CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 63-2

CORROSION OF URANIUM-BEARING AND URANIUM-FREE "STELCOLOY" LOW ALLOY STEELS SUBSEQUENT TO EXPOSURE IN ACID MINE WATER AT DENISON MINES, ELLIOT LAKE, ONTARIO

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Two sheets of "Stelcoloy" low alloy steel, one alloyed with 0.06% uranium, were immersed in an acid mine water at Denison Mines, Elliot Lake, Ontario, for a period of one month.

At the end of this period the uranium-bearing alloy showed a generally smoother appearance. From laboratory measurements of weight loss and thickness loss, the uranium-bearing alloy showed about 30% less corrosion than the uranium-free alloy.

Confirmation of this single test, by repeat tests carried out on fresh specimens, is needed.

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INTRODUCTION

Under the supervision of J.P. Orton[1], the Steel Company of Canada prepared a heat of uranium-bearing "Stelcoloy"* low alloy steel, by addition of ferro-uranium to the ingot. The resulting uranium content was said to be 0.04%. The steel was then rolled and cut to produce twelve sheets 12 in. x 12 in. x 0.165 in., which were stamped U-1 to U-12. Twelve similar sheets, without uranium, were stamped U-13 to U-24. The sheets were sent to Denison Mines, Limited, Elliot Lake, Ontario, for field testing at various corrosive locations in their mill and mine.

Upon arrival at Denison, two 3/4 in. diameter support holes were drilled along one edge of the specimens, and measurements of weight and average thickness were carried out prior to installation at corrosive sites[2]. Specimens U-9 and U-21, the former containing uranium, were installed on May 29, 1962, in acid mine water in the ditch from No. 2 sump on the 2600 ft level[3]. After an exposure of about one month in this medium, it was observed that the uranium-bearing steel seemed the more corrosion-resistant of the pair. Consequently, the steels were removed from test and sent to the Physical Metallurgy Division for evaluation. A small sample of water taken from the ditch was also sent to the Physical Metallurgy Division.

VISUAL EXAMINATION

On arrival, both specimens of steel were covered with a loosely adherent material that appeared to be a mixture of rust and mud. After this was scrubbed off, it was seen that the surface of specimen U-9 (uranium-bearing) was generally smoother than U-21 (uranium-free). This is shown in Figures 1 and 2.

Attack was particularly severe along the lower edge of U-21. This shows up to some extent on a comparison of lower edges in Figures 1 and 2.

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*See Table 1 for base composition.

WEIGHT AND DIMENSIONS

Subsequent to the visual examination, the specimens were derusted by dipping them for approximately thirty seconds in inhibited hydrochloric acid at room temperature*.

The specimens were then weighed, and the average thickness determined with a micrometer according to the method originally reported by Denison Mines(2). Using the weight and thickness data reported by Denison Mines for the specimens prior to the test, average corrosion during the time in the ditch water was calculated (Table 2).

It will be noted that U-9 (uranium-bearing) showed less corrosion than U-21 by both methods of calculation. The losses calculated from thickness measurements were lower, as the micrometer measured the highest points on the rough metal surfaces.

X-RAY EXAMINATION

X-ray diffraction measurements, carried out by the Metal Physics Section of the Physical Metallurgy Division, showed that the oxide from the two specimens was the same, and consisted of $Fe_2O_3.H_2O$.

WATER ANALYSIS

The small sample of water taken from the ditch in which the specimens had corroded was submitted to the Industrial Waters Section, Mineral Processing Division, for analysis. The results reported (necessarily incomplete, and of lower than standard accuracy, because of the small quantity of water submitted) appear in Table 3. It was noted by J.F.J. Thomas, of the Industrial Waters Section, that the water was "high in iron and acid".

DISCUSSION OF RESULTS

According to the data of Table 1, and other available information, specimens U-9 and U-21 appeared to be comparable, except for the uranium content.

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*20 g of antimony trioxide (Sb_2O_3) to each liter of 27.5 wt % hydrochloric acid.

According to the measurements of weight and thickness (Table 2) alloy U-9 (uranium-bearing) corroded 16-24 mils* during the one-month immersion in acid mine water, while alloy U-21 (uranium-free) corroded 27-33 mils. Thus U-9 showed about 30% less corrosion than U-21. However, two comments can be made.

1. Since details of the testing procedures are lacking, it is not entirely certain that the two specimens were exposed to equivalent conditions.

2. The corrosion rates for both alloys are extremely high, far beyond rates to be expected in most practical service conditions.

CONCLUSIONS

While the examination of "Stelcoloy" specimens indicated that alloying with 0.06% uranium might increase the corrosion resistance to an acid mine water, this single result requires confirmation before it can be accepted as valid.

REFERENCES

1. J.P. Orton, Steel Co. of Canada, Hamilton, Ontario, letter to M.J. de Bastiani, Denison Mines, Elliot Lake, Ontario, April 2, 1962.

2. F.C. Lendrum, Denison Mines, Elliot Lake, Ontario, letter to W.A. Morgan, Physical Metallurgy Division, Ottawa, Ontario, May 11, 1962.

3. F.C. Lendrum, Denison Mines, Elliot Lake, Ontario, letter to W.A. Morgan, Physical Metallurgy Division, Ottawa, Ontario, July 10, 1962.

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*1 mil = 10^{-3} inches.

TABLE 1

Chemical and Semi-quantitative Spectrographic Analysis of the "Stelcoloy" Specimens

Element	Steel Co. of Canada (1) Base Analysis, Per cent	Mines Branch Analysis, Specimen U-9 (Uranium-bearing) Per cent	Mines Branch Analysis, Specimen U-21 (Uranium-free) Per cent
Al	-	0.15	0.20
C	0.11	0.10*	0.12*
Co	-	0.004	0.2
Cr	0.44	0.6	0.7
Cu	0.35	0.4	0.5
Mn	-	0.8	0.9
Ni	0.41	0.7	0.8
P	0.06	0.057*	0.056*
S	0.029	0.021*	0.029*
Si	-	0.6	0.6
Ti	-	0.004	0.005
U	-	0.06*	0.001*
V	-	0.008	0.009

*Chemical Analyses

TABLE 2

Corrosion of "Stelcoloy" Steel Plates during Immersion of Approximately One Month in an Acid Mine Water

Calculated from Weight Changes	U-9 (Uranium-bearing)	U-21 (Uranium-free)
Initial weight, grams	3132	3027
Final weight, grams	2220	1790
Weight loss, grams	912	1237
Weight loss, mg, cm^2	488	661
Corrosion, mils*	24	33
Calculated from Thickness Changes	**U-9 (Uranium-bearing)**	**U-21 (Uranium-free)**
Initial thickness (cm)	0.425	0.413
Final Average thickness (cm)	0.342	0.274
Change in thickness (cm)	0.083	0.139
Corrosion, mils*	16	27

*1 mil = 10^{-3} inches

TABLE 3

Analyses of Acid Mine Water in which Stelcoloy Specimens were Immersed

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MINES BRANCH
MINERAL PROCESSING DIVISION

INDUSTRIAL WATERS SECTION
40 Lydia Street, Ottawa, Ont.

ANALYSIS OF WATER SAMPLE(S) .....19.....

(In parts per million)

Location	Near Elliot Lake, Ontario
Source of water	Mine Process water - Denison Mines Ltd.
Sampling point	
Reference	Dr. G. Biefer
Laboratory number	9471
Date of sampling	July 11, 1962
Storage period (days)	112
Temp. at sampling (°C)	-
Temp. at testing (°C)	24.9
Appearance, odour, etc.	
Oxygen consumed ($KMnO_4$)	
Chem. oxygen demand (C.O.D.)	
Carbon dioxide (CO_2), calculated	
pH	2.45
Colour (Hazen units)	
Turbidity (Units)	
~~xxxxxxxxxxxxxxxxxxxxxxxxxx~~	Acidity
~~xxxxxxxxxxxxxxxxxxxxxxxxxx~~	to pH 7.0 130 ppm as $CaCO_3$
Susp. matter, dried at 105°C.	
" " , ignited at 550°C.	
Res. on evap., dried at 105°C.	
" " " , ignited at 550°C.	
Conductance, micromhos at 25°C.	5126
Hardness as $CaCO_3$ (Total	669 *
(Non-carbonate	669
Calcium (Ca)	102 *
Magnesium (Mg)	
Strontium (Sr)	
Sodium (Na)	
Potassium (K)	
Lithium (Li)	
Iron (Fe) Total	High
Dissolved	
Aluminum (Al)	
Manganese (Mn) Total	
Dissolved	
Copper (Cu)	
Zinc (Zn)	
Lead (Pb)	
Ammonia (NH_3)	
Carbonate (CO_3)	
Bicarbonate (HCO_3)	
Sulphate (SO_4)	1,085
Chloride (Cl)	108
Fluoride (F)	
Phosphate (PO_4)	
Nitrate (NO_3)	
Silica (SiO_2)	
Sum of constituents	
Saturation index at test temperature	
Stability index at test temperature	
% sodium	

Remarks: * Insufficient water and accuracy low.

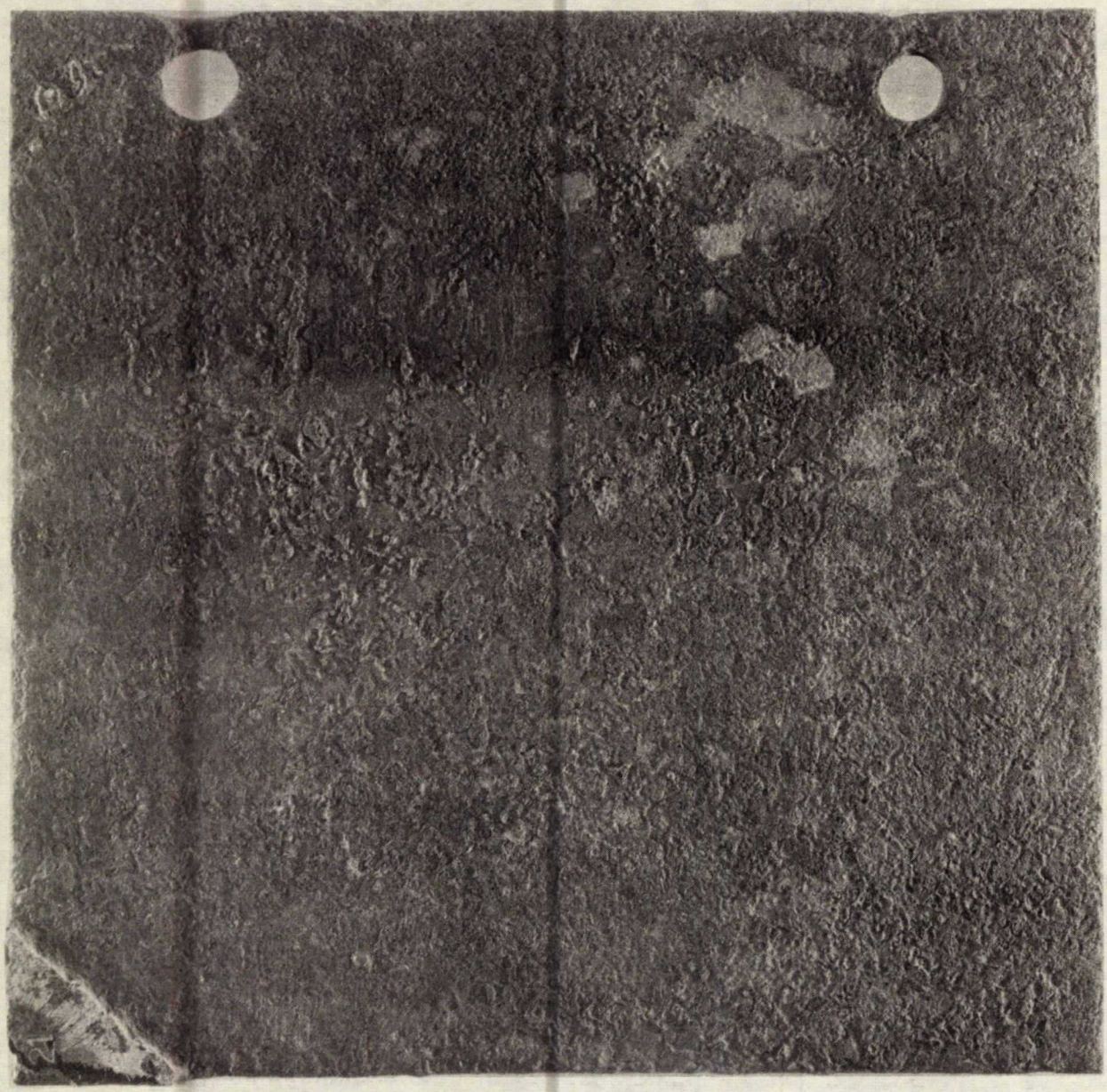

Figure 1. Specimen U-21 (Uranium-free) after immersion in acid mine water. Approx. 1/2 size.

Figure 2. Specimen U-9 (Uranium-bearing) after immersion in acid mine water. Approx. 1/2 size.