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OTTAWA July 3, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1900.

Effect of Corrosion on the Strength of Certain Magnesium and Aluminium Alloys and Steel.

(Copy No. 10)

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R E P O R T

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Background:

In a telephone conversation held on June 5, 1945, with Colonel E. C. Thorne, of the Directorate of Engineer Development, Quartermaster General Branch, Department of National Defence (Army), Ottawa, Ontario, it was requested that a comparison be made of the loss of strength of magnesium alloy AZ31X, aluminium alloy 75 ST and mild steel under corrosive conditions. It was also requested that a study be made of the effect of combining aluminium and steel and magnesium and steel under corrosive conditions.

The magnesium and aluminium alloys to be tested

(Background, cont'd) -

were to be supplied by Colonel Thorne and the steel was to be supplied by these Laboratories.

TESTS PERFORMED:

The mechanical properties of the aluminium, magnesium and steel were determined. Then four samples of the magnesium alloy, four samples of the steel and two samples of the aluminium alloy (one from each of the extrusions submitted) were placed in the Intermittent Immersion Corrosion Test at about 90° F., using 20 per cent salt (sodium chloride) solution as the corroding material. At the same time two assemblies each consisting of a steel sheet (S.A.E. 1025) and a magnesium sheet (alloy AZ31X) held together by a steel nut and bolt, and two assemblies each consisting of a steel sheet (S.A.E. 1025) and a piece of the aluminium alloy extrusion (alloy 75 ST) held together by a steel nut and bolt, were placed in the Intermittent Immersion Corrosion test under the same conditions.

I. - Mechanical Properties of the Metals.

The mechanical properties of four samples of steel, four samples of magnesium alloy, and two samples of aluminium alloy (one from each extrusion tested) were determined. The results are shown in Tables I, II and III respectively.

Table I. - Mechanical Properties of Steel S.A.E. 1025.

Size of test specimen, inches	Area of cross-section, sq. in.	Ultimate strength, p.s.i.	0.2 per cent proof strength, p.s.i.	Elongation in 2 inches, per cent
0.0285 X 0.498	0.0142	59,600	43,000	30
0.0285 X 0.498	0.0142	58,800	42,300	27
0.0285 X 0.496	0.0141	58,700	42,550	27
0.0285 X 0.499	0.0142	60,400	43,600	29
Average		59,370	42,860	28

(Tests Performed, cont'd) -

Table II. - Mechanical Properties of Magnesium Alloy AZ31X.

Size of test specimen, inches	Area of cross-section, sq. in.	Ultimate strength, p.s.i.	0.2 per cent proof strength, p.s.i.	Elongation in 2 inches, per cent
0.496 X 0.062	0.0307	36,200	18,400	22.0
0.497 X 0.062	0.0307	36,450	18,900	23.0
0.500 X 0.062	0.0310	36,900	19,440	22.5
0.500 X 0.062	0.0310	35,500	18,700	22.0
Average		36,260	18,860	22.5

Table III. - Mechanical Properties of Aluminium Alloy 75ST.

Extrusion	Size of test specimen, inches	Area of cross-section, sq. in.	Ultimate strength, p.s.i.	0.2 per cent proof strength, p.s.i.	Elongation in 2 inches, per cent
A	0.127 X 0.499	0.0634	88,400	80,000	10.0
B	0.102 X 0.499	0.0509	84,500	76,700	11.5

-

II. Corrosion Test on Single Metals.

The single samples of the metals were started together in the corrosion test.

(a) Magnesium Alloy AZ31X -

After 48 hours, one sample was removed from from the test. Its mechanical properties were:

Ultimate strength, 28,600 p.s.i.
0.2 per cent proof strength, 16,800 p.s.i.
Elongation in 2 inches, 6 per cent.

After 90 hours one sample was removed from the test. Its mechanical properties were:

Ultimate strength, 25,300 p.s.i.
0.2 per cent proof strength, 14,250 p.s.i.
Elongation in 2 inches, 6 per cent.

After 192 hours the two remaining samples were removed from the test. Figure 1(a) shows their appearance. Their mechanical properties were:

(Tests Performed, cont'd) -

Ultimate strength, 12,100 p.s.i.
12,070 "

Average, 12,085 "

Elongation in 2 inches, 3 per cent
1 "

Average, 2 "

(b) <u>Steel S.A.E. 1025</u> -

After 90 hours one sample was removed from the test. Its mechanical properties were:

Ultimate strength, 54,600 p.s.i.
0.2 per cent proof strength, 41,700 p.s.i.
Elongation in 2 inches, 24 per cent.

After 192 hours one sample was removed from the test. Its mechanical properties were:

Ultimate strength, 56,800 p.s.i.
0.2 per cent proof strength, 41,900 p.s.i.
Elongation in 2 inches, 26 per cent.

After 360 hours the two remaining samples were removed from the test. Figure 1(c) shows the condition of one of them. Their mechanical properties were:

Ultimate strength, 54,900 p.s.i.
53,700 "
Average 54,300 "

0.2 per cent proof strength, 38,300 p.s.i.
38,700 "
Average, 38,500 "

Elongation in 2 inches, 27 per cent
26 "
Average, 26.5 per cent

(c) <u>Aluminium Alloy 75 ST</u> -

After 192 hours one sample (that taken from extrusion A) was removed from the test. Its mechanical properties were:

Ultimate strength, 87,100 p.s.i.
0.2 per cent proof strength, 79,600 p.s.i.
Elongation in 2 inches, 6.5 per cent.

(Tests Performed, cont'd) -

After 360 hours the other sample (that taken from extrusion B) was removed from the test. Figure 1(b) shows its condition. Its mechanical properties were:

Ultimate strength, 82,100 p.s.i.
0.2 per cent proof strength, 69,400
Elongation in 2 inches, 12 per cent.

III. Corrosion Test On Metal Assemblies.

(a) Steel-Magnesium Assembly -

After 17 hours in the Intermittent Immersion Corrosion Test, the two steel-magnesium assemblies were removed. The steel sheets and nuts and bolts were entirely free from corrosion. The magnesium sheets were very badly corroded, much more so than if they had not been connected to the steel.

Figure 2(a) shows the condition of the assemblies. Figure 2(b) shows the condition of magnesium sample which had been subjected to the same treatment without being in contact with steel.

(b) Steel-Aluminium Assembly -

After 360 hours in the Intermittent Immersion Corrosion Test, the two steel-aluminium assemblies were removed. The steel nuts and bolts and the parts of the steel sheets which were fairly close to the aluminium were free from corrosion. There was a small amount of corrosion on the remainder of the steel sheets, much less than if they had not been connected

(Tests Performed, cont'd) -

to the aluminium. There was much more corrosion on the aluminium than if it had not been connected to the steel.

The condition of the two assemblies (back and front views) is shown in Figure 3(b). The condition of aluminium tested alone under the same conditions is shown in Figure 3(a). The condition of steel sheet tested alone under the same conditions is shown in Figure 3(c).

Conclusions:

On the basis of the above experimental data the following conclusions can be drawn:

1. (a) On the basis of the changes in ultimate strength during the corrosion test, the average penetration of the different metals per hour due to the corrosion was as follows:

Aluminium, 0.000,004 inch (based on 360 hours).
Steel, 0.000,003 inch (based on 360 hours).
Magnesium, 0.0001 inch (based on 192 hours).

(b) On the basis of the changes in proof strength during the corrosion test, the average penetration of the different metals per hour due to the corrosion was as follows:

Aluminium, 0.00001 inch (based on 360 hours).
(Note: The value based on the change in ultimate strength probably is more accurate. Unfortunately, there were no additional samples for check purposes.)
Steel, 0.000,004 inch (based on 360 hours).
Magnesium, 0.0001 inch (based on 90 hours).

It should be noted that both aluminium corrosion and magnesium corrosion were of the pitting type, while that of the steel was comparatively uniform. Accordingly, the maximum value of penetration per hour will

(Conclusions, cont'd) -

be considerably greater than the average value given above in the case of the aluminium and magnesium but it will be only slightly greater in the case of the steel. For the purposes of this investigation the values for average penetration probably will be more useful than those for maximum penetration.

2. (a) Magnesium gives excellent protection to steel connected electrically to it. At the same time, the magnesium corrodes much faster in contact with the steel than when it is alone.

(b) Aluminium gives some protection to steel connected electrically to it. At the same time the aluminium corrodes faster in contact with the steel than when it is alone.

Important Notes:

1. The penetration values given are for magnesium alloy AZ31X, aluminium alloy 75 ST and steel S.A.E. 1025. Other alloys of these metals would give widely different results.

2. In cases where two different metals are in contact, the rate of corrosion of the anodic metal (magnesium or aluminium in the present case) is governed to a certain extent by the ratio of the area of the anodic metal to the area of the cathodic metal. In the tests described above the rate of corrosion of the magnesium (or aluminium) in the assembly would have been much less if the area of the magnesium (or aluminium) had been very great compared to the area of the steel.

3. The values for average penetration should not be used directly in engineering calculations because the conditions of the accelerated test are different from actual service conditions. However, it is believed that the ratio of

(Important Notes, cont'd) -

penetration of magnesium : penetration of aluminium : penetration of steel will be approximately the same as under service conditions.

Further Investigation:

Since the above tests were completed, a sample of aluminium alloy 17 ST was received (June 27) from Colonel Thorne, to be tested comparatively with samples of the three metals used in the present investigation. In performing this test the various metal samples will be made with approximately the same thickness. This should improve the accuracy of the results.

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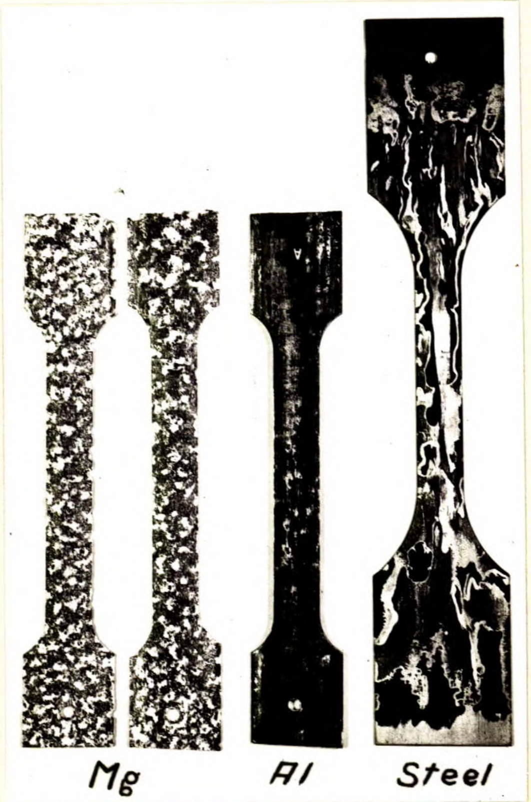
Figure 1.



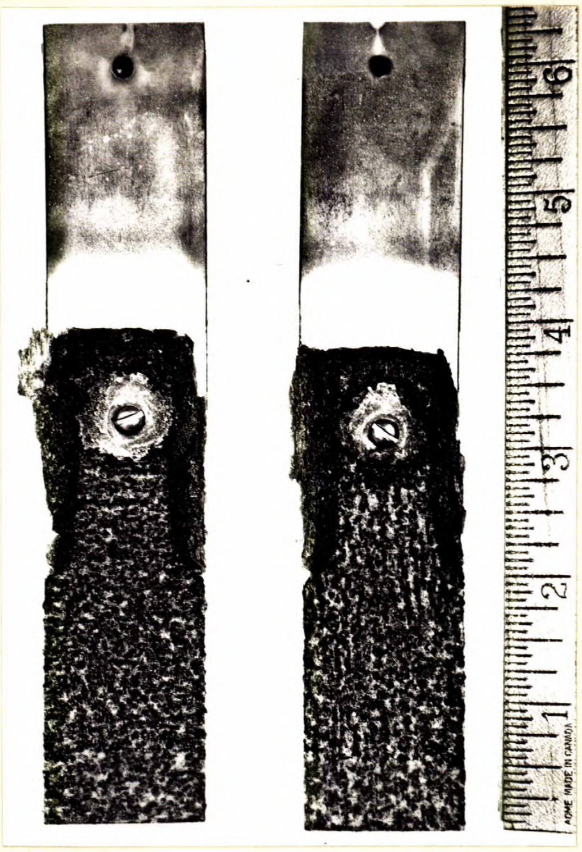
(a) (b) (c)

SAMPLES OF MAGNESIUM ALLOY, ALUMINIUM ALLOY AND STEEL AT THE END OF THE INTERMITTENT IMMERSION CORROSION TEST.

The corrosion product was removed in each case.

(a) Magnesium alloy after 192 hours in the test.
(b) Aluminium alloy after 360 hours in the test.
(c) Steel after 360 hours in the test.

Figure 2.



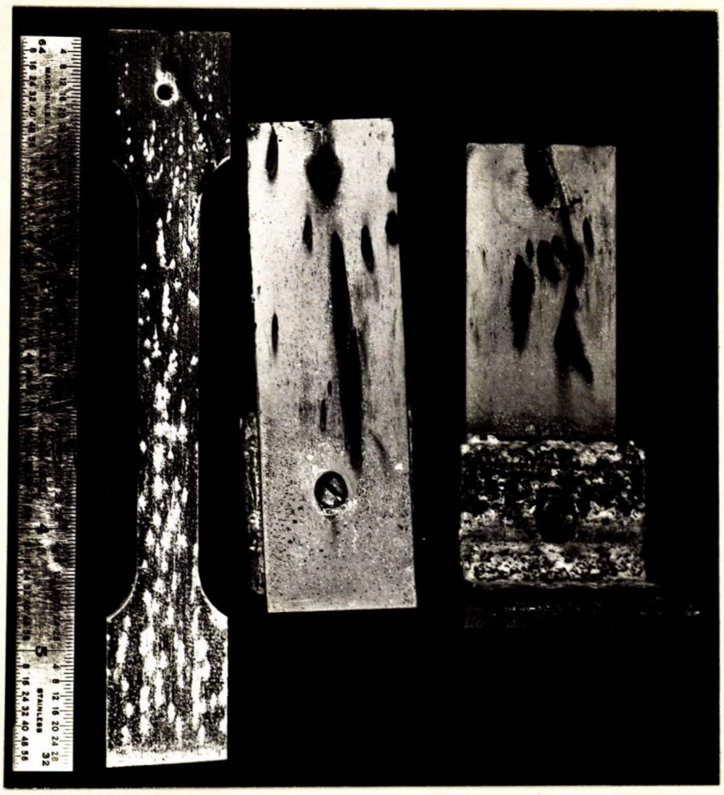
(a)

CONDITION OF STEEL SHEETS (ABOVE), CONNECTED TO MAGNESIUM SHEETS (BELOW) BY STEEL BOLTS AND NUTS, AFTER 17 HOURS IN THE INTERMITTENT IMMERSION CORROSION TEST.

(b)

CONDITION OF MAGNESIUM SHEET ALONE AFTER 17 HOURS IN THE INTERMITTENT IMMERSION CORROSION TEST.

Figure 3.



(a) (b)

(a) CONDITION OF ALUMINIUM ALONE AFTER 360 HOURS IN THE INTERMITTENT IMMERSION CORROSION TEST.
(b) CONDITION OF STEEL SHEETS (ABOVE) CONNECTED TO ALUMINIUM (BELOW) BY STEEL BOLTS AND NUTS, AFTER 360 HOURS IN THE INTERMITTENT IMMERSION CORROSION TEST. Front and back views.

The corrosion product was not removed in either (a) or (b).

(c)
CONDITION OF STEEL SHEET ALONE AFTER 360 HOURS IN THE INTERMITTENT IMMERSION CORROSION TEST.

The corrosion product was not removed.

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