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Reactor Experimental Engineering Division

THE CORROSION OF HOT-PRESSED, EXTRUDED, AND VACUUM CAST BERYLLIUM IN SIMULATED COOLING WATER FOR THE MATERIALS TESTING REACTOR

by

James Reed

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INTRODUCTION

This report is issued as Part I-D of a series of reports concerned with corrosion studies for the Materials Testing Reactor by the Corrosion Group of the Reactor Experimental Engineering Division at Oak Ridge National Laboratory.* Most of these data have been previously published in progress reports and memoranda. Another report, Part I-E, will be issued at a later date to cover the results of long-term tests made on representative samples of beryllium used in the construction of the Materials Testing Reactor.

The technology of hot-pressed beryllium production had advanced rapidly by the end of 1949. Additional corrosion information was needed to determine the type of beryllium metal best suited for reflector material. The effects of surface cold work, metal purity, and water quality on the corrosion resistance required further investigation. Consequently, the beryllium corrosion program was oriented to provide this information.

The test results given in this report have been divided into two parts. Part I is devoted to corrosion studies made on hot-pressed and vacuum cast extruded metal which was considered representative of production. Part II is concerned with the results of tests made on special cast and hot-pressed beryllium which contained added impurities.

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* Other reports issued in this series include:

Part I: Interim Report on the Corrosion of Beryllium in Simulated Cooling Water for the Proposed Development Reactor, James L. English, ORNL-298, March 16, 1949.

Part I-A: Initial Corrosion Tests on Brush Process QM and QRM Beryllium, Arnold R. Olsen, ORNL-733, July 14, 1950.

Part I-B: The Corrosion of Beryllium in Simulated Cooling Water for the Materials Testing Reactor, James L. English, ORNL-772, January 23, 1951.

Part I-C: The Effect of Metallurgical Variables on the Corrosion of Extruded Beryllium, Arnold R. Olsen, ORNL-1146.

Part II: The Corrosion of 356 Aluminum in Simulated Cooling Water for the Proposed Materials Testing Reactor, James L. English, ORNL-681, July 20, 1950.

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ABSTRACT

The results of stagnant tests to determine the effects of production method, surface cold work, water quality, and metal purity on the corrosion resistance of beryllium to aqueous media are reported. Distilled water, with and without added ionic impurities, containing hydrogen peroxide (0.005M) at a temperature of 85°C was the corrosive medium.

The corrosion resistance of three types of hot-pressed beryllium and vacuum cast extruded beryllium was almost identical after 12 months of exposure. Corrosion rates of 0.007, 0.008, and 0.009 mils/mo. were obtained for QM-V, QPT, and QRM hot-pressed samples, respectively. A rate of 0.008 mils/mo. was obtained for the vacuum cast extruded metal. The most significant corrosion damage was caused by light pitting which was slightly more severe on the QRM metal. The maximum pit depths obtained for the hot-pressed metal were 15.7 mils for the QRM, 7.1 mils for the QM-V, and 3.1 mils for the QPT. The greatest pit depth obtained on the vacuum cast extruded metal was 7.4 mils. The greatest number of pits on the QRM metal was 6 pits/cm^2. Pit frequencies for the other three types were, in most instances, lower than this value.

The effect of surface cold work produced by grinding and milling on the corrosion resistance of hot-pressed beryllium was studied. Surfaces produced by grinding cuts of 0.005, 0.010, and 0.020" were equally corrosion resistant for a period of 10 months. Cold-worked surfaces produced by milling cuts 1/8" or less in depth exhibited about the same corrosion resistance as the ground surfaces. Cold work produced by deep milling cuts of 1/4 and 1/2" increased the initial corrosion, but the long-term effect was less pronounced. The pitting on deeply cold-worked metal (1/2" milling cut) was more localized after 10 months of exposure. Grinding improved the corrosion resistance of deeply cold-worked surfaces.

The susceptibility of beryllium to pitting was greatly accelerated by the presence of chloride, sulfate, and cupric ions in the corrosive medium. In order to avoid excessive pitting, the concentrations of these constituents should be maintained as low as economically feasible. Tolerable upper limits are 0.2 ppm chloride, 2.0 ppm sulfate, and 0.02 ppm cupric ions.

Tests were run to determine the corrosive effects of various impurities normally present in beryllium. Cast beryllium containing additions of aluminum, iron, and silicon exhibited no detrimental effects attributable to these constituents after 13 months of exposure. The impurity concentrations studied were as follows: 0.30, 0.44, 0.73, and 1.05% Al; 0.23, 0.34, and 0.40% Fe; and 0.186 and 0.201% Si. Hot-pressed metal containing 0.11, 0.23, and 0.26% Be_2C showed no significant difference in corrosion resistance after 7 months of exposure.

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PART I

THE CORROSION RESISTANCE OF PRODUCTION HOT-PRESSED AND VACUUM CAST EXTRUDED BERYLLIUM

This part of the report covers corrosion studies made on hot-pressed and vacuum cast extruded beryllium samples which were considered comparable representatives of production during 1949. These studies were made to determine the effect of production method, machining technique, and water quality on the corrosion resistance of beryllium.

Test Materials and Treatment

The test samples of QM-V, QPT, and QRM hot-pressed beryllium metal were procured from The Brush Beryllium Company in the form of small slabs having the following dimensions: 1" x 1" x 1/4". A 3/16" diameter hole was drilled near one corner. Various machining methods were used on all three types so that the effect of surface cold work on the corrosion resistance could be studied. The reported chemical analyses of these materials are given in Table I.

A brief description of the chemical and metallurgical background of the three types of hot-pressed beryllium is as follows:

1. QPT beryllium refers to powder metallurgy shapes produced from less than 200 mesh powder which was made by crushing, rolling, and attritioning pressure furnace primary grade pebbles. Primary grade pebbles are produced by the pressure furnace reduction of beryllium fluoride with magnesium. This material generally assays 98.5% or better.

2. QRM beryllium refers to powder metallurgy shapes produced from less than 200 mesh powder which was made by crushing, rolling, and attritioning pressure furnace remelt beryllium pebbles. Remelt beryllium is produced in a pressure furnace by melting beryllium metal in the fluoride slag remaining from pressure furnace primary reduction runs. This metal assays 98.5% or better. Its magnesium and slag content is lower than in QPT metal.

3. QM-V beryllium refers to powder metallurgy shapes produced from less than 200 mesh powder made by chipping and attritioning vacuum cast billets.

The general procedure used by The Brush Beryllium Company for machining the test samples was as follows: After rough-machining the hot-pressed blocks, slabs 1" in thickness were cut on a Peerless saw. These slabs were cut into approximately 1" cross sections on a shaper and were then ground to size. The ground 1" cross-section bars were cut into slabs of various thickness on a Radiac. The two faces of these slabs produced by the Radiac cuts were then machined and/or ground by the various procedures given in the extreme left-hand columns of Tables VII, VIII, and IX.

All milling machine cuts were made with a 6" carbide-tipped end mill-HA grade, 135 rpm, and 1.180" feed per minute. Coolant used was synthetic turpentine. All grinding was done on a Brown and Sharpe surface grinder using a crystalline wheel, No. 32A60-H8YBE, 10" x 1/2" x 3" hole. Table feed was 20' per minute. The wheel rotated at approximately 2300 rpm. The Radiac cutting wheel used was type C-90, LRE-23, 10" diameter x 1/32" thick.

Test samples of extruded metal were machined from a bar which was produced by the extrusion of a vacuum cast billet. This billet was cast by the Beryllium Corporation from metal supplied by The Brush Beryllium Company. The billet was extruded at a temperature of 1800°F. The extrusion ratio of the bar was 4.1:1. A complete analysis of this material was not available. The reported analysis for a few of the elements is as follows:

Element Determined	Chemical Analysis
Fe	0.125%
Al	0.09%
Mg	25 ppm
Mn	235 ppm
Cr	180 ppm
Ni	195 ppm

The test samples, 1" diameter x 1/4" thick, from this bar were finish-machined by lathe cuts of approximately 0.005" in depth.

The samples were cleaned in cold, 25% nitric acid for 20 minutes, rinsed in water, acetone, and alcohol, dried in an oven at 110°C for 15 to 20 minutes, and weighed prior to exposure.

[redacted]

TABLE I

CHEMICAL ANALYSES OF HOT PRESSED BERYLLIUM

Elements Determined	Lot No. Y4478BP QM-V	Lot No. Y4460BP QRM	Lot No. Y4483BP QPT
		In Wt. Per Cent	
Ag	0.00005 a	0.00005 a	0.00005 a
Al	0.10	0.33	0.17
Cd	0.00002 nd	0.00002 nd	0.00002 nd
Co	0.0001 nd	0.0001 nd	0.0001 nd
Cu	0.007	0.015	0.018
Fe	0.10	0.26	0.28
Li	- 0.00003	- 0.00003	- 0.00003
Mg	0.013	0.042	0.02
Mn	0.008	0.013	0.012
Ni	0.023	0.02	0.012
Si	0.038	0.068	0.055
Zn	0.006 a	0.006 a	0.006 a

The analyses given above are reported by National Spectrographic Laboratory.

Assay	99.28	98.87	99.04
BeO	1.34	*	1.26
Slag	0.33	*	0.11
Be_2C	0.16	*	0.29
Fe	0.117	0.18	0.199
Al	0.15	0.20	0.18
Mg	*	0.10	0.02
Ni	*	0.05	*
Cr	*	0.009	*

The analyses given above are reported by The Brush Beryllium Company, Cleveland, Laboratory.

---

a means approximately
nd means not detected at sensitivity of designated per cent
* no analysis was reported for these elements

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Description of Corrosion Test Method

Distilled water containing 0.005M hydrogen peroxide to simulate the effects of irradiation on the water was used as the test media. The temperature of the test media was maintained at 85°C; the pH within the range of 5.5 to 6.5. An analysis is given in Table II as representative of the water quality used during the course of the tests.

Test samples were suspended in either 5 or 16 liter capacity jars. The smaller jars, 5 liter 3-neck distilling flasks, were supported on a transite box containing a 375 watt infra-red bulb for heating. The temperature was controlled by a Merc-to-Merc thermoregulator-relay system. Reflux condensers prevented solution loss. The larger jars were maintained at 85°C in electrically heated water baths. Plastic-coated aluminum lids were used to minimize solution loss and contamination of the water. The pH of the water was adjusted three times weekly, if necessary, within the range of 5.5 to 6.5 by the use of either dilute nitric acid or sodium hydroxide. The hydrogen peroxide concentration was maintained approximately 0.005M by the addition of 4% hydrogen peroxide every 4 hours. Peroxide analyses were made three times each week. The test media were replaced weekly with fresh water.

A few tests were run to determine the effect of water quality on the corrosion resistance of beryllium. For these tests, additions of known troublesome impurities - chloride, sulfate, and cupric ions - were made to the test media. These impurities were added weekly as sodium chloride, sodium sulfate, and cupric sulfate. Tests were run which contained 0.5 and 1.0 ppm of chloride; 5, 10, and 15 ppm of sulfate; and 0.1, 0.2, and 0.5 ppm of cupric ions.

Samples were removed from each test periodically for corrosion damage evaluation. The samples were cleaned with a surgical brush, dried in an oven at 110°C for 15 to 20 minutes, and weighed. They were then defilmed in 25% nitric acid for 20 minutes, dried, and weighed again. The pits were counted and the maximum pit depth on each sample was determined with the aid of a microscope. The pit counts given in this report include only the pits which were readily observed with the naked eye. The penetration rates were based on the defilmed weight losses. A different set of samples was used for each periodic corrosion damage evaluation.

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TABLE II

TYPICAL ANALYSIS OF DISTILLED WATER USED IN CORROSION TESTS

Specific resistance, ohms/cm^3 at 25°C	3×10^5
pH	5.5
Soap hardness ($CaCO_3$)	5.0 ppm
Dissolved CO_2	2.3 ppm
Dissolved solids	7.2 ppm
Non-volatile solids	5.9 ppm
SiO_2	2.6 ppm
Fe	0.2 ppm
Al	0.01 ppm
Cu	0.02 ppm
Ni	0.05 ppm
Cr	0.05 ppm
Ca	0.25 ppm
Mg	0.21 ppm
Na	1.0 ppm
SO_4	2.0 ppm
Cl	0.2 ppm
CO_3	3.1 ppm
HCO_3	4.3 ppm

[redacted]

Data and Discussion of Results

The data and discussion have been divided into three sections based on comparisons of the relative corrosion characteristics for different production methods, different machining techniques, and minor differences in water quality.

The Relative Corrosion Resistance of Hot-Pressed and Vacuum Cast Extruded Beryllium

Corrosion data are given in Tables III, IV, V, and VI. These results cover exposure periods of 1, 2, 3, 5, 7, 9, and 12 months for samples of each of the three types of hot-pressed metal and the vacuum cast extruded metal.

The hot-pressed metal showed light corrosion damage throughout the course of the tests. The average corrosion rates based on 12 months of exposure for the QM-V, QPT, and QRM beryllium were 0.007, 0.008, and 0.009 mils/mo., respectively. Comparisons of the weight losses and corrosion rates with respect to exposure time are shown in Figures I and 2. The weight losses and corrosion rates shown on these plots are average values for the samples used for each exposure period. The QM-V metal exhibited an almost constant rate after the first month of exposure. The QPT material unexpectedly exhibited a minimum rate of 0.006 mils/mo. after 2 months. The rate increased to a maximum of 0.011 mils/mo. after 5 months then decreased gradually to an almost constant value of 0.008 mils/mo. at the conclusion of the test. The corrosion rate for QRM metal was erratic during the first 7 months of exposure, reaching a maximum value of 0.014 mils/mo. after 3 and 7 months. During the latter 5 months, the rate decreased gradually to 0.009 mils/mo.

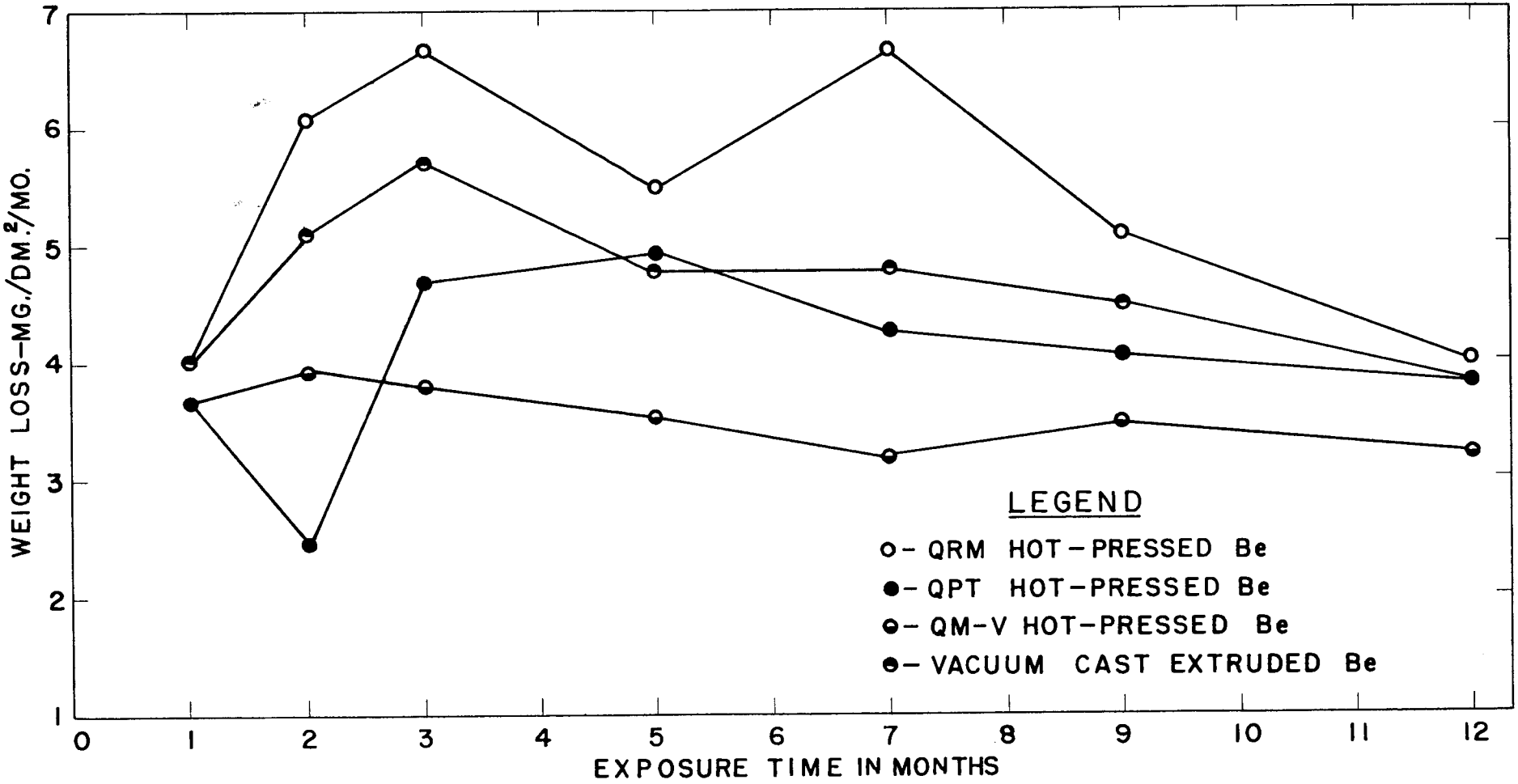
The most noticeable corrosion damage on all three types of hot-pressed metal was the formation of a fairly uniform distribution of shallow pits. In general, the frequency and depth of the pits on the QRM metal were greater than those obtained on the QM-V and QPT material. The greatest pit depth obtained on the QRM metal was 15.7 mils after 7 months of exposure. The greatest number of pits observed was 6.0 pits/cm^2 on a sample exposed for 2 months. The maximum pit depths observed on the QM-V and QPT samples were 7.1 and 3.1 mils after 2 and 12 months of exposure, respectively. The pit frequencies for these materials, in most instances, were approximately one-half as great as those observed on the QRM metal. Numerous extremely small pits

occurred on some of the QM-V and QPT samples after 12 months. The non-homogeneity of the metal apparently caused the erratic behavior of the pitting attack. In many instances, the greatest number of pits, as well as pit depths, were not observed on samples exposed the entire 12 months. Photographs of samples after various periods of exposure are shown in Figures 3, 4, and 5.

The corrosion rates obtained for the vacuum cast extruded beryllium were low throughout the course of the test. The average rate after 12 months of exposure was 0.008 mils/mo. A maximum rate of 0.012 mils/mo. was obtained after 3 months of exposure followed by a decreasing rate for the last 9 months. The metal was susceptible to light pitting. The pit depths were erratic. A maximum pit depth of 7.4 mils was obtained on a sample after 7 months of exposure. Pit frequencies were comparable to those obtained for the QM-V and QPT metal. Photographs of samples after various periods of exposure are shown in Figure 6.

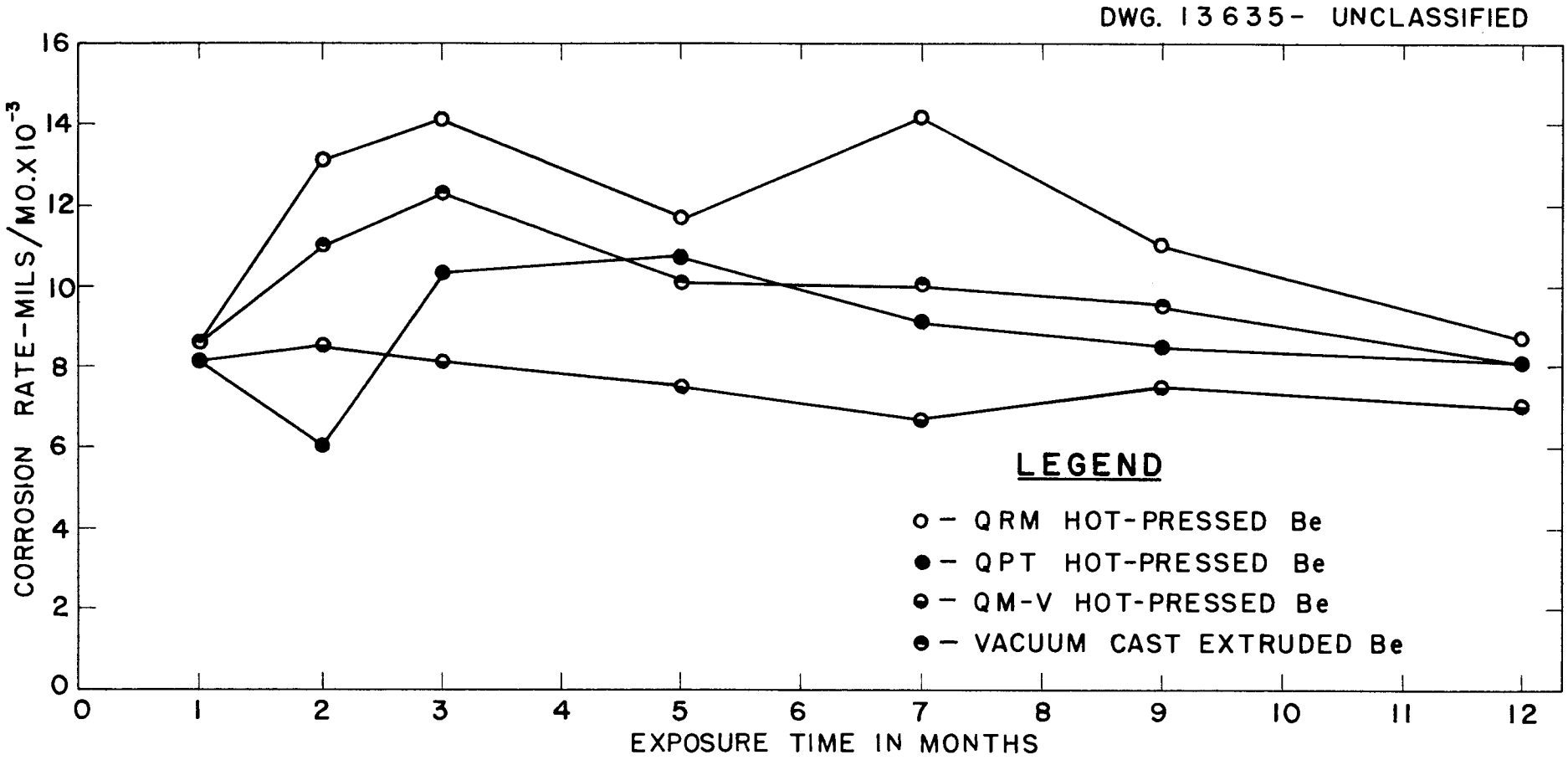
These studies show no appreciable difference in the corrosion resistance of hot-pressed and vacuum cast extruded beryllium after 1 year of exposure to distilled water (0.005M H_2O_2, pH 5.5-6.5, 85°C). The corrosion rates were low, varying between 0.007 and 0.009 mils/mo. The most significant corrosion was caused by shallow pitting which was slightly more severe on the QRM metal.

DWG. 13634- UNCLASSIFIED



WEIGHT LOSS VS. TIME RELATIONSHIP FOR VACUUM CAST AND HOT-PRESSED BERYLLIUM EXPOSED TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

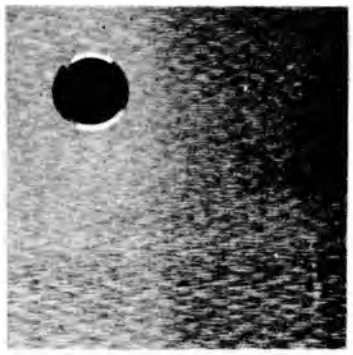
FIG. 1



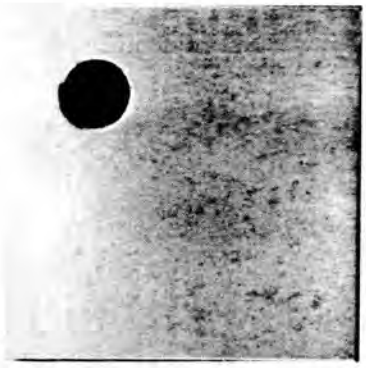
CORROSION RATE VS. TIME RELATIONSHIP FOR VACUUM CAST AND HOT-PRESSED BERYLLIUM EXPOSED TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

FIG. 2

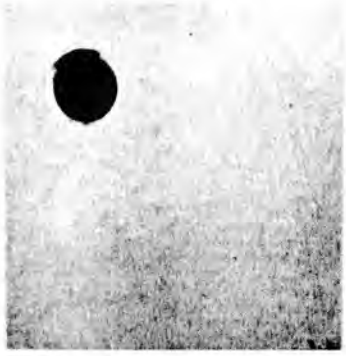
UNCLASSIFIED
PHOTO NO. 6-3157



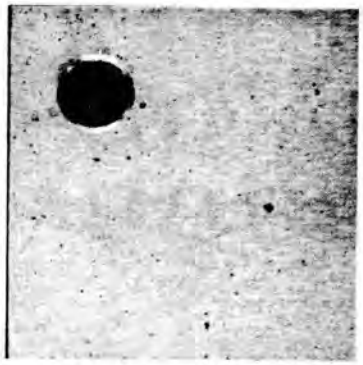
1 MONTH



2 MONTHS

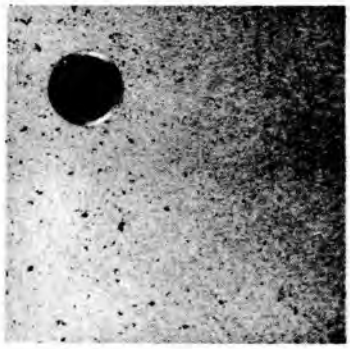


5 MONTHS



7 MONTHS

9 MONTHS



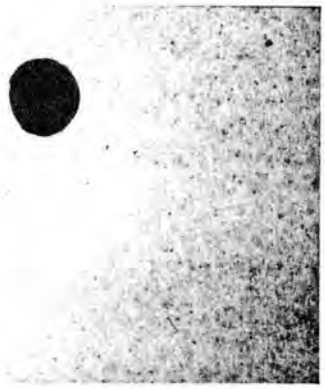
12 MONTHS

FIGURE 3. QM-V BERYLLIUM SAMPLES (LOT NO. Y4478BP) AFTER EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C (Mag.).

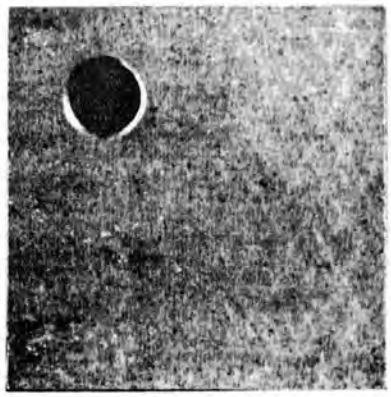
UNCLASSIFIED
PHOTO NO. 6-3158

1 MONTH

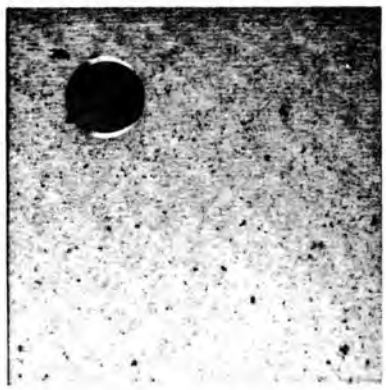
2 MONTHS



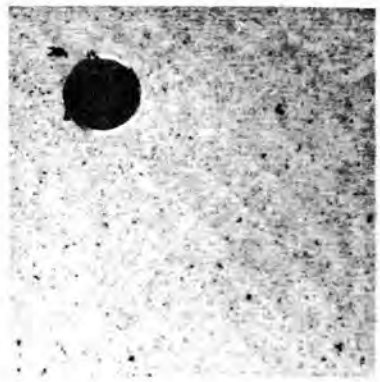
5 MONTHS



7 MONTHS



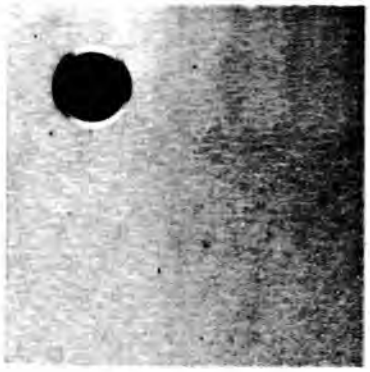
9 MONTHS



12 MONTHS

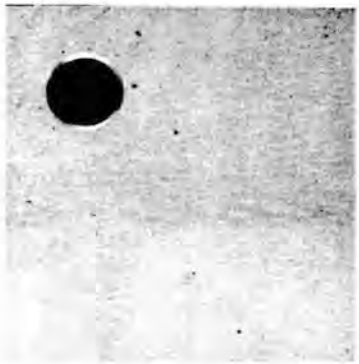
FIGURE 4. QRM BERYLLIUM SAMPLES (LOT NO. Y4460BP) AFTER EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85° C (Mag.)

UNCLASSIFIED
PHOTO NO. 6-3159

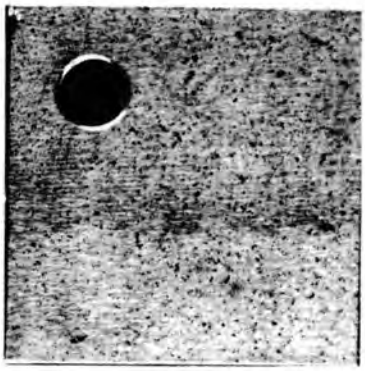


1 MONTH

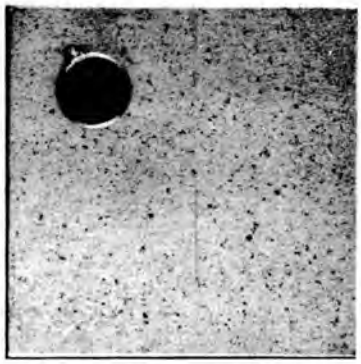
2 MONTHS



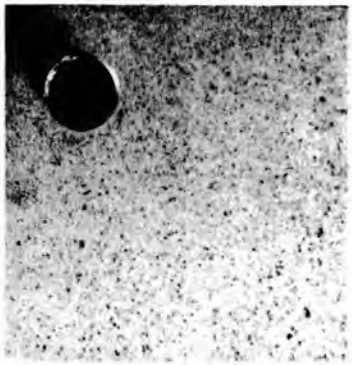
5 MONTHS



7 MONTHS



9 MONTHS



12 MONTHS

FIGURE 5. QPT BERYLLIUM SAMPLES (LOT NO. Y4483BP) AFTER EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C (Mag.).

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PHOTO NO. 6-3160

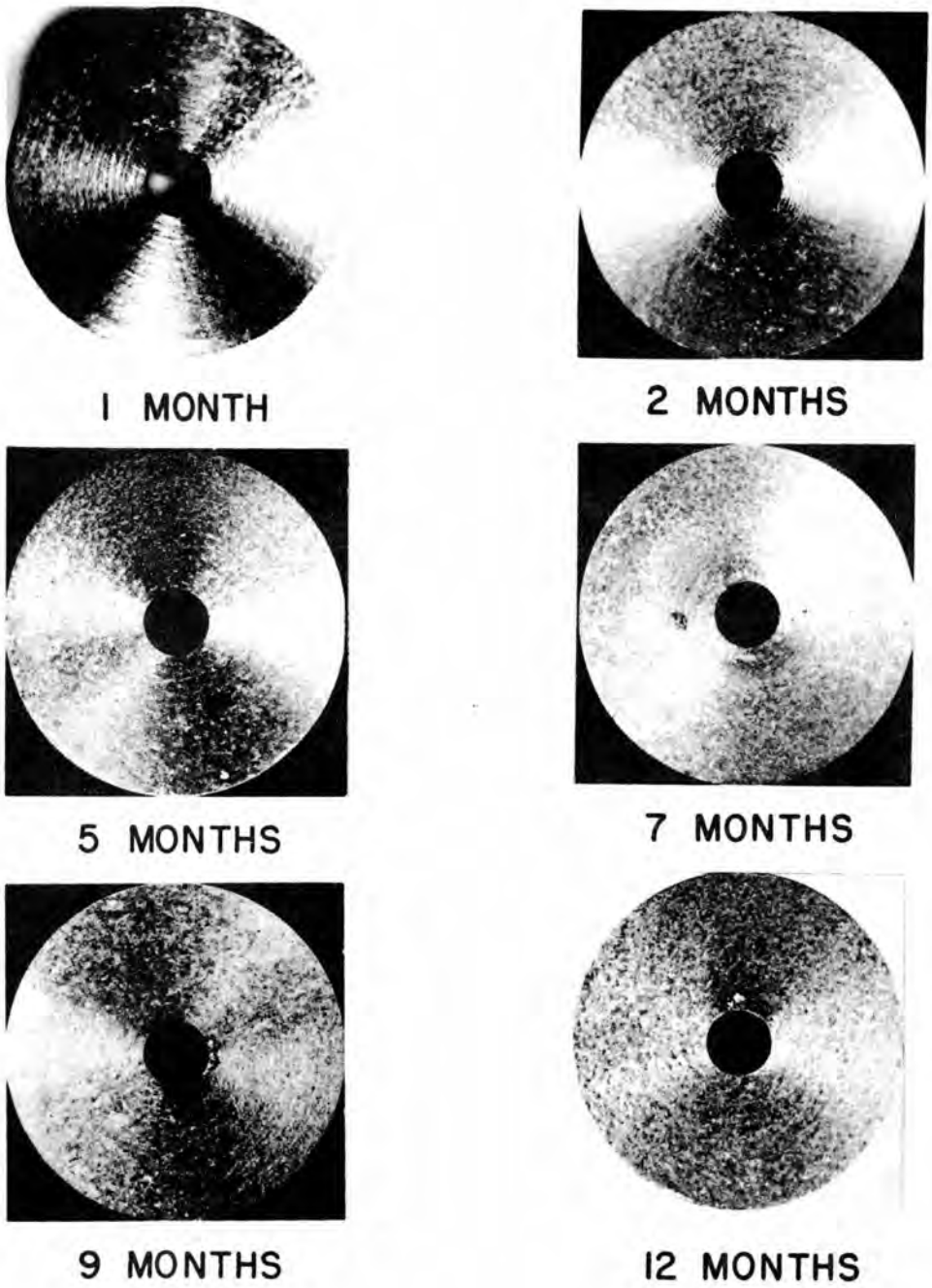

FIGURE 6. VACUUM CAST EXTRUDED BERYLLIUM SAMPLES (BILLET NO. 164) AFTER EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C (Mag.).

[redacted]

TABLE III

THE CORROSION OF QM-V BERYLLIUM (LOT NO. Y4478BP) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
Neg.	-	2.7	0.006	1
"	-	4.5	0.010	"
"	-	3.6	0.008	"
"	-	3.6	0.008	"
"	-	4.5	0.010	"
"	-	3.2	0.007	"
0.8	0.7	3.8	0.008	2
2.0	3.2	3.8	0.008	"
0.9	2.1	4.0	0.009	"
0.5	1.3	6.4	0.014	"
0.3	3.5	2.9	0.006	"
0.5	2.1	2.4	0.005	"
2.9	2.4	3.8	0.008	"
1.3	0.9	4.6	0.010	"
2.4	2.0	4.3	0.009	"
3.7	0.9	2.9	0.006	"
0.6	7.1	3.2	0.007	"
1.7	1.0	5.1	0.011	"
1.1	0.9	3.8	0.008	3
1.2	1.5	4.6	0.010	"
0.9	2.1	4.3	0.009	"
0.7	1.3	4.3	0.009	"
2.2	0.7	2.9	0.006	"
1.7	0.9	3.2	0.007	"
1.0	1.3	2.9	0.006	5
1.1	0.9	3.3	0.007	"
0.8	1.5	3.4	0.007	"
2.4	1.4	3.6	0.008	"
1.3	1.1	3.9	0.008	"
1.7	2.1	4.3	0.009	"
1.0	2.3	2.6	0.005	7
1.6	0.8	3.2	0.007	"
1.2	2.8	3.5	0.007	"
0.8	1.3	3.2	0.007	"
0.9	0.9	2.9	0.006	"
0.7	1.5	3.7	0.008	"

[redacted]

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TABLE III (CONT'D)

THE CORROSION OF QM-V BERYLLIUM (LOT NO. Y4478BP) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
1.9	1.1	3.2	0.007	9
2.3	0.9	3.7	0.008	"
0.7	1.7	3.3	0.007	"
1.9	1.2	2.9	0.006	"
4.3	3.2	4.3	0.009	"
3.1	1.5	3.9	0.008	"
0.6	1.4	3.1	0.007	12
Num.	1.6	3.2	0.007	"
"	1.3	3.2	0.007	"
"	1.2	3.2	0.007	"
2.5	1.4	3.3	0.007	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE IV

THE CORROSION OF QPT BERYLLIUM (LOT NO. Y4483BP) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
Neg.	-	3.5	0.007	1
"	-	3.9	0.008	"
"	-	3.9	0.008	"
"	-	4.4	0.010	"
"	-	3.0	0.006	"
"	-	4.4	0.010	"
2.8	1.8	1.6	0.004	2
2.0	2.0	2.7	0.007	"
2.2	2.3	2.9	0.007	"
1.6	0.9	1.6	0.004	"
2.7	1.2	2.7	0.007	"
2.2	1.0	3.2	0.008	"
1.3	1.0	2.7	0.007	"
2.0	1.1	2.0	0.005	"
3.2	1.1	2.9	0.007	"
2.9	1.3	2.5	0.006	"
2.7	1.0	2.5	0.006	"
3.8	1.9	2.3	0.005	"
2.3	1.9	4.2	0.009	3
3.1	2.1	4.4	0.010	"
4.1	0.9	2.7	0.007	"
1.3	1.1	3.2	0.011	"
2.0	1.3	5.5	0.012	"
2.9	2.4	6.0	0.013	"
1.9	1.3	3.9	0.008	5
2.2	1.1	4.9	0.011	"
2.9	1.7	5.0	0.011	"
1.4	0.9	5.1	0.011	"
2.0	2.3	5.1	0.011	"
3.6	1.8	5.5	0.012	"
2.7	1.7	3.2	0.007	7
2.9	0.8	4.6	0.010	"
2.4	2.1	3.9	0.008	"
1.7	0.8	5.2	0.011	"
2.5	1.4	4.2	0.009	"
3.4	1.8	4.9	0.010	"

[redacted]

[redacted]

TABLE IV (CONT'D)

THE CORROSION OF QPT BERYLLIUM (LOT NO. Y4483BP) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
1.7	1.2	2.7	0.007	9
3.9	2.7	2.8	0.007	"
2.7	1.9	4.0	0.009	"
3.5	2.2	4.1	0.009	"
3.1	1.1	4.2	0.009	"
5.1	3.0	4.9	0.010	"
1.7	1.3	3.0	0.006	12
1.6	2.0	3.7	0.008	"
Num.	1.8	3.5	0.008	"
"	3.1	3.8	0.008	"
"	1.7	4.4	0.009	"
0.9	0.9	4.5	0.010	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

[redacted]

TABLE V

THE CORROSION OF QRM BERYLLIUM (LOT NO. Y4460BP) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
Neg.	-	4.1	0.009	1
"	-	4.1	0.009	"
"	-	4.5	0.010	"
"	-	4.1	0.009	"
"	-	3.6	0.008	"
"	-	3.6	0.008	"
3.9	9.9	4.7	0.010	2
3.7	12.2	6.2	0.013	"
4.9	4.7	6.4	0.014	"
3.2	6.3	7.2	0.015	"
6.0	4.7	6.4	0.014	"
4.5	2.8	6.0	0.013	"
4.7	2.8	6.4	0.014	"
6.7	3.9	9.3	0.020	"
5.7	4.7	4.1	0.009	"
3.1	3.5	5.7	0.012	"
3.9	10.6	6.5	0.014	"
4.9	2.8	4.7	0.010	"
3.2	2.9	4.1	0.009	3
4.1	5.1	6.4	0.014	"
6.1	6.7	6.0	0.013	"
5.1	12.0	9.3	0.020	"
1.7	3.5	7.3	0.015	"
1.9	4.9	6.4	0.014	"
1.3	4.1	5.1	0.011	5
1.9	5.1	5.3	0.011	"
2.3	3.2	5.3	0.011	"
5.2	6.6	5.5	0.012	"
4.1	2.0	5.6	0.012	"
3.9	2.5	6.2	0.013	"
2.5	15.7	6.5	0.014	7
2.7	4.7	7.1	0.015	"
1.9	7.9	6.4	0.014	"
2.4	7.9	5.5	0.012	"
1.4	7.1	7.3	0.016	"
1.2	7.9	6.7	0.014	"

[redacted]

[redacted]

TABLE V (CONT'D)

THE CORROSION OF QRM BERYLLIUM (LOT NO. Y4460BP) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
2.1	4.1	4.1	0.009	9
3.2	3.9	5.2	0.011	"
2.8	4.9	6.2	0.013	"
3.9	7.1	5.1	0.011	"
3.1	7.6	4.7	0.010	"
4.2	2.9	5.6	0.012	"
3.5	1.6	3.6	0.008	12
4.8	2.4	3.8	0.008	"
2.8	2.0	4.0	0.009	"
5.4	2.8	4.1	0.009	"
4.0	2.4	4.2	0.009	"
4.8	4.2	4.1	0.009	"

* $mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

[redacted]

TABLE VI

THE CORROSION OF VACUUM CAST EXTRUDED BERYLLIUM (HEAT NO. 164) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
Neg.	-	3.9	0.008	1
"	-	5.2	0.011	"
"	-	4.5	0.010	"
"	-	4.5	0.010	"
"	-	3.9	0.008	"
"	-	2.6	0.006	"
Neg.	-	4.7	0.010	2
"	-	5.4	0.012	"
0.2	2.8	4.1	0.009	"
Neg.	-	4.1	0.009	"
0.5	2.4	4.4	0.009	"
0.3	0.8	5.4	0.012	"
1.1	3.2	7.1	0.015	"
0.4	2.4	4.1	0.009	"
0.3	1.4	5.4	0.012	"
Neg.	-	6.4	0.014	"
0.3	2.4	4.7	0.010	"
0.7	3.5	5.4	0.012	"
0.5	3.7	5.4	0.012	3
1.2	4.1	4.1	0.009	"
1.3	2.9	6.4	0.014	"
2.3	1.2	7.2	0.015	"
0.9	1.7	6.0	0.013	"
3.1	0.9	5.2	0.011	"
2.1	1.9	4.4	0.009	5
1.9	4.1	4.5	0.010	"
3.1	2.3	4.6	0.010	"
3.2	5.6	4.9	0.010	"
2.9	3.2	5.2	0.011	"
5.2	3.7	5.3	0.011	"
6.4	5.5	4.9	0.010	7
5.1	7.4	4.2	0.008	"
Num.	7.0	7.2	0.015	"
1.2	6.3	5.0	0.011	"
6.4	0.9	4.7	0.010	"
3.3	0.8	2.7	0.006	"

[redacted]

[redacted]

TABLE VI (CONT'D)

THE CORROSION OF VACUUM CAST EXTRUDED BERYLLIUM (HEAT NO. 164) EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
3.2	2.7	5.0	0.011	9
1.9	1.9	4.4	0.009	"
4.6	4.2	3.8	0.008	"
2.7	5.5	4.2	0.009	"
5.5	3.2	4.4	0.009	"
Num.	7.0	5.3	0.011	"
Num.	1.6	3.1	0.007	12
2.0	5.5	3.8	0.008	"
0.1	7.2	3.8	0.008	"
6.9	1.9	3.4	0.007	"
2.1	5.5	4.6	0.010	"
0.9	3.1	4.1	0.009	"

* $mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

[redacted]

The Effect of Surface Cold Work on the Corrosion Resistance of Beryllium

Corrosion data are given in Tables VII, VIII, and IX which show the effect of surface cold work on the corrosion resistance of hot-pressed beryllium. These results cover exposure periods of 1, 2, and 10 months for samples of QM-V, QPT, and QRM beryllium. The final machining operations listed in the above-mentioned tables were made on surfaces produced by a Radiac wheel. A complete summary of the machining techniques used is included in a preceding section, Test Materials and Treatment.

An examination of the data shows that the initial corrosion resistance is affected by surface cold work. In general, surfaces produced by grinding cuts of 0.005, 0.010, and 0.020" exhibited about the same corrosion resistance after 2 months of exposure. The high penetration rates obtained for the QRM samples are not believed to have been caused by machining technique. The numerous small pits on these samples were distributed uniformly over the entire surface. The sides of all the samples were machined by the same procedure, yet no comparable pitting was observed on the other samples. Surfaces produced by milling cuts of 1/8" or less in depth exhibited about the same corrosion resistance as the ground surfaces. Higher weight losses were obtained as the depth of milling cut was increased. The corrosion rates, based on 2 months of exposure, for surfaces produced by 1/2" milling cuts were 2 to 3 times higher than those obtained for ground surfaces. Grinding improved the corrosion resistance of these deeply, cold-worked surfaces. However, the improvements due to shallow grinding decreased as the depth of milling cut was increased. No severe damage occurred on any of the samples as evidenced by the low weight losses.

A comparison of the weight losses after 10 months of exposure shows no appreciable differences in the overall corrosion rates. The pitting was more localized on the surfaces produced by 1/2" milling cuts. This phenomenon was probably caused by the non-uniformity in the depth of surface cold work. Consequently, many of the pit diameters were larger although no significant difference in pit depths occurred. A more uniform distribution of pits occurred when these surfaces were finish-machined by light grinding. Photographs of QPT samples after 10 months of exposure are shown in Figures 7, 8, and 9.

It is concluded from the results of these tests that the corrosion resistance of beryllium is not appreciably influenced by cold work produced by grinding or shallow milling cuts. However, surfaces produced by milling cuts of 1/4" or greater in depth were more susceptible to corrosion during the initial 2 months of exposure. After 10 months of exposure, the overall corrosion was about the same for both milled and ground surfaces. The only long-term difference in corrosion behavior observed was the uneven distribution of pitting on surfaces produced by 1/2" milling cuts.

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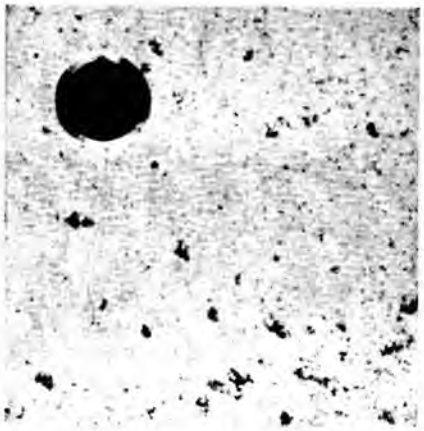
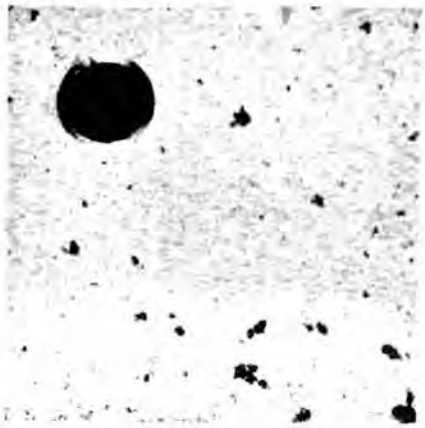
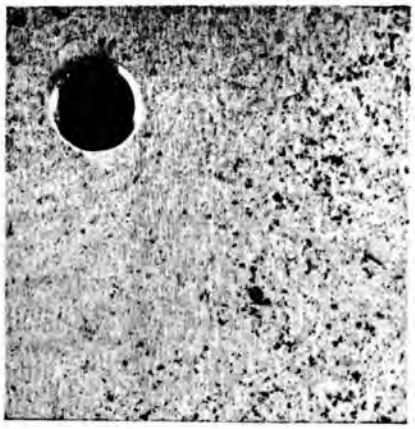


0.005" GRINDING CUT



0.010" GRINDING CUT



0.020" GRINDING CUT

FIGURE 7. QPT BERYLLIUM SAMPLES (LOT NO. Y4483BP) MACHINED BY DIFFERENT PROCEDURES AFTER 10 MONTHS EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C (Mag).

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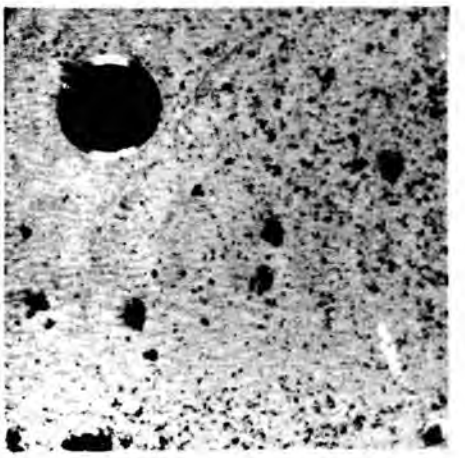
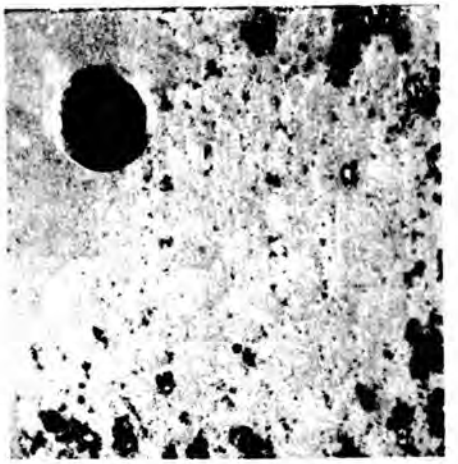
0.020" SINGLE MILLING MACHINE CUT.



0.125" SINGLE MILLING MACHINE CUT FOLLOWED BY LIGHT GRINDING CUT.



0.250" SINGLE MILLING MACHINE CUT.

FIGURE 8. QPT BERYLLIUM SAMPLES (LOT NO. Y4483BP) MACHINED BY DIFFERENT PROCEDURES AFTER 10 MONTHS EXPOSURE TO 0.005M HYDROGEN PER-

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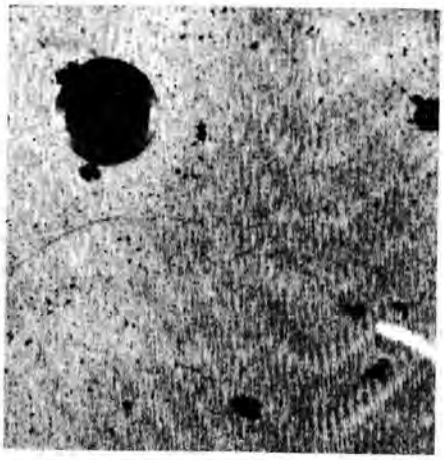
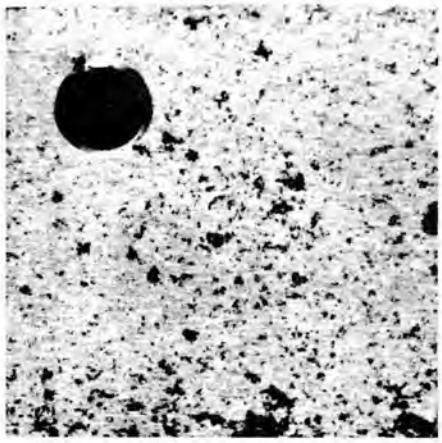


0.250" SINGLE MILLING MACHINE CUT FOLLOWED BY LIGHT GRINDING CUT.

0.500" SINGLE MILLING MACHINE CUT.



0.500" SINGLE MILLING MACHINE CUT FOLLOWED BY LIGHT GRINDING CUT.

FIGURE 9. QPT BERYLLIUM SAMPLES (LOT NO. Y4483BP) MACHINED BY DIFFERENT PROCEDURES AFTER 10 MONTHS EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C (Mag.).

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TABLE VII

THE CORROSION OF QM-V BERYLLIUM (LOT NO. Y-4478BP) MACHINED AND/OR GROUND BY DIFFERENT WAYS EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Final Machining Operation	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
0.005" grinding cut	Neg.	-	5.1	0.011	1
	0.7	7.2	9.9	0.022	2
	1.7	4.7	4.7	0.010	2
	1	2.6	4.3	0.009	10
	0.8	4.3	4.1	0.009	10
0.010" grinding cut	Neg.	-	5.1	0.011	1
	0.5	5.1	7.0	0.015	2
	0.9	4.7	7.6	0.017	2
	0.2	4.3	4.7	0.010	10
	0.2	4.3	4.5	0.010	10
0.020" grinding cut	-	-	6.1	0.013	1
	3.7	5.0	9.1	0.020	2
	4.7	5.5	7.6	0.017	2
	7.7	2.8	5.9	0.013	10
	6.2	2.2	5.9	0.013	10
0.020" single milling machine cut	Neg.	-	8.7	0.019	1
	3.7	5.0	13.1	0.029	2
	5.3	7.1	12.0	0.026	2
	2.7	4.3	4.9	0.013	10
	2.4	3.5	4.4	0.011	10
0.125" single milling machine cut followed by light grinding cut	Neg.	-	3.6	0.008	1
	3.2	4.5	10.2	0.017	2
	3.2	5.1	5.6	0.012	2
	0.1	1.5	4.0	0.009	10
	0.2	2.8	3.9	0.008	10
0.250" single milling machine cut	Neg.	-	9.7	0.021	1
	4.4	4.9	18.9	0.041	2
	2.0	5.9	14.9	0.032	2
	1.7	3.9	3.6	0.008	10
	1.7	4.7	3.3	0.007	10

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TABLE VII (CONT'D)

THE CORROSION OF QM-V BERYLLIUM (LOT NO. Y-4478BP) MACHINED AND/OR GROUND BY DIFFERENT WAYS EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Final Machining Operation	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
0.250" single milling machine cut followed by light grinding cut	Neg.	-	5.1	0.011	1
	2.0	5.0	8.2	0.018	2
	1.6	6.5	11.4	0.025	2
	0.2	1.9	3.7	0.008	10
	0.3	1.6	3.6	0.008	10
0.500" single milling machine cut	Neg.	-	8.7	0.019	1
	3.9	5.9	25.4	0.056	2
	3.7	4.7	20.1	0.044	2
	3.1	3.9	3.2	0.007	10
	1.4	3.5	3.7	0.008	10
0.500" single milling machine cut followed by light grinding cut	Neg.	-	7.6	0.016	1
	3.1	4.0	8.8	0.019	2
	0.8	4.8	7.6	0.017	2
	0.2	1.3	4.0	0.008	10
	1.0	2.8	4.4	0.009	10

*$mg/dm^2/mo$ - Milligrams per square decimenter per month

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TABLE VIII

THE CORROSION OF QPT BERYLLIUM (LOT NO. Y-4483BP) MACHINED AND/OR GROUND BY DIFFERENT WAYS EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Final Machining Operation	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
0.005" grinding cut	Neg.	-	7.1	0.015	1
	9.2	4.3	9.4	0.020	2
	9.9	5.9	8.2	0.018	2
	3.3	3.2	5.9	0.013	10
	2.2	2.4	6.1	0.013	10
0.010" grinding cut	Neg.	-	6.6	0.014	1
	5.2	4.2	11.9	0.025	2
	2.3	4.5	11.0	0.023	2
	3.7	2.0	5.6	0.012	10
	3.7	2.0	5.4	0.012	10
0.020" grinding cut	8.4	1.1	7.1	0.015	1
	1.3	5.1	8.9	0.019	2
	2.1	5.1	9.6	0.021	2
	1.6	3.1	5.3	0.011	10
	1.4	2.4	5.8	0.012	10
0.020" single milling machine cut	Neg.	-	8.7	0.019	1
	2.4	5.5	8.5	0.018	2
	2.4	4.3	8.9	0.019	2
	2.0	3.2	5.6	0.012	10
	3.4	4.5	5.7	0.012	10
0.125" single milling machine cut	Neg.	-	9.2	0.020	1
	4.9	4.9	6.6	0.014	2
	4.2	4.3	8.9	0.019	2
	2.0	2.6	4.4	0.009	10
	1.5	3.2	4.6	0.010	10
0.250" single milling machine cut	Neg.	-	8.7	0.019	1
	2.8	6.2	12.6	0.027	2
	2.7	4.7	11.9	0.025	2
	4.3	3.2	6.7	0.014	10
	3.6	6.7	6.2	0.013	10

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TABLE VIII (CONT'D)

THE CORROSION OF QPT BERYLLIUM (LOT NO. Y-4483BP) MACHINED AND/OR GROUND BY DIFFERENT WAYS EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Final Machining Operation	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
0.250" single milling machine cut followed by light grinding cut	Neg.	-	5.1	0.011	1
	3.4	4.7	8.9	0.019	2
	1.6	3.7	8.7	0.019	2
	0.8	2.8	4.8	0.010	10
	1.7	4.7	4.9	0.011	10
0.500" single milling machine cut	Neg.	-	9.2	0.020	1
	2.9	4.3	12.4	0.026	2
	3.4	4.3	12.4	0.026	2
	4.4	2.8	5.7	0.012	10
	2.9	5.8	5.1	0.011	10
0.500" single milling machine cut followed by light grinding cut	Neg.	-	6.1	0.013	1
	2.0	4.7	10.8	0.023	2
	0.2	7.3	7.1	0.015	2
	3.1	3.2	5.4	0.012	10
	3.1	6.3	6.2	0.013	10

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE IX

THE CORROSION OF QRM BERYLLIUM (LOT NO. Y-4460BP) MACHINED AND/OR GROUND BY DIFFERENT WAYS EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Final Machining Operation	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
0.005" grinding cut	Neg.	-	7.6	0.016	1
	3.8	9.9	8.6	0.018	2
	2.1	4.1	6.2	0.013	2
	3.1	4.3	7.5	0.016	10
	1.3	6.3	7.5	0.016	10
0.010" grinding cut	Neg.	-	6.1	0.013	1
	Num.	8.3	16.9	0.036	2
	Num.	3.9	15.8	0.034	2
	1.3	4.0	7.7	0.016	10
	1.1	4.7	8.5	0.018	10
0.020" grinding cut	9.5	10.2	6.6	0.014	1
	4.0	2.9	7.0	0.015	2
	4.0	5.1	6.2	0.013	2
	2.4	6.3	5.8	0.012	10
	3.0	2.4	6.6	0.014	10
0.020" single milling machine cut followed by light grinding cut	Neg.	-	7.6	0.016	1
	4.5	9.4	8.6	0.018	2
	6.3	6.7	8.0	0.017	2
	3.5	7.1	6.2	0.013	10
	4.5	4.2	6.1	0.013	10
0.125" single milling machine cut followed by light grinding cut	Neg.	-	7.1	0.015	1
	5.7	13.8	6.7	0.014	2
	2.7	-	5.4	0.011	2
	3.7	5.5	5.9	0.013	10
	2.0	4.7	5.9	0.013	10
0.250" single milling machine cut followed by light grinding cut	Neg.	-	5.1	0.011	1
	3.8	5.1	11.2	0.024	2
	2.9	4.3	10.4	0.022	2
	15.5	5.9	7.8	0.017	10
	4.2	3.5	6.2	0.013	10

[redacted]

[redacted]

TABLE IX (CONT'D)

THE CORROSION OF QRM BERYLLIUM (LOT NO. Y-4460BP) MACHINED AND/OR GROUND BY DIFFERENT WAYS EXPOSED TO DISTILLED WATER CONTAINING 0.005M HYDROGEN PEROXIDE AT 85°C

Final Machining Operation	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
0.500" single milling machine cut followed by light grinding cut	1.0	3.5	8.1	0.017	1
	3.8	4.5	10.9	0.024	2
	3.7	7.1	9.6	0.021	2
	4.3	4.3	11.5	0.025	2
	5.1	5.5	11.2	0.024	2
	2.3	7.3	7.0	0.015	10
	2.8	3.3	7.2	0.015	10
	0.7	3.9	6.2	0.013	10
	1.3	3.2	6.3	0.013	10

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

The Effect of Water Quality on the Corrosion Resistance of Beryllium

Previous studies have shown that the corrosion resistance of beryllium to aqueous media was greatly influenced by certain ionic constituents. The presence of the salts of heavy metals (especially copper), chlorides, and sulfates is generally detrimental. In order to study further the effects of these ions, samples of QRM beryllium were exposed to distilled water containing additions of these impurities.

Corrosion data for samples exposed for 153 days to distilled water containing 0.5 and 1.0 ppm chloride ions, added as sodium chloride, are given in Table X. The large weight losses obtained were caused by severe pitting. The pits on the samples exposed to 1.0 ppm chloride grew in diameter to encompass the entire exposed surfaces. The removal of the white corrosion products revealed deeply etched metal. The average corrosion rates obtained for the samples exposed to water containing 0.5 and 1.0 ppm chloride ions were 0.15 and 0.38 mils/mo., respectively. Photographs of exposed samples are shown in Figure 10.

The results obtained from tests containing sulfate ions, added as sodium sulfate, show that these ions accelerate pitting to a lesser extent than chloride ions. These data are given in Table XI. The average corrosion rates for samples exposed to water containing 5, 10, and 15 ppm sulfate ions were 0.031, 0.042, and 0.044 mils/mo., respectively. All of the samples were covered with numerous pits accompanied by voluminous corrosion products. The maximum pit depth observed was 5.8 mils after 182 days of exposure. Photographs of exposed samples are shown in Figure 11.

Corrosion data for samples exposed for 75 days to distilled water containing cupric ions, added as cupric sulfate, are given in Table XII. These results show that the presence of cupric ions in water greatly accelerates the pitting of beryllium. The average corrosion rates for samples exposed to water containing 0.1, 0.2, and 0.5 ppm cupric ions were 0.048, 0.053, and 0.110 mils/mo., respectively. Photographs of exposed samples are shown in Figure 12.

The corrosion data for similar QRM metal exposed to distilled water containing no added impurities are given in Table V. The water used for these tests contained approximately 0.2 ppm chloride, 2.0 ppm sulfate, and 0.02 ppm cupric ions. The pitting attack on these samples was greatly diminished by the use of high purity water.

Summarizing, the corrosion resistance of beryllium to oxygen-saturated water is greatly influenced by the presence of chloride, sulfate, and cupric ions. These ions accelerate corrosion, especially pitting. In order to avoid excessive pitting, the concentration of these ions should be maintained as low as economically feasible. Tolerable upper limits are 0.2 ppm chloride, 2.0 ppm sulfate, and 0.02 ppm cupric ions. The water in contact with beryllium metal is much more influential in controlling the rate of attack than minor changes in the composition of the metal.

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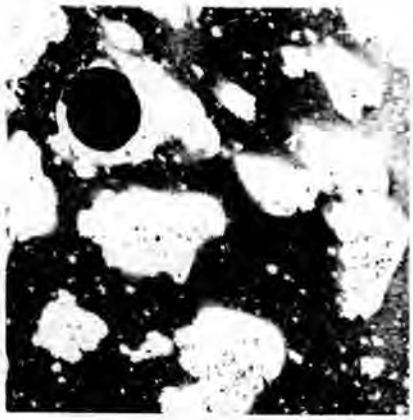
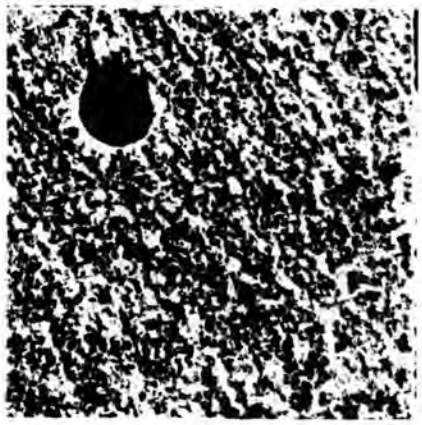


0.5 PPM Cl^-



1.0 PPM Cl^-

FIGURE 10. CORROSION PRODUCT FORMATION ON QRM BERYLLIUM SAMPLES (LOT NO. Y4460BP) AFTER 154 DAYS EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C CONTAINING ADDITIONS OF CHLORIDE.

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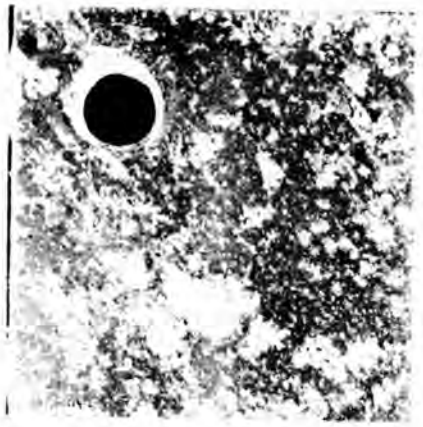
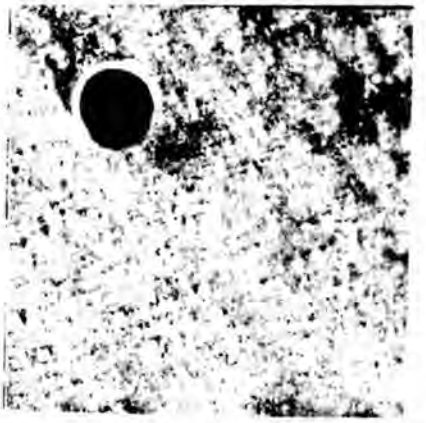
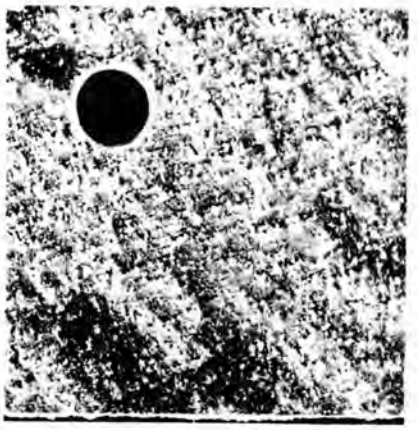
PHOTO NO. 6-3165



5 PPM $SO_4^{=}$



10 PPM $SO_4^{=}$



15 PPM $SO_4^{=}$

FIGURE 11. CORROSION PRODUCT FORMATION ON QRM BERYLLIUM SAMPLES (LOT NO. Y4460BP) AFTER 182 DAYS EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C CONTAINING ADDITIONS OF SULFATE.

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PHOTO NO. 6-3166

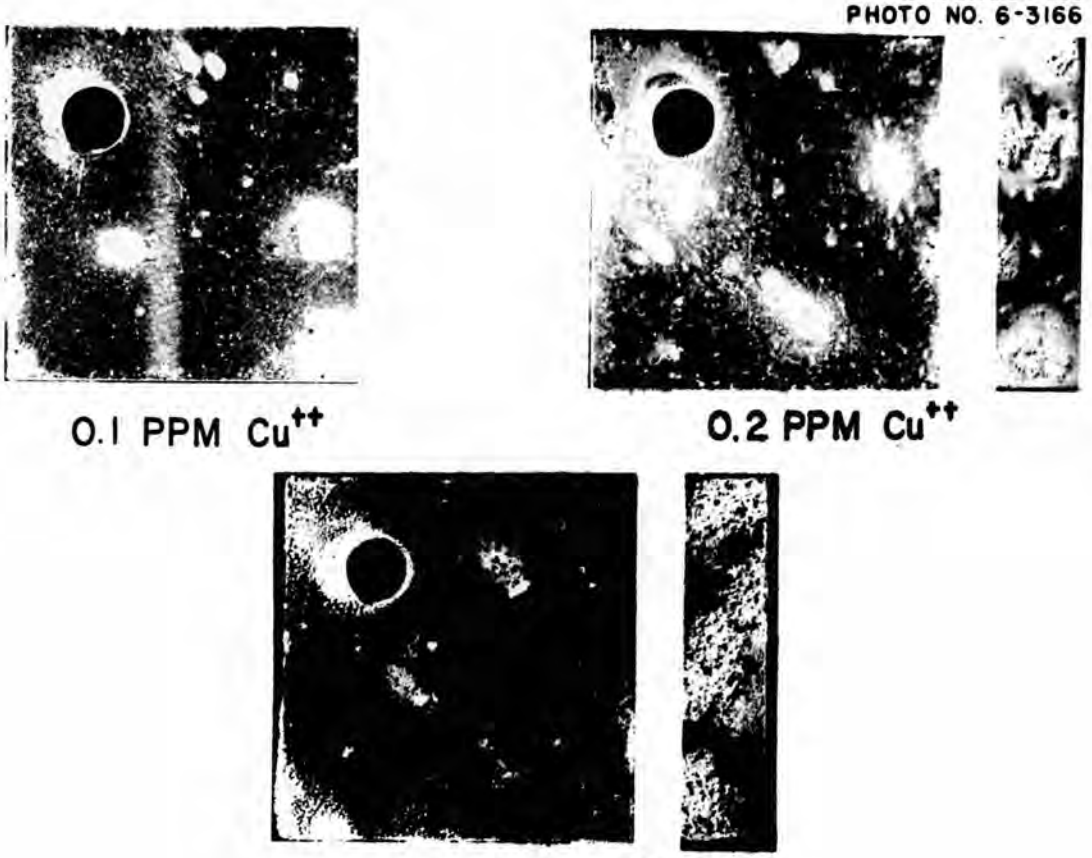

FIGURE 12. CORROSION PRODUCT FORMATION ON QRM BERYLLIUM SAMPLES (LOT NO. Y4460BP) AFTER 75 DAYS EXPOSURE TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C CONTAINING ADDITIONS OF CUPRIC IONS

[redacted]

TABLE X

THE EFFECT OF CHLORIDE IONS ON THE STATIC CORROSION OF HOT-PRESSED BERYLLIUM EXPOSED FOR 153 DAYS TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

Chloride Concentration, ppm	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/cm^2/mo$	Penetration Rate, mils/mo
0.5	Numerous	3.9	49.4	0.10
0.5	Numerous	2.0	107.2	0.22
0.5	Numerous	3.0	77.0	0.16
0.5	Numerous	3.1	49.7	0.10
0.5	Numerous	4.7	78.2	0.16
0.5	Numerous	4.9	72.6	0.15
1.0	Numerous	*	186.4	0.38
1.0	Numerous	*	181.5	0.37
1.0	Numerous	*	196.0	0.40
1.0	Numerous	*	177.5	0.36
1.0	Numerous	*	175.8	0.36
1.0	Numerous	*	202.2	0.42

* Removal of thick deposit of corrosion products revealed an etched surface.

[redacted]

[redacted]

TABLE XI

THE EFFECT OF SULFATE IONS ON THE STATIC CORROSION OF HOT-PRESSED BERYLLIUM EXPOSED FOR 182 DAYS TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

Sulfate Concentration, ppm	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/cm^2/mo$	Penetration Rate, mils/mo
5	Numerous	5.8	13.0	0.028
5	Numerous	3.4	15.7	0.034
10	Numerous	5.0	18.2	0.039
10	Numerous	3.9	20.9	0.045
15	Numerous	3.9	19.2	0.041
15	Numerous	3.4	21.2	0.046

TABLE XII

THE EFFECT OF CUPRIC IONS ON THE STATIC CORROSION OF HOT-PRESSED BERYLLIUM EXPOSED FOR 75 DAYS TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

Copper Concentration, ppm	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/cm^2/mo$	Penetration Rate, mils/mo
0.1	7.3	7.5	43.2	0.049
0.1	11.1	6.1	41.2	0.046
0.2	Numerous	5.5	44.8	0.050
0.2	Numerous	10.4	49.6	0.056
0.5	Numerous	6.4	85.5	0.096
0.5	Numerous	5.5	108.8	0.122

[redacted]

PART II

THE EFFECT OF IMPURITIES ON THE CORROSION RESISTANCE OF BERYLLIUM

Previous corrosion studies have shown that it is difficult to evaluate the corrosion effects of one of several different impurities normally present in production beryllium. For this reason, studies were made on special vacuum cast and hot-pressed samples prepared by the Brush Beryllium Company which contained various concentrations of added impurities considered most likely to influence the corrosion resistance. These impurities, consisting of aluminum, iron, silicon, and beryllium carbide, were added to portions of the same base material prior to casting or hot-pressing. The same matrix was used in an effort to minimize differences in chemical compositions due to impurities other than the added constituent.

Test Materials and Treatment

Test specimens used to determine the effect of aluminum, iron, and silicon were machined from a series of 11 vacuum cast billets. Control specimens were machined from 2 of these billets which contained no added impurities. The following castings were produced with impurity additions as shown:

Casting No.	Impurity Added	Impurity Content of Casting
B-15	None	-
B-16	None	-
B-17	0.2% Al	0.30% Al
B-18	0.4% Al	0.44% Al
B-19	0.6% Al	0.73% Al
B-20	0.8% Al	1.05% Al
B-21	0.1% Fe	0.23% Fe
B-22	0.2% Fe	0.34% Fe
B-23	0.4% Fe	0.40% Fe
B-28	0.1% Si	0.186% Si
B-29	0.2% Si	0.201% Si

The castings were rough-machined on a lathe and then cut into discs, 1 1/4" diameter x 1/4" thick, on a Radiac. These discs were polished on No. 80 grit followed by No. 180 grit emery cloth. Chemical and spectrographic analyses of these samples are given in Tables XIII through XVIII.

Test specimens containing beryllium carbide additions were produced by the Q-Process. Hot-pressed discs were produced from less than 200 mesh powder which contained additions of beryllium carbide. The analysis of the base material determined by the Brush Beryllium Company is as follows:

Constituent Determined	Chemical Analysis
Assay	99.26%
BeO	0.58%
Be_2C	0.14%
Al	200 ppm
Fe	1100 ppm
Mn	76 ppm
Cr	168 ppm
Mg	100 ppm
Ni	275 ppm

Beryllium carbide determinations made on chips of hot-pressed rods are as follows:

Be_2C Additions to Powder	Be_2C Content of Chips
0.10%	0.11%
0.24%	0.23%
0.50%	0.26%

The hot-pressed shapes were machined in the form of discs, 1 1/4" diameter x 1/4" thick. These discs were polished on No. 80 grit followed by No. 180 grit emery cloth.

Description of Corrosion Test Method

The corrosion test method was the same as previously described in Part I of this report with the exception that the same samples were used throughout the course of the tests. The four samples of each impurity group were removed periodically from the test media, washed gently in distilled water, dried, weighed, and examined for corrosion damage. The samples were not defilmed since corrosion damage was light, resulting in no significant weight changes due to corrosion product accumulations.

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TABLE XIII

CHEMICAL ANALYSES OF CAST BERYLLIUM CONTAINING NO ADDED IMPURITIES

Elements Determined	Casting No. B-15		Casting No. B-16	
	C*	S**	C*	S**
Assay %	98.59		99.49	
BeO "	0.94		0.40	
Be_2C "	0.21		0.14	
Al ppm	1000	920	900	380
Fe ppm	1800	1900	1700	1500
Mn ppm		240		200
Si ppm	437	440	484	440
Ag ppm		- 1		- 1
Cd ppm		-0.02		-0.02
Co ppm		- 1 nd		- 1 nd
Cu ppm		80		70
Li ppm		-0.03		-0.03
Mg ppm		80 a		40 a
Ni ppm		100		60
Zn ppm		60 a		60 a

*C - Analysis determined by chemical methods

**S - Analysis determined by spectrographic methods
nd - means not detected at sensitivity of designated per cent
a - means approximately

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TABLE XIV

CHEMICAL ANALYSES OF CAST BERYLLIUM
CONTAINING ADDITIONS OF ALUMINUM

Elements Determined	Casting No. B-17 0.2% Al Addition		Casting No. B-18 0.4% Al Addition	
	C*	S**	C*	S**
Assay %	99.45		99.41	
BeO "	0.36		0.62	
Be_2C "	0.30		0.15	
Al ppm	3000	4600	4400	7300
Fe ppm	1700	1600	1900	1700
Mn ppm		240		240
Si ppm	513	370	520	400
Ag ppm		- 1		- 1
Cd ppm		-0.02		-0.02
Co ppm		- 1 nd		- 1 nd
Cu ppm		70		90
Li ppm		-0.03		-0.03
Mg ppm		20 a		10 a
Ni ppm		80		70
Zn ppm		60 a		60 a

*C - Analysis determined by chemical methods

**S - Analysis determined by spectrographic methods
nd - means not detected at sensitivity of designated per cent
a - means approximately

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TABLE XV

CHEMICAL ANALYSES OF CAST BERYLLIUM CONTAINING ADDITIONS OF ALUMINUM

Elements Determined		Casting No. B-19 0.6% Al Addition		Casting No. B-20 0.8% Al Addition	
		C*	S**	C*	S**
Assay	%	99.45		99.06	
BeO	"	0.33		0.55	
Be_2C	"	0.20		0.14	
Al	ppm	7300	15600	10,500	17,800
Fe	ppm	2100	1900	1800	2100
Mn	ppm		250		240
Si	ppm	586	450	490	490
Ag	ppm		- 1		- 1
Cd	ppm		-0.02		-0.02
Co	ppm		- 1 nd		- 1 nd
Cu	ppm		90		130
Li	ppm		-0.03		-0.03
Mg	ppm		70 a		- 10
Ni	ppm		50		50
Zn	ppm		60 a		60 a

*C - Analysis determined by chemical methods

**S - Analysis determined by spectrographic methods
nd - means not detected at sensitivity of designated per cent
a - means approximately

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TABLE XVI

CHEMICAL ANALYSES OF CAST BERYLLIUM CONTAINING ADDITIONS OF IRON

Elements Determined	Casting No. B-21 0.1% Fe Addition		Casting No. B-22 0.2% Fe Addition	
	C*	S**	C*	S**
Assay %	99.36		99.13	
BeO "	0.32		0.45	
Be_2C "	0.34		0.19	
Al ppm	430	430	900	460
Fe ppm	2300	2300	3400	2700
Mn ppm	216	200	192	190
Si ppm	300	370	737	350
Ag ppm		- 1		- 1
Cd ppm		-0.02		-0.02
Co ppm		- 1 nd		- 1 nd
Cu ppm		90		90
Li ppm		-0.03		-0.03
Mg ppm		50 a		30 a
Ni ppm		50		40
Zn ppm		60 a		60 a

*C - Analysis determined by chemical methods

**S - Analysis determined by spectrographic methods
nd - means not detected at sensitivity of designated per cent
a - means approximately

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[redacted]

TABLE XVII

CHEMICAL ANALYSIS OF CAST BERYLLIUM CONTAINING ADDITIONS OF IRON

Elements Determined	Casting No. B-23 0.4% Fe Addition C*	S**
Assay %	99.37	
BeO "	0.57	
Be_2C "	0.11	
Al ppm	1000	370
Fe ppm	4000	2600
Mn ppm	236	240
Si ppm	739	300
Ag ppm		1 a
Cd ppm		-0.02
Co ppm		- 1 nd
Cu ppm		70
Li ppm		-0.03
Mg ppm		40 a
Ni ppm		50
Zn ppm		60 a

*C - Analysis determined by chemical methods

**S - Analysis determined by spectrographic methods
nd - means not detected at sensitivity of designated per cent
a - means approximately

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TABLE XVIII

CHEMICAL ANALYSES OF CAST BERYLLIUM
CONTAINING ADDITIONS OF SILICON

Elements Determined	Casting No. B-28 0.1% Si Addition		Casting No. B-29 0.2% Si Addition	
	C*	S**	C*	S**
Assay %	99.24		99.12	
BeO "	0.61		0.44	
Be_2C "	0.14		0.23	
Al ppm	800	500	900	450
Fe ppm	1900	2170	1900	1620
Mn ppm		220		190
Si ppm	1860	2500	2010	3150
Ag ppm		1 a		1a
Cd ppm		-0.02		-0.02
Co ppm				
Cu ppm		30		40
Li ppm				
Mg ppm		10		- 10
Ni ppm		60		40
Zn ppm		- 30		- 30

*C - Analysis determined by chemical methods

**S - Analysis determined by spectrographic methods
a - means approximately

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Test Results and Discussion of Data

Corrosion data for the impurity samples are included in Tables XIX through XXXII. These results cover an exposure period of 13 months for the samples containing additions of aluminum, iron, and silicon and the first 7 months of exposure for the samples containing beryllium carbide.

A comparison of the corrosion behavior of the various groups of cast beryllium reveals no detrimental effects attributable to any one of the impurity constituents. The average corrosion rates after 13 months of exposure for the four samples of each group containing additions of aluminum, iron, and silicon varied between 0.0058 and 0.0076 mils/mo. The average corrosion rates for the two groups of control samples were 0.0062 and 0.0064 mils/mo. The corrosion rates obtained during the first four months of exposure, in many instances, were erratic, but were low. During the latter 9 months of exposure, almost constant average rates were obtained which generally fell within the range of 0.0060 to 0.0070 mils/mo. These small differences in corrosion rates cannot be attributed to any single constituent. In many instances, the differences in corrosion rates for the four samples of the same group were greater than the differences in the average corrosion rates of the several groups after the same exposure period. Plots of weight losses versus exposure time are shown in Figures 13 through 16. The weight losses shown on these plots are average values for the four samples of each impurity variation.

The most significant corrosion damage observed on the cast material was the formation of shallow pits after several months of exposure. The pit densities for the control samples and those containing additions of iron and silicon averaged, in most instances, less than 3 pits/cm^2. after 13 months of exposure. The samples containing additions of aluminum, with the exception of the group containing 0.73% Al, exhibited a greater susceptibility to pitting. The highest pit densities were obtained on the group of samples containing 1.05% Al, averaging 7.8 pits/cm^2 after 13 months of exposure. The maximum pit depths obtained for all of the samples after 13 months of exposure were generally less than 2 mils.

A comparison of the corrosion data for the hot-pressed samples containing additions of beryllium carbide reveals no significant differences in corrosion behavior. The average corrosion rates after 7 months of exposure for the groups containing 0.11, 0.23, and 0.26% Be_2C were 0.0064, 0.0072, and 0.0074 mils/mo, respectively. The corrosion rates increased slightly with increasing carbide content. However, the differences are too small to be considered significant. These tests are still in progress and longer exposure periods may reveal marked changes in the corrosion behavior. A plot of weight loss versus exposure time is shown in Figure 17. Numerous small pits formed on all of the samples during the second month of exposure. The maximum pit depth obtained after 7 months of exposure was 2.4 mils. This pit occurred on a sample containing 0.11% Be_2C. The hot-pressed samples showed a greater

susceptibility to pitting than the cast samples. This phenomenon may be due to differences in metallurgical background rather than to variations in chemical compositions. Many of the cast samples contained impurities, including Be_2C, in greater concentrations than were present in the hot-pressed samples.

From the results of these tests, it is concluded that no single constituent can be identified as being detrimental to the corrosion resistance of beryllium. Although the same base material was used, all of the various groups of samples contained many common impurities present in variable concentrations. This makes it difficult to determine the corrosion effect of the added constituent. However, a comparison of the data with the chemical compositions of the cast samples shows no significant detrimental effects attributable to aluminum, iron, and silicon in concentrations below 1.05, 0.40, and 0.20%, respectively. The maximum concentrations of these elements in the two groups of control samples were as follows: Al 0.10%, Fe 0.18%, and Si 0.048%. Thus, the maximum impurity concentrations tested were tenfold greater for aluminum, twofold greater for iron, and fourfold greater for silicon.

The Be_2C content of the cast samples ranged from 0.11 to 0.34% while this constituent in the hot-pressed samples, intended as the group to study the effect of Be_2C, only ranged from 0.11 to 0.26%. This is unfortunate as the intended carbide contents of the latter material were 0.2, 0.4, and 0.6%. If Be_2C is detrimental to corrosion resistance, then the almost uniform pitting of both cast and hot-pressed beryllium may be caused by this constituent.

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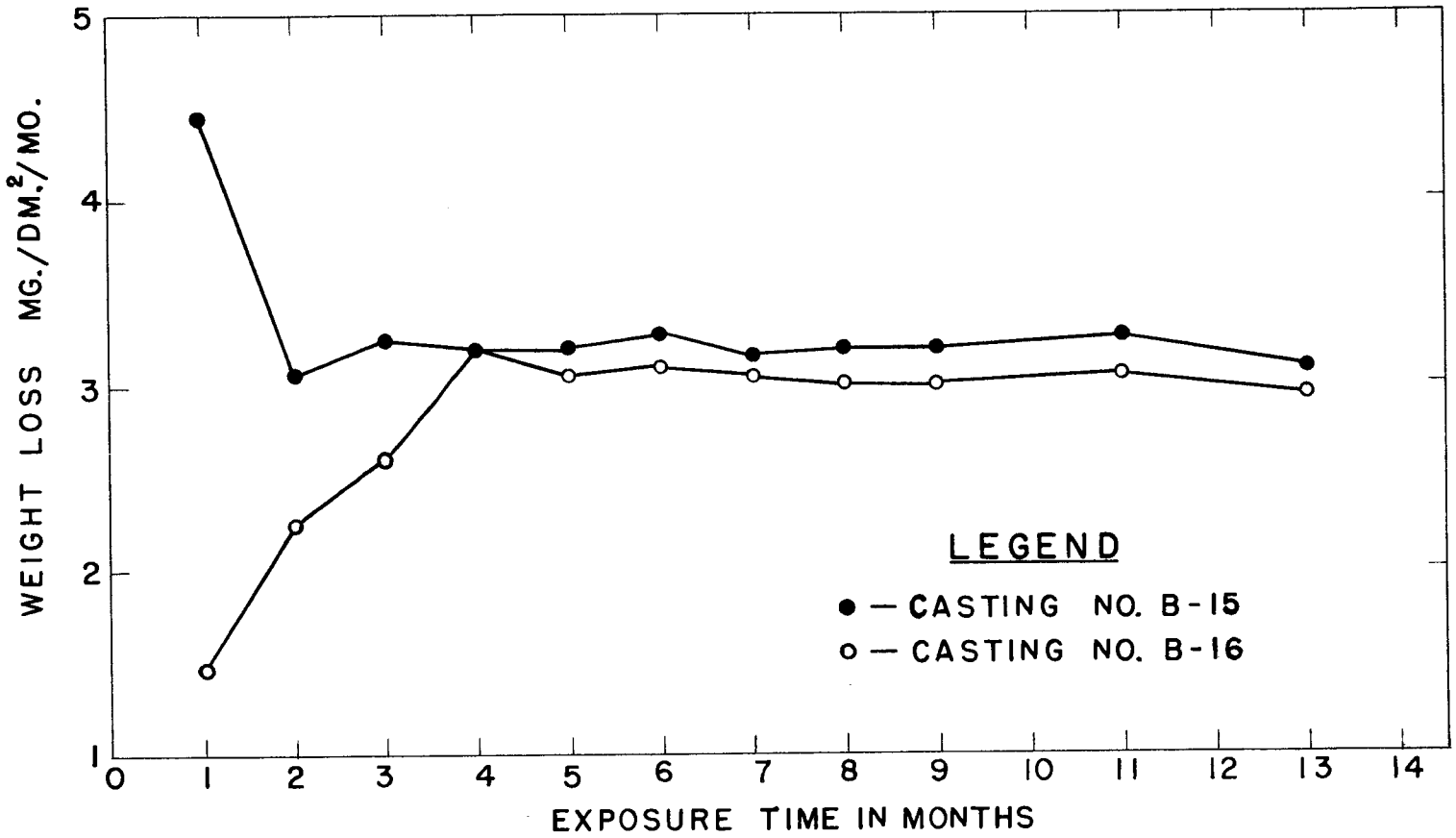
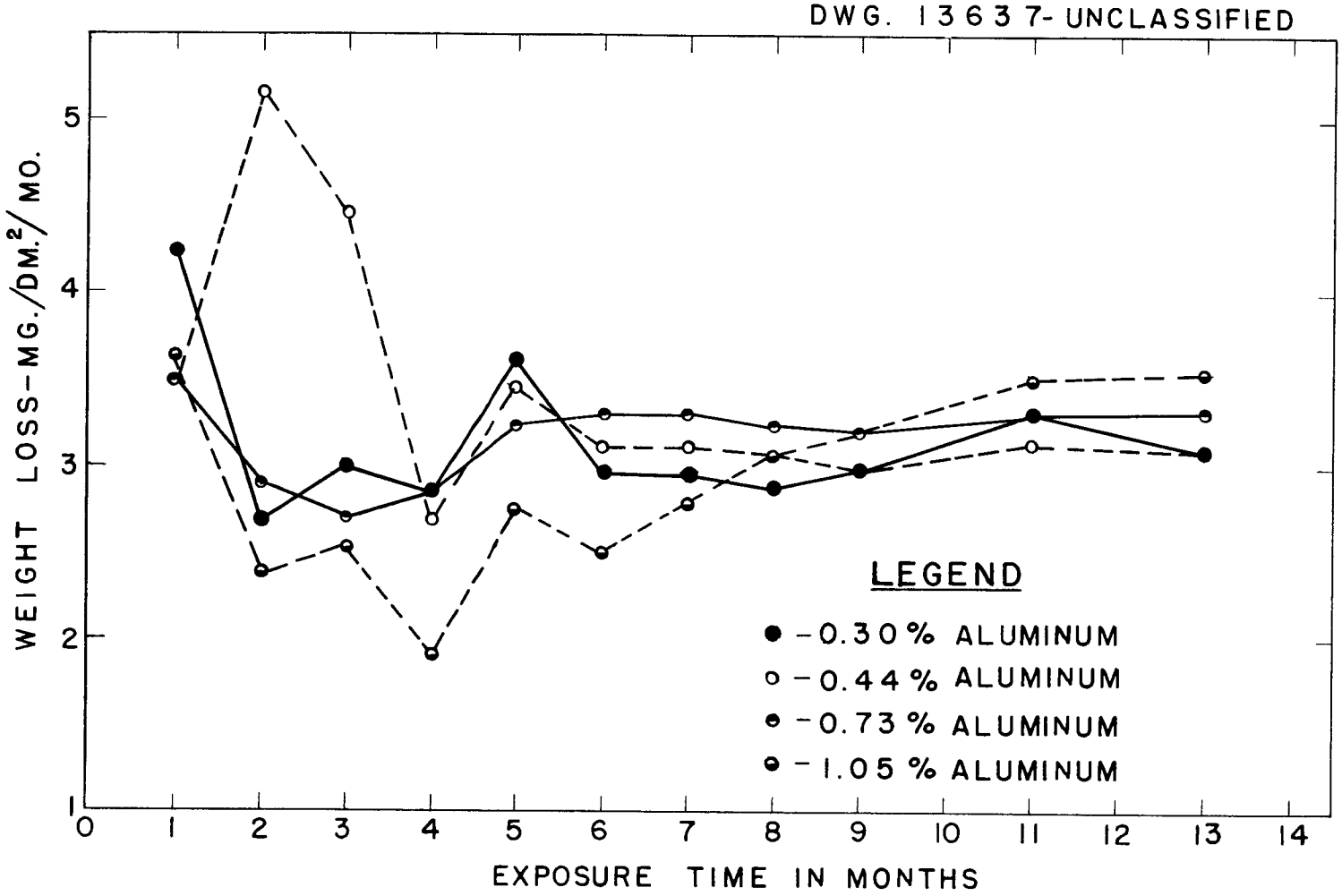
DWG. 13636- UNCLASSIFIED



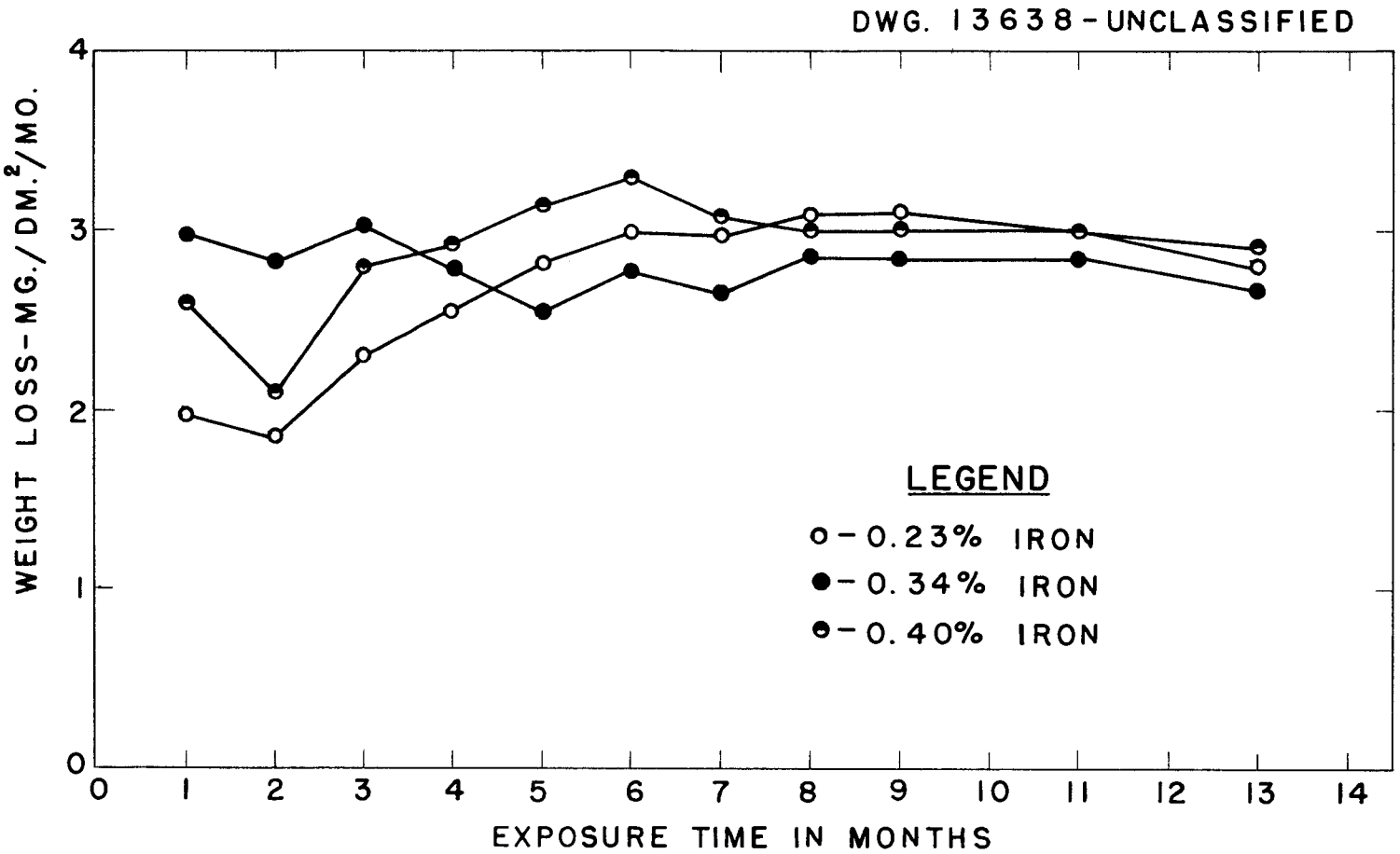
WEIGHT LOSS VS. TIME RELATIONSHIP FOR CAST BERYLLIUM CONTAINING NO IMPURITY ADDITIONS EXPOSED TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

FIG. 13



WEIGHT LOSS VS. TIME RELATIONSHIP FOR CAST BERYLLIUM CONTAINING ADDITIONS OF ALUMINUM EXPOSED TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

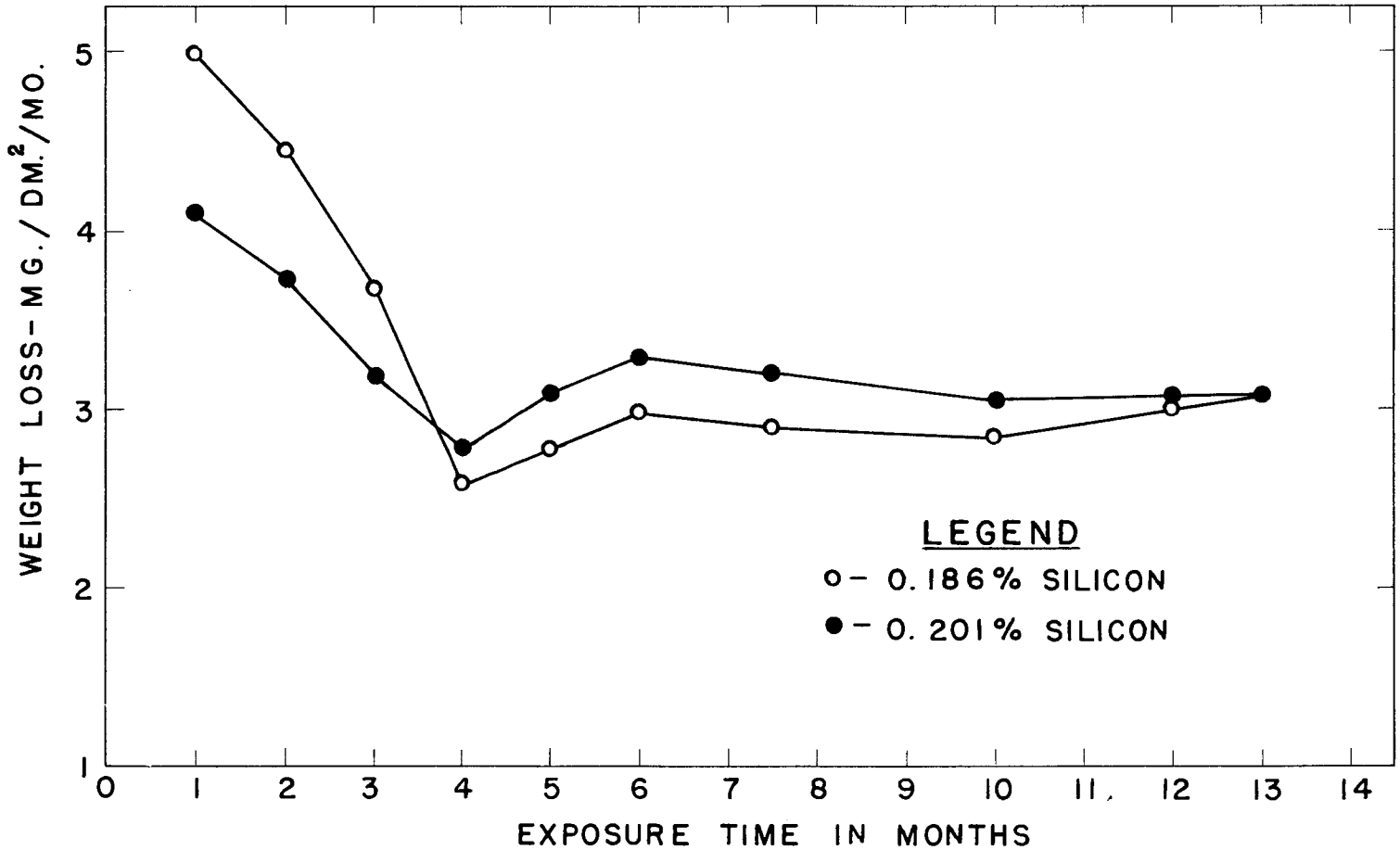
FIG. 14



WEIGHT LOSS VS. TIME RELATIONSHIP FOR CAST BERYLLIUM CONTAINING ADDITIONS OF IRON EXPOSED TO 0.005 HYDROGEN PEROXIDE SOLUTION AT 85°C

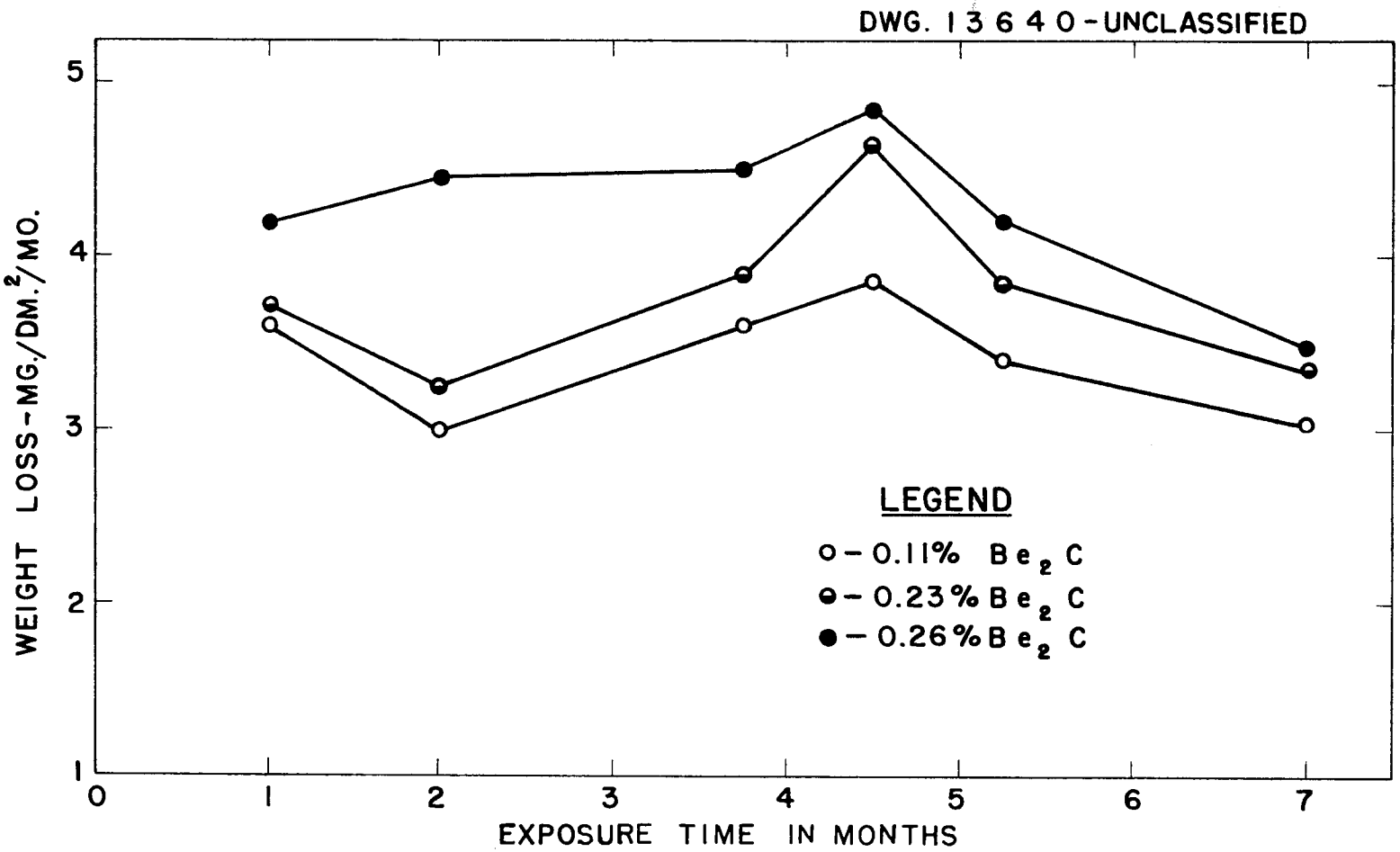
FIG. 15

DWG. 13639 - UNCLASSIFIED



WEIGHT LOSS VS. TIME RELATIONSHIP FOR CAST BERYLLIUM CONTAINING ADDITIONS OF SILICON EXPOSED TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

FIG. 16



WEIGHT LOSS VS. TIME RELATIONSHIP FOR HOT-PRESSED BERYLLIUM CONTAINING ADDITIONS OF BERYLLIUM CARBIDE EXPOSED TO 0.005M HYDROGEN PEROXIDE SOLUTION AT 85°C

FIG. 17

[redacted]

TABLE XIX

THE CORROSION OF CAST BERYLLIUM (CASTING NO. B-15) CONTAINING NO IMPURITY ADDITIONS EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.99	0.0064	1
B	-	-	6.97	0.0149	"
C	-	-	2.99	0.0064	"
D	-	-	4.98	0.0106	"
A	-	-	2.69	0.0058	2
B	-	-	3.43	0.0073	"
C	-	-	3.18	0.0068	"
D	-	-	2.94	0.0063	"
A	-	-	3.05	0.0065	3
B	-	-	3.53	0.0076	"
C	-	-	3.36	0.0072	"
D	-	-	3.21	0.0069	"
A	-	-	2.64	0.0057	4
B	-	-	3.70	0.0079	"
C	-	-	3.24	0.0069	"
D	-	-	3.24	0.0069	"
A	-	-	2.97	0.0064	5
B	-	-	3.49	0.0076	"
C	-	-	3.21	0.0069	"
D	-	-	3.12	0.0067	"
A	-	-	3.25	0.0070	6
B	-	-	3.42	0.0073	"
C	-	-	3.42	0.0073	"
D	-	-	3.26	0.0070	"

[redacted]

[redacted]

TABLE XIX (CONT'D)

THE CORROSION OF CAST BERYLLIUM (CASTING NO. B-15) CONTAINING NO IMPURITY ADDITIONS EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	3.33	0.0071	7
B	-	-	3.21	0.0069	"
C	-	-	3.14	0.0067	"
D	-	-	2.95	0.0063	"
A	1.7	1.0	3.33	0.0071	8
B	2.0	1.3	3.28	0.0070	"
C	1.5	0.9	3.21	0.0069	"
D	1.1	0.7	2.93	0.0063	"
A	1.7	1.0	3.26	0.0070	9
B	2.2	1.4	3.37	0.0072	"
C	2.1	0.9	3.26	0.0070	"
D	1.1	0.8	2.95	0.0063	"
A	1.7	1.0	3.15	0.0068	11
B	2.4	1.6	3.48	0.0074	"
C	3.2	1.0	3.23	0.0069	"
D	1.1	0.8	3.23	0.0069	"
A	2.1	1.0	2.98	0.0064	13
B	2.7	1.7	3.31	0.0071	"
C	3.3	1.0	3.06	0.0066	"
D	1.5	0.9	3.10	0.0066	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

[redacted]

TABLE XX

THE CORROSION OF CAST BERYLLIUM (CASTING NO. B-16) CONTAINING NO IMPURITY ADDITIONS EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	1.49	0.0032	1
B	-	-	1.99	0.0043	"
C	-	-	1.49	0.0032	"
D	-	-	1.00	0.0021	"
A	-	-	3.18	0.0068	2
B	-	-	2.44	0.0052	"
C	-	-	2.44	0.0052	"
D	-	-	0.98	0.0021	"
A	-	-	2.40	0.0051	3
B	-	-	2.88	0.0062	"
C	-	-	3.21	0.0069	"
D	-	-	1.92	0.0041	"
A	-	-	3.01	0.0064	4
B	-	-	3.00	0.0064	"
C	-	-	4.04	0.0086	"
D	-	-	2.89	0.0062	"
A	-	-	2.84	0.0061	5
B	-	-	2.74	0.0059	"
C	-	-	3.78	0.0081	"
D	-	-	2.83	0.0061	"
A	-	-	2.95	0.0063	6
B	-	-	2.95	0.0063	"
C	-	-	3.73	0.0080	"
D	-	-	2.88	0.0062	"

[redacted]

[redacted]

TABLE XX (CONT'D)

THE CORROSION OF CAST BERYLLIUM (CASTING NO. B-16) CONTAINING NO IMPURITY ADDITIONS EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.95	0.0063	7
B	-	-	2.62	0.0056	"
C	-	-	3.84	0.0082	"
D	-	-	2.76	0.0059	"
A	0.7	0.7	2.87	0.0061	8
B	0.9	0.6	2.58	0.0055	"
C	1.2	0.7	3.90	0.0084	"
D	2.5	1.0	2.70	0.0058	"
A	0.8	0.7	2.85	0.0061	9
B	0.9	0.7	2.69	0.0058	"
C	1.4	0.8	3.88	0.0083	"
D	2.5	0.9	2.75	0.0059	"
A	0.8	0.7	2.89	0.0062	11
B	0.9	0.8	2.68	0.0057	"
C	1.9	0.8	3.83	0.0082	"
D	2.7	0.9	2.93	0.0063	"
A	1.3	0.9	2.85	0.0061	13
B	1.1	0.8	2.57	0.0056	"
C	2.0	0.8	3.52	0.0076	"
D	3.4	0.9	2.85	0.0061	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

[redacted]

TABLE XXI

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.30% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	6.48	0.0139	1
B	-	-	3.49	0.0075	"
C	-	-	5.48	0.0117	"
D	-	-	1.49	0.0032	"
A	-	-	3.67	0.0079	2
B	-	-	2.45	0.0052	"
C	-	-	3.42	0.0073	"
D	-	-	1.22	0.0026	"
A	-	-	3.37	0.0072	3
B	-	-	2.45	0.0052	"
C	-	-	3.69	0.0079	"
D	-	-	2.41	0.0052	"
A	-	-	3.29	0.0070	4
B	-	-	2.95	0.0063	"
C	-	-	2.72	0.0058	"
D	-	-	2.61	0.0056	"
A	-	-	4.28	0.0092	5
B	-	-	3.54	0.0076	"
C	-	-	3.44	0.0074	"
D	-	-	3.16	0.0068	"
A	-	-	3.01	0.0064	6
B	-	-	3.16	0.0068	"
C	-	-	3.08	0.0066	"
D	-	-	2.62	0.0056	"

[redacted]

[redacted]

TABLE XXI (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.30% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	2.3	0.7	3.22	0.0069	7
B	1.9	0.7	3.02	0.0065	"
C	2.9	0.6	2.89	0.0062	"
D	0.9	0.9	2.70	0.0058	"
A	4.4	0.9	3.15	0.0067	8
B	4.7	1.2	2.87	0.0061	"
C	4.4	0.6	2.81	0.0060	"
D	1.9	0.8	2.70	0.0058	"
A	4.9	1.1	3.27	0.0070	9
B	5.2	1.2	3.02	0.0065	"
C	5.1	0.7	2.87	0.0061	"
D	2.1	0.9	2.77	0.0059	"
A	6.9	1.3	3.48	0.0075	11
B	7.5	1.3	3.32	0.0071	"
C	7.0	1.0	2.99	0.0064	"
D	2.4	1.1	3.07	0.0066	"
A	8.9	1.4	3.22	0.0069	13
B	7.6	1.3	3.07	0.0066	"
C	7.0	1.0	3.11	0.0067	"
D	2.8	1.4	2.96	0.0063	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

[redacted]

[redacted]

TABLE XXII

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.44% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	1.99	0.0043	1
B	-	-	3.49	0.0075	"
C	-	-	4.48	0.0096	"
D	-	-	3.98	0.0085	"
A	-	-	4.41	0.0094	2
B	-	-	5.63	0.0121	"
C	-	-	5.14	0.0110	"
D	-	-	5.38	0.0115	"
A	-	-	4.82	0.0103	3
B	-	-	4.33	0.0093	"
C	-	-	4.97	0.0106	"
D	-	-	3.69	0.0079	"
A	-	-	2.72	0.0058	4
B	-	-	2.38	0.0051	"
C	-	-	3.63	0.0078	"
D	-	-	2.04	0.0044	"
A	-	-	3.72	0.0080	5
B	-	-	3.26	0.0070	"
C	-	-	3.91	0.0084	"
D	-	-	2.79	0.0060	"
A	-	-	3.47	0.0074	6
B	-	-	2.93	0.0063	"
C	-	-	3.70	0.0079	"
D	-	-	2.39	0.0051	"

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TABLE XXII (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.44% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	4.2	0.6	3.21	0.0069	7
B	1.7	0.6	3.08	0.0066	"
C	2.7	0.7	3.54	0.0076	"
D	2.0	0.6	2.64	0.0057	"
A	7.0	0.7	3.27	0.0070	8
B	2.9	0.8	2.98	0.0064	"
C	4.1	0.9	3.49	0.0075	"
D	2.5	0.7	2.70	0.0058	"
A	7.2	0.7	3.17	0.0068	9
B	3.7	0.9	2.87	0.0061	"
C	4.4	1.0	3.42	0.0073	"
D	2.7	0.8	2.77	0.0059	"
A	7.5	0.7	3.19	0.0068	11
B	5.5	1.1	3.03	0.0065	"
C	5.9	1.3	3.41	0.0073	"
D	3.1	1.1	2.91	0.0062	"
A	3.7	0.8	3.03	0.0065	13
B	5.5	1.1	2.96	0.0063	"
C	5.9	1.1	3.28	0.0070	"
D	3.3	1.3	2.89	0.0062	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXIII

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.73% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	1.99	0.0043	1
B	-	-	1.99	0.0043	"
C	-	-	5.48	0.0117	"
D	-	-	4.47	0.0096	"
A	-	-	1.98	0.0042	2
B	-	-	2.69	0.0058	"
C	-	-	3.67	0.0079	"
D	-	-	3.18	0.0068	"
A	-	-	1.61	0.0034	3
B	-	-	2.57	0.0055	"
C	-	-	2.89	0.0062	"
D	-	-	3.69	0.0079	"
A	-	-	2.04	0.0044	4
B	-	-	2.93	0.0063	"
C	-	-	3.18	0.0068	"
D	-	-	3.29	0.0070	"
A	-	-	2.79	0.0060	5
B	-	-	3.16	0.0068	"
C	-	-	3.26	0.0070	"
D	-	-	3.72	0.0080	"
A	-	-	2.87	0.0061	6
B	-	-	2.87	0.0061	"
C	-	-	4.03	0.0086	"
D	-	-	3.56	0.0076	"

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TABLE XXIII (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.73% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	1.5	0.9	3.02	0.0065	7
B	-	-	2.83	0.0061	"
C	0.8	0.7	3.73	0.0080	"
D	2.2	0.8	3.73	0.0080	"
A	2.2	1.1	2.82	0.0060	8
B	0.8	0.6	2.93	0.0063	"
C	1.4	0.7	3.54	0.0076	"
D	2.3	0.7	3.54	0.0076	"
A	2.3	1.2	2.82	0.0060	9
B	1.1	0.8	2.97	0.0064	"
C	1.4	0.8	3.52	0.0075	"
D	2.3	0.8	3.42	0.0073	"
A	2.8	1.4	3.07	0.0066	11
B	1.4	1.0	2.86	0.0061	"
C	1.5	0.9	3.57	0.0076	"
D	2.3	1.0	3.65	0.0078	"
A	2.8	1.5	3.22	0.0069	13
B	1.4	1.2	3.00	0.0064	"
C	1.6	1.0	3.50	0.0075	"
D	3.1	1.0	3.50	0.0075	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXIV

THE CORROSION OF CAST BERYLLIUM CONTAINING 1.05% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.59	0.0055	1
B	-	-	3.49	0.0075	"
C	-	-	4.98	0.0106	"
D	-	-	3.59	0.0077	"
A	-	-	1.71	0.0037	2
B	-	-	2.45	0.0052	"
C	-	-	2.94	0.0063	"
D	-	-	2.45	0.0052	"
A	-	-	2.73	0.0058	3
B	-	-	2.41	0.0052	"
C	-	-	3.21	0.0069	"
D	-	-	1.77	0.0038	"
A	-	-	2.04	0.0044	4
B	-	-	1.93	0.0041	"
C	-	-	2.49	0.0053	"
D	-	-	1.13	0.0024	"
A	-	-	2.98	0.0064	5
B	-	-	2.78	0.0060	"
C	-	-	3.89	0.0083	"
D	-	-	1.39	0.0030	"
A	-	-	2.64	0.0056	6
B	-	-	2.64	0.0056	"
C	-	-	3.41	0.0073	"
D	-	-	1.32	0.0028	"

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TABLE XXIV (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 1.05% ALUMINUM EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	1.3	0.9	2.70	0.0058	7
B	2.7	0.9	2.57	0.0055	"
C	1.3	0.5	3.47	0.0074	"
D	3.1	0.4	2.38	0.0051	"
A	3.6	0.8	3.04	0.0065	8
B	3.9	1.1	2.81	0.0060	"
C	3.6	0.8	3.71	0.0079	"
D	5.7	0.6	2.76	0.0059	"
A	3.9	0.9	3.22	0.0069	9
B	4.2	1.2	2.97	0.0064	"
C	4.1	0.8	3.82	0.0082	"
D	6.3	0.7	2.76	0.0060	"
A	6.9	1.0	3.52	0.0075	11
B	7.4	1.4	3.32	0.0072	"
C	7.9	0.8	3.90	0.0083	"
D	8.4	0.8	3.18	0.0068	"
A	7.2	1.3	3.57	0.0076	13
B	7.8	1.1	3.25	0.0070	"
C	7.9	0.9	4.00	0.0086	"
D	8.4	1.0	3.36	0.0072	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXV

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.23% IRON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.99	0.0064	1
B	-	-	0.99	0.0021	"
C	-	-	1.98	0.0042	"
D	-	-	1.98	0.0042	"
A	-	-	1.47	0.0031	2
B	-	-	1.22	0.0026	"
C	-	-	2.94	0.0063	"
D	-	-	1.71	0.0037	"
A	-	-	1.93	0.0041	3
B	-	-	2.57	0.0055	"
C	-	-	2.24	0.0048	"
D	-	-	2.41	0.0052	"
A	-	-	1.63	0.0035	4
B	-	-	2.56	0.0055	"
C	-	-	2.79	0.0060	"
D	-	-	3.25	0.0070	"
A	-	-	2.25	0.0048	5
B	-	-	2.43	0.0052	"
C	-	-	3.37	0.0072	"
D	-	-	3.28	0.0070	"
A	-	-	2.36	0.0051	6
B	-	-	2.88	0.0062	"
C	-	-	3.29	0.0070	"
D	-	-	3.37	0.0072	"

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TABLE XXV (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.23% IRON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.42	0.0052	7
B	-	-	2.88	0.0062	"
C	-	-	3.21	0.0069	"
D	-	-	3.47	0.0074	"
A	1.3	1.1	2.43	0.0052	8
B	1.6	0.9	2.89	0.0062	"
C	-	-	3.42	0.0073	"
D	0.7	0.8	3.65	0.0078	"
A	1.3	1.1	2.44	0.0052	9
B	1.6	0.9	2.91	0.0062	"
C	-	-	3.37	0.0072	"
D	0.7	0.8	3.58	0.0077	"
A	1.4	0.9	2.50	0.0053	11
B	1.6	0.9	2.98	0.0064	"
C	-	-	3.19	0.0068	"
D	0.7	0.8	3.32	0.0071	"
A	1.6	0.7	2.45	0.0052	13
B	1.6	0.9	2.91	0.0062	"
C	-	-	2.94	0.0063	"
D	0.8	0.8	3.01	0.0064	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXVI

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.34% IRON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	3.98	0.0085	1
B	-	-	2.49	0.0053	"
C	-	-	1.99	0.0043	"
D	-	-	3.49	0.0075	"
A	-	-	3.18	0.0068	2
B	-	-	1.96	0.0042	"
C	-	-	2.45	0.0052	"
D	-	-	3.67	0.0079	"
A	-	-	2.73	0.0048	3
B	-	-	2.08	0.0045	"
C	-	-	2.88	0.0062	"
D	-	-	4.48	0.0096	"
A	-	-	2.56	0.0055	4
B	-	-	2.09	0.0045	"
C	-	-	2.67	0.0057	"
D	-	-	3.84	0.0082	"
A	-	-	2.34	0.0050	5
B	-	-	2.06	0.0044	"
C	-	-	2.62	0.0056	"
D	-	-	3.28	0.0070	"
A	-	-	2.35	0.0050	6
B	-	-	2.27	0.0049	"
C	-	-	2.51	0.0054	"
D	-	-	4.00	0.0086	"

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TABLE XXVI (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.34% IRON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.49	0.0053	7
B	-	-	2.29	0.0049	"
C	-	-	2.49	0.0053	"
D	-	-	3.34	0.0072	"
A	0.5	0.6	2.66	0.0053	8
B	2.0	0.7	2.78	0.0060	"
C	1.2	0.7	2.78	0.0060	"
D	0.6	0.8	3.24	0.0069	"
A	0.5	0.6	2.70	0.0058	9
B	2.0	0.8	2.80	0.0060	"
C	1.2	0.8	2.75	0.0059	"
D	0.6	0.8	3.22	0.0069	"
A	0.6	0.6	2.64	0.0057	11
B	2.0	1.1	2.76	0.0059	"
C	1.2	1.0	2.76	0.0059	"
D	0.6	0.8	3.19	0.0068	"
A	0.7	0.6	2.52	0.0054	13
B	2.1	1.1	2.52	0.0054	"
C	1.3	1.0	2.66	0.0057	"
D	0.6	0.8	3.05	0.0065	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXVII

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.40% IRON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	1.00	0.0021	1
B	-	-	2.97	0.0064	"
C	-	-	2.49	0.0053	"
D	-	-	3.99	0.0085	"
A	-	-	1.22	0.0026	2
B	-	-	2.08	0.0045	"
C	-	-	2.45	0.0052	"
D	-	-	2.69	0.0058	"
A	-	-	2.41	0.0052	3
B	-	-	2.73	0.0058	"
C	-	-	2.88	0.0062	"
D	-	-	3.21	0.0069	"
A	-	-	2.56	0.0055	4
B	-	-	2.79	0.0060	"
C	-	-	2.90	0.0062	"
D	-	-	3.37	0.0072	"
A	-	-	2.90	0.0062	5
B	-	-	3.18	0.0068	"
C	-	-	3.30	0.0071	"
D	-	-	3.18	0.0068	"
A	-	-	3.06	0.0065	6
B	-	-	3.29	0.0070	"
C	-	-	3.13	0.0067	"
D	-	-	3.61	0.0077	"

[redacted]

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TABLE XXVII (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.40% IRON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	2.95	0.006	7
B	-	-	3.08	0.007	"
C	-	-	3.01	0.006	"
D	-	-	3.21	0.007	"
A	0.3	0.6	3.01	0.0064	8
B	0.9	1.5	3.13	0.0067	"
C	0.4	0.6	2.89	0.0062	"
D	1.1	0.8	3.13	0.0067	"
A	0.3	0.6	2.95	0.0063	9
B	0.9	1.5	3.11	0.0067	"
C	0.4	0.6	2.95	0.0063	"
D	1.1	0.8	3.16	0.0068	"
A	0.3	0.6	2.95	0.0063	11
B	0.9	1.5	3.15	0.0067	"
C	0.5	0.6	2.89	0.0062	"
D	1.1	0.8	3.15	0.0067	"
A	0.3	0.6	2.80	0.0060	13
B	1.3	1.3	2.98	0.0064	"
C	0.5	0.6	2.83	0.0060	"
D	1.1	0.8	2.91	0.0062	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXVIII

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.186% SILICON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85° C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	3.98	0.0085	1
B	-	-	3.98	0.0085	"
C	-	-	3.98	0.0085	"
D	-	-	4.48	0.0096	"
A	-	-	4.16	0.0089	2
B	-	-	3.91	0.0084	"
C	-	-	3.43	0.0073	"
D	-	-	3.43	0.0073	"
A	-	-	3.85	0.0082	3
B	-	-	3.20	0.0068	"
C	-	-	3.21	0.0069	"
D	-	-	2.41	0.0052	"
A	-	-	3.69	0.0079	4
B	-	-	2.80	0.0060	"
C	-	-	2.65	0.0057	"
D	0.2	1.1	1.97	0.0042	"
A	0.4	1.3	3.67	0.0079	5
B	0.3	1.3	3.13	0.0067	"
C	-	-	2.78	0.0060	"
D	0.2	2.6	2.86	0.0061	"
A	0.7	1.4	3.69	0.0079	6
B	0.4	1.1	3.47	0.0074	"
C	0.6	0.8	3.09	0.0066	"
D	0.5	1.9	2.94	0.0063	"

[redacted]

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TABLE XXVIII (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.186% SILICON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	1.4	1.0	3.52	0.0075	7 1/2
B	0.8	1.1	3.27	0.0070	"
C	1.7	0.9	3.02	0.0065	"
D	1.1	1.1	2.96	0.0063	"
A	1.8	1.0	3.12	0.0067	10
B	0.8	1.7	3.12	0.0067	"
C	1.8	1.0	3.08	0.0066	"
D	1.2	1.7	2.90	0.0062	"
A	2.0	1.0	2.99	0.0064	12
B	3.3	1.7	2.98	0.0064	"
C	2.4	1.0	3.18	0.0068	"
D	1.8	1.7	3.03	0.0065	"
A	2.1	1.1	3.02	0.0065	13
B	3.3	1.7	3.16	0.0068	"
C	2.8	1.1	3.16	0.0068	"
D	2.1	1.9	3.06	0.0066	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXIX

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.201% SILICON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	4.98	0.0106	1
B	-	-	4.48	0.0096	"
C	-	-	2.99	0.0064	"
D	-	-	7.48	0.0160	"
A	-	-	2.94	0.0063	2
B	-	-	4.89	0.0104	"
C	-	-	4.65	0.0100	"
D	-	-	5.38	0.0115	"
A	-	-	2.41	0.0052	3
B	-	-	4.01	0.0086	"
C	-	-	4.02	0.0086	"
D	-	-	4.33	0.0093	"
A	-	-	1.87	0.0040	4
B	-	-	2.36	0.0051	"
C	0.2	1.0	3.00	0.0064	"
D	0.1	2.2	3.11	0.0067	"
A	-	-	2.39	0.0051	5
B	-	-	2.71	0.0058	"
C	0.3	2.0	2.95	0.0063	"
D	0.2	1.9	3.08	0.0066	"
A	0.7	0.6	2.49	0.0053	6
B	-	-	2.72	0.0058	"
C	0.5	1.7	3.16	0.0068	"
D	0.3	1.9	3.54	0.0076	"

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TABLE XXIX (CONT'D)

THE CORROSION OF CAST BERYLLIUM CONTAINING 0.201% SILICON EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	1.4	0.9	2.41	0.0052	7 1/2
B	0.6	0.9	2.72	0.0058	"
C	0.9	1.0	3.09	0.0066	"
D	0.6	1.7	3.39	0.0073	"
A	1.6	0.9	2.58	0.0056	10
B	0.7	0.9	2.83	0.0061	"
C	0.9	6.1	2.94	0.0063	"
D	0.6	1.7	3.03	0.0065	"
A	1.8	1.0	2.85	0.0061	12
B	0.7	0.8	2.96	0.0063	"
C	0.9	6.1	3.14	0.0067	"
D	0.6	1.7	2.99	0.0064	"
A	2.0	1.1	3.05	0.0065	13
B	0.9	0.9	3.16	0.0068	"
C	1.0	6.2	3.08	0.0066	"
D	0.7	1.9	3.19	0.0068	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXX

THE CORROSION OF HOT-PRESSED BERYLLIUM CONTAINING 0.11% Be_2C EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	4.49	0.0096	1
B	-	-	3.46	0.0074	"
C	-	-	4.15	0.0089	"
D	-	-	2.32	0.0050	"
A	Numerous	0.6	3.78	0.0081	2
B	"	0.5	2.83	0.0061	"
C	"	0.4	3.21	0.0069	"
D	"	0.4	2.17	0.0046	"
A	"	1.7	3.85	0.0082	3 3/4
B	"	0.9	3.21	0.0069	"
C	"	0.7	3.96	0.0085	"
D	"	0.6	3.48	0.0074	"
A	"	2.1	3.54	0.0076	4 1/2
B	"	0.9	3.64	0.0078	"
C	"	0.9	4.09	0.0087	"
D	"	0.6			"
A	"	2.1	3.42	0.0073	5 1/4
B	"	1.3	3.04	0.0065	"
C	"	0.9	3.57	0.0077	"
D	"	1.0	3.64	0.0078	"
A	"	2.4	3.18	0.0068	7
B	"	1.6	2.73	0.0058	"
C	"	1.0	3.06	0.0065	"
D	"	1.1	3.10	0.0066	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXXI

THE CORROSION OF HOT-PRESSED BERYLLIUM CONTAINING 0.23% Be_2C EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	4.86	0.0104	1
B	-	-	3.45	0.0074	"
C	-	-	3.97	0.0085	"
D	-	-	2.59	0.0055	"
A	Numerous	0.4	3.90	0.0084	2
B	"	0.5	3.21	0.0069	"
C	"	0.5	3.44	0.0074	"
D	"	0.4	2.48	0.0053	"
A	"	0.7	4.32	0.0092	3 3/4
B	"	0.9	3.85	0.0082	"
C	"	0.9	4.00	0.0086	"
D	"	0.9	3.42	0.0073	"
A	"	0.9	5.13	0.0109	4 1/2
B	"	1.1	4.27	0.0091	"
C	"	0.9	4.79	0.0102	"
D	"	0.9	4.53	0.0097	"
A	"	1.4	4.07	0.0087	5 1/4
B	"	1.3	3.73	0.0080	"
C	"	1.1	3.72	0.0080	"
D	"	1.1	3.86	0.0083	"
A	"	1.6	3.58	0.0077	7
B	"	1.3	3.06	0.0065	"
C	"	1.2	3.48	0.0075	"
D	"	1.3	3.26	0.0070	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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TABLE XXXII

THE CORROSION OF HOT-PRESSED BERYLLIUM CONTAINING 0.26% Be_2C EXPOSED TO DISTILLED WATER (0.005M H_2O_2) AT 85°C

Sample No.	Pit Count per cm^2	Maximum Pit Depth, mils	Weight Loss, $mg/dm^2/mo$*	Penetration Rate, mils/mo	Exposure Time, Months
A	-	-	3.64	0.0078	1
B	-	-	4.97	0.0106	"
C	-	-	3.97	0.0085	"
D	-	-	4.22	0.0090	"
A	Numerous	0.6	4.16	0.0089	2
B	"	0.5	4.52	0.0097	"
C	"	0.4	4.88	0.0104	"
D	"	0.4	4.26	0.0091	"
A	"	0.7	4.10	0.0088	3 3/4
B	"	0.8	4.10	0.0088	"
C	"	0.7	5.12	0.0109	"
D	"	0.7	4.63	0.0099	"
A	"	0.9	4.44	0.0095	4 1/2
B	"	1.3	4.70	0.0100	"
C	"	0.7	5.40	0.0115	"
D	"	0.9	4.96	0.0106	"
A	"	1.3	3.86	0.0083	5 1/4
B	"	1.4	4.07	0.0087	"
C	"	0.9	4.73	0.0101	"
D	"	1.0	4.14	0.0089	"
A	"	1.5	3.21	0.0069	7
B	"	1.6	3.42	0.0073	"
C	"	0.9	+160.5	----	"
D	"	0.9	3.79	0.0081	"

*$mg/dm^2/mo$ - Milligrams per square decimeter per month

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