
| Aluminum uncoupled                          | -       | -                | .0517     | -        | -      | -                | .2133     | -      | -      | -                | .6516     |
|   | -       | -                | .0323     | -        | -      | -                | .2106     | -      | -      | -                | .7140     |
|   | -       | -                | .0601     | -        | -      | -                | .1902     | -      | -      | -                | .7884     |

- The corrosion rate of the aluminum was increased from 2-30 times by coupling it to HY-130, with the effect increasing with increasing exposed areas of the steel. The corrosion rate of aluminum when coupled to steel at 30 ft/s can be described as catastrophic; while at 0 ft/s the effect can be considered moderate.

- The corrosion rate of aluminum increased 7-15 times with increasing sea-water velocity.

- Some corrosion-erosion damage was noted on the high velocity aluminum specimens.

Several HY-130 specimens were not sandblasted before the coating system was applied. Coating adhesion on these specimens after exposure was extremely poor (too low for measurement) as the coating was literally "falling off." Poor adhesion of these non-sand-blasted specimens can be attributed either to the very smooth (<10 rms) surface finish on the specimens, or the presence of a contaminant, such as machine oil, which was not completely removed by the precoating specimen preparation procedure. In contrast, the coating adherence on properly prepared and sand-blasted specimens was excellent, with no instances of failure except due to impact.

Recognizing the limitations of applying small specimen data to a large craft, it is nevertheless important to mention the severe attack which might occur on an aluminum-hulled hydrofoil before lift-off velocity, due to the galvanic effects of uncoated portions of the HY steel struts and foils. Coating integrity is therefore critical, not only for corrosion-erosion protection of the steel, but for the prevention of galvanic corrosion of the aluminum. In addition, the importance of using proper application procedures to ensure good coating adhesion cannot be overemphasized.



Figure 1  
Rotating Disk Test Apparatus

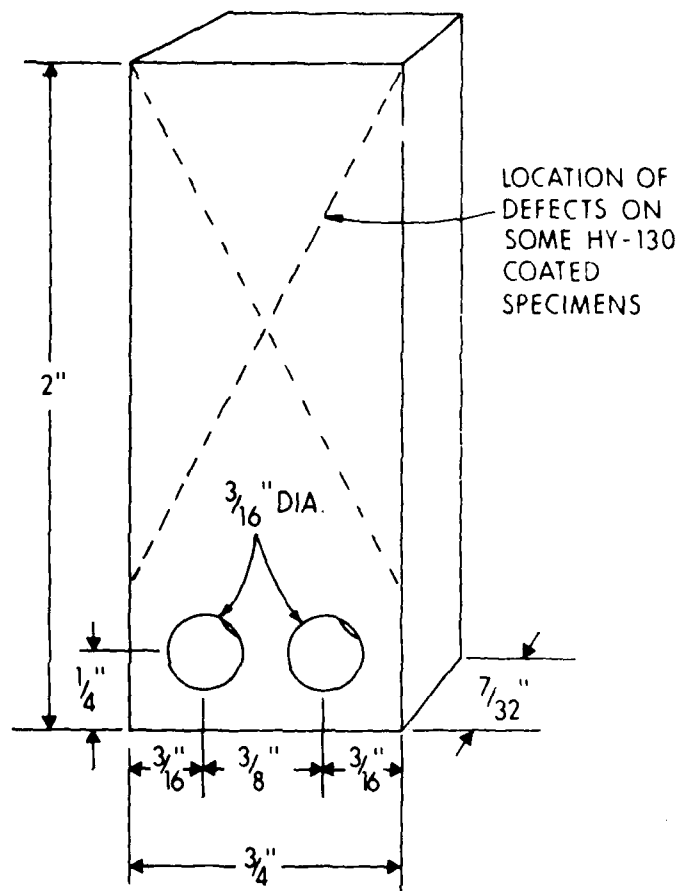


Figure 2  
Rotating Disk Corrosion Test Specimen

UNCOUPLED



0 FT/S



15 FT/S



30 FT/S

COUPLED TO ALUMINUM



Figure 3  
HY-130 Steel, Fully Coated

1

UNCOUPLED



0 FT/S



15 FT/S



30 FT/S

COUPLED TO ALUMINUM

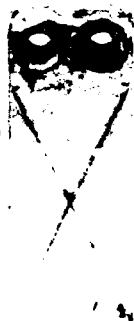


Figure 4  
HY-130 Steel, Coated with Defect

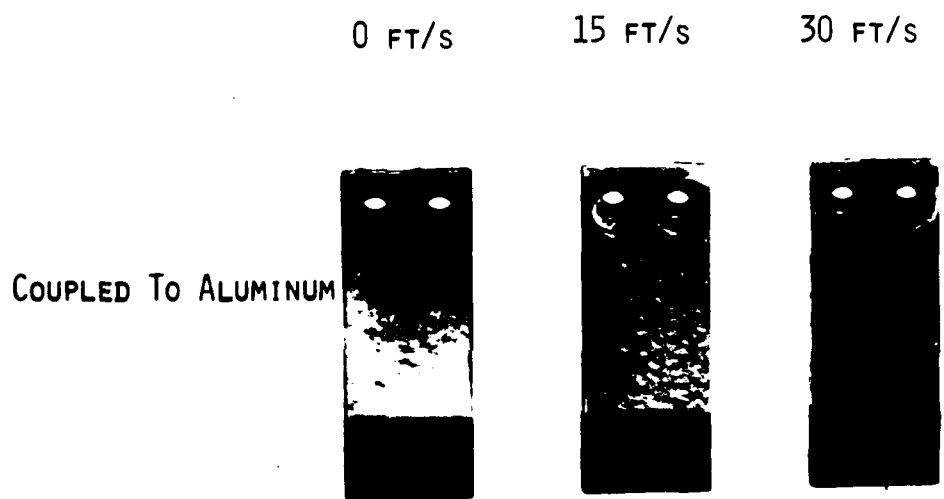


Figure 5  
HY-130 Steel, Partially Coated  
(No Specimens Tested in Uncoupled Condition)



UNCOUPLED



0 FT/s

15 FT/s

30 FT/s

COUPLED TO ALUMINUM



Figure 6  
HY-130 Steel, Uncoated

COUPLED To HY130 STEEL



FULLY  
COATED

COATING  
DEFECT

PARTIALLY  
COATED

UNCOATED

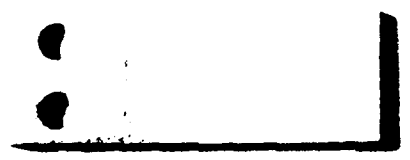
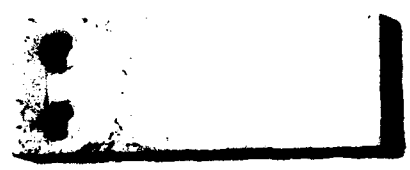
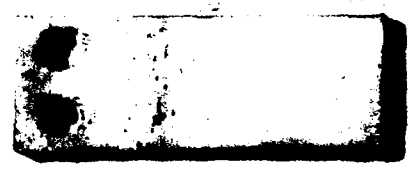


Figure 7  
5456-H117 Aluminum, 0 FT/S

UNCOATED

COUPLED To HY130 STEEL

FULLY  
COATED

COATING  
DEFECT

PARTIALLY  
COATED

UNCOATED

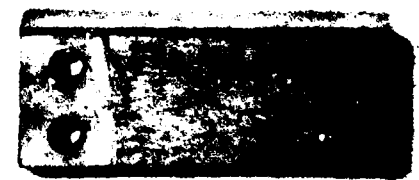


Figure 8  
5456-H117 Aluminum, 15 FT/S

COUPLED TO HY130 STEEL

FULLY  
COATED

COATING  
DEFECT

PARTIALLY  
COATED

UNCOATED

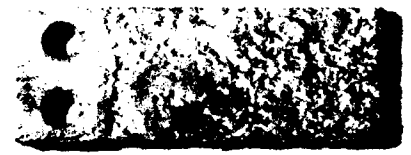


Figure 9  
5456-H117 Aluminum, 30 FT/S

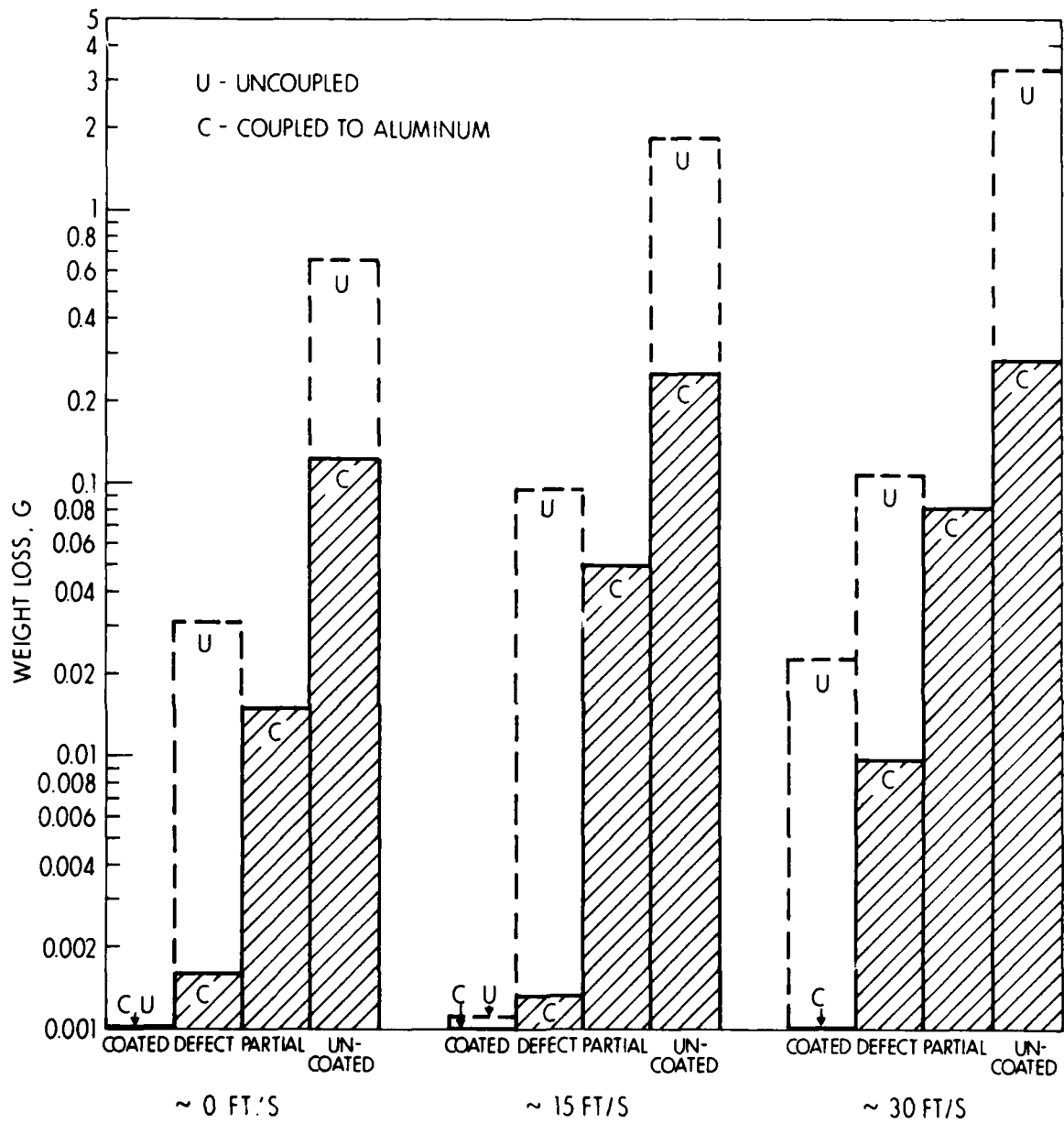


Figure 10  
Corrosion of Coated HY-130

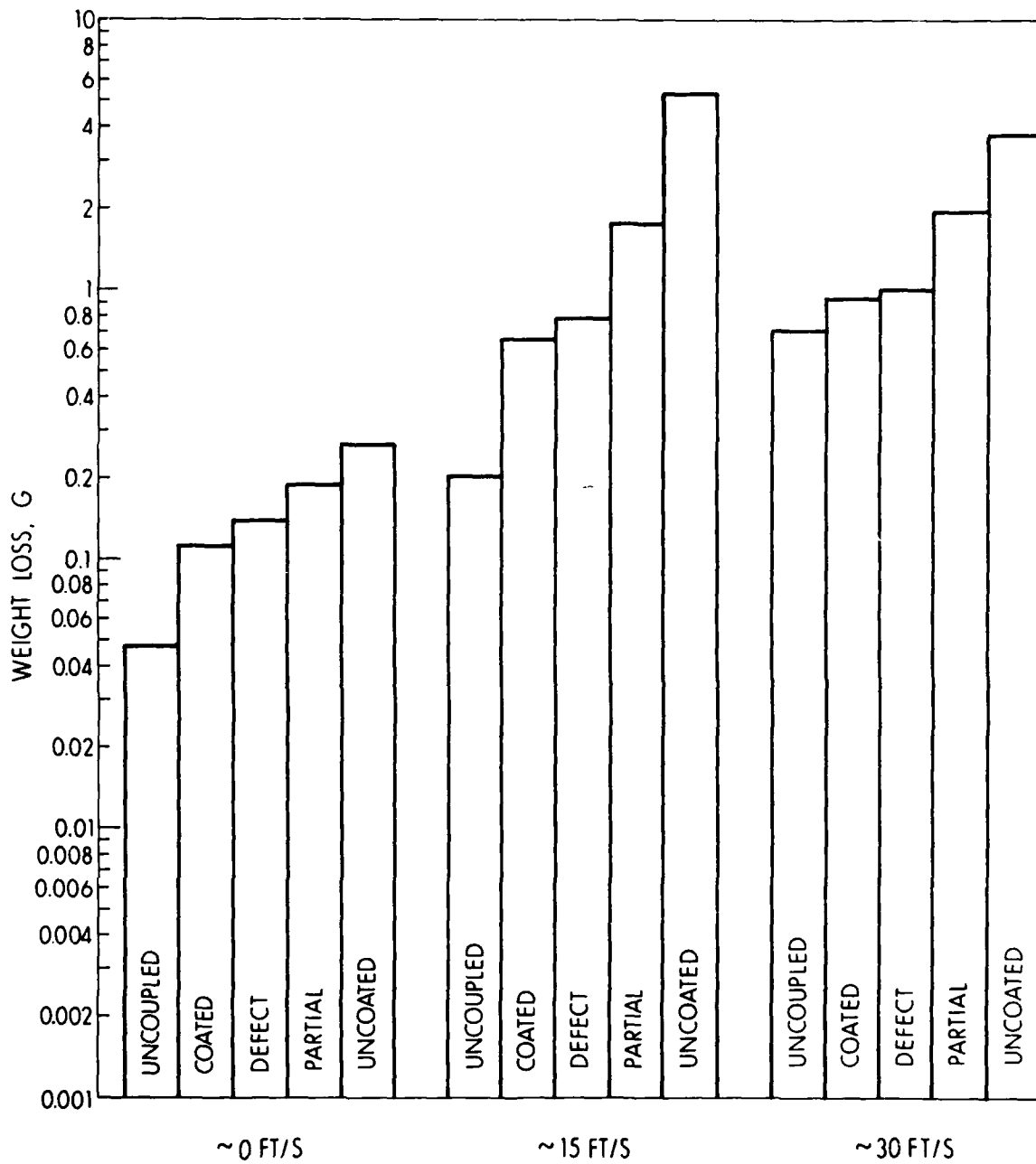


Figure 11  
Corrosion of Aluminum Coupled to HY-130

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