Galvanic Corrosion Behavior of Wear-Resistant Materials for Mechanical Shaft Seals

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ABSTRACT

Shaft seals currently used on submarines employ mating wear surfaces which are supported by Monel carrier rings. Galvanic corrosion effects between various candidate mating materials and Monel have been investigated by the exposure of couples in seawater. The 14 materials exposed included seven cobalt-chromium alloys, six sintered carbide materials, and one copper-lead-tin alloy. The results indicate that galvanic coupling to Monel had no adverse effect on the corrosion behavior of five of the cobalt-chromium alloys, and one of the sintered carbide materials.

ADMINISTRATIVE INFORMATION

This investigation is conducted under Sub-project S-F013 07 01, Task 3723. The study of corrosion behavior of potential seal materials is a part of the material development phase of this task.

TECHNICAL REFERENCE

1 - Basil, J. L., "Corrosion of Mechanical Seal Materials Induced by Coupling to Carbon," MEL R&D Rept 117/64 of 21 Aug 1964

TABLE OF CONTENTS

GALVANIC CORROSION BEHAVIOR OF WEAR RESISTANT MATERIALS FOR MECHANICAL SHAFT SEALS

1.0 INTRODUCTION

Mechanical face-type seals for main propulsion shafting of submarines, involve a number of materials operating in seawater. It is essential for reliable operation that these materials be compatible with respect to galvanic corrosion. In a contemporary model, the mating seal faces are carbon and a cobalt-chromium type of hard-facing alloy. These are supported by Ni-Cu (Monel) alloy carrier rings. Shaft sleeves and housings are also Monel alloy. Since the amount of Monel is much greater than that of either seal face, the optimum condition would be for the seal-face materials to be slightly cathodic with respect to Monel. The use of a seal-face material which was anodic to the carrier metal and therefore subject to accelerated attack would be highly undesirable.

A previous report[1] presented results of a study concerning the effect of coupling several grades of carbon to a variety of metals. These showed the carbons to be very "noble" in behavior and cathodic to all metals with which they were paired, except for one complex nickel-base alloy. This report presents comparable information regarding a variety of hard-facing materials.

2.0 MATERIALS

Seven cobalt-chromium alloys and six sintered carbide materials were included in this study as possible mating-ring insert materials. In addition, Bearium Metal, a copper-lead-tin alloy was also included. This alloy has been of interest as a possible alternate to carbon because of desirable wear characteristics, although it was considered unlikely that it would have adequate corrosion resistance for use in mechanical seals. Nominal compositions are shown in Table 1.

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[1] Superscript refers to similarly numbered entry in the Technical Reference

Table 1

Nominal Composition Materials Tested, Weight Percent

Material	Trade Name	MEL Material Code	C	Mn	Mo	Cr	Co	Fe	W	Si	Ni	Cu	Pb	Sn	Others
Co-Cr-W alloy	Tantung G	ECA	3	2		29.5	47.5	3.5	16.5						0.2 B, 4.5 Ta + Cb
Co-Cr-Ni-Mo alloy	Cobenium	AMK	0.15	2	7	20	40.0	~15			15				0.4 Be
Co-Cr-W-Ni-Mo alloy	Stellite 6K	ECB	1.6	2.0*	1.5*	31	~51	3.0*	4.5	2.0*	3.0*				
Co-Cr-W-Ni-Mo alloy	Stellite 6B	ECC	1.1	2.0*	1.5*	30	~53	3.0*	4.5	2.0*	3.0*				
Co-Cr-W-V-Ni-Mo alloy	Stellite 98M2	ECD	2.0	1.0*	0.8*	30	~37	2.5*	18.5	1.0*	3.5*				4.0 V
Co-Cr-W-Ni-V alloy	Stellite 3	ECE	2.45	1.0*		30.5	~44	3.0*	12.5	1.0*	3.0*				2.0 V
Co-Cr-W-Ni-V alloy	Star J	ECF	2.5	1.0*		32	~39	3.0*	17.0	1.0*	2.5*				2.0 V
Cu-Pb-Sn alloy	Bearium Metal	DVI										70	20	10	
Ni-Cu alloy	Monel	ECM	0.12	0.9				1.4			66	31			
Titanium carbide with Ni-Mo binder	Kennametal K162B	ECG													25 Ni + Mo, Balance TiC
Tungsten-titanium carbide with Co binder	Kennametal K82	ECH					13								Balance WC-TiC
Tungsten carbide with Co binder	Kennametal K96	ECI					6								Balance WC
Tungsten-tantalum carbides, no binder	Kennametal K601	ECJ													WC-TaC (no binder)
Tungsten carbide with Cr-Co binder	Kennametal K701	ECK													10 Cr + Co, Balance WC
Tungsten carbide with Ni binder	Kennametal K801	ECL									6				Balance WC

*Maximum

3.0 INVESTIGATION

Galvanic corrosion behavior of each metal relative to Monel was determined by comparison of the corrosion rate of an uncoupled specimen to that of one coupled to Monel in a one-year sea-water exposure. Uncoupled specimens were 2-7/8 x 1-3/16 x 1/8 inches (area: 7.8 sq in). Specimens of equal size (7.8 sq in) were used in the test of Bearium Metal coupled to Monel. With the other materials, however, an area ratio of approximately 4:1 between Monel and the seal-face material was obtained by use of specimens of the following sizes:

Monel: 6 x 1-3/16 x 1/32 inches (area: 14.7 sq in)

Seal Material: 1-1/4 x 1-3/16 x 1/8 inches (area: 3.6 sq in)

The two specimens in each couple were spaced 3/8 inch apart by a nonmetallic sleeve on a Monel bolt and nut which joined them electrically. The Monel member of the couple was supported by porcelain insulators on a frame, as shown in Figure 1. The uncoupled specimens were supported individually in a similar manner.

The specimens were exposed in natural seawater flowing at a velocity of 2 feet per second in a wooden trough at the Harbor Island Corrosion Laboratory, Wrightsville Beach, North Carolina. Duration of the exposure was 353 days.

Supplementary information on the corrosion behavior was obtained for five of the cobalt-base alloys by measurement of open-circuit potentials. The data were obtained with the polarization apparatus at the Harbor Island Corrosion Laboratory on two different occasions. The first was a 30-day period with an average sea-water temperature of 77 F; the second was a 45-day period with an average sea-water temperature of 46 F. A saturated calomel half-cell was used for the measurements. Water velocity in the polarization cells was maintained at 13 feet per second.

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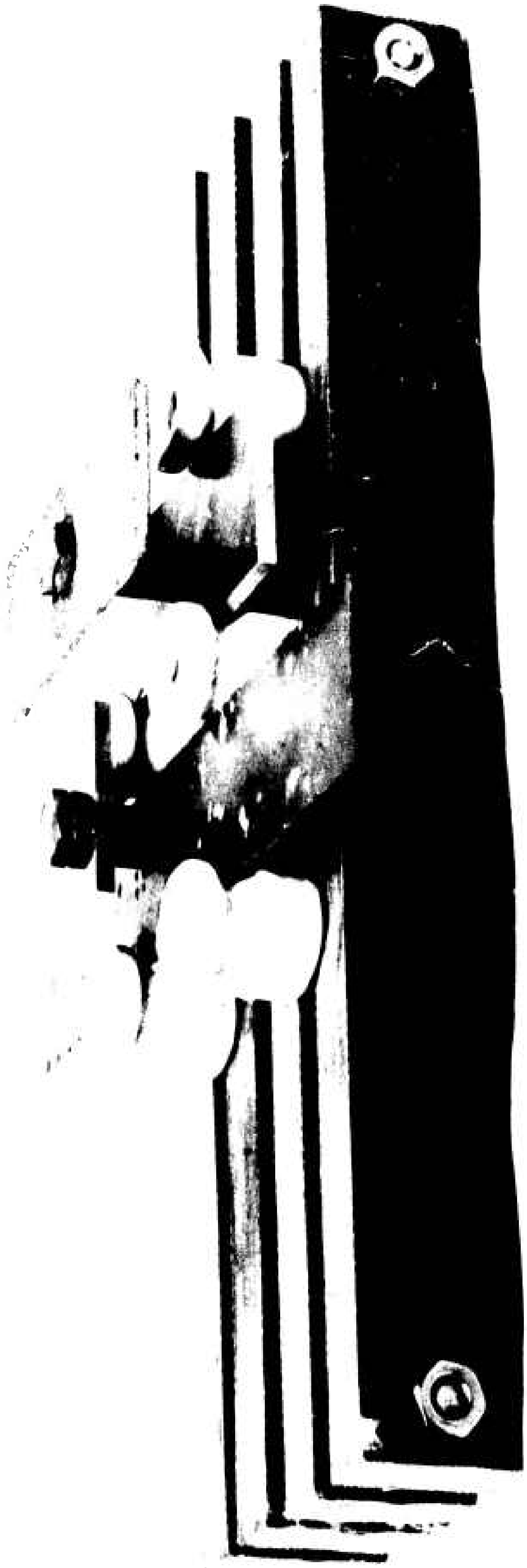

Figure 1
Support Frame Showing Manner of Exposure of Monel
Coupled to Other Materials (Insulators Support the Monel Specimens)

4.0 RESULTS AND DISCUSSION

Results of the corrosion tests are summarized in Table 2. Of primary interest are the corrosion rates of the seal-face alloys when coupled to Monel. In addition, the coupled-to-uncoupled weight-loss ratio should be unity or less, to indicate that the alloy is cathodic to Monel. On this basis, five cobalt-chromium alloys and one sintered carbide material, Kennametal K601, appear to have desirable corrosion characteristics. Accelerated corrosion rates of Stellite 3 and Stellite Star J, and most of the sintered carbides, could pose galvanic corrosion problems in seals where area ratios would be more unfavorable than those programmed for this investigation.

Table 2

Results of Corrosion Tests

Material	Corrosion Rate of Test Metal mils/year		Rate Ratio Coupled/Uncoupled
	Coupled to Monel	Uncoupled	
Tantung G	<0.1	-	-
Cobenium	<0.1	0.5	~0.2
Stellite 6K	<0.1	<0.1	~1
Stellite 6B	<0.1	<0.1	~1
Stellite 98M2	<0.1	<0.1	~1
Stellite 3	3.4	1.5	2.3
Stellite Star J	1.2	<0.1	12
Kennametal K162B	1.9	-	-
Kennametal K82	6.6	-	-
Kennametal K96	2.7	3.5	0.8
Kennametal K601	<0.1	1.2	0.1
Kennametal K701	4.6	2.6	1.8
Kennametal K801	3.6	2.8	1.3
Bearium Metal	18.1	2.4	7.5

Metallographic examination of the corrosion test samples revealed that only general attack occurred on the cobalt-chromium alloys. In the case of the sintered carbide materials, however, selective attack of the metallic binders (nickel-molybdenum, cob. lt, nickel, or chromium-cobalt) was found. An example of this attack is shown in Figure 2. The one sintered carbide which was essentially free of attack in the coupled corrosion test is a binderless material.

The high corrosion rate of Bearium Metal coupled to Monel is not surprising, since copper-base alloys are generally anodic to nickel-copper alloys in seawater.

Results of potential measurements made in flowing seawater with five cobalt-chromium alloys are presented in Figure 3. The bar graph shows the minimum, mean, and maximum values obtained for each alloy in each of the two test runs. The difference in water temperature between the two runs had little effect on the mean values which ranged from 40 to 100 millivolts, negative, with reference to a saturated calomel half-cell. These data provide supplementary evidence of the noble corrosion characteristics of these five alloys.

5.0 CONCLUSIONS

On the basis of the results presented, it can be concluded that Stellite 6K, Stellite 6B, Stellite 98M2, Tantung G, Cobenium, and Kennametal K601 are not subject to galvanic corrosion when coupled to Monel in seawater. Because of relatively high uncoupled corrosion rates and/or being anodic to Monel, the following materials would present corrosion difficulties in seawater when coupled to Monel: Stellite 3, Stellite Star J, Kennametal K162B, Kennametal K82, Kennametal K96, Kennametal K701, Kennamental K801, and Bearium Metal.

From Kennametal's photograph

Figure 2
Kennametal K162B Carbide After Corrosion Test
(Note Attack of Metallic Binder Particles on Left,
1500X, Nital Etch)

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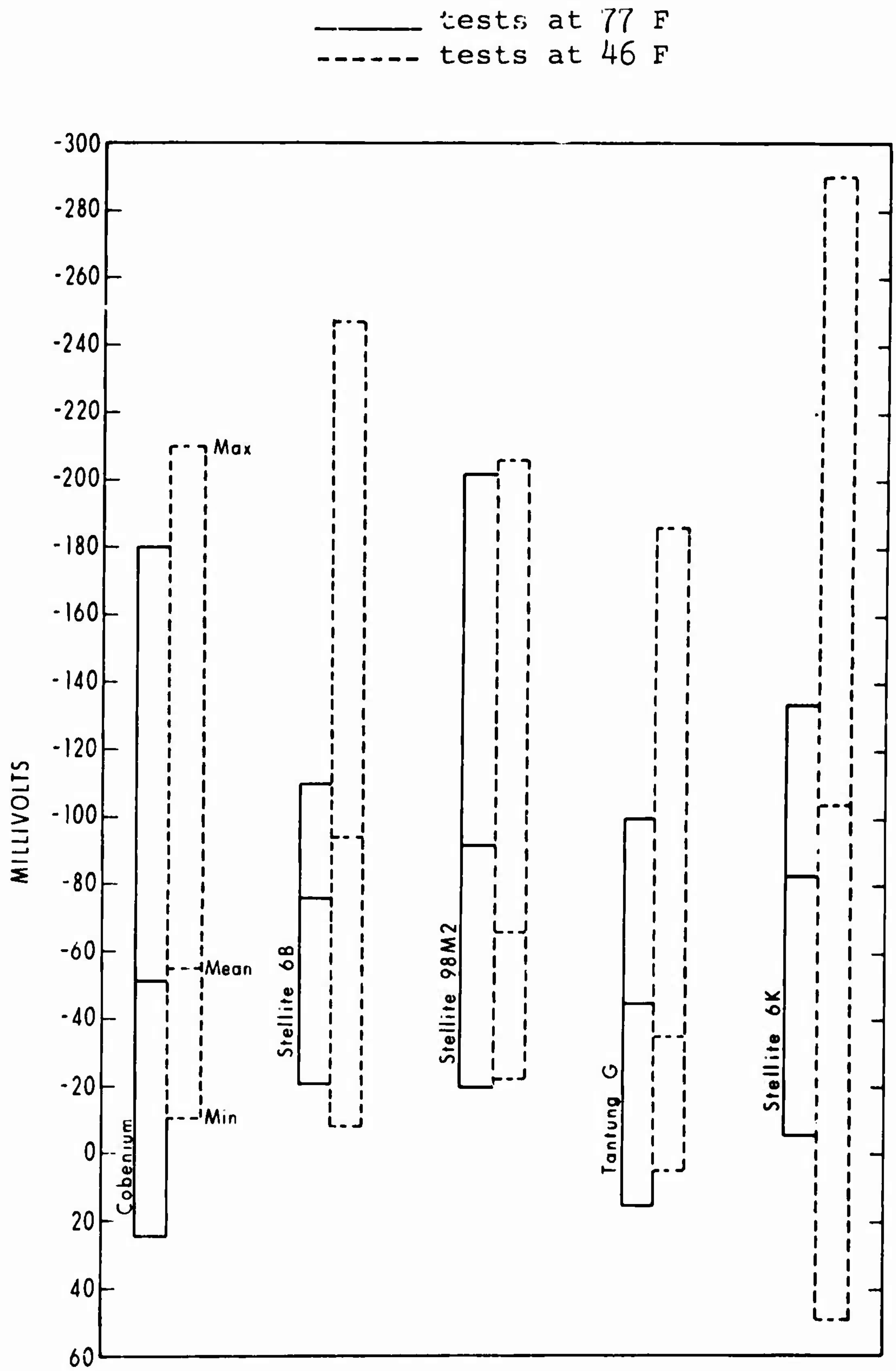

Figure 3 - Open-Circuit Potentials of Cobalt Base Alloys in Flowing Seawater

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