CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 61-122

THE CORROSION OF AISI 4615 AND AISI 410 STEELS IN 3% NaCl SOLUTION AND IN MINE WATER FROM SHAFT #6, COLLIERY #4, DOMINION COAL COMPANY LIMITED, GLACE BAY, N. S.

by

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PHYSICAL METALLURGY DIVISION

COPY NO. 8

OCTOBER 18, 1961

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SUMMARY OF RESULTS

Short term aqueous corrosion tests were carried out in 3% NaCl solution and also in mine shaft drainage water to determine whether an AISI 410 threaded steel pin could be used successfully as a part in an AISI 4615 shackle assembly that supports a mine hoisting cage.

The 410 steel was found to be cathodically protected by 4615 steel. Thus protected, the 410 steel showed little corrosion. Unprotected, it was found to be subject to severe pitting attack, particularly in crevices.

It was concluded that the 410 steel cross-pin should not be used unless cathodically protected by contact with the 4615 steel nut and shackle. In view of the pitting observed for 410, the combination should be used cautiously, with frequent examinations, until its reliability under service conditions has been established.

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INTRODUCTION

The Dominion Coal Company Limited had reported that they found excessive thread corrosion on the cross-pins used in the shackle assembly that supported the cages in their mine shafts. The shackles, pins, and chains were all AISI 4615 steel.

The chain manufacturers, McKinnon Columbus Chain Limited, consulted the Mines Branch regarding this problem. The use of a more corrosion resistant alloy for the cross-pins, such as AISI 410, appeared feasible. However, it was thought possible that 4615 steel might suffer severe galvanic corrosion at contact points with the more noble 410 steel. To throw some light on this question and also to determine, in general, the suitability of 410 from a corrosion standpoint, it was decided to carry out some laboratory tests which would simulate, as closely as possible, the service conditions existing at the mine. As an answer was required as soon as possible, the investigation was restricted to relatively simple short term tests. The results of the series of tests in 3% NaCl solution were reported by letter to Mr. E. Kennard, General Manager, McKinnon Columbus Chain Limited, by Dr. G.J. Biefer on July 25th 1961. Further tests with water obtained from shaft #6 of the Dominion Coal Company mine have generally confirmed the results from the original salt solution tests.

EXPERIMENTAL PROCEDURE

The sample of AISI 4615 steel was obtained from McKinnon Columbus Chain Limited as heat-treated chain links; the AISI 410 steel, as forged, was available at the Mines Branch. The analysis of the two steels is given in Table 1.

The steels were cut into a number of flat-faced specimens and surface finished with #0 emery paper.

Mine drip water was requested from the Dominion Coal Company. Pending its arrival, it was decided to carry out galvanic tests in 3% NaCl solution.

The brine solution was made up from analytical NaCl (3% by weight) and distilled water. Weighed specimens were clamped together face to face by plastic clothes pins in the following combinations:

4615 - 410
4615 - 4615
410 - 410

The assemblies were then half submerged in the salt solution at room temperature. As the test proceeded, electrical contact was maintained through the relatively uncorroded areas.

After nine days the samples were removed from the salt solution. The loose oxide was removed from the specimens by dipping in ultrasonically agitated water with a detergent addition. The specimens were then dried, weighed and examined.

When the mine water arrived from Glace Bay, it was analysed (see Table 2) and used as the corrosive medium in a second corrosion experiment.

Due to a shortage of steel samples, only one couple could be tested, viz, 4615-410, along with single specimens of 4615 and 410.

Testing procedures were similar to those previously described, and after nine days exposure the samples were cleaned, dried, weighed and examined.

RESULTS

The results of the first test in 3% NaCl solution are given in Table 3. The corrosion rate was calculated from the weight loss. The galvanic potential between 4615 and 410 was measured daily and found to stabilize after a few days at about 0.20 volts, the 410 steel being positive (ie, noble with respect to the 4615 steel).

The conductivity of the 3% NaCl solution was found to be 43,000 micromhos at 25°C.

Photographs of the corroded samples are shown in Figure 1.

The results of this experiment showed clearly that the 4615 steel corrodes sacrificially when in contact

with 410 steel, thus providing excellent cathodic protection for the 410 steel. It might be noted that the two specimens adhered tightly together after the test, a hammer blow being required to separate them. This indicates there might be a tendency towards galling in the threads of a 410 cross-pin used with a 4615 shackle.

The 4615-4615 couple was seen to corrode relatively evenly, with no deep pits, and showed a heavy red oxide coating. Below the red coating a thinner black coating lay next to the metal. The samples of this couple were also difficult to part.

The 410-410 couple exhibited the most insidious type of corrosion. The external faces appeared whole and bright, even under microscopic examination, but the inside faces showed a severe pitting attack which was visible only when the specimens were parted. This indicated that 410 steel was subject to severe crevice corrosion. The 410-410 couple was easily parted.

The results of second test using mine water as the corrosive medium are given in Table 4.

The galvanic potential between 4615 and 410 steel at room temperature in mine water was found to be 0.29 volts, the 410 steel being positive. The mine water had a conductivity of 14,400 micromhos at 25°C.

Examination of the 4615-410 couple showed that, as in the previous experiment, the 410 alloy was almost completely unattacked. Below a thin loosely-adherant white coating, the metal was smooth, bright, and unpitted. The 4615 alloy exhibited a heavy layer of rust, and was roughened (though not pitted) beneath the rust. Comparison of the corrosion rates for the coupled and non-coupled 410 steel specimens indicated that the 4615 was cathodically protecting the 410 alloy. X-ray diffraction measurements failed to identify the white coating adhering to the coupled 410 specimen.

The single 4615 specimen exhibited a heavy relatively smooth red oxide. Some black rust lay next to the metal, and also on the less corroded portion above the surface.

The single 410 specimen had a few red oxide spots which brushed off readily. Under microscopic examination a small spongy area was located, as well as several deep sharp pits. The white coating observed for the coupled 410 steel was absent.

CONCLUSIONS

1. Based on the results of the laboratory tests, 410 steel cross-pins, when used with 4615 steel nuts and shackles, should exhibit negligible corrosion. The severe wastage

of threads observed previously with 4615 cross-pins should be eliminated.

The AISI 4615 nut and yoke might be subject to increased corrosion but this is considered to be relatively unimportant because of their great mass and relatively even and easily visible corrosion.

2. 410 steel should not be used for both the pin and the nut, as dangerous hidden pitting might occur in the crevice between the two.

3. If a 410 steel nut is used as the welded head on the 410 steel pin, it is essential to make sure the welds are tight and there are no crevices which would allow pitting attack. The weld metal should be 410 alloy to minimize galvanic attack at the weld.

4. It should be emphasized that these recommendations are based on a limited number of short-term laboratory tests and are not necessarily applicable to the much more complex and ill-defined service conditions at the Dominion Coal Company pits.

If 410 cross-pins are used with 4615 steel shackle assemblies under service conditions, the assemblies should be inspected very carefully and frequently, particularly at first, to ensure that the 410 steel is free from the potentially dangerous pitting attack.

In conclusion it should be emphasized that this report deals solely with galvanic effects between 410 and 4615 steels. Consideration of the mechanical suitability of 410 for this application is outside the scope of this investigation.

TABLE 1.

Compositions of Alloys Used in the Corrosion Tests

Element	Weight, Per Cent	
	AISI 410	AISI 4615*
Carbon	0.15	0.13 - 0.18
Chromium	13.5	-
Manganese	0.6	0.45 - 0.65
Molybdenum	-	0.20 - 0.30
Nickel	0	1.65 - 2.00
Phosphorus	less than 0.02	0.040 max
Sulphur	less than 0.03	0.040 max
Silicon	0.5	0.20 - 0.35

* Nominal composition.

TABLE 2

Analysis* of Water from Shaft #6, Colliery #4, Dominion Coal Company, Glace Bay, N.S.

pH 7.3, Turbidity 3, Hardness total 2,716

Element or Ion	Concentration, ppm
Calcium	287
Copper	0
Potassium	69
Magnesium	355
Sodium	2700
Zinc	0
Bicarbonate $(HCO_3)^-$	252
Chloride Cl^-	4836
Sulphate $(SO_4)^{--}$	1028

* Industrial Waters Section, Mineral Processing Division.

TABLE 3

Results of Corrosion Test for Nine Days
in 3% NaCl Solution at Room Temperature

Couple	Specimen	Corrosion Rate mils/yr *	Appearance	
			Outside	Inside
4615-410	4615	65	Thick red rust	Partly black Partly bright
	410	Nil	Slight tarnish	Bright
4615-4615	4615 (av)	26	Thick red rust	Partly bright Partly greenish
410-410	410 (av)	5.4	Bright	Bright, severe pitting

* 1 mil = 1 thousandth of an inch.

TABLE 4

Results of Corrosion Test for Nine Days
at Room Temperature in Water from Shaft #6,
Colliery #4, Dominion Coal Company, Glace Bay, N.S.

Couple	Specimen	Corrosion Rate mils/yr*	Appearance	
			Outer Surface	Inside Surface
4615-410	4615	9.6	Heavy red rust layer	Bright
	410	0.2	Thin white coating	Some white coating
Single Specimen only	4615	10	Red and black rust	-
Single Specimen only	410	1.9	Bright, a few deep sharp pits	-

* 1 mil = 1 thousandth of an inch.

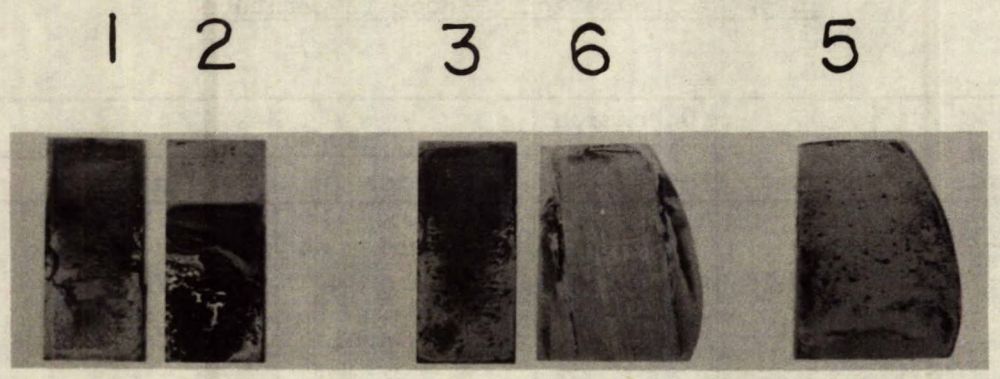

Figure 1. Samples of AISI 4615 and AISI 410 Steels Corroded in 3% NaCl Solution Nine Days at 25°C.

1. Inside face 4615-4615 couple.
2. Exposed face 4615-4615 couple.
3. Inside face 4615 of 4615-410 couple.
6. Inside face 410 of 4615-410 couple.
5. Inside face 410 of 410-410 couple.

Not shown: the smooth clean outside face of the 410 of 410-410 couple.

HMW/ls