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U. S. Bureau of Mines
Metals Corrosion Laboratory
College Park, Maryland

CORROSION STUDIES ON TITANIUM AND ZIRCONIUM METALS

Semiannual Report for July-December 1951

U. S. Bureau of Mines
Metals Corrosion Laboratory
College Park, Maryland

Corrosion Studies on Titanium and Zirconium Metals

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Semiannual Report for July-December 1951

A comprehensive corrosion resistance investigation of titanium, zirconium, and their alloys was initiated in June 1947. These corrosion studies involve a wide variety and concentration of media including acids, bases, salts, and organic compounds. Temperature and pressure variables have also been incorporated in the broad program.

From the earliest laboratory tests, these two relatively new metals have exhibited unique corrosion resistant properties. More recently, numerous evaluation studies have shown that titanium is a potential replacement for stainless steels in many applications. Zirconium, on the other hand, is similar in corrosion properties to tantalum and may ultimately be used as a replacement or substitute for the less abundant and more expensive metal. Due to the general similarity of titanium to stainless steels and zirconium to tantalum, these metals and alloys have been used in companion or parallel corrosion tests for comparison data of their relative corrosion resistance.

In the present reporting period corrosion data has been obtained for titanium, zirconium, and stainless steel in various concentrations of sulfuric, nitric, hydrochloric, and phosphoric acids. The effect of mixed acid solutions on zirconium was determined. Titanium, zirconium, and stainless steel were also tested in inorganic chlorides, hypochlorite solutions, and organic compounds. Embrittlement tests in concentrated hydrochloric acid under pressure were made on zirconium-tin alloys. Zirconium-titanium alloys (induction melted in graphite) were exposed to the corrosive action of phosphoric, hydrochloric, and sulfuric acids. The corrosion resistance of arc melted zirconium-titanium alloys was determined in cupric and ferric chloride solutions and in aqua regia. A series of zirconium alloys was subjected to tests in various rocket fuels. The complete resistance of all these alloys to attack by anhydrous hydrazine was of special interest.

Galvanic couple tests and electrode potential measurements involving titanium in synthetic ocean water and 0.1 N hydrochloric acid and zirconium in synthetic ocean water indicates that these metals are electropositive (noble) with respect to certain common metals. Copper, aluminum, tin, lead, magnesium, and zinc undergo galvanic corrosion when coupled with titanium in synthetic ocean water at 35°C. Nickel and monel do not corrode under these conditions. When coupled with titanium in 0.1 N hydrochloric acid, magnesium and zinc undergo rapid galvanic corrosion, copper and monel are attacked moderately, and nickel corrodes very slowly. Magnesium coupled with zirconium in synthetic ocean water is rapidly consumed by galvanic action. Although titanium and zirconium show small losses in weight under certain conditions, corrosion rates are always under 1 mil per year.

I. Chemical Corrosion Studies

Zirconium and stainless steel - sulfuric acid:

Zirconium gave corrosion rates of less than 0.35 mils per year at 60°C in air aerated solutions of sulfuric acid ranging in concentration from 10 to 60 percent (Table I). Carpenter No. 20 stainless steel in these same concentrations of acid showed a steady increase in corrosion rate with increasing concentration of acid. In a 10 percent solution a rate of 0.68 mil per year was obtained, whereas the rate in 60 percent solutions was 15.8 mils per year.

Rates for zirconium in boiling sulfuric acid solutions from 10 to 50 percent concentration were less than 0.28 mil per year.

Zirconium - nitric acid:

Corrosion rates for zirconium exposed at 100°C to concentrations of air aerated nitric acid ranging from 10 to 69.5 percent did not exceed 0.23 mil per year (Table I).

Zirconium - mixed acid:

Zirconium was tested at 35°C and 100°C in various concentrations of mixed acid (concentrated sulfuric and concentrated nitric) from 1 percent sulfuric plus 99 percent nitric to 35 percent sulfuric plus 65 percent nitric. In most of the tests at 35°C the samples were covered with tightly adhering black films resulting in slight gains in weight. At 100°C gains in sample weight were recorded for concentrations of sulfuric acid up to 10 percent in the mixed acid. For a 20 percent sulfuric plus 80 percent nitric mixture the corrosion rate was 118 mils per year. The rate for a 25 percent sulfuric plus 75 percent nitric mixture was 149 mils per year.

Titanium, zirconium, and stainless steel - phosphoric acid:

In helium aerated solutions of phosphoric acid at 35°C titanium gave progressively increasing corrosion rates from a minimum of 0.84 mil per year in 10 percent acid to a maximum of 39.6 mils per year in 80 percent acid (Table II). Comparable values in air aerated phosphoric acid solutions were appreciably lower. For example, rates for titanium in helium and air aerated 30 percent acid were respectively, 15.7 and 0.77 mils per year. Under these conditions zirconium showed very low corrosion rates with a maximum of 0.48

mil per year in 70 percent acid. Rates in air aerated solutions were higher than in helium aerated. For example, corrosion rates for zirconium in helium and air aerated 40 percent acid were 0.09 and 0.44 mil per year, respectively. Rates for Carpenter No. 20 stainless steel did not exceed 0.1 mil per year in any concentration with either type of aeration.

At 60°C corrosion rates for titanium were much lower in air aerated than in helium aerated solutions through 30 percent acid concentration. However, the type of aeration had no effect in higher concentrations of acid since corrosion rates for titanium samples in the air and helium aerated solutions were almost identical. Zirconium and stainless steel were fully resistant to all concentrations of both air and helium aerated acid. The maximum rate for the former was 2.33 mils per year in helium aerated 85 percent acid while that for the latter was 0.51 mil per year in helium aerated 60 percent acid.

Corrosion rates for titanium were excessive at 100°C in all but the weakest solutions of phosphoric acid. The stainless steel was far more resistant. For example, in helium aerated 20 percent acid the rate for titanium was 516 mils per year, for the stainless steel only 1.20 mils per year. Zirconium was fully resistant at this temperature in concentrations of helium aerated acid from 5 to 60 percent, giving a maximum rate of 3.53 mils per year in the higher concentrations.

In boiling phosphoric acid solutions titanium was satisfactorily resistant if the concentration did not exceed 3 percent.

Stainless steel - hydrochloric acid:

Results of a series of tests at 35°C with Carpenter No. 20 stainless steel in both air and helium aerated hydrochloric acid solutions showed that this type of steel is much more resistant under oxygen-free conditions (Table III). In 7.5 percent acid a rate of 58 mils per year was obtained in the air aerated solution whereas the rate was only 8.16 mils per year in the helium aerated (oxygen-free) solution. In 20 percent acid the respective rates were 110 mils per year and 30.6 mils per year.

<u>Titanium, zirconium, and stainless steel - inorganic chlorides:</u>

Air aerated 3 percent sodium chloride solution at 100°C had no effect on zirconium. Corrosion rates were zero for titanium in 20 percent nickel chloride solution at 35°C, in 25 percent aluminum chloride at 60°C, and in 5 percent aluminum chloride at 100°C. Carpenter No. 20 stainless steel had a rate of 299 mils per year in 25 percent aluminum chloride at 100°C.

<u>Titanium, zirconium, stainless steel, and Hastelloy C - hypochlorite solutions:</u>

Titanium, zirconium, and Hastelloy C were found to be resistant to 2 and 6 percent calcium hypochlorite and Dakin's solution (0.5 percent sodium hypochlorite) at 35°C, 60°C, and 100°C (Table IV). Carpenter No. 20 and type 316 stainless steels were susceptible to pitting in these solutions.

<u>Titanium, zirconium, and stainless steel - organic compounds:</u>

Corrosion rates for titanium, zirconium, and Carpenter No. 20 stainless steel were all negligible in air aerated 5, 25, 50, 75 and 99.5 percent acetic acid solutions at 35°C, 60°C, and 100°C (Table V).

Titanium at 35°C and zirconium at 100°C were completely resistant in air aerated 5 and 20 percent aniline hydrochloride solutions. In these same solutions at 100°C although the stainless steel samples gave rates of only 1.57 and 5.20 mils per year they were susceptible to severe pitting attack.

At 100°C zirconium was unaffected by helium aerated solutions containing 10, 25, 50, and 90 percent formic acid and by non-aerated and static 50 and 90 percent formic acid solutions. In these same solutions the stainless steel was fully resistant except in non-aerated and static 90 percent formic acid where the corrosion rate was 12.4 mils per year. Titanium showed excellent corrosion resistance in helium aerated 90 percent formic acid at 100°C (0.12 mil per year) but in 50 percent acid was only slightly resistant (142 mils per year).

Zirconium-tin alloys - hydrochloric acid under pressure:

Zirconium-tin alloys prepared by resistance melting in graphite and containing 1.1, 2.2, 3.0, 3.5, and 4.8 percent tin were exposed to concentrated (37 percent) hydrochloric acid at 60°C for six days. The samples were sealed in glass tubes half filled with acid (70-85 ml.) and tested under the pressure developed at this temperature (approximately 3 atmospheres). Corrosion rates for these alloys were respectively 5.97, 36.7, 26.3, 32.7, and 33.6 mils per year. The alloy containing 2.2 percent tin was severely embrittled; however, the other alloys were not affected by this type of attack.

Zirconium-titanium alloys - inorganic acids:

Zirconium-titanium alloys containing 20.6, 35.4, 45.1 and 85.4 percent titanium were tested at 35°C for six days in air aerated phosphoric acid solutions ranging in concentration from 50 to 85 percent, at 60°C in solutions from 30 to 85 percent, and 100°C in solutions from 10 to 70 percent. Results were also obtained for these alloys in air aerated hydrochloric acid solutions at 100°C in concentrations from 5 to 20 percent and in these same solutions (non-aerated) at their boiling points. Data at 100°C in air aerated sulfuric acid solutions in concentrations from 10 to 60 percent was secured (Table VI).

Information obtained from these tests demonstrates further the validity of the conclusions derived from previous tests (semiannual report for January-June 1951), i.e., that in general, (1) increasing amounts of titanium in the alloy causes a corresponding increase in the corrosion rate for all concentrations of the three acids studied, and (2) increasing acid concentrations cause a corresponding increase in the corrosion rate of each of the alloys.

The remarkable increase in corrosion resistance imparted to titanium by the addition of as little as 14 percent zirconium is demonstrated by the following examples. In 10 percent phosphoric acid at 100°C a 200-fold increase in corrosion resistance is attained, the rate for the alloy containing 14 percent zirconium being 2.29 mils per year as compared to 455 mils per year for unalloyed titanium. More than a 70-fold increase is realized in 5 percent hydrochloric acid at 100°C, the rate for the alloy being 13.0 mils per year while that for the titanium is 938 mils per year in only 4 percent acid solution. The rate for the alloy in 10 percent sulfuric acid at 100°C is 94.2 mils per year while that for the unalloyed titanium is 811 mils per year in only 5 percent acid solution. This gives more than a 9-fold increase in corrosion resistance.

Titanium-zirconium alloys - inorganic compounds:

Table VII lists data for five arc melted zirconium-titanium alloys in 15 percent cupric chloride and 25 percent ferric chloride at 35°C together with arc melted titanium and arc melted zirconium. Titanium was completely resistant to these compounds. Zirconium and its alloys suffered intergranular attack, the degree of embrittlement in general was proportional to the amount of zirconium present. At the end of six days zirconium and its alloys were completely embrittled in aqua regia (3 parts of concentrated hydrochloric acid plus 1 part concentrated nitric acid) at room temperature. Arc melted titanium was fully resistant.

Zirconium alloys - rocket fuels:

A number of arc melted binary zirconium alloys were totally immersed in various rocket fuels at room temperature for thirty days. Tests in aniline were made with 39 alloys containing the following elements: aluminum, manganese, cobalt, cerium, tantalum, and tin; in ethyl aniline with 103 alloys containing silver, molybdenum, antimony, tantalum, cerium, cobalt, manganese, aluminum, copper, tungsten, chromium, beryllium, iron, nickel, and silicon; in xylidine with 44 alloys containing silver, molybdenum, antimony, iron, chromium, beryllium, and tin; in furfuryl alcohol with 74 alloys containing chromium, beryllium, nickel, silicon, tungsten, copper, silver, molybdenum, antimony, iron, and tin; in jet fuel (JP-3) with 51 alloys containing nickel, silicon, tungsten, copper, chromium, beryllium, aluminum, manganese, cobalt, cerium, tantalum, and tin; in a mixture of 70 percent xylidine and 30 percent gasoline (leaded) and also in a mixture of 65 percent aniline and 35 percent furfuryl alcohol with 35 alloys containing nickel, silicon, tungsten, copper, and tin; and in methyl and ethyl alcohol with 5 alloys containing tin (Tables VIII-XIV). Except for very slight losses or gains in weight none of the alloys showed any signs of corrosion.

Thirty day room temperature tests in anhydrous hydrazine (95 percent) had negligible effect on samples of titanium and zirconium (both arc and induction melted), stainless steel, zirconium-titanium alloys (both arc and induction melted), zirconium-iron alloys (induction melted), and a number of arc melted binary zirconium alloys. None of the samples showed any visible signs of corrosion and maximum weight changes were a gain of 0.4 milligrams and a loss of 0.7 milligrams (Table XV).

II. Galvanic Corrosion Studies

The investigation of the galvanic behavior of titanium was continued with coupling tests in synthetic ocean water (A.S.T.M. designation D-1141-52T) and in 0.1 N hydrochloric acid. Work on zirconium was started with the study of zirconium-magnesium couples in synthetic ocean water. The tests, generally 30 days in length, were carried out in quadruplicate at 35°C. Equal areas of metals were used and each vessel contained an uncoupled specimen of each metal in addition to the couple. Electrode potential measurements were made with a saturated calomel half-cell. Potentials for the uncoupled metals at the beginning and at the end of the experiments indicated the effects of immersion in the solutions. These values, combined with measurements on coupled specimens, demonstrate polarization effects, as do the open circuit potential measurements. The titanium metal used in these experiments was commercially pure and was prepared by powder metallurgy techniques. The zirconium was high purity, arc melted material. Both metals were in the cold-rolled condition. The other metals used in these tests were commercially pure. All specimens were surfaced with 3/0 emery paper prior to immersion.

Titanium was resistant to non-aerated, air-aerated, and helium-aerated synthetic ocean water, either uncoupled or coupled with such metals as copper, aluminum, monel, nickel, tin, lead, magnesium, and zinc (Table XVI-XXII). In tests summarized in Tables XVI, XVII, and XVIII the members of each couple were connected through a one ohm resistance. Galvanic currents were to be calculated from voltage drops across this resistance. However, there was no measureable flow of current between coupled specimens of titanium and copper or titanium and monel in these experiments. A small current (0.2-0.6 ma.) flowed initially between titanium and aluminum but this was reduced to zero within 24 hours. There was no significant difference in corrosion between coupled and uncoupled specimens of copper, monel, and aluminum. Electrode potential measurements indicated that copper and monel were initially more noble than titanium but later became less noble. Aluminum was less noble than titanium throughout the tests.

In subsequent experiments the metals in a couple were connected directly to each other and the currents were measured with a zero resistance ammeter. Tests involving nickel, tin, copper, and aluminum with titanium in non-aerated and air-aerated synthetic ocean water were repeated using this method (Table XIX). Currents flowed continuously through all couples except titanium-nickel. In the titanium-nickel couple there was a 5 microampere current for about one-half hour. Nickel did not corrode chemically or galvanically. Tin, aluminum, and copper were attacked by galvanic action, the magnitude of the attack being greatest for tin and least for copper. Electrode potential measurements indicated that titanium was more noble than the other metals.

Titanium was always electropositive with respect to lead in synthetic ocean water (Table XX). Lead corroded chemically and galvanically when coupled with titanium, as indicated by the greater weight losses of the coupled specimens and by measured galvanic currents. Lead was consumed more rapidly in non-aerated solutions than in air-aerated and helium aerated solutions.

The electrode potentials of titanium and nickel were quite similar in helium-aerated synthetic ocean water (Table XXI). There was no flow of current through titanium-nickel couples and nickel did not corrode chemically or galvanically. Magnesium, zinc, and tin were less noble than titanium in helium-aerated synthetic ocean water (Table XXI). Magnesium was attacked very rapidly by galvanic action; zinc and tin were consumed more slowly.

On the basis of electrode potential measurements titanium was slightly electronegative (less noble) with respect to monel in helium-aerated synthetic ocean water (Table XXII) and monel was resistant in this solution. Copper and aluminum were electronegative with respect to titanium and these metals were attacked by chemical and galvanic action. The values of chemical and galvanic corrosion of aluminum were low because of the adherence of corrosion products.

Titanium sometimes corroded slightly when immersed uncoupled in non-aerated or air-aerated 0.1 N hydrochloric acid but did not corrode appreciably coupled with magnesium, zinc, copper, nickel or monel (Tables XXIII, XXIV and XXV). Uncoupled specimens of magnesium and zinc were attacked rapidly in both non-aerated and air-aerated 0.1 N hydrochloric acid and coupled specimens showed much higher rates. Corrosion was somewhat more rapid in the air-aerated solutions. Although tests involving magnesium and zinc were only 20 to 72 hours in length, the corrosion of these metals was so rapid that the acid was consumed during the tests. Since the galvanic currents changed with pH good average values for current were not obtained in these experiments. Hence, the galvanic corrosion rates in Tables XXIII and XXIV are based upon the maximum observed flow of current and are included merely as an indication of possible corrosion. Uncoupled specimens of copper, monel, and nickel corroded at moderate rates in non-aerated 0.1 N hydrochloric acid while galvanic corrosion rates, as indicated by increased weight-losses of the coupled specimens and by galvanic current measurements, were moderate for copper and monel and slight for nickel (Table XV). Electrode potential measurements indicate that titanium is electropositive (noble) with respect to magnesium, zinc, copper, nickel, and monel.

Uncoupled specimens of zirconium and specimens coupled with magnesium corroded slightly in air-aerated synthetic ocean water, less in non-aerated, and not appreciably in helium-aerated (Table X[illegible]). Uncoupled specimens of magnesium corroded rather slowly under these conditions, apparently because of the formation of an adherent protective coating. However, coupled specimens corroded galvanically at high rates. Electrode potential measurements indicated that zirconium was noble with respect to magnesium in this environment but somewhat less so than titanium.

Additional tests with titanium-metal couples in 0.1 N hydrochloric acid are in progress. Data now available indicate that titanium is noble with respect to tin, aluminum, nickel, and lead. Early observations show that zirconium is noble with respect to copper and zinc in substitute ocean water. There is a flow of current in zirconium-copper and zirconium-zinc couples but not in zirconium-titanium couples.

Future Program

The program for the immediate future will include a continuation of tests on titanium and zirconium metals and their alloys with inorganic and organic compounds at different concentrations and temperatures. A comparison of the relative corrosion resistance of arc melted metals (both titanium and zirconium) and metals melted in graphite will be continued. Further tests will be made on zirconium alloys in materials used for rocket fuels and in simulated marine atmosphere (salt spray) tests.

Galvanic corrosion research will be continued including additional experiments with titanium-metal and zirconium-metal couples in hydrochloric acid and substitute ocean water. Work in sodium hydroxide solution will also be initiated.

Table 1. -- Zirconium and Stainless Steel -- Sulfuric, Nitric, and Mixed Acids

Solution (percent by weight)	Aeration	Corrosion rate--mils per year: Zirconium 60°C	Zirconium 100°C	Zirconium Boiling+	Stainless Steel 60°C
10 H_2SO_4	Air	0.21	--	0.14	0.68
20 H_2SO_4	Air	0.31	--	0.13	0.28
30 H_2SO_4	Air	0.21	--	0.18	3.25
40 H_2SO_4	Air	0.23	--	0.25	4.44
45 H_2SO_4	None	--	--	0.22	--
50 H_2SO_4	Air	0.23	--	0.28	12.2
60 H_2SO_4	Air	0.23	--	--	15.8
10 HNO_3	Air	--	0.22	--	--
20 HNO_3	Air	--	0.16	--	--
30 HNO_3	Air	--	0.23	--	--
40 HNO_3	Air	--	0.14	--	--
50 HNO_3	Air	--	0.16	--	--
60 HNO_3	Air	--	0.06	--	--
69.5 HNO_3	Air	--	0.12	--	--

+ Boiling samples were not aerated.
Solutions air-aerated at rate of 250 ml. per minute.
Specimen configuration: Zirconium - 1"x1"x0.040" and 1/2"x2"x0.040" (boiling tests)
Stainless steel - 1"x1"x0.082"

Table 2. -- Titanium, Zirconium, and Stainless Steel -- Phosphoric Acid

Solution percent by weight	Temp. °C	Titanium: Helium Aerated	Titanium: Air Aerated	Stainless Steel: Helium Aerated	Stainless Steel: Air Aerated	Zirconium: Helium Aerated	Zirconium: Air Aerated
		Corrosion rate -- mils per year					
5	35	0.76	0.13+	--	--	--	--
10	35	0.84	0.30	0.00	0.01	0.00	0.05
20	35	10.6	0.60	0.01	0.00	0.07	0.23
30	35	15.7	0.77	0.03	0.00	0.13	0.37
40	35	21.0	13.4	0.01	0.05	0.09	0.44
50	35	24.3	18.5	0.03	0.08	0.12	0.49
60	35	30.9	22.4	0.04	0.05	0.25	0.49
70	35	34.7	26.8	0.01	0.03	0.48	0.53
80	35	39.6	29.0	0.06	0.05	0.33	0.56+
85	35	36.4	29.7+	0.04	0.08+	0.27	0.50
5	60	16.5	0.74+	--	--	--	--
10	60	29.6	1.50+	0.05	0.13	0.06	0.54
20	60	55.5	13.7+	0.05	0.12	0.23	0.55
30	60	91.2	59.0+	0.11	0.21	0.21	0.85
40	60	123.	128.+	0.41	0.25	0.39	0.83
50	60	169.	179.+	0.25	0.04+	0.44	0.46+
60	60	224.	239.+	0.51	0.08+	0.60	0.46+
70	60	278.	280.+	--	--	--	--
75	60	--	--	0.24	0.07+	1.75	0.74+
80	60	342.	340.+	--	--	--	--
85	60	--	367.+	0.16	0.07+	2.33	1.56+
1	100	123.	0.12+	0.14	0.09+	--	--
3	100	35.7	62.0+	0.14	0.12+	--	--
5	100	118.	202.+	0.13	0.09+	0.00	0.03+
10	100	302.	455.+	0.15	0.15+	0.09	0.21+
15	100	422.	480.+	1.37	0.21+	--	--
20	100	516.	385.+	1.20	0.26+	0.35	0.63+
30	100	950.	1040.+	5.48	0.24+	0.47	0.86+
40	100	1250.	1550.+	5.22	0.28+	0.58	1.16+
50	100	1570	1845.+	3.39	0.34+	1.03	1.68+
55	100	--	--	--	--	1.70	--
60	100	--	--	2.95	4.25	3.53	3.84+
70	100	--	--	--	4.81	--	9.27+
80	100	--	--	--	7.51	--	24.8+
85	100	--	--	--	5.62	--	43.3+
1	Boiling	9.60++	--	--	--	--	--
3	Boiling	18.2++	--	--	--	--	--
5	Boiling	89.4++	--	--	--	--	--

Table 2 (contd.)

Aeration rate: Helium - 100 ml. per minute
Air - 250 ml. per minute

Specimen configuration: Titanium - 1"x1"x0.060"
Stainless Steel - 1"x1"x0.082"
Zirconium - 1"x1"x0.040"

\+ Data obtained in earlier tests and included here for comparison purposes

++ Boiling solutions were non-aerated.

Table 3. -- Stainless Steel - Hydrochloric Acid (35°C)

Solution (percent by weight)	Corrosion rate - mils per year	
	Air aerated	Helium aerated
7.5	58.0	8.16
10.0	73.4	10.6
12.5	62.1	10.0
15.0	87.3	9.16
17.5	97.0	14.1
20.0	110.	30.6

Aeration: Air - 250 ml. per minute
Helium - 100 ml. per minute
Specimen configuration: 1"x1"x0.082"

Table 4. Titanium, Zirconium, Stainless Steel, and Hastelloy C Hypochlorite Solutions

Solution (percent by weight)	Temp. °C	Corrosion rate - mils per year				
		Titanium	Zirconium	Carpenter No.20 Stainless Steel	Type 316 Stainless Steel	Hastelloy C
2 $Ca(clo)_2$	35	0.00	0.12+	0.62+	0.00	0.00
6 $Ca(clo)_2$	35	0.00	0.03+	34.7+	21.6+	0.03+
Dakin's solution	35	0.00+	0.17+	0.19+	3.56	0.14
2 $Ca(clo)_2$	60	0.09	0.01+	0.03	0.04	0.02
6 $Ca(clo)_2$	60	0.04	0.05	0.04	0.15	0.03
Dakin's solution	60	0.01	0.07	0.50	5.13	0.11
2 $Ca(clo)_2$	100	0.05	0.00	0.05	0.15	0.09
6 $Ca(clo)_2$	100	0.05	0.00	0.41	0.54	0.24
Dakin's solution	100	0.03	0.10	1.62	1.62	0.11

+ Data obtained in earlier tests and included here for comparison purposes.

Table 8. -- Titanium, Zirconium, and Stainless Steel
Organic Compounds

Solution (percent by weight)	Aeration	Corrosion rate - mils per year: Titanium 35°C	Titanium 60°C	Titanium 100°C	Stainless Steel 35°C	Stainless Steel 60°C	Stainless Steel 100°C	Zirconium 35°C	Zirconium 60°C	Zirconium 100°C
5 CH_3COOH	Air	0.02	0.00	0.00	0.00	0.03	0.04	0.03	0.03	--
25 CH_3COOH	Air	0.00	0.00	0.00	0.00	0.01	0.07	0.07	0.01	--
50 CH_3COOH	Air	0.00	0.00	0.01	0.05	0.01	0.08	0.03	0.00	--
75 CH_3COOH	Air	0.00	0.00	0.00	0.09	0.01	0.12	0.04	--	--
99.5 CH_3COOH	Air	0.05	0.00	0.01	0.10	0.00	0.23	0.04	--	--
5 $C_6H_5NH_2Hcl$	Air	--	--	--	--	--	1.57+	--	--	0.00
20 $C_6H_5NH_2Hcl$	Air	--	--	--	--	--	5.20+	--	--	0.00
10 HCOOH	Helium	--	--	--	--	--	0.39	--	--	0.03
25 HCOOH	Helium	--	--	--	--	--	2.20	--	--	0.01
50 HCOOH	Helium	--	--	142	--	--	3.80	--	--	0.02
90 HCOOH	Helium	--	--	0.12	--	--	200	--	--	0.06
50 HCOOH	Non-aerated and static	--	--	--	--	--	1.85	--	--	0.09
90 HCOOH	Non-aerated and static	--	--	--	--	--	12.4	--	--	0.09

+ Samples pitted

Specimen configuration: Titanium - 1/2"x2"x0.060"
Zirconium - 1/2"x2"x0.040"
Stainless Steel - 1/2"x2"x0.080"

Table 6. Zirconium-Titanium Alloys - Phosphoric, Hydrochloric, and Sulfuric Acid

Solution (percent by wgt.)	Temp. °C	Corrosion Rate - mils per year 1346	1372	1373	1375	Ti	Zr
50 H_3PO_4	35	2.19	6.39	9.03	15.8	18.5	0.49
60 H_3PO_4	35	5.32	14.2	25.3	33.2	22.4	0.49
70 H_3PO_4	35	8.94	24.6	42.6	56.7	28.8	0.53
80 H_3PO_4	35	16.4	36.0	56.8	75.2	29.0	0.56
85 H_3PO_4	35	16.8	41.1	65.2	77.5	29.7	0.50
30 H_3PO_4	60	3.72	9.90	13.7	19.8	59.0	0.85
40 H_3PO_4	60	9.32	29.1	46.8	89.3	128	0.83
50 H_3PO_4	60	23.2	72.9	108	200	179	0.46
60 H_3PO_4	60	46.8	120	214	322	239	0.46
70 H_3PO_4	60	80.4	174	284	369	280	0.74 1/
80 H_3PO_4	60	127	270	386	469	340	---
85 H_3PO_4	60	414	292	433	518	367	1.56
10 H_3PO_4	100	0.63	0.39	0.73	2.29	455	0.21
20 H_3PO_4	100	7.10	8.56	9.55	15.9	685	0.63
30 H_3PO_4	100	17.1	36.2	46.0	227	1040	0.86
40 H_3PO_4	100	60.4	139	285	>991	1550	1.16
50 H_3PO_4	100	204	645	>1065	---	1845	1.68
60 H_3PO_4	100	302	>1105	---	---	---	3.84
70 H_3PO_4	100	746	---	---	---	---	9.27
5 HCl	100	0.20	1.01	3.54	13.0	938 2/	0.09
10 HCl	100	0.97	5.08	23.3	105	---	0.10
15 HCl	100	1.08	13.3	60.1	221	---	0.58
17.5 HCl	100	4.91	32.7	152	>669	---	---
20 HCl	100	5.69	34.5	183	---	---	0.69
5 HCl	Boiling	0.62	31.4	55.1	33.4	---	
10 HCl	Boiling	3.87	27.5	119	487	---	
15 HCl	Boiling	9.00	256	634	>1350	---	
17.5 HCl	Boiling	0.01	283	---	---	---	---
20 HCl	Boiling	45.0	---	---	---	---	0.21
10 H_2SO_4	100	0.84	12.5	30.7	94.2	811 3/	---
20 H_2SO_4	100	1.38	22.9	52.5	151	---	---
30 H_2SO_4	100	1.62	25.5	49.0	992	---	---
40 H_2SO_4	100	2.56	51.2	171	---	---	---
50 H_2SO_4	100	30.8	446	815	---	---	0.51
60 H_2SO_4	100	96.4	---	---	---	---	0.60

1/ - 75 percent acid concentration.
2/ - 4 percent acid concentration.
3/ - 5 percent acid concentration.

Alloy No.*	Percent Ti	Percent C	Specimen Configuration
1346	20.6	0.20	1"x1"x0.041"
1372	35.4	0.37	1"x1"x0.054"
1373	45.1	0.56	1"x1"x0.053"
1375	85.4	0.78	1"x1"x0.049"

*Note: These alloys were prepared by induction melting in graphite and sheath-rolling at 850°C. They were then sand-blasted and pickled.

Ti - Cold rolled titanium (powder metallurgy)

Zr - Cold rolled zirconium (induction melted in graphite)

Table 7. -- Arc Melted Zirconium-Titanium Alloys - Inorganic Compounds

Solution (percent by weight)	Corrosion rate - mils per year							
	1413 100 pct. Zr	3007 100 pct. Ti	3008 100 pct. Ti	3009 3 pct. Ti	3010 6 pct. Ti	3102 9 pct. Ti	3011 12 pct. Ti	3012 15 pct. Ti
15 $CuCl_2$	692	0.00	0.00	817	692	420	283	100
25 $FeCl_3$	127	0.00	0.00	>1010	>1040	398	652	323
Aqua Regia	>996	0.23	0.00	>1050	>1040	>1050	>1040	>1065

Specimen configuration - 1/2"x2"x0.040"

Table 8. -- Zirconium Alloys - Aniline

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1747	1.0 Al	3.3985	-0.0001
48	1.0 Al	3.2163	0.0000
51	2.0 Al	3.1975	0.0000
52	2.0 Al	2.7530	0.0000
55	3.0 Al	3.0458	0.0000
56	3.0 Al	3.5968	0.0000
1882	1.0 Mn	3.2468	0.0000
83	1.0 Mn	3.4047	0.0000
86	3.0 Mn	2.7329	-0.0001
87	3.0 Mn	3.0226	-0.0001
90	5.0 Mn	2.8107	0.0000
91	5.0 Mn	3.0874	0.0000
94	10.0 Mn	2.6512	0.0000
95	10.0 Mn	3.6605	-0.0001
98	1.0 Co	2.8246	0.0000
99	1.0 Co	3.1031	-0.0001
1902	3.0 Co	2.7948	0.0000
03	3.0 Co	3.1204	-0.0001
06	5.0 Co	2.7622	0.0001
07	5.0 Co	2.4214	0.0000
10	7.0 Co	2.7828	0.0000
11	7.0 Co	4.1848	0.0000
18	5.0 Ta	3.4519	-0.0002
19	5.0 Ta	2.6741	-0.0001
22	10.0 Ta	2.9108	0.0000
23	10.0 Ta	2.9137	0.0000
34	15.0 Ta	3.2553	0.0000
35	15.0 Ta	2.9700	0.0000
14	1.0 Ce	2.8112	0.0000
15	1.0 Ce	2.9849	-0.0001
26	2.0 Ce	2.1301	0.0000
27	2.0 Ce	2.8685	0.0000
30	3.0 Ce	1.8222	0.0000
31	3.0 Ce	2.3190	0.0000
WA-1711	4.8 Sn	5.8862	0.0000
13	3.0 Sn	5.8796	-0.0001
17	2.2 Sn	5.6060	0.0000
18	3.5 Sn	5.8223	0.0000
19	1.1 Sn	5.6418	0.0000

Specimen configuration - 1/2"x1"x0.040" (approximately)

Table 9. -- Zirconium Alloys - Ethyl Aniline

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1721	1.0 Ag	4.0462	0.0000
22	1.0 Ag	3.4852	0.0000
25	3.0 Ag	3.3574	-0.0001
26	3.0 Ag	2.9784	0.0000
29	5.0 Ag	3.0171	0.0001
30	5.0 Ag	3.1179	0.0000
33	10.0 Ag	2.0678	0.0000
34	10.0 Ag	1.9530	0.0000
43	1.0 Ni	3.9309	0.0000
44	1.0 Ni	3.0482	-0.0001
47	1:0 Al	3.3979	-0.0001
48	1.0 Al	3.2157	0.0002
51	2.0 Al	3.1969	-0.0001
52	2.0 Al	2.7525	-0.0002
55	3.0 Al	3.0451	0.0000
56	3.0 Al	3.5960	0.0000
60	1.0 Si	3.3827	0.0000
61	1.0 Si	3.2801	0.0001
64	2.0 Si	1.8696	0.0002
65	2.0 Si	2.1272	0.0001
68	3.0 Si	3.1109	0.0001
69	3.0 Si	3.3495	0.0001
72	3.0 Ni	3.4982	0.0001
73	3.0 Ni	2.4432	0.0000
81	5.0 Ni	2.6677	0.0001
82	5.0 Ni	3.0902	0.0000
85	8.0 Ni	3.0680	0.0001
86	8.0 Ni	2.2529	0.0001
1805	1.0 W	3.2228	0.0001
06	1.0 W	3.2845	0.0001
09	5.0 W	3.1640	0.0000
10	5.0 W	3.1356	0.0000
14	10.0 W	2.9644	0.0003
15	10.0 W	3.5172	0.0001
18	1.0 Mo	3.6681	0.0000
19	1.0 Mo	2.5286	0.0000
22	3.0 Mo	2.8389	0.0000
23	3.0 Mo	2.9584	0.0000
26	5.0 Mo	2.4083	0.0000
27	5.0 Mo	2.75[illegible]4	0.0000

Table 9 (contd.)

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1830	10.0 Mo	2.6890	0.0001
31	10.0 Mo	3.8638	0.0000
37	1.0 Sb	2.9692	0.0000
42	3.0 Sb	3.6042	0.0001
43	3.0 Sb	3.0808	-0.0002
46	5.0 Sb	3.1391	0.0000
47	5.0 Sb	3.1044	0.0001
50	1.0 Fe	2.4369	0.0000
51	1.0 Fe	4.0125	0.0001
54	3.0 Fe	3.9413	-0.0001
55	3.0 Fe	3.7463	0.0000
58	5.0 Fe	2.9480	0.0000
59	5.0 Fe	3.1259	0.0000
62	1.0 Cu	2.7273	0.0001
63	1.0 Cu	2.3926	0.0000
66	3.0 Cu	3.5741	0.0000
67	3.0 Cu	2.1484	0.0000
70	5.0 Cu	3.4186	0.0001
71	5.0 Cu	2.4638	0.0002
74	7.0 Cu	3.3694	0.0001
75	7.0 Cu	2.9110	0.0001
78	10.0 Cu	2.9351	0.0000
79	10.0 Cu	2.3970	0.0000
82	1.0 Mn	3.2460	0.0002
83	1.0 Mn	3.4040	0.0001
86	3.0 Mn	2.7324	-0.0001
87	3.0 Mn	3.0220	0.0000
90	5.0 Mn	2.8101	0.0002
91	5.0 Mn	3.0768	-0.0001
94	10.0 Mn	2.6506	0.0000
95	10.0 Mn	3.6596	0.0002
98	1.0 Co	2.8239	0.0001
1899	1.0 Co	3.1024	0.0001
1902	3.0 Co	2.7941	-0.0001
03	3.0 Co	3.1198	0.0000
06	5.0 Co	2.7612	0.0000
07	5.0 Co	3.4207	-0.0001
10	7.0 Co	2.7822	0.0000
11	7.0 Co	4.1840	-0.0002
14	1.0 Ce	2.8106	0.0000
15	1.0 Ce	2.9844	0.0000

Table 9 (contd.)

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1918	5.0 Ta	3.4512	-0.0001
19	5.0 Ta	2.6733	-0.0001
22	10.0 Ta	2.9100	0.0000
23	10.0 Ta	2.9131	-0.0001
26	2.0 Ce	2.1294	0.0000
27	2.0 Ce	2.8678	-0.0001
30	3.0 Ce	1.8216	0.0001
31	3.0 Ce	2.3182	-0.0001
34	15.0 Ta	3.2545	-0.0002
35	15.0 Ta	2.9695	-0.0002
2054	1.0 Cr	2.8859	-0.0001
55	1.0 Cr	2.4609	0.0000
58	2.0 Cr	2.8791	-0.0001
59	2.0 Cr	2.2854	-0.0001
64	5.0 Cr	3.0893	0.0000
65	5.0 Cr	2.5906	-0.0001
89	8.0 Cr	2.7008	0.0000
90	8.0 Cr	2.6717	-0.0001
93	1.0 Be	1.9123	0.0000
94	1.0 Be	1.7845	0.0000
97	2.0 Be	2.1646	0.0000
WA-2098	2.0 Be	4.2232	0.0000

Specimen configuration: 1/2"x1"x0.040" (approximately)

Table 10. -- Zirconium Alloys - Xylidine

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1711	4.8 Sn	6.4206	0.0001
13	3.0 Sn	5.7181	-0.0001
17	2.2 Sn	5.6477	0.0000
18	3.5 Sn	6.2015	0.0001
19	1.1 Sn	5.4902	0.0000
21	1.0 Ag	4.0464	0.0000
22	1.0 Ag	3.4855	-0.0001
25	3.0 Ag	3.3575	0.0001
26	3.0 Ag	2.9787	0.0000
29	5.0 Ag	3.0172	-0.0001
30	5.0 Ag	3.1180	-0.0001
33	10.0 Ag	2.0681	-0.0001
34	10.0 Ag	1.9532	0.0000
1818	1.0 Mo	3.6686	0.0000
19	1.0 Mo	2.5287	0.0000
22	3.0 Mo	2.8390	-0.0001
23	3.0 Mo	2.9587	-0.0002
26	5.0 Mo	2.4085	-0.0001
27	5.0 Mo	2.7536	0.0000
30	10.0 Mo	2.6894	0.0000
31	10.0 Mo	3.8641	0.0000
37	1.0 Sb	2.9095	-0.0001
42	3.0 Sb	3.6043	0.0000
43	3.0 Sb	3.0810	-0.0002
46	5.0 Sb	3.1394	-0.0001
47	5.0 Sb	3.1056	0.0001
50	1.0 Fe	2.4372	0.0000
51	1.0 Fe	4.0126	-0.0001
54	3.0 Fe	3.9415	0.0000
55	3.0 Fe	3.7466	0.0000
58	5.0 Fe	3.9483	-0.0001
59	5.0 Fe	3.1260	0.0001
2054	1.0 Cr	2.8866	-0.0005
55	1.0 Cr	2.4615	-0.0005
58	2.0 Cr	2.8796	-0.0003
59	2.0 Cr	2.2860	-0.0004
64	5.0 Cr	3.0900	-0.0005
65	5.0 Cr	2.5911	-0.0002
89	8.0 Cr	2.7009	0.0000
90	8.0 Cr	2.6723	-0.0004
93	1.0 Be	1.9121	0.0004
94	1.0 Be	1.7852	-0.0005
97	2.0 Be	2.1650	-0.0002
WA-2098	2.0 Be	4.2237	[illegible].0005

Specimen configuration: 1/2"x1"x0.040" (approximately)

Table 11. -- Zirconium Alloys - Furfuryl Alcohol

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1711	4.8 Sn	6.0314	0.0003
13	3.0 Sn	6.1390	0.0002
17	2.2 Sn	5.8266	0.0003
18	3.5 Sn	5.9520	0.0001
19	1.1 Sn	5.6955	0.0002
21	1.0 Ag	4.0464	0.0000
22	1.0 Ag	3.4854	0.0000
25	3.0 Ag	3.3576	0.0000
26	3.0 Ag	2.9787	-0.0001
29	5.0 Ag	3.0171	0.0002
30	5.0 Ag	3.1179	0.0001
33	10.0 Ag	2.0680	0.0000
34	10.0 Ag	1.9532	-0.0001
43	1.0 Ni	3.9311	0.0000
44	1.0 Ni	3.0482	0.0000
60	1.0 Si	3.3832	0.0000
61	1.0 Si	3.2806	-0.0001
64	2.0 Si	2.1278	0.0000
65	2.0 Si	2.1278	0.0000
68	3.0 Si	3.1111	0.0000
69	3.0 Si	3.3499	-0.0001
72	3.0 Ni	3.4996	0.0000
73	3.0 Ni	2.4434	0.0000
81	5.0 Ni	2.6680	0.0000
82	5.0 Ni	3.0905	0.0000
85	8.0 Ni	3.0582	0.0000
86	8.0 Ni	2.2532	-0.0001
1805	1.0 W	3.2230	0.0000
06	1.0 W	3.2848	-0.0002
09	5.0 W	3.1644	0.0000
10	5.0 W	3.1358	0.0000
14	10.0 W	2.9648	0.0001
15	10.0 W	3.5175	0.0000
18	1.0 Mo	3.6686	-0.0002
19	1.0 Mo	2.5287	0.0001
22	3.0 Mo	2.8389	0.0001
23	3.0 Mo	2.9585	0.0000
26	5.0 Mo	2.4084	0.0001
27	5.0 Mo	2.7536	0.0000
30	10.0 Mo	2.6894	-0.0002
31	10.0 Mo	3.8641	-0.0001

Table 11 (contd.)

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1837	1.0 Sb	2.9694	0.0000
42	3.0 Sb	3.6043	0.0000
43	3.0 Sb	3.0808	0.0001
46	5.0 Sb	3.1393	0.0000
47	5.0 Sb	3.1057	-0.0007
50	1.0 Fe	2.4372	-0.0001
51	1.0 Fe	4.0125	0.0002
54	3.0 Fe	3.9415	-0.0002
55	3.0 Fe	3.7466	-0.0001
58	5.0 Fe	2.9482	-0.0001
59	5.0 Fe	3.1261	-0.0001
62	1.0 Cu	2.7276	0.0000
63	1.0 Cu	2.3928	0.0000
66	3.0 Cu	3.5745	0.0000
67	3.0 Cu	2.1487	0.0000
70	5.0 Cu	3.4189	0.0000
71	5.0 Cu	2.4641	0.0000
74	7.0 Cu	3.3700	-0.0000
75	7.0 Cu	2.9113	0.0000
78	10.0 Cu	2.9355	-0.0001
79	10.0 Cu	2.3977	0.0000
2054	1.0 Cr	2.4048	0.0000
55	1.0 Cr	2.7223	0.0000
58	2.0 Cr	2.4274	0.0000
59	2.0 Cr	1.9425	0.0000
64	5.0 Cr	2.8502	0.0000
65	5.0 Cr	3.2985	0.0000
89	8.0 Cr	3.1466	0.0000
90	8.0 Cr	3.5176	0.0000
93	1.0 Be	2.3340	-0.0001
94	1.0 Be	2.2828	0.0000
97	2.0 Be	3.0678	-0.0001
WA-2098	2.0 Be	2.7641	0.0001

Specimen configuration: 1/2"x1"x0.040" (approximately)

Table 12. -- Zirconium Alloys - Jet Fuel (JP-3)

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-1711	4.8 Sn	6.3222	0.0000
13	3.0 Sn	6.0918	0.0001
17	2.2 Sn	5.8786	0.0000
18	3.5 Sn	5.8472	0.0001
19	1.1 Sn	5.6786	0.0000
47	1.0 Al	3.3984	-0.0004
48	1.0 Al	3.2163	-0.0003
51	2.0 Al	3.1975	-0.0005
52	2.0 Al	2.7530	-0.0004
55	3.0 Al	3.0458	-0.0005
56	3.0 Al	3.5968	-0.0006
1882	1.0 Mn	3.2468	-0.0005
83	1.0 Mn	3.4047	-0.0005
86	3.0 Mn	2.7328	-0.0003
87	3.0 Mn	3.0225	-0.0003
90	5.0 Mn	2.8107	-0.0004
91	5.0 Mn	3.0874	-0.0005
94	10.0 Mn	2.6512	-0.0004
95	10.0 Mn	3.6604	-0.0005
98	1.0 Co	2.8246	-0.0006
99	1.0 Co	3.1030	-0.0002
1902	3.0 Co	2.7948	-0.0006
03	3.0 Co	3.1203	-0.0002
06	5.0 Co	2.7623	-0.0006
07	5.0 Co	3.4214	-0.0004
10	7.0 Co	2.7828	-0.0004
11	7.0 Co	4.1848	-0.0006
14	1.0 Ce	2.8112	-0.0004
15	1.0 Ce	2.9848	-0.0003
18	5.0 Ta	3.4517	-0.0004
19	5.0 Ta	2.6740	-0.0004
22	10.0 Ta	2.9108	-0.0004
23	10.0 Ta	2.9137	-0.0004
26	2.0 Ce	2.1301	-0.0004
27	2.0 Ce	2.8665	-0.0005
30	3.0 Ce	1.8222	-0.0004
31	3.0 Ce	2.3190	-0.0004
34	15.0 Ta	3.2553	-0.0006
35	15.0 Ta	2.9700	-0.0004

Table 12 (contd.)

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-2054	1.0 Cr	2.8866	0.0000
55	1.0 Cr	2.4615	0.0000
58	2.0 Cr	2.8796	0.0000
59	2.0 Cr	2.2380	0.0000
64	5.0 Cr	3.0900	0.0000
65	5.0 Cr	2.5911	0.0000
89	8.0 Cr	2.7010	-0.0001
90	8.0 Cr	2.6723	0.0000
93	1.0 Be	1.9120	0.0001
94	1.0 Be	1.7852	0.0000
97	2.0 Be	2.1650	0.0000
WA-2098	2.0 Be	4.2237	0.0000

Specimen configuration: 1/2"x1"x0.040" (approximately)

Table 13. -- Zirconium Alloys - Xylidine - Gasoline and Aniline Furfuryl Alcohol Mixtures

Alloy Number	Composition (percent by weight)	Weight of sample in grams A	Weight of sample in grams B	Gain or loss (-) in weight (grams) A	Gain or loss (-) in weight (grams) B
WA-1711	4.8 Sn	6.5028	6.0687	0.0000	0.0000
13	3.0 Sn	5.6473	6.1328	0.0001	-0.0001
17	2.2 Sn	5.8267	5.8008	0.0001	0.0001
18	3.5 Sn	5.9250	6.0474	0.0000	0.0001
19	1.1 Sn	5.7752	5.7423	0.0001	0.0000
43	1.0 Ni	3.9311	3.7337	-0.0002	-0.0001
44	1.0 Ni	3.0482	1.2677	0.0000	-0.0001
60	1.0 Si	3.3832	3.4530	-0.0003	-0.0001
61	1.0 Si	3.2805	3.4296	-0.0002	0.0000
64	2.0 Si	1.8700	1.2343	-0.0001	-0.0002
65	2.0 Si	2.1278	2.9951	-0.0003	-0.0013
68	3.0 Si	3.1111	2.7995	0.0000	-0.0001
69	3.0 Si	3.3498	3.6061	0.0000	0.0000
72	3.0 Ni	3.4996	3.5340	-0.0010	0.0002
73	3.0 Ni	2.4434	1.9812	0.0000	0.0001
81	5.0 Ni	2.6380	2.6309	-0.0002	0.0000
82	5.0 Ni	3.0905	1.7784	-0.0002	-0.0001
85	8.0 Ni	3.0582	3.0105	-0.0001	0.0000
86	8.0 Ni	2.2531	1.4102	-0.0001	0.0000
1805	1.0 W	3.2230	3.1360	0.0000	-0.0002
06	1.0 W	3.2846	3.4423	0.0001	0.0000
09	5.0 W	3.1644	3.1594	-0.0003	0.0000
10	5.0 W	3.1358	3.3388	-0.0001	-0.0002
14	10.0 W	2.9649	3.3027	-0.0001	0.0001
15	10.0 W	3.5175	3.6059	-0.0002	-0.0001
62	1.0 Cu	2.7276	3.2475	-0.0001	-0.0003
63	1.0 Cu	2.3928	1.2615	-0.0001	-0.0002
66	3.0 Cu	3.5745	3.0351	-0.0002	-0.0001
67	3.0 Cu	2.1487	1.4951	-0.0001	-0.0002
70	5.0 Cu	3.4189	4.2904	-0.0001	-0.0002
71	5.0 Cu	2.4641	1.3381	-0.0001	-0.0002
74	7.0 Cu	3.3699	3.4747	-0.0003	-0.0006
75	7.0 Cu	2.9113	1.3532	-0.0001	-0.0002
78	10.0 Cu	2.9354	3.3005	0.0000	-0.0003
WA-1879	10.0 Cu	2.3977	1.1521	-0.0004	-0.0001

A - A mixture of 70 percent xylidine and 30 percent gasoline (leaded).
B - A mixture of 65 percent aniline and 35 percent furfuryl alcohol.
Specimen configuration: 1/2"x1"x0.040" (approximately).

Table 12 (contd.)

Alloy Number	Composition (percent by weight)	Weight of sample in grams	Gain or loss (-) in weight (grams)
WA-2054	1.0 Cr	2.8866	0.0000
55	1.0 Cr	2.4615	0.0000
58	2.0 Cr	2.8796	0.0000
59	2.0 Cr	2.2860	0.0000
64	5.0 Cr	3.0900	0.0000
65	5.0 Cr	2.5911	0.0000
89	8.0 Cr	2.7010	-0.0001
90	8.0 Cr	2.6723	0.0000
93	1.0 Be	1.9120	0.0001
94	1.0 Be	1.7852	0.0000
97	2.0 Be	2.1650	0.0000
WA-2098	2.0 Be	4.2237	0.0000

Specimen configuration: 1/2"x1"x0.040" (approximately)

Table 15.--Titanium, Zirconium, Zirconium Alloys, and Stainless Steel

Anhydrous Hydrazine

Alloy Number	Composition (percent by wgt.)	Weight of sample in grams	Gain or loss(-) in wgt. (grams)
WA - 1711	4.8 Sn	3.1481	0.0000
13	3.0 Sn	2.7606	0.0000
17	2.2 Sn	2.9010	0.0000
18	3.5 Sn	2.7550	0.0000
19	1.1 Sn	2.8171	0.0001
21	1.0 Ag	4.0466	0.0001
22	1.0 Ag	3.4863	0.0002
25	3.0 Ag	3.3581	0.0001
26	3.0 Ag	2.9792	0.0002
29	5.0 Ag	3.0173	0.0000
30	5.0 Ag	3.1179	0.0001
33	10.0 Ag	2.0685	0.0000
34	10.0 Ag	1.9536	0.0001
47	1.0 Al	3.3989	0.0001
48	1.0 Al	3.2158	0.0002
51	2.0 Al	3.1980	0.0002
52	2.0 Al	2.7527	0.0003
55	3.0 Al	3.0454	0.0002
56	3.0 Al	3.5971	0.0002
60	1.0 Si	3.3839	0.0001
61	1.0 Si	3.2812	0.0001
64	2.0 Si	1.8707	0.0000
65	2.0 Si	2.1279	0.0000
68	3.0 Si	3.1112	0.0000
69	3.0 Si	3.3504	0.0000
43	1.0 Ni	3.9313	0.0001
44	1.0 Ni	3.0488	0.0000
72	3.0 Ni	3.4998	0.0000
73	3.0 Ni	2.4440	0.0000
81	5.0 Ni	2.6686	0.0000
82	5.0 Ni	3.0914	0.0001
85	8.0 Ni	3.0587	0.0001
86	8.0 Ni	2.2535	0.0001
1805	1.0 W	3.2231	0.0001
6	1.0 W	3.2855	0.0002
9	5.0 W	3.1648	0.0002
10	5.0 W	3.1360	0.0001

Table 15 (contd.)

Alloy Number	Composition (percent by wgt.)	Weight of sample in grams	Gain or loss(-) in wgt. (grams)
14	10.0 W	2.9654	0.0001
15	10.0 W	3.5172	0.0001
18	1.0 Mo	3.6687	0.0003
19	1.0 Mo	2.5267	0.0002
22	3.0 Mo	2.8391	0.0002
23	3.0 Mo	2.9588	0.0004
26	5.0 Mo	2.4085	0.0000
27	5.0 Mo	2.7542	-0.0001
30	10.0 Mo	2.6903	0.0000
31	10.0 Mo	3.8647	0.0000
37	1.0 Sb	2.9702	0.0000
42	3.0 Sb	3.6043	0.0000
43	3.0 Sb	3.0817	0.0002
46	5.0 Sb	3.1397	0.0001
47	5.0 Sb	3.1044	0.0001
50	1.0 Fe	2.4374	0.0000
51	1.0 Fe	4.0127	-0.0001
54	3.0 Fe	3.9418	0.0000
55	3.0 Fe	3.7471	-0.0001
58	5.0 Fe	2.9486	0.0001
A - 1859	5.0 Fe	3.1263	0.0000
W - 1009B	2.6 Fe	1.5951	0.0001
W - 1011B	4.0 Fe	2.2005	0.0000
W - 1012M	1.2 Fe	1.6660	0.0001
WA - 1862	1.0 Cu	2.7278	0.0000
63	1.0 Cu	2.3938	0.0001
66	3.0 Cu	3.5750	0.0001
67	3.0 Cu	2.1490	0.0001
70	5.0 Cu	3.4189	0.0000
71	5.0 Cu	2.4647	0.0000
74	7.0 Cu	3.3703	0.0000
75	7.0 Cu	2.9112	0.0000
78	10. Cu	2.9356	0.0000
79	10. Cu	2.3983	0.0000
82	1.0 Mn	3.2467	0.0001
83	1.0 Mn	3.4040	0.0001
86	3.0 Mn	2.7327	0.0002
87	3.0 Mn	3.0222	0.0001
90	5.0 Mn	2.8102	0.0001
91	5.0 Mn	3.0776	0.0002
94	10.0 Mn	2.6512	0.0001
95	10.0 Mn	3.6603	0.0001
98	1.0 Co	2.8245	-0.0002
99	1.0 Co	3.1029	0.0000
1902	3.0 Co	2.7955	0.0001
3	3.0 Co	3.1205	0.0000

Table 15 (contd.)

Alloy Number	Composition (percent by wgt.)	Weight of sample in grams	Gain or loss(-) in wgt. (grams)
6	5.0 Co	2.7623	0.0000
7	5.0 Co	3.4213	0.0000
10	7.0 Co	2.7836	-0.0001
11	7.0 Co	4.1853	-0.0001
18	5.0 Ta	3.4522	-0.0001
19	5.0 Ta	2.6745	0.0000
22	10.0 Ta	2.9105	0.0000
23	10.0 Ta	2.9135	0.0000
34	15.0 Ta	3.2555	-0.0001
WA - 1935	15.0 Ta	2.9705	0.0000
W - 1060	1.08 Ta	1.6954	0.0000
WA - 1914	1.0 Ce	2.8108	0.0002
15	1.0 Ce	2.9856	0.0002
26	2.0 Ce	2.1300	0.0001
27	2.0 Ce	2.8686	0.0002
30	3.0 Ce	1.8219	0.0000
31	3.0 Ce	2.3186	0.0000
2054	1.0 Cr	2.8870	0.0001
55	1.0 Cr	2.4618	0.0000
58	2.0 Cr	2.8803	0.0000
59	2.0 Cr	2.2866	0.0000
64	5.0 Cr	3.0906	0.0001
65	5.0 Cr	2.5918	0.0001
89	8.0 Cr	2.7007	0.0001
90	8.0 Cr	2.6726	0.0002
93	1.0 Be	1.9125	0.0001
94	1.0 Be	1.7855	0.0003
97	2.0 Be	2.1653	0.0003
WA - 2098	2.0 Be	4.2234	0.0003
W - 1071	3.7 Cb	1.7805	0.0003
1001B	10.3 Ti	1.3948	-0.0001
1002A	32.9 Ti	2.7874	-0.0001
1003B	46.4 Ti	2.3002	-0.0001
1004A	71.8 Ti	1.3698	-0.0002
3009	3.0 Ti	1.1830	-0.0001
3010	6.0 Ti	1.6009	-0.0002
3011	12.0 Ti	1.3878	-0.0007
3012	15.0 Ti	0.8801	-0.0002
3102	9.0 Ti	1.4342	-0.0003
9	100. Zr	2.0073	-0.0001
1413A	100. Zr	2.0077	-0.0002
923-3	100. Ti	2.1880	-0.0002
3007	100. Ti	1.4642	-0.0003
20 S.S.	29 Ni-20 Cr	6.2100	-0.0004
316 S.S.	18 Cr-12Ni	3.0361	-0.0003

Table 15 (contd.)

All samples were run at room temperature, non-aerated and static.

Samples WA-1711 thru WA-1859, WA-1862 thru WA-1935, WA-1914 thru thru WA-2098, and 3009 thru 3102 are arc melted zirconium alloys. Specimen configuration - 1/2"x1"x0.040" (approx.).

Samples 1009B thru W-1012M, W-1060, and W-1071 thru 1004A are zirconium alloys induction melted in graphite. Specimen configuration - 1/2"x1"x0.040". Samples 9 and 1413A are, respectively, induction and arc melted zirconium. Specimen configuration - 1/2"x1"x0.040."

Samples 923-3 and 3007 are, respectively, powder metallurgy and arc melted titanium. Specimen configuration - 1/2"x1"x0.055".

Sample 20 S.S. is a highly alloyed stainless steel (Carpenter No. 20) with the following nominal analysis: chromium 20.00, nickel 29.00, molybdenum 2.00 min., copper 3.00 min., silicon 1.00, carbon 0.07 max., manganese 0.75. Specimen configuration - 1/2"x1"x0.082".

Sample 316 S.S. is a stainless steel with the following nominal analysis: chromium 18.00, nickel 12.00, molybdenum 1.75 min., silicon 1.00 max., carbon 0.10 max., and manganese 2.00 max. Specimen configuration - 1/2"x1"x0.050".

Table 16. -- Titanium - Copper Couples in Synthetic Ocean Water

Metal	Aeration	Corrosion Rate mils per year		Galvanic Corrosion mils per year calc. from current	Open Circuit Potential*, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
							Coupled		Uncoupled	
		Coupled	Uncoupled		Initial	Final	Initial	Final	Initial	Final
Copper	Non-aerated	1.34	1.13	--	--	--	0.028	0.118	0.024	0.104
Titanium	Non-aerated	0.00	0.00	--	--	--	-0.175	0.308	-0.125	0.297
Cu-Ti Coupled	Non-aerated	--	--	0.0	-0.180	0.147	--	--	--	--
Cu-Ti Uncoupled	Non-aerated	--	--	--	-0.137	0.164	--	--	--	--
Copper	Air-aerated	0.37	0.42	--	--	--	0.075	0.176	0.077	0.138
Titanium	Air-aerated	0.00	0.00	--	--	--	-0.142	0.283	-0.149	0.298
Cu-Ti Coupled	Air-aerated	--	--	0.0	-0.195	0.120	--	--	--	--
Cu-Ti Uncoupled	Air-aerated	--	--	--	-0.197	0.161	--	--	--	--

Duration of tests: 720 hrs.

* Positive value indicates titanium was positive member of couple.

Negative value indicates copper was positive member.

Table 17. -- Titanium - Aluminum Couples in Synthetic Ocean Water

Metal	Aeration	Corrosion Rate mils per year Coupled	Corrosion Rate mils per year Uncoupled	Galvanic Corrosion mils per year calc. from current	Open Circuit Potential+, volts Initial	Open Circuit Potential+, volts Final	Electrode Potential, volts (referred to standard hydrogen electrode) Coupled Initial	Coupled Final	Uncoupled Initial	Uncoupled Final
Aluminum	Non-aerated	0.00	0.00	--	--	--	-0.495	-0.703	-0.502	-0.686
Titanium	Non-aerated	0.00	0.00	--	--	--	-0.132	-0.388	-0.136	0.036
Al-Ti Coupled	Non-aerated	--	--	0.0	0.368	0.362	--	--	--	--
Al-Ti Uncoupled	Non-aerated	--	--	--	0.382	0.718	--	--	--	--
Aluminum	Air-aerated	0.00	0.32	--	--	--	-0.453	-0.584	-0.453	-0.529
Titanium	Air-aerated	0.00	0.00	--	--	--	-0.167	-0.385	-0.128	-0.048
Al-Ti Coupled	Air-aerated	--	--	0.0	0.309	0.240	--	--	--	--
Al-Ti Uncoupled	Air-aerated	--	--	--	0.348	0.491	--	--	--	--

Duration of tests: 720 hrs.

+ Positive value indicates titanium was positive member of couple.

Table 18. -- Titanium - Monel Couples in Synthetic Ocean Water

Metal	Aeration	Corrosion Rate mils per year		Galvanic Corrosion mils per year	Open Circuit Potential+, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
							Coupled		Uncoupled	
		Coupled	Uncoupled	calc. from current	Initial	Final	Initial	Final	Initial	Final
Monel	Non-aerated	0.08	0.07	--	--	--	0.066	0.141	0.066	0.091
Titanium	Non-aerated	0.00	0.00	--	--	--	-0.080	0.275	-0.099	0.339
Monel-Ti Coupled	Non-aerated	--	--	0.0	-0.147	0.143	--	--	--	--
Monel-Ti Uncoupled	Non-aerated	--	--	--	-0.166	0.242	--	--	--	--
Monel	Air-aerated	0.07	0.05	--	--	--	0.045	0.158	0.053	0.136
Titanium	Air-aerated	0.00	0.00	--	--	--	-0.102	0.307	-0.103	0.208
Monel-Ti Coupled	Air-aerated	--	--	0.0	-0.142	0.156	--	--	--	--
Monel-Ti Uncoupled	Air-aerated	--	--	--	-0.150	0.091	--	--	--	--

Duration of tests: 720 hrs.

+ Positive value indicates titanium was positive member of couple.
  Negative value indicates monel was positive member.

Table 19. -- Titanium-Metal Couples in Synthetic Ocean Water

Metal	Aeration	Corrosion Rate mils per year	Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts		Electrode Potential, volts (referred to standard hydrogen electrode) Metal Member of Couple		Titanium Member of Couple	
				Initial	Final	Initial	Final	Initial	Final
Nickel	Non-aerated	0.00	0.	-0.079	0.041	0.004	0.112	-0.078	0.134
Nickel	Air-aerated	0.00	0.	-0.089	-0.007	-0.017	0.196	-0.106	0.184
Tin	Non-aerated	0.27	0.4	0.114	0.249	-0.249	-0.245	-0.130	-0.017
Tin	Air-aerated	6.01	8.6	0.129	0.334	-0.202	-0.258	-0.095	0.073
Copper	Non-aerated	2.02	0.11	-0.173	0.238	0.040	0.107	-0.152	0.342
Copper	Air-aerated	2.42	0.15	-0.031	0.285	0.021	-0.002	-0.032	0.282
Aluminum	Non-aerated	0.55	0.31	0.363	0.330	-0.480	-0.565	-0.133	-0.237
Aluminum	Air-aerated	1.41	1.03	0.407	0.305	-0.478	-0.521	-0.098	-0.222

Duration of test: 480 hrs.

Corrosion Rate of Titanium was zero or negligible in all cases.

Table 20. -- Titanium-Lead Couples in Synthetic Ocean Water

Metal	Aeration	Corrosion Rate, mils per year		Galvanic Corrosion mils per year	Open Circuit Potential, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
							Coupled		Uncoupled	
		Coupled	Uncoupled	calc. from current	Initial	Final	Initial	Final	Initial	Final
Lead	Non-aerated	2.47	0.51	--	--	--	-0.356	-0.210	-0.354	-0.164
Titanium	Non-aerated	0.00	0.01	--	--	--	-0.125	0.149	-0.099	0.223
Pb-Ti Coupled	Non-aerated	--	--	2.72	0.270	0.331	--	--	--	---
Pb-Ti Uncoupled	Non-aerated	--	--	--	0.279	0.356	--	--	--	--
Lead	Air-aerated	1.61	0.58	--	--	--	-0.351	-0.214	-0.347	-0.135
Titanium	Air-aerated	0.00	0.01	--	--	--	-0.094	0.103	-0.083	0.072
Pb-Ti Coupled	Air-aerated	--	--	1.63	0.276	0.323	--	--	--	--
Pb-Ti Uncoupled	Air-aerated	--	--	--	0.275	0.204	--	--	--	--
Lead	Helium-aerated	1.55	0.34	--	--	--	-0.368	-0.220	-0.356	-0.176
Titanium	Helium-aerated	0.00	0.00	--	--	--	-0.126	-0.076	-0.096	0.122
Pb-Ti Coupled	Helium-aerated	--	--	1.36	0.278	0.339	--	--	--	--
Pb-Ti Uncoupled	Helium-aerated	--	--	--	0.276	0.360	--	--	--	--

Duration of tests: Non-aerated and air-aerated - 696 hrs.
Helium-aerated - 720 hrs.

Table 21. -- Titanium-Metal Couples in Synthetic Ocean Water (Helium-Aerated)

Metal	Corrosion Rate mils per year Coupled	Uncoupled	Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts Initial	Final	Electrode, Potential, volts referred to standard hydrogen electrode Coupled Initial	Coupled Final	Uncoupled Initial	Uncoupled Final
Magnesium	1295.	0.00	--	--	--	-1.354	-1.354	-1.354	-1.354
Titanium	0.00	0.00	--	--	--	-0.177	-0.521	-0.107	-0.026
Mg-Ti Coupled	--	--	.61	1.289	0.891	--	--	--	--
Mg-Ti Uncoupled	--	--	--	1.317	1.343	--	--	--	--
Nickel	0.00	0.01	--	--	--	-0.111	0.132	-0.059	0.054
Titanium	0.01	0.00	--	--	--	-0.119	0.124	-0.111	0.035
Ni-Ti Coupled	--	--	0.	-0.004	0.025	--	--	--	--
Ni-Ti Uncoupled	--	--	--	-0.037	-0.011	--	--	--	--
Tin	0.35	0.44	--	--	--	-0.274	-0.255	-0.266	-0.235
Titanium	0.00	0.01	--	--	--	-0.131	-0.013	-0.123	0.003
Sn-Ti Coupled	--	--	.24	0.149	0.254	--	--	--	--
Sn-Ti Uncoupled	--	--	--	0.152	0.238	--	--	--	--
Zinc	3.76	1.81	--	--	--	-0.831	-0.812	-0.831	-0.704
Titanium	00.00	0.00	--	--	--	-0.134	-0.275	-0.114	-0.041
Zn-Ti Coupled	--	--	3.79	0.724	0.548	--	--	--	--
Zn-Ti Uncoupled	--	--	--	0.734	0.665	--	--	--	--

Duration of tests: Magnesium - 43-1/2 hrs.
All others - 720 hrs.

Table 22. -- Titanium-Metal Couples in Synthetic Ocean Water (Helium-Aerated)

Metal	Corrosion Rate mils per year		Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts		Electrode Potential, volts referred to standard hydrogen electrode			
						Coupled		Uncoupled	
	Coupled	Uncoupled		Initial	Final	Initial	Final	Initial	Final
Copper	1.54	1.46	--	--	--	-0.003	-0.029	-0.043	-0.029
Titanium	0.00	0.01	--	--	--	-0.131	0.238	-0.071	0.242
Cu-Ti Coupled	--	--	0.22	-0.088	0.290	--	--	--	--
Cu-Ti Uncoupled	--	--	--	0.004	0.241	--	--	--	--
Aluminum	0.54	0.00	--	--	--	-0.521	-0.541	-0.541	-0.534
Titanium	0.01	0.01	--	--	--	-0.135	-0.260	-0.116	-0.044
Al-Ti Coupled	--	--	0.80	0.429	0.275	--	--	--	--
Al-Ti Uncoupled	--	--	--	0.510	0.555	--	--	--	--
Monel	0.01	0.01	--	--	--	-0.032	0.122	-0.017	0.086
Titanium	0.00	0.00	--	---	--	-0.260	-0.099	-0.213	0.052
Monel-Ti Coupled	--	--	0.00	-0.215	0.087	--	--	--	--
Monel-Ti Uncoupled	--	--	--	-0.222	-0.029	--	--	--	--

Duration of tests: 720 hrs.

Table 23. -- Titanium-Magnesium Couples in One-Tenth Normal Hydrochloric Acid

Metal	Aeration	Corrosion Rate mils per year		Maximum Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
							Coupled		Uncoupled	
		Coupled	Uncoupled		Initial	Final	Initial	Final	Initial	Final
Magnesium	Non-aerated+	1820.	336.	--	--	--	-1.524	-1.284	-1.474	-1.374
Titanium	Non-aerated	0.00	0.03	--	--	--	-0.050	-1.184	0.013	-0.086
Mg-Ti Coupled	Non-aerated	--	--	2180	1.55	0.43	--	--	--	--
Mg-Ti Uncoupled	Non-aerated	--	--	--	1.51	1.40	--	--	--	--
Magnesium	Air-aerated++	2290.	1250.	--	--	--	-1.564	-1.284	-1.584	-1.324
Titanium	Air-aerated	0.00	0.03	--	--	--	0.122	-1.204	0.123	-0.009
Mg-Ti Coupled	Air-aerated	--	--	2910	1.69	0.47	--	--	--	--
Mg-Ti Uncoupled	Air-aerated	--	--	--	1.69	1.28	--	--	--	--

+ Length of test 20 hrs. Initial pH of solution 1.1; final pH 8.1

++ Length of test 24 hrs. Final pH of solution 9.1

Table 24. -- Titanium-Zinc Couples in One-Tenth Normal Hydrochloric Acid

Metal	Aeration	Corrosion Rate, mils per year		Maximum Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
							Coupled		Uncoupled	
		Coupled	Uncoupled		Initial	Final	Initial	Final	Initial	Final
Zinc	Non-aerated+	462.	232.	--	--	--	-0.722	-0.741	-0.727	-0.737
Titanium	Non-aerated	0.00	0.29	--	--	--	0.014	-0.734	0.047	0.096
Zn-Ti Coupled	Non-aerated	--	--	195.	0.827	0.273	--	--	--	--
Zn-Ti Uncoupled	Non-aerated	--	--	--	0.802	0.627	--	--	--	--
Zinc	Air-aerated++	747.	348.	--	--	--	-0.720	-0.753	-0.723	-0.751
Titanium	Air-aerated	0.00	0.51	--	--	--	0.001	-0.744	-0.030	0.318
Zn-Ti Coupled	Air-aerated	--	--	85.	0.758	0.336	--	--	--	--
Zn-Ti Uncoupled	Air-aerated	--	--	--	0.727	0.992	--	--	--	--

\+ Length of test 72 hrs. Initial pH of solution 1.1; final pH 6.1

++ Length of test 48 hrs. Final pH 3.6

Table 25. -- Titanium-Metal Couples in Non-Aerated One-Tenth Normal Hydrochloric Acid +

Metal	Corrosion Rate, mils per year		Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
						Coupled		Uncoupled	
	Coupled	Uncoupled		Initial	Final	Initial	Final	Initial	Final
Copper	79.5	41.2	--	--	--	0.137	0.320	0.137	0.278
Titanium	0.01	0.01	--	--	--	0.176	0.348	0.185	0.440
Cu-Ti Coupled	--	--	21.3	0.099	0.112	--	--	--	--
Cu-Ti Uncoupled	--	--	--	0.080	0.170	--	--	--	--
Nickel	10.1	9.7	--	--	--	-0.032	0.061	-0.035	0.045
Titanium	0.00	0.01	--	--	--	0.061	0.054	0.082	0.301
Ni-Ti Coupled	--	--	0.4	0.116	0.182	--	--	--	--
Ni-Ti Uncoupled	--	--	--	0.130	0.362	--	--	--	--
Monel	37.2	20.9	--	--	--	0.137	0.295	0.136	0.249
Titanium	0.01	0.00	--	--	--	0.041	0.294	0.079	0.525
Monel-Ti Coupled	--	--	10.6	0.039	0.101	--	--	--	--
Monel-Ti Uncoupled	--	--	--	0.277	0.277	--	--	--	--

+Length of tests: Monel and copper - 768 hrs.
Nickel - 720 hrs.

Table 26. -- Zirconium-Magnesium Couples in Synthetic Ocean Water+

Metal	Aeration	Corrosion Rate mils per year		Galvanic Corrosion mils per year calc. from current	Open Circuit Potential, volts		Electrode Potential, volts (referred to standard hydrogen electrode)			
							Coupled		Uncoupled	
		Coupled	Uncoupled		Initial	Final	Initial	Final	Initial	Final
Magnesium	Non-aerated	770.	9.2	--	--	--	-1.364	-1.344	-1.374	-1.344
Zirconium	Non-aerated	0.09	0.17	--	--	--	-0.265	-1.234	-0.268	-0.307
Mg-Zr Coupled	Non-aerated	--	--	294.	1.09	0.120	--	--	--	--
Mg-Zr Uncoupled	Non-aerated	--	--	--	1.10	1.20	--	--	--	--
Magnesium	Air-aerated	352.	8.1	--	--	--	-1.404	-1.344	-1.394	-1.354
Zirconium	Air-aerated	0.96	0.62	--	--	--	-0.295	-1.314	-0.293	-0.126
Mg-Zr Coupled	Air-aerated	--	--	278.	1.10	0.770	--	--	--	--
Mg-Zr Uncoupled	Air-aerated	--	--	--	1.10	1.23	--	--	--	--
Magnesium	Helium-aerated	708.	21.0	--	--	--	-1.404	-1.334	-1.414	-1.364
Zirconium	Helium-aerated	0.00	0.00	--	---	--	-0.394	-1.324	-0.393	-0.280
Mg-Zr Coupled	Helium-aerated	--	--	211.	0.990	0.672	--	--	--	--
Mg-Zr Uncoupled	Helium-aerated	--	--	--	1.03	1.32	--	--	--	--

+ Length of tests: Non-aerated - 43 hrs.
Air-aerated - 30 hrs.
Helium-aerated - 72 hrs.