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GENERAL ENGINEERING LABORATORY

INVESTIGATION OF THE SLIDING BEHAVIOR OF A NUMBER OF ALLOYS UNDER DRY AND WATER LUBRICATED CONDITIONS

by

R. E. LEE, JR.

REPORT NO. 60GL20

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INTRODUCTION

The object of this investigation was to study the sliding behavior of materials that are presently under consideration for use as components in a pressurized reactor. These materials, in addition to having to meet the physical and mechanical property requirements dictated by design considerations, must also adhere to friction and wear limitations, i.e., characteristics important to the insurance of satisfactory sliding performance under service conditions. In these areas where relative motion between mating surfaces occur, high friction, wear and surface damage in such forms as galling and scoring, can have a pronounced effect on the overall performance of the components during operation.

The results of these tests will provide information typical of two conditions under which relative motion will occur, namely, assembly (dry), and start up (200 F).

The first part of the program was devoted to studying the sliding behavior of typical structural materials in their conventional or uncoated state. The second part was carried out to determine what types of coatings would have sufficient protective properties to prevent galling and excessive wear between sliding members, when at least one of the members were coated.

CONCLUSIONS

Under the conditions tested:

SUMMARY OF RESULTS

Conventional Materials

1.

2.

3.

4. Table 1 summarizes the significant results of the uncoated structural materials, and Table 3 gives a detailed description of these tests.

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Coated Materials

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3.

9.

10. Table 2 summarizes the significant results of the coated material sliding tests and Table 4 gives a detailed description of these tests.

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Table I

SIGNIFICANT RESULTS

Conventional Materials

Specimens		Coefficient of Friction (Avg.)				Overall Wear			
		Dry Lub (μ)		Deoxygenated Water (μ)		Dry Lub (mils)		Deoxygenated Water (mils)	
Slider	Flat	100 psi	1500 psi	100 psi	1500 psi	100 psi	1500 psi	100 psi	1500 psi

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Table 2

SIGNIFICANT RESULTS

Coated Materials

Specimens		Coefficient of Friction (Avg.)				Overall Wear			
		Dry Lub (μ)		Deoxygenated Water (μ)		Dry Lub (mils)		Deoxygenated Water (mils)	
Slider	Flat	100 psi	1500 psi	100 psi	1500 psi	100 spi	1500 psi	100 psi	1500 psi

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APPARATUS AND PROCEDURE - DESCRIPTION

(Test Conditions - see pg. 12)

The tests were conducted on a wear test apparatus in which a 3/4 inch slider with a truncated end consisting of a 13/64 inch diameter surface, was mounted in a reciprocating arm, and moved relative to the surface of a stationary 2 inch long by 1/2 inch wide by 1/4 inch thick flat specimen, at a velocity of 1 1/2 ft/min. One end of the arm was so mounted that the free end was able to move in either a vertical or horizontal plane. See Figure 9 for a photograph of the apparatus.

Sliding was obtained by moving the arm back and forth by means of an air actuated piston. To measure static and kinetic friction, the piston was disconnected and the arm was moved manually. A rod located at the end of the arm was instrumented with strain gages so that the friction force could be continuously recorded when so desired.

Measurements, consisting of change in height of lever arm, and change in length of truncated slider, were made for each run. The change in height was reported as overall wear since it contained the combined wear of both slider and flat. The height of the arm above the base plate was measured at several fixed positions with a dial indicator which was rigidly fastened to the base plate. Heat was supplied by resistance heaters in contact with the bottom of the flat. The flat specimen which was held stationary on a supporting table, was housed within an enclosure which could hold a lubricant. The top half of the enclosure surrounded the slider specimen and was fastened to the moving arm. This allowed for better control of argon gas blanketing and heating. The temperature was measured by a thermocouple clamped in proximity to the surface of the flat. The sliding tests run in deoxygenated water at 200°F had argon gas introduced under positive pressure into the enclosed test area to prevent the influx of oxygen. Argon was bubbled into the water reservoir of the test enclosure and simultaneously brought in through another inlet to blanket the surface of the water. Gas was also bubbled into the water supply. A front view schematic diagram of this setup can be seen in Figure 10. Prior to testing, the specimens were washed with soap and water, and rinsed in alcohol to eliminate any oil or other types of contaminant films.

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After cleaning, the specimens were mounted in the apparatus and brought to the desired operating temperature under load. The height of the arm above the base plate was measured. The arm was moved manually for the first few cycles while static and kinetic friction were continuously recorded. The air actuated cylinder was then engaged to move the arm. A counter connected to the air actuated piston arm recorded the number of cycles. The slider moved 18 cycles/min for a total displacement of 18 inches or 1 1/2 ft/min. At the conclusion of 2000 cycles, the height of the arm was again measured and the test concluded. Macroscopic, and microscopic examination (at 12X and 36X) were made of the specimens upon completion of each test. Photographs were taken at 10X magnification of several tested specimens whose resulting wear surfaces were considered to be of special interest.

DEFINITION OF TEST TERMS

Finish	Average surface roughness (microinches)
Load	Unit loading on a 13/64 inch diameter slider specimen surface
Cycles	Tests were conducted at 18 cycles/minute where each cycle consisted of a reciprocating movement of two 1/2" strokes making the total displacement 18 inches/minute. The test duration was for 2000 cycles except in the case of excessive wear or coating failure.
Temperature	Temperature at which tests were conducted were: 74°F - unlubricated 200°F - bulk water (deoxygenated) temperature argon gas was introduced under positive pressure into the water reservoir and inclosed test area to prevent influx of oxygen. LiOH was added to the water resulting in a pH of 9.5-10.5
Friction Coefficient	f_{static} - initial coefficient of static friction taken at start of test
	$f_{initial}$ - initial kinetic coefficient of friction taken at start of test
	f_{final} - final kinetic coefficient of friction taken at end of 2000 cycle run
	f_{min} - lowest kinetic coefficient of friction recorded throughout test
	f_{max} - highest kinetic coefficient of friction recorded throughout test
	f_{avg} - average kinetic coefficient of friction values measured throughout test

Friction readings were taken at the following intervals throughout the test:

Initial, 50, 500, 1000 and 2000 cycles

Wear	Overall wear was measured at the end of each test. The overall wear was measured by means of a dial indicator that read to within 0.0001 inches, and was taken with the test specimen surfaces in actual contact. Slider wear was determined by measuring the slider length before and after each test. Plus (+) indicates material buildup on the surface due to deformation and/or material transfer. Minus (-) indicates material loss from the surface or surfaces due to wear and/or surface damage.

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LIST OF FIGURES

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APPENDIX

Material	Nominal Composition %	Configuration	Hardness [1]KHN	Hardness Rockwell
Inconel	77.0 Ni, 15.0 Cr, 7.0 Fe, 0.25Cu, 0.25 Si 0.25 Mn, 0.06 C, 0.007 S	Slider Flat	294 229	28C 96B
AISI 304 Stainless Steel	19.0 Cr, 9.5 Ni, 2.0 Mn, 1.0 Si, 0.16 C	Slider Flat	274 226	24C 95B
Zircaloy 2	1.5 Sn, 0.1 Fe, 3.0 Ni, 0.1 Cr, Bal Zr	Slider	263	22C
Inconel X	73.0 Ni, 15.0 Cr, 7.0 Fe, 0.05 Cu, 0.40 Si, 0.75 Al, 0.50 Mn, 0.05 C, 0.007 S, 2.50 Ti, 0.90 Cb + Ta	Slider	439	43C
AISI 4340 Steel	0.40 C, 0.70 Mn, 0.28 Si, 1.80 Ni, 0.80 Cr, 0.25 Mo, 0.040 S, 0.040 P	Slider	343	34C
Chromium Plate		Chromium Plate on Inconel Flat	805	63C
Chromium Plate		Chromium Plate on AISI 304 SS Flat	835	65C
Stellite 6 Overlay	28.0 Cr, 4.0 W, 1.0 C, Bal Co	Stellite 6 Overlay on Inconel Flat	581	52C
Colmonoy 6 Overlay	13.0-20.0 Cr, 2.75-4.0 Cr, 65.0-75.0 Ni, 10.0 Mn_{max}, Fe, C	Colmonoy 6 Overlay on Inconel Flat	805	63C
Electrolize Coating	Chromium Alloy - Proprietary	Electrolize On Inconel Flat	477	46C
Electroless Nickel Plate (Kanigen)	90.0-92.0 Ni, 8.0-10.0 P, 0.040 C, 0.0023 O_2, 0.0047 N_2, 0.0016 H_2	Nickel Plate On Inconel Flat	563	51C
Electrolytic Nickel Plate		Nickel Plate On Inconel Flat	567	52C

[1]Knoop hardness measurements were made on a Tukon Hardness Tester using a 1 Kg load, and 20X objective. The only exception was the Electrolize coating whose hardness was measured at a 200 gm load. The Rockwell hardness values were obtained from conversion tables.

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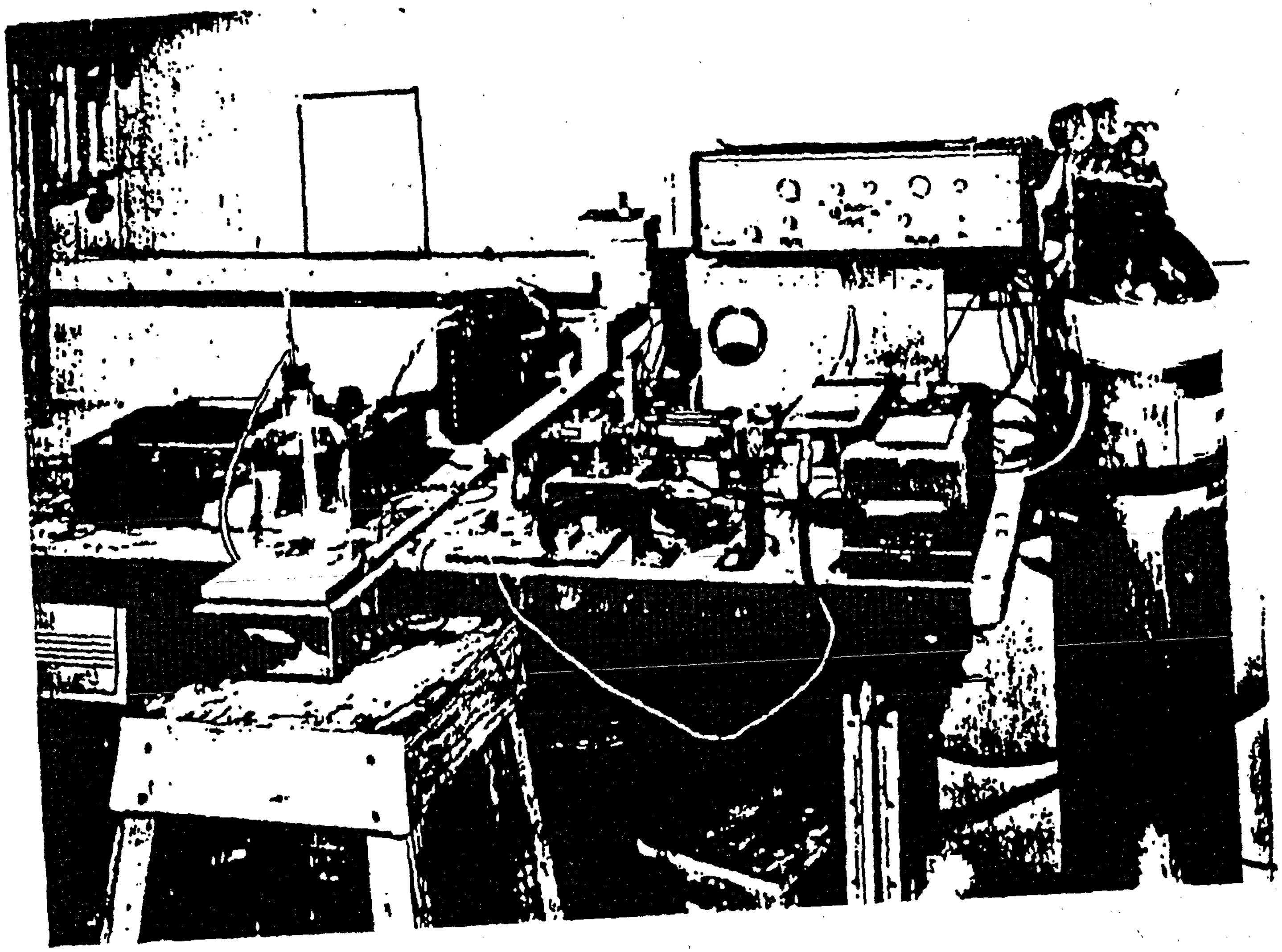

Fig. 9. Wear test apparatus.