PNC TN941 77−179Tr

In-Sodium Tests of Hard Facing Materials (II)
Test Result in Room Temperature Argon

Nov. 1978

POWER REACTOR AND NUCLEAR FUEL DEVELOPMNT CORPORATION

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Test Result in Room Temperature Argon

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A series of experiments have been carried out to develop and screen friction and wear resistant materials used for sliding components of a sodium cooled reactor. Preceding studies[(1)∿(5)] clarified the short-term friction and wear characteristics of various materials in 450°C sodium.

A present study relates to clarify friction and wear behavior in argon environment, where a part of sliding components are located, and compare test data in room temperature argon with those in 450°C sodium.

The results obtained are as follows:

(1) Static friction coefficients (μs) in argon were almost lower than 0.2. They were apt to be lower than those in sodium.

(2) Kinetic friction coefficients (μk) in argon varied with load. The difference of μk in argon and sodium depended on material combination.

(3) Wear rates were remarkably high in argon. Wear rates of Colmonoy and Stellite were not detected in sodium, but were detected in argon.

(4) Sliding surface was more roughened in argon, and hardness of sliding surface was almost lower in argon than in sodium.

(5) There is the significant difference between friction and wear characteristics in argon and those in sodium. Then, it is difficult that in-sodium behavior is estimated with in-argon data.

(6) The above-mentioned difference in room temperature argon and 450°C sodium will be greater when the test is carried out in higher temperature argon.

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** FBR Project

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1. Preface

Sliding parts of the fast breeder reactor are located in the liquid sodium or in the cover gas argon. Regarding the friction and wear behaviors of sliding material in sodium, the short term friction and wear characteristics are clearly described in reports[(1)-(5)]. However, in-argon tests have not been carried out anywhere and it is necessary to obtain the basic data for the design by carrying out the similar tests in argon.

In this report, series of tests were carried out in room temperature argon under the same test conditions and on the same material combinations as applied for the tests in sodium and the friction and wear behaviors in argon were clarified. By comparing those data obtained in room temperature argon with those obtained in 450°C sodium, the differences of friction and wear characteristics in practical reactor atmospheres and the effects of sodium on friction and wear were clarified.

2. Test Methods

2.1 Test Equipment

In-argon tests were carried out by filling room temperature argon in the SW-1 Test Pot of the Self-Welding and Wearing Test Loop where in-sodium tests had been made. The used equipment was the same as used for in-sodium tests. As for the details of equipment, refer our previous reports[(3)-(4)].

2.2 Test Methods

Conditions of the friction test and those of the wear test are shown in Table 1 and Table 2, respectively. Conditions applied for in-sodium tests are also shown in these tables for comparison. Dimensions of test specimen, sliding speed and the method of gradual load increase are all same as adopted for in-sodium tests[(3),(4)].

The chemical composition, combination and coating method of specimens are shown in Table 3, Table 4 and Table 5, respectively. Specimens used for in-argon tests were those of the same batch prepared for in-sodium tests applying the same coating methods.

Material names in the various figures of this report were represented by symbols shown in Table 3.

3. Test Results

3.1 Friction Coefficient

Relations between load and static friction coefficient μs in room temperature argon on various material combinations are shown by solid line in Fig. 1. The combinations except Inconel X vs. Inconel X, Colmonoy No. 6 and Stellite No. 1 vs. Stellite No. 1 show μs below 0.2. Dotted lines shown in Fig. 1 are those obtained by 450°C sodium tests. Room temperature argon showed lower μs than 450°C sodium and the load dependency of μs in argon was smaller.

Relations between load and dynamic friction coefficient μk in room temperature argon on various material combinations are shown by solid line in Fig. 2. It is understood that there is considerable load dependency of μk in argon. Dotted lines shown in Fig. 2 are those obtained in 450°C sodium. It is clear that μk in sodium indicates smaller load dependency. Unlike in the case of μs, μk in argon and sodium vary according to the combinations of material. Inconel X, Stellite No. 1, LC-1C and LW-1N40 indicate remarkably higher μk in sodium, while μk of Colmonoy No. 6, Colmonoy No. 6 vs. Deloro Stellite SF-60M and Colmonoy No. 6 vs. Stellite No. 1 indicate higher μk in argon.

The friction coefficients under the load of 220 kg (contact stress 1 kg/mm^2) in Fig. 1 and 2 are shown in Fig. 3-1 and 3-2, respectively.

3.2 Wear Rate

Comparison of wear characteristics of various material combinations are made by the integrated value ΣW_D of wear depth (sum of the rotor and stator) until each load by increasing the load at 15 minutes intervals at the sliding speed of 3.6 cm/sec. The maximum measurement sensitivity of the wear depth in this test was approximately 4 μm.

Relations between load and ΣW_D in room temperature argon are shown in Fig. 4. Comparing the data with those obtained in 450°C sodium, shown in Fig. 5, the wear rates in argon are higher for all of the material combinations. The wear depths of Stellite alloys and Colmonoy alloys in argon gas were over approx. 100 μm, where as their wear rates in sodium were below the measurement sensitivity. The possible reasons for the re-upswing of the wear depth curve of LC-1C and LW-1N40 at the high load will be that the excessive wear of the carbide coating material of approx. 200 μm thickness caused the exposure of the base metal (SUS 304) to the surface and the sliding of carbide material vs. carbide material was changed to SUS 304 vs. carbide material or SUS 304 vs SUS 304. It was found that Colmonoy No. 5 and Stellite No. 6, among all of the tested materials, indicated excellent wear resistant characteristics both in room temperature argon and 450°C argon.

Wear depth W_D, Wear volume W_V and Specific wear rate W_S which were obtained by scanning the wear scar on the Stator specimen to the diameter direction by surface roughness tester are shown in Table 6. Wear rates were always higher in argon than in sodium on all of the material combinations.

3.3 Metallographic Examination

3.3.1 Surface Roughness

Roughness of the sliding surfaces before and after the tests in room temperature argon and 450°C sodium are shown in Table 7. Surface roughness of all of the materials after test in argon remarkably increased. Even Stellite and Colmonoy alloys which indicated small surface roughness change in sodium indicated large increase of surface roughness in argon.

3.3.2 Hardness

Surface hardness data before and after the tests in room temperature argon and 450°C sodium are shown in Table 8. The surface hardness generally increased after test because of the plastic deformations caused by sliding. Comparing the surface hardness after test in argon and in sodium, hardness in argon are generally lower than those in sodium. However, Colmonoy alloys and Deloro Stellite SF-60M indicated lower hardness in sodium than in argon.

3.3.3 Microscopic Structure

Cross-sectional microstructures of sliding parts of various materials after test in room temperature argon and 450°C sodium are shown in Photo. 1 - Photo. 13. However, microstructures of Colmonoy No. 4 and No. 5 were those obtained after the continuous sliding for 10 hours under the load of 220 kg (contact stress 1 kg/mm^2) at the sliding speed of 3.6 cm/sec. in 450°C sodium and it can be seen that plastic deformations occurred until the inner structures.

Comparing the microstructures in argon and sodium, plastic deformation tends to occur in argon more significantly than in sodium. Especially, it was recognized that a part of the coating layer of carbide material was removed in argon.

4. Discussions

4.1 Friction and Wear in Argon

As shown in Fig. 1, μs of almost all of the materials are below 0.2 at room temperature. One of the reasons will be the residuum of oxide film formed on the surface in the atmosphere before test.

As shown in Fig. 2, μk during continuously one-directional sliding depends on the load. As shown in Fig. 4, Table 7 and Photos. 1 ∿ 13, plastic deformation occurs at the sliding surface and, subsequently, roughness of sliding surface increases and wear rate increases in argon unlikely in-sodium test. This will be due to the destroy of the oxide film on the material surface by the continuous sliding, the subsequent direct contact of the material and the decrease of the material strength caused by the temperature raise by friction.

Tests in high temperature argon were made by the SW-2 test section and μk are reported[(7),(8),(9)] at 280°C and 540°C. Though the sliding mode was oscillating rotation which was different from the test conditions in this report. μk of Stellite No. 6, Colmonoy No. 6 and Cr plated material increase with temperature.

Relations obtained by SW-2 between μk and load on

Stellite and Colmonoy material in the various environments are shown in Fig. 6.

4.2 Comparisons in Argon and Sodium

Comparisons of the test data obtained in room temperature argon and 450°C sodium are made as follows:

(1) Load dependency of μs in both environments are small. The μs values in argon is smaller than in sodium.

(2) Load dependency of μk was observed in argon.

(3) Changes of microstructure, roughness and hardness on surface are more remarkable in argon than in sodium.

(4) Wear rate in argon is higher than in sodium.

Since measurements of μs were made under low sliding speed and short sliding distance and no surface deformation occurred, it is considered that the low load dependency of μs was thus resulted. The possible reason of lower μs in argon than in sodium should be due to the fact that the test was carried out in room temperature argon and the residuum of the oxide film formed on material surface in the atmosphere was easier in argon.

By the continuously one directional sliding (15 minutes sliding at each load) applied for μk measurements, the oxide film on material surface is destroyed and thus μk and W_D increase.

By comparing physical properties of argon and sodium as shown in Table 9, the thermal conductivity of argon is smaller by three times than sodium and the specific heat of argon is about 1/3 of that of sodium. Because the cooling performance of argon is much worse than sodium, the temperature at sliding surface is higher in argon and the oxide film tends to be destroyed, and the deterioration of material strength toughness occurs. On the other hand, the oxide film is destroyed due to strong affinity of sodium with oxygen, but there is a possibility of the formation of $Na_xCr_yO_z$ on material surface in sodium as shown in Fig. 7. According to the literature survey[(10),(11)], the structure of the composite oxide is possibly $NaCrO_2$ and this improves anti-friction and anti-wear properties of the material. It is further estimated that these differences would be enlarged in high temperature argon.

Ratios of friction coefficients in sodium and argon on various materials under the load of 220 kg are shown in Figs. 8-1 and 8-2.

5. Conclusions

By the friction and wear tests in room temperature argon, the following points were made clear.

(1) The μs values in room temperature argon were below 0.2 on almost all of the material combinations. They are smaller than those obtained in 450°C sodium.

(2) The μk values in room temperature argon vary with load.

(3) Remarkable wear rates are obtained in room temperature argon. Colmonoy and Stellite which do not wear in sodium wear in argon.

(4) Plastic deformation and surface roughenning tend to occur at the sliding surface in room temperature argon, while the sliding surface hardness after exposure to 450°C sodium is higher.

(5) There are considerable differences of friction and wear characteristics between in argon and in sodium. It is, accordingly, difficult to estimate the performances in sodium, basing on the data obtained in argon.

(6) It is considered that the differences between room temperature argon and 450°C sodium would be enlarged if the test is carried out in higher temperature argon.

It is supposed that such differences between in-argon and in-sodium and above-mentioned are caused by the following reasons:

(1) The oxide film previously formed on the material surface will remain in argon when tested at room temperature and short sliding distance.

(2) When continuous sliding is made in argon, less friction heat is removed due to the lower heat conductivity of argon by three times than that of sodium and the lower specific heat which is approximately 1/3 of that of sodium.

(3) Although oxide film formed on the material surface in the atmosphere is destroyed in sodium, $Na_xCr_yO_z$ is newly formed on the surface, and this will act as the lubricant.

The results obtained by the tests in room temperature argon were reported and the difference between in-argon data and those obtained in 450°C sodium were discussed herewith.

Among the sliding parts of reactor components, those of fuel exchanger, driving mechanism of control rod and fuel transfer machine which are located above reactor core are exposed to argon. Although solid lubricants etc. can be applied to achieve anti-friction and anti-wear performances for those parts where temperature is low and sodium vapor is absent, it is necessary to take prudent attitude in planning the selection of materials for complicated parts where lubricants can not be applied, high temperature parts or high speed sliding parts.

The authors wish to express their appreciation to Mr. R. Saito, Sodium Engineering Division Manager and Messrs. K. Mochizuki and K. Yamamoto, Senior Engineers in FBR Project. Also the authors wish to express their appreciation to Mr. S. Mizobuchi, presently the Central Research Laboratory of Ebara Manufacturing Co., Ltd. Many thanks to the room mates who made kind cooperation for loop operations and for analysing tests.

6. References

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(2) S. Kano, et al. "ibid. (II)", SN 941, 74-12

(3) S. Kano, et al. "ibid. (III)", SN 941, 74-80

(4) S. Kano, et al. "ibid. (IV)", SN 941, 75-73

(5) S. Kano, et al. "ibid. (V)", SN 941, 75-73

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(7) S. Mizobuchi, et al. "ibid. (V)", SN 941, 75-49

(8) S. Mizobuchi, et al. "ibid. (VI)", SN 941, 76-32

(9)

(10) S. Mozobuchi, et al. ZN 942, 74-08

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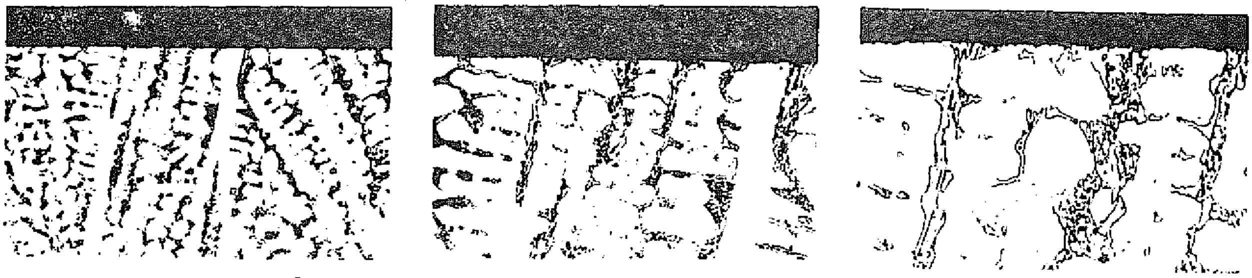
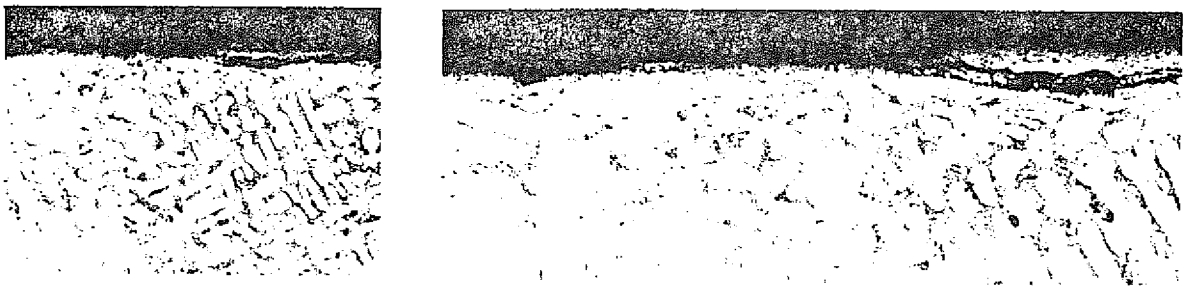
(13) Dennetsukogakushiryo, 3rd Edition JSME (1975)

(A) In-Sodium Test



x100 x200 x400

(B) In-Argon Test

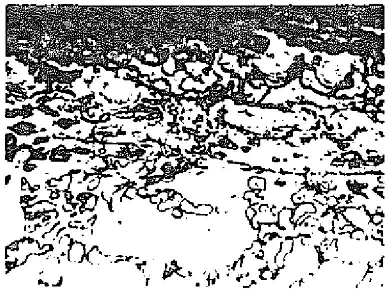


x100 x200

Photo. 2 Cross-Sectional Micrographs of Stellite No.6
(vs. Stellite No.6)

(A) In-Sodium Test

x100



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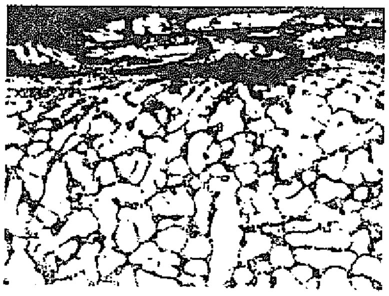
(B) In-Argon Test

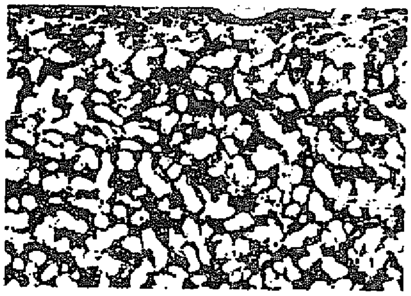


x100

x400

Photo. 3 Cross-Sectional Micrographs of Colmonoy No.4
(vs. Colmonoy No.4)

(A) In-Sodium Test



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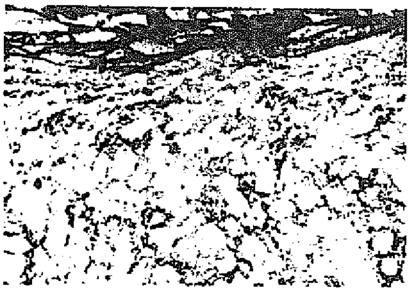
x400

(B) In-Argon Test

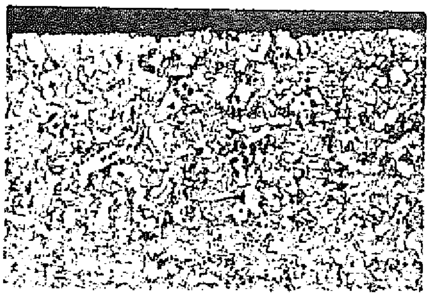


x100

x400

Photo. 4 Cross-Sectional Micrographs of Colmonoy No.5
(vs. Colmonoy No.5)

(A) In-Sodium Test



x100

x200

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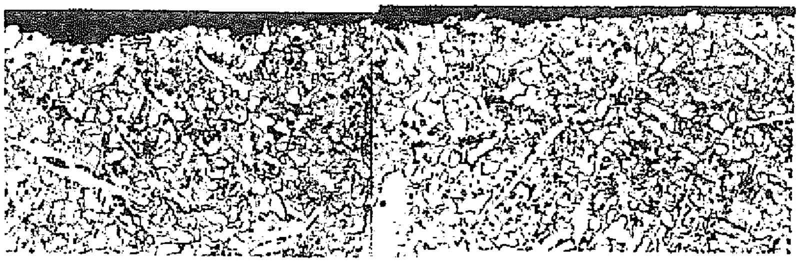

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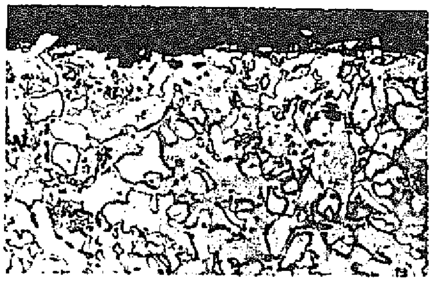
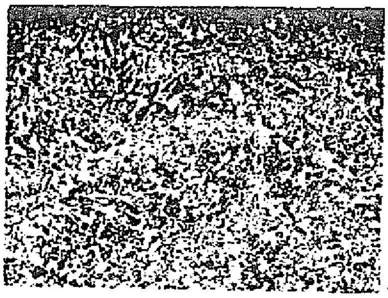


x200

x400

Photo. 5 Cross-Sectional Micrographs of Colmonoy No.6
(vs. Colmonoy No.6)

(A) In-Sodium Test



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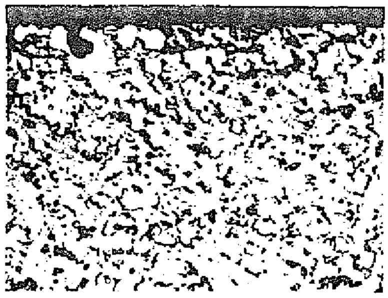

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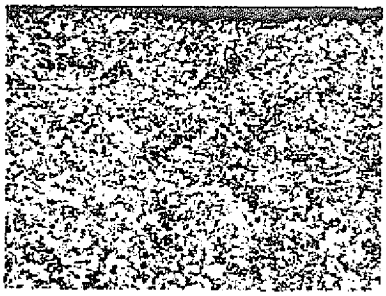

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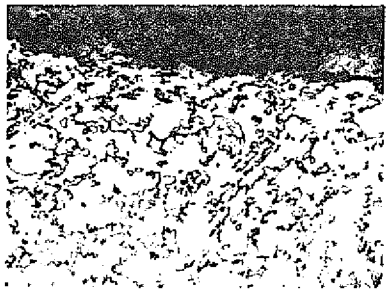
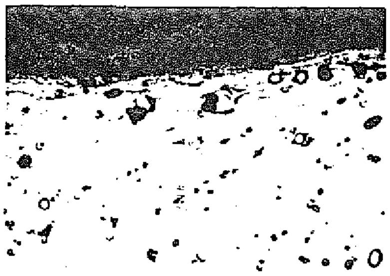


x400

Photo. 6 Cross-Sectional Micrographs of Deloro Stellite SF-60M (vs. Deloro Stellite SF-60M)

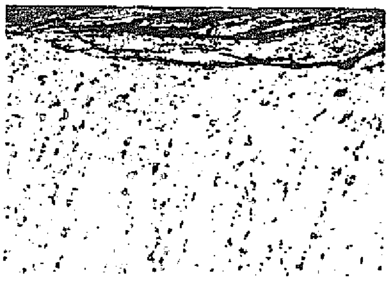
(A) In-Sodium Test

X100



X400

(B) In-Argon Test



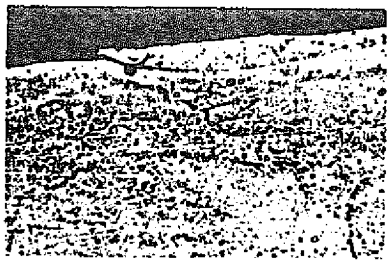
X100

X400

Photo. 7 Cross-Sectional Micrographs of Hastelloy C
(vs. Hastelloy C)

(A) In-Sodium Test

x100



x400

x200

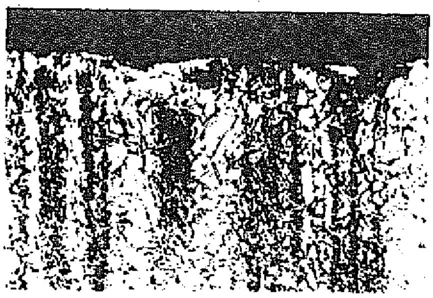
(B) In-Argon Test

x100

x400

Photo. 8 Cross-Sectional Micrographs of Inconel X
(vs. Inconel X)

(A) In-Sodium Test



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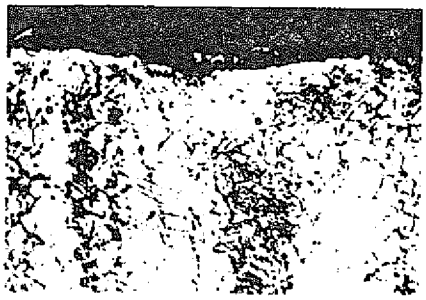
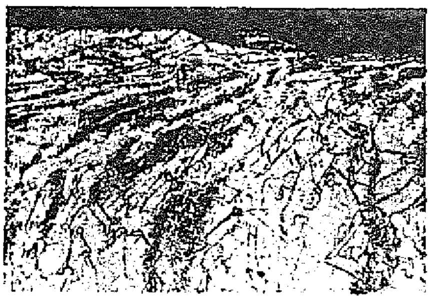


x200

(B) In-Argon Test

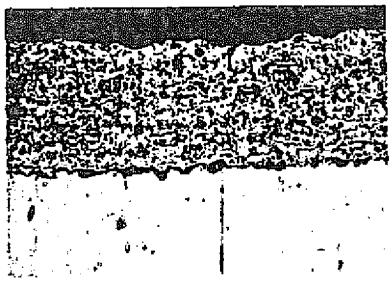


x100

x200

Photo. 9 Cross-Sectional Micrographs of Inconel 718
(vs. Inconel 718)

(A) In-Sodium Test

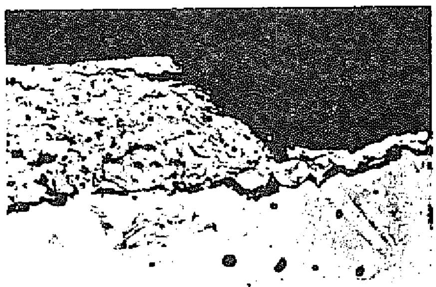


x100

(B) In-Argon Test

x50

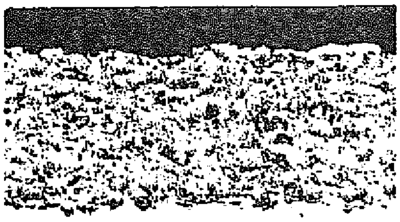
x100



x200

Photo. 10 Cross-Sectional Micrographs of LC-1C
(vs. LC-1C)

(A) In-Sodium Test



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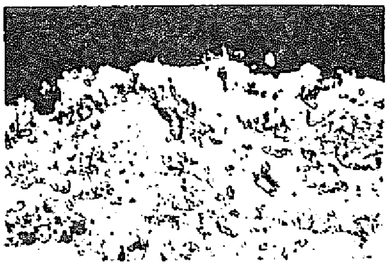

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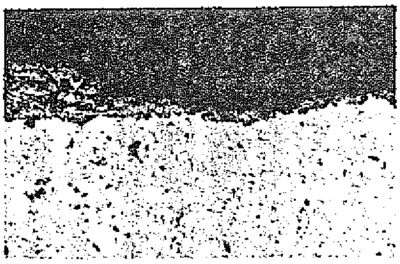
(B) In-Argon Test



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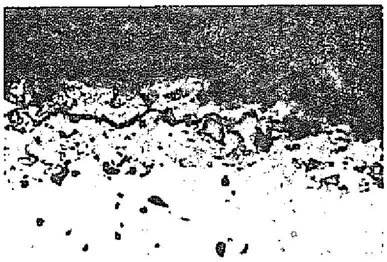

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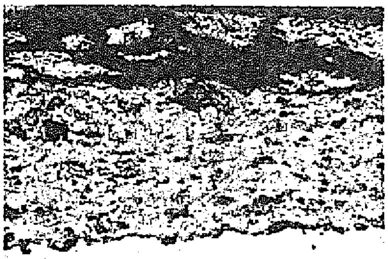

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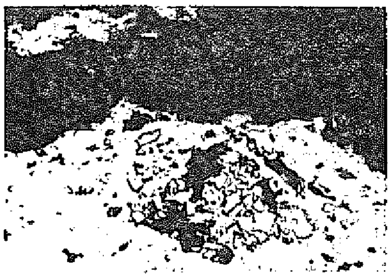
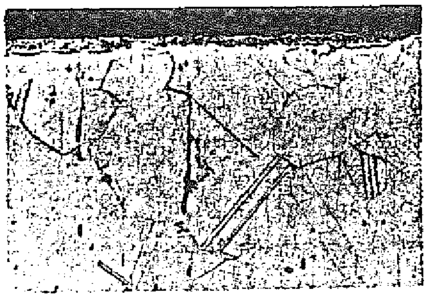


x400

Photo. 11 Cross-Sectional Micrographs of LW-1N40
(vs. LW-1N40)

(A) In-Sodium Test



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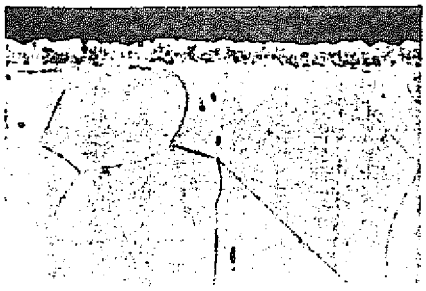

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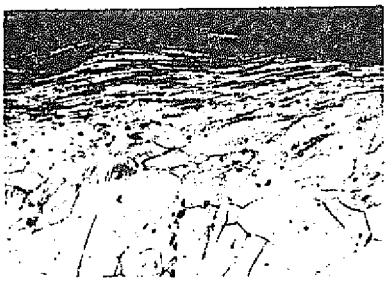
(B) In-Argon Test

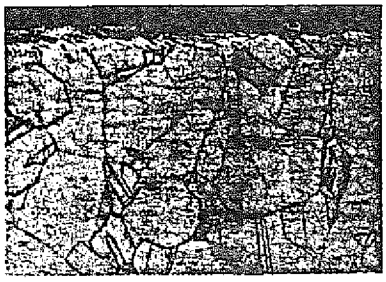


x100

x400

Photo. 12 Cross-Sectional Micrographs of SUS304 (vs. SUS304)

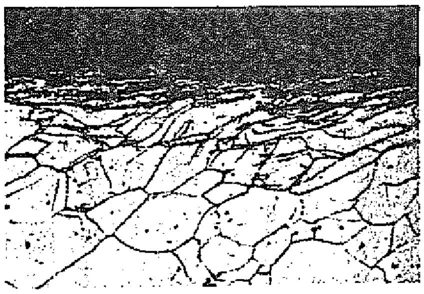
(A) In-Sodium Test



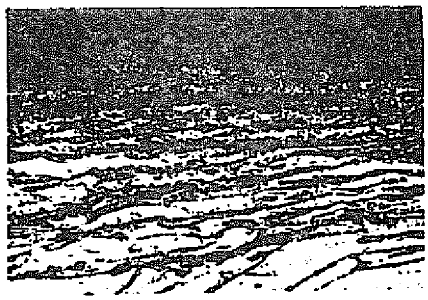
x100

x200

(B) In-Argon Test



x100



x400

Photo. 13 Cross-Sectional Micrographs of SUS304
(vs. Stellite No.6)

Table 1 Condition of Friction Test

	In-Argon Test	In-Sodium Test
Test Temperature (°C)	Room Temperature	280 and/or 450
Cold Trap Temperature (°C)	——	200
Configuration of Test Piece	Ring and Disc	Similar to In-Argon Test
Apparent Contact Area of Test Piece (cm^2)	2.2	〃
Load	Incremental Load	〃
Sliding Velocity (cm/sec)	~ 0.3	〃
Quantity to be Determined	Initial Torque	〃

Table 2 Condition of Wear Test

	In-Argon Test	In-Sodium Test
Test Temperature (°C)	Room Temperature	450
Cold Trap Temperature (°C)	——	200
Configuration of Test Piece	Ring and Disc	Similar to In-Argon Test
Apparent Contact Area of Test Piece (cm^2)	2.2	〃
Load	Incremental Load	〃
Sliding Velocity (cm/sec)	3.6	〃
Total Sliding Time (hrs)	2.5	〃
Quantity to be Determined	Sliding Torque, Wear Rate	

Final Load 390 kg

Table 3 Chemical Composition (w/o)

Material	Symbol	C	Si	Ni	Co	Cr	Fe	Mn	W	Cu	Ti	AL	Mo	V	Nb	Ta	P	S	B
Type 304 SS	304	0.06	0.59	8.63		18.64	Bal	1.54											
Stellite NO.1	S1	2.58	1.16		Bal	31.33	0.28		12.49										
Stellite NO.6	S6	1.04	1.17		Bal	28.65	0.27		4.20										
Colmonoy NO.4	C4	0.40	3.00	Bal		10.00	3.20												2.00
Colmonoy NO.5	C5	0.54	3.47	Bal		11.50	3.47												2.05
Colmonoy NO.6	C6	0.75	4.25	Bal		13.50	4.75												3.00
Deloro Stellite SF-60M	DS		4.5	Bal		15	4.5												3
Hastelloy C	HC	0.07	0.34	Bal	TR.	14.65	5.92	0.54	3.31				15.46	0.03			0.008	<0.005	
Inconell x 750	IX	0.023	0.05	73.07		15.14	7.15	TR.		TR.	2.56	0.76			1.01			<0.005	
Inconell 718	I718	0.06	0.09	52.77	0.03	18.74	Bal	0.14		0.03	1.00	0.65	3.05		4.84		0.010	0.003	0.003
LC-1C	LC-1C	85 % Cr_3C_2 + 15 % Ni Cr																	
LW-1N40	LW-1N40	85 % WC + 15 % Co																	

Table 4 Material Combination

Stator	Rotor
S6	S6
304	S6
S1	S1
304	S1
S1	C6
C6	DS
C5	C6
DS	DS
C4	C4
C5	C5
C6	C6
IX	IX
I718	I718
HC	HC
LC-1C	LC-1C
LW-1N40	LW-1N40
304	304

Table 5 Coating Method

Coated on SUS 304

Material	Coating Methed	Coating Thickness (mm)
Stellite No. 1, No. 6 and No. 12	Oxy-Acetylene Gas Weld	~ 2
Colmonoy No. 4, No. 5 and No. 6	〃	~ 2
Deloro Stellite SF-60M (150~250 Mesh)	Sprayed Coating	~ 2
LC-1C (-325 Mesh)	Detonation-Gun Coating	~ 0.2
LW-1N40 (-325 Mesh)	〃	~ 0.2

Test pieces of Type 304 SS, Hastelloy C, Inconel X750, and Inconel 718 were prepared by mechanical fabrication

Table 6 Wear Rate

Material Combination		Wear Rate of Stator					
		after Tested in Sodium			after Tested in Argon		
Stator	Rotor	W_D (μm)	W_V (mm^3)	W_S (mm^2/kg)	W_D (μm)	W_V (mm^3)	W_S (mm^2/kg)
S6	S6	4	0.18	2.87×10^{-9}	14.5	2.72	4.34×10^{-8}
304	S6	8	0.31	4.94×10^{-9}	82	34.18	5.45×10^{-7}
S1	S1	~0	~0	~0	38	6.79	1.08×10^{-7}
304	S1				25	410.49	6.55×10^{-6}
S1	C6	0.7	0.037	5.88×10^{-10}	27	6.20	9.89×10^{-8}
C6	DS	~0	~0	~0	35	3.30	5.26×10^{-8}
C5	C6	~0	~0	~0	72	9.46	1.5×10^{-7}
DS	DS	~0	~0	~0	13	0.86	1.38×10^{-8}
C5	C5	~0	~0	~0	49	9.27	1.48×10^{-7}
C6	C6	2.5	0.11	1.81×10^{-9}	12	0.80	1.28×10^{-8}
IX	IX	96	30.53	4.87×10^{-7}	117	45.20	7.21×10^{-7}
I718	I718	13.1	1.20	1.92×10^{-8}	52	23.66	3.77×10^{-7}
HC	HC	5.1	0.73	1.16×10^{-8}	108	48.92	7.80×10^{-7}
LC-1C	LC-1C	11	1.68	2.68×10^{-8}	170	89.75	1.43×10^{-6}
LW-1N40	LW-1N40	~0	~0	~0	162	61.24	9.77×10^{-7}
304	304	5	0.37	5.90×10^{-9}	83	33.22	5.30×10^{-7}

Sliding Velocity : 3.6 cm/sec Final Load : 390 kg

Table 7 Roughness

Hmax

Material Combination		Roughness (μm)				
		as Received		after Tested in Sadium		after Tested in Argon, Stator
Stator	Rotor	Stator	Rotor	Stator	Rotor	
S6	S6	1	1	1.5	3.2	5
304	S6	0.4	1	3	0.6	21
S1	S1	0.4	0.4		0.6	14
304	S1	0.4	0.4			10
S1	C6	0.4	1	0.7	1	7
C6	DS	1	0.6	2	0.9	13
C5	C6	1	1	1.4	1.5	12
DS	DS	0.6	0.6			8
C5	C5	1	1			19
C6	C6	1	1	1	2	13
IX	IX	0.7	0.7	12	4	20
HC	HC	2	2	2	3	22
LC-1C	LC-1C	0.4	0.4	4	6	23
LW-1N40	LW-1N40	14	14	10	9	22
304	304	0.4	0.4	2.4	9	34

Table 8 Microhardness

100g

Material Combination		Microhardness (Hv)					
		as Received		after Tested in Sodium		after Tested in Argon	
Stator	Rotor	Stator	Rotor	Stator	Rotor	Stator	Rotor
S6	S6	585		907		722	
304	S6	298	585	669	752	606	592
S1	S1	870(1650)		914		907	
304	S1	298	870	457	813	473	767
S1	C6	870	824	1035	835	882	988
C6	DS	824(1854)	762	752	894	813	907
C5	C6	464	824	657	592	782	772
DS	DS	762		715		792	
C5	C5	464		634		894	
C6	C6	824		615		837	
IX	IX	459		592		572	
I 718	I 718	503		583		592	
HC	HC	429		714		627	
LC-1C	LC-1C	782		1033		847	
LW-1N40	LW-1N40	1267		1427		1168	
304	304	298		639		525	

The number in parenthesis shows the hardness of carbide precipitated in matrix.

Table 9 Physical properties of Argon(12) and Sodium(13) under the pressure of 1 kg/cm^2

	Temp. [°C]	Density [kg/m^3]	Specific heat [kcal/kg·°C]	Viscosity [kg·sec/m^2]	Thermal conductivity [kcal/m·h·°C]
Argon	0	1.785	0.1247	2.166x10^{-6}	1.406x10^{-2}
	100	1.305	0.1245	2.774 〃	1.815 〃
	200	1.029	0.1245	3.307 〃	2.180 〃
	300	0.8494	0.1244	3.789 〃	2.512 〃
	400	0.7231	〃	4.234 〃	2.812 〃
	500	0.6296	〃	4.654 〃	3.094 〃
	600	0.5579	〃	5.052 〃	3.358 〃
Sadium	0	—	—	—	—
	100	927	0.333	6.94x10^{-5}	74.7
	200	904	0.326	4.61 〃	70.5
	300	880	0.321	3.52 〃	66.3
	400	856	0.316	2.90 〃	62.1
	500	832	0.312	2.51 〃	57.9
	600	808	0.309	2.12 〃	53.7

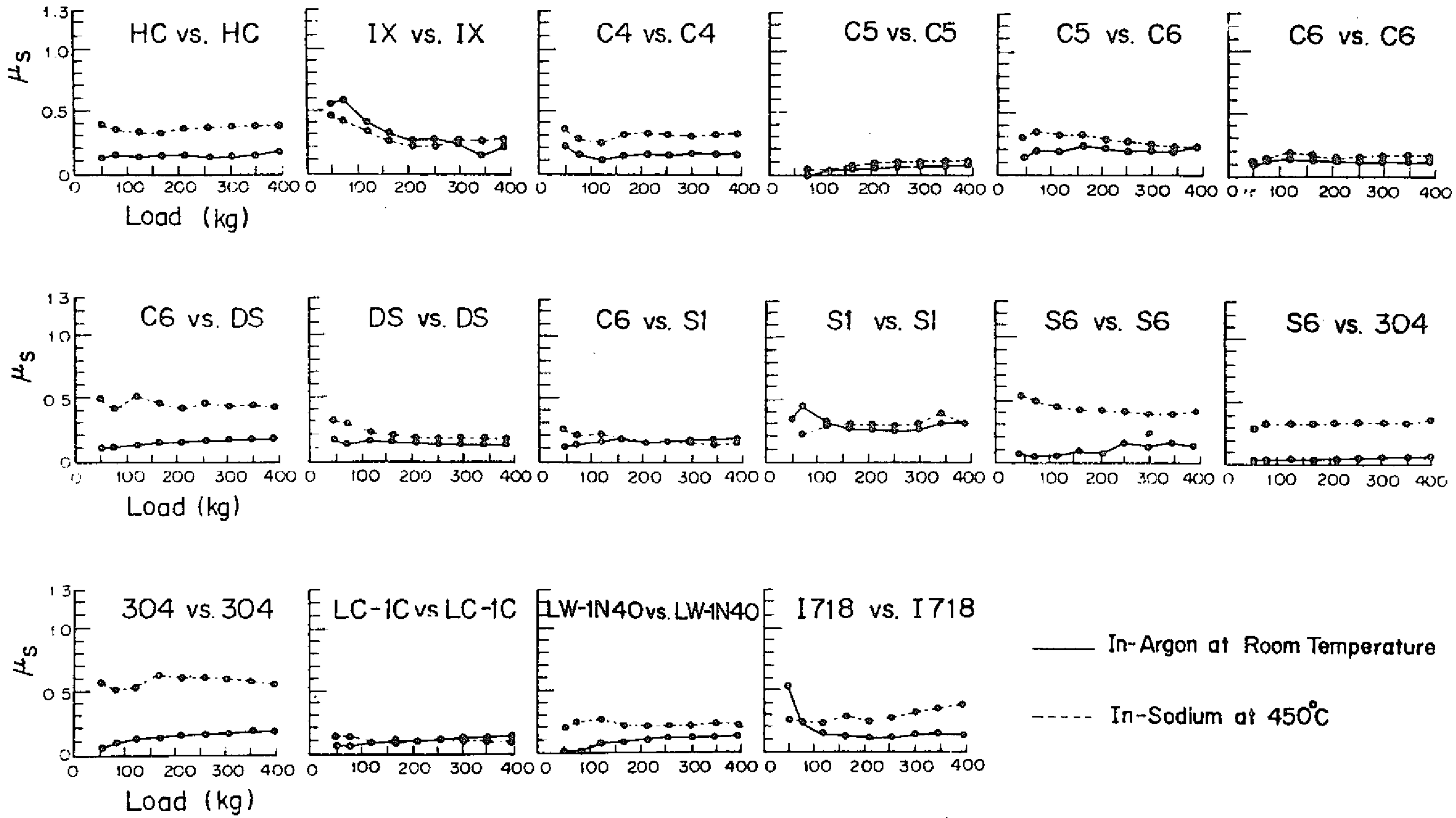


Fig. 1 μ_S vs. Load

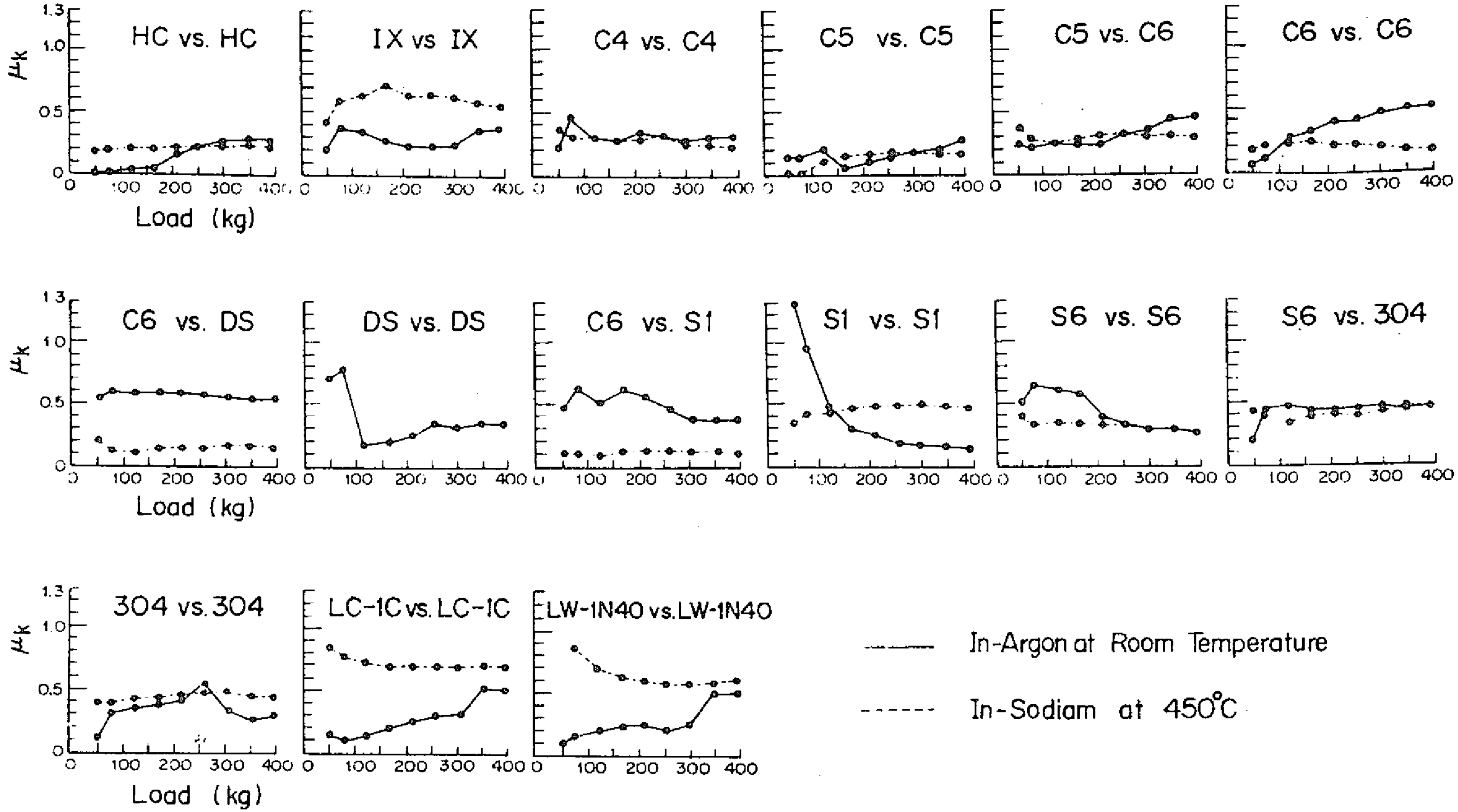


Fig. 2 μ_k vs. Load

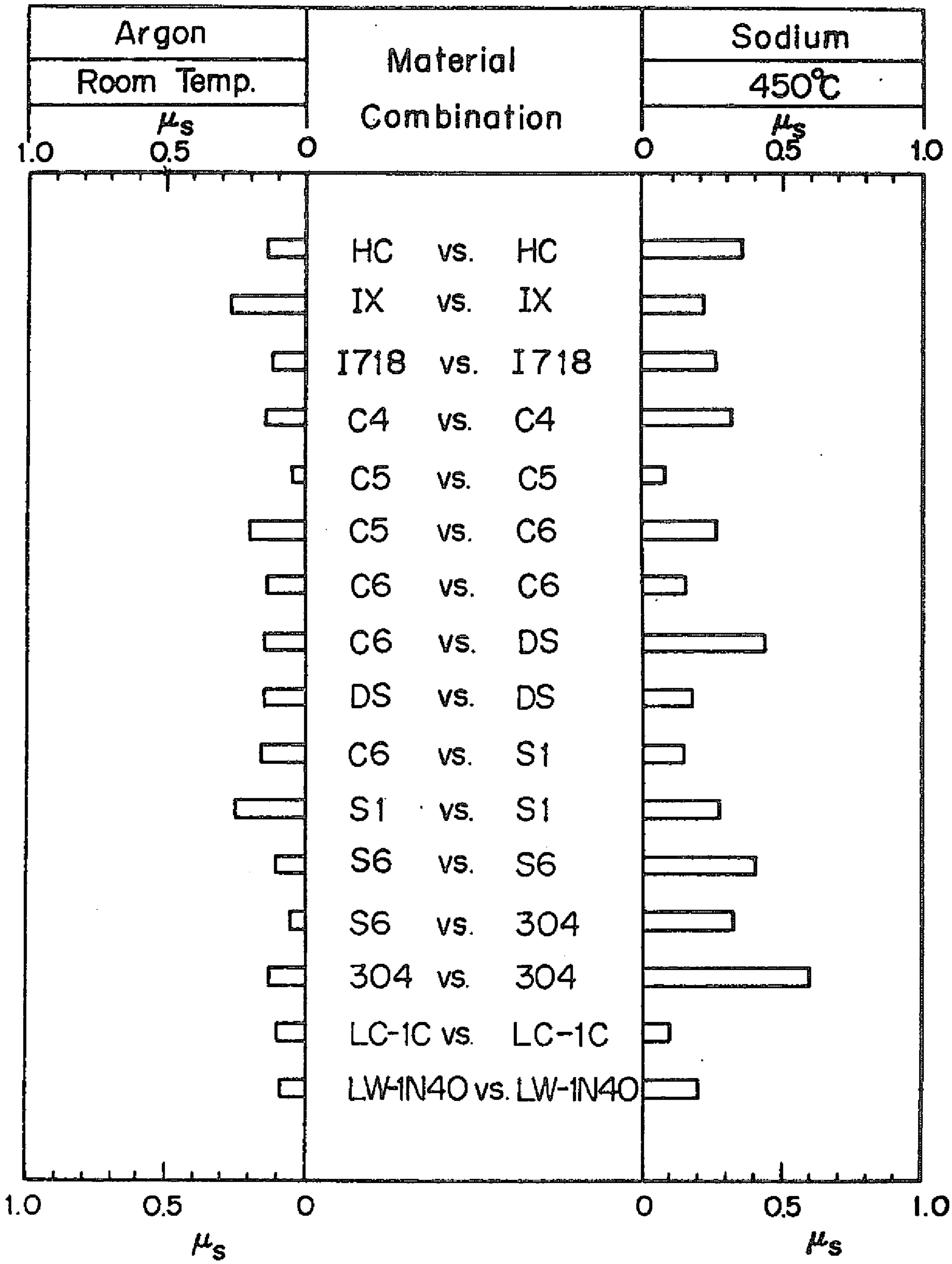


Fig. 3-1 Static Friction Coefficient μ_s under the Load of 220 kg

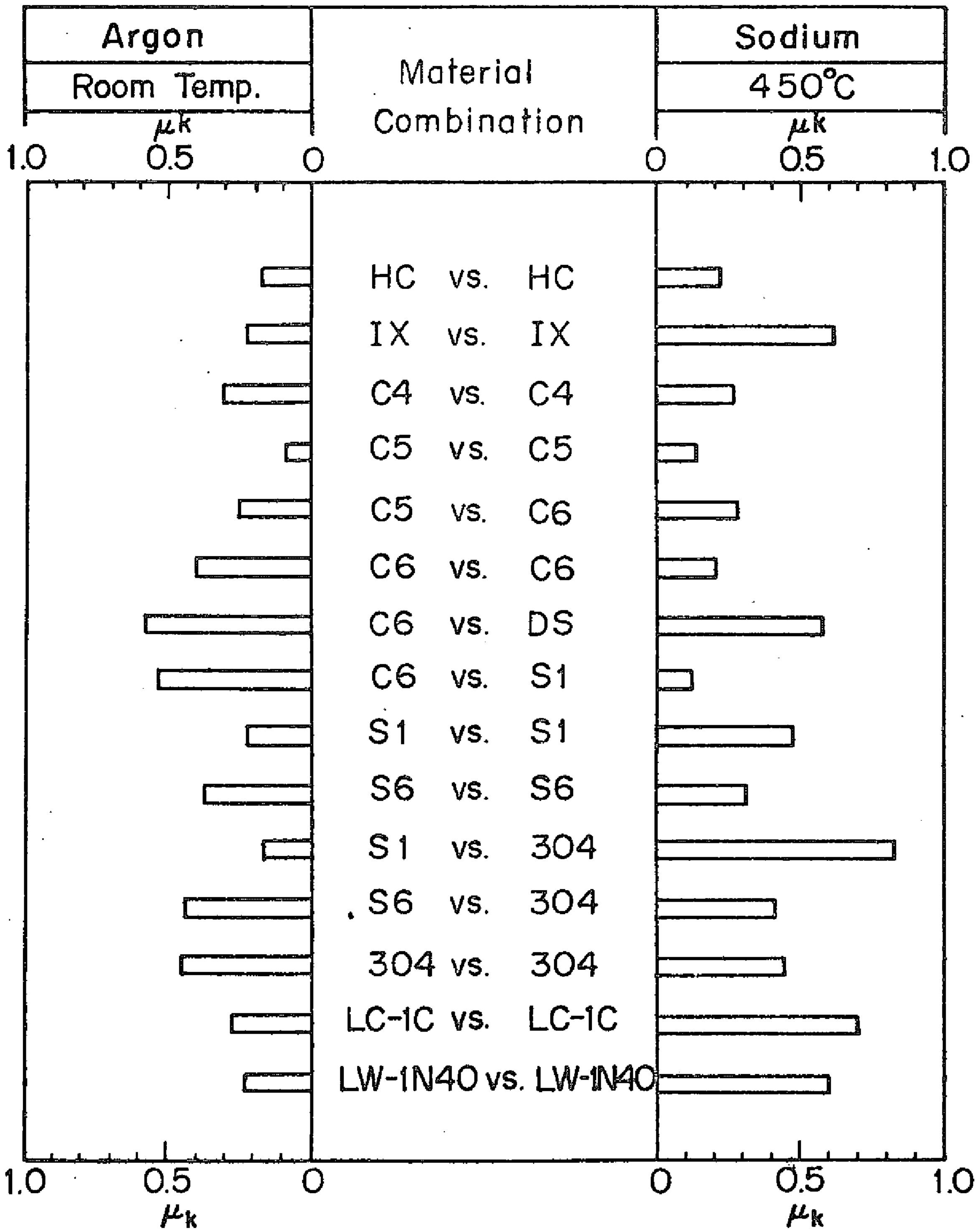


Fig. 3-2 Kinetic Friction Coefficient μ_k under the Load of 220 kg

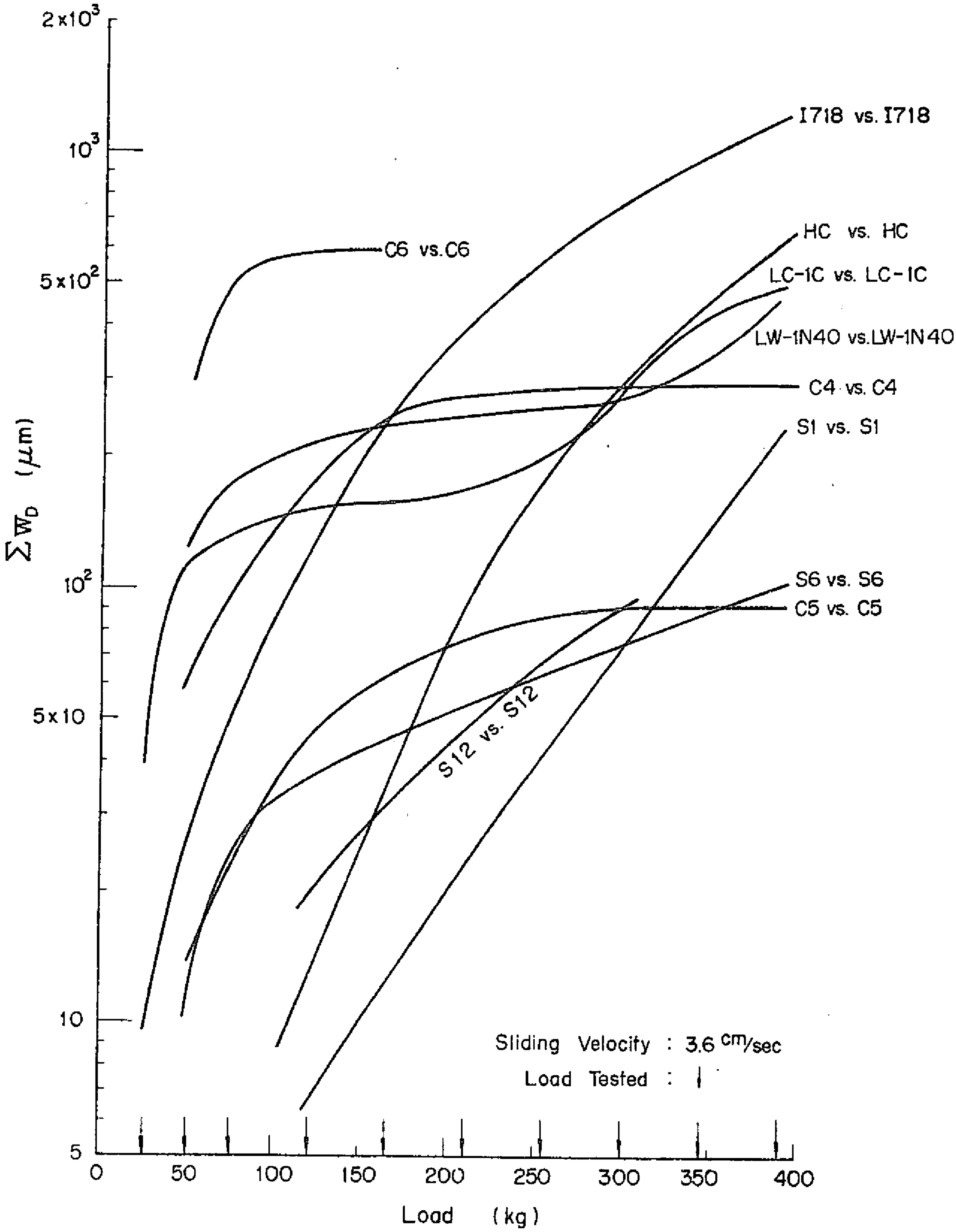


Fig. 4 Wear Depth vs. Load in Argon at Room Temperature

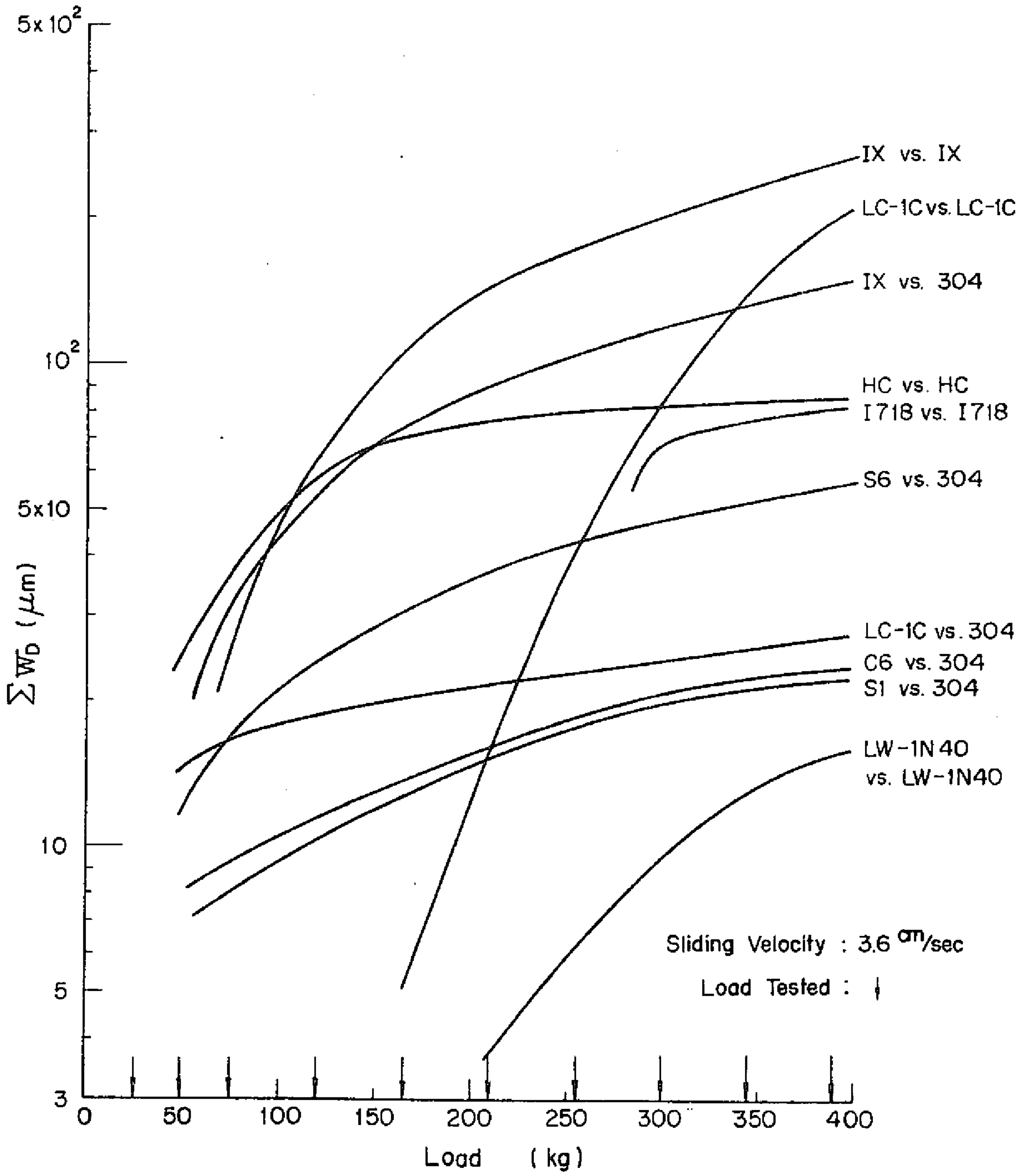


Fig. 5 Wear Depth vs. Load in Sodium at 450°C

C5 vs. C5
C5 vs. C6
C6 vs. C6
C6 vs. DS
C6 vs. S1
S1 vs. S1
S6 vs. S6

} Not Detectable

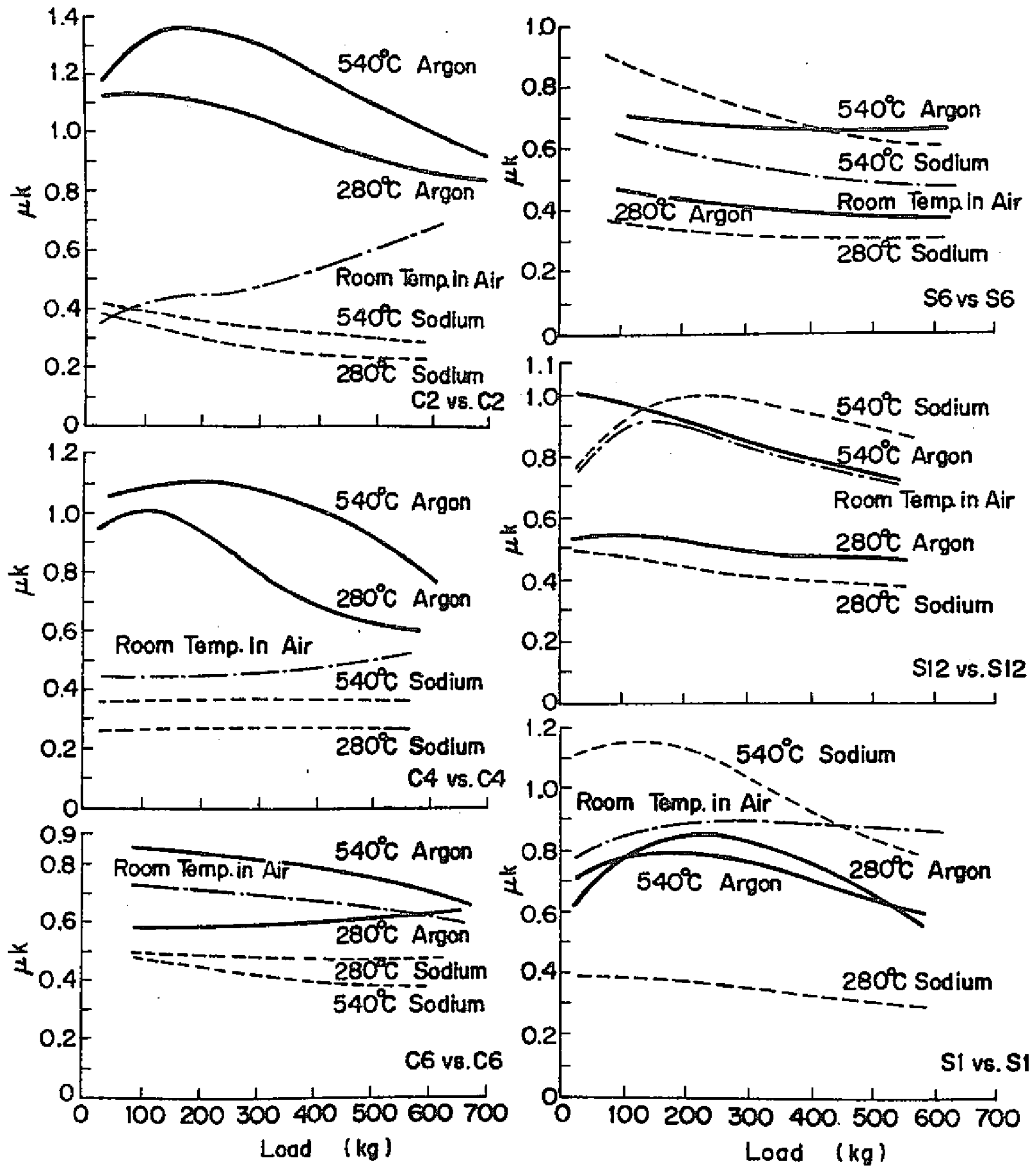


Fig. 6 Relation between μ_k and load in different environments (SW-2)

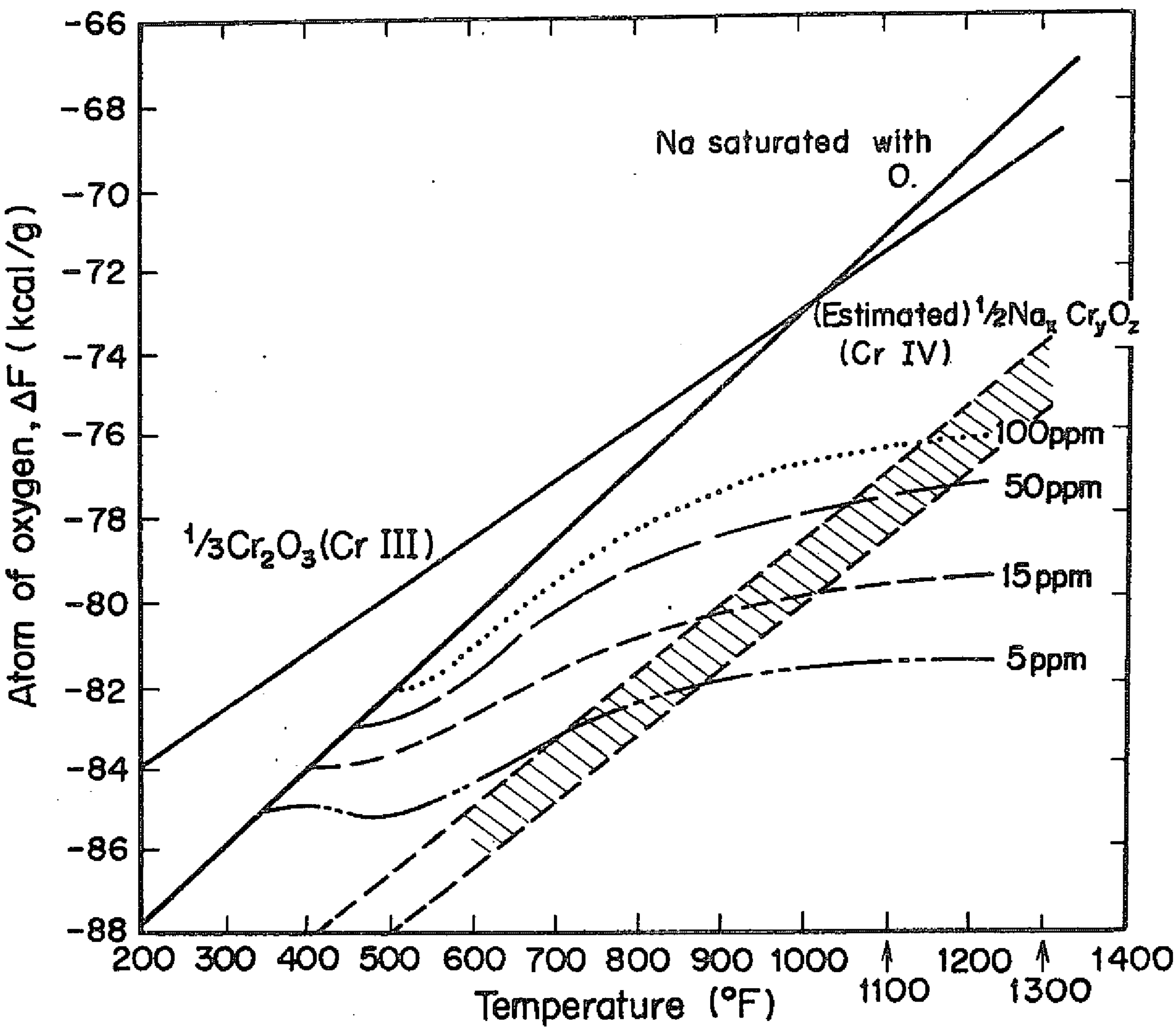


Fig. 7 Free Energies of Interest in Sodium-Oxygen-Chromium

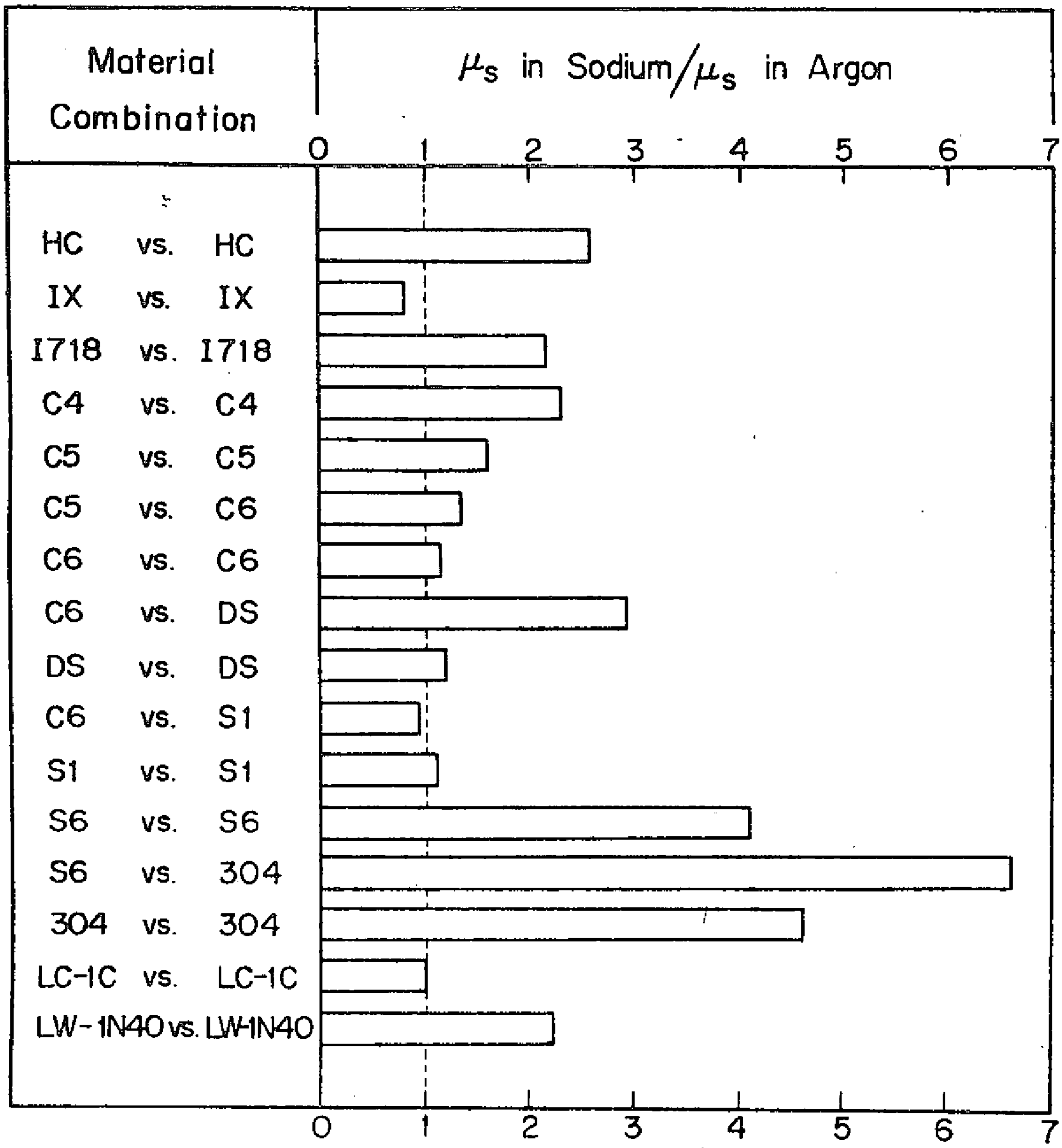


Fig. 8-1 Ratio of Static Friction Coefficients in Sodium and Argon under the Load of 220 kg.

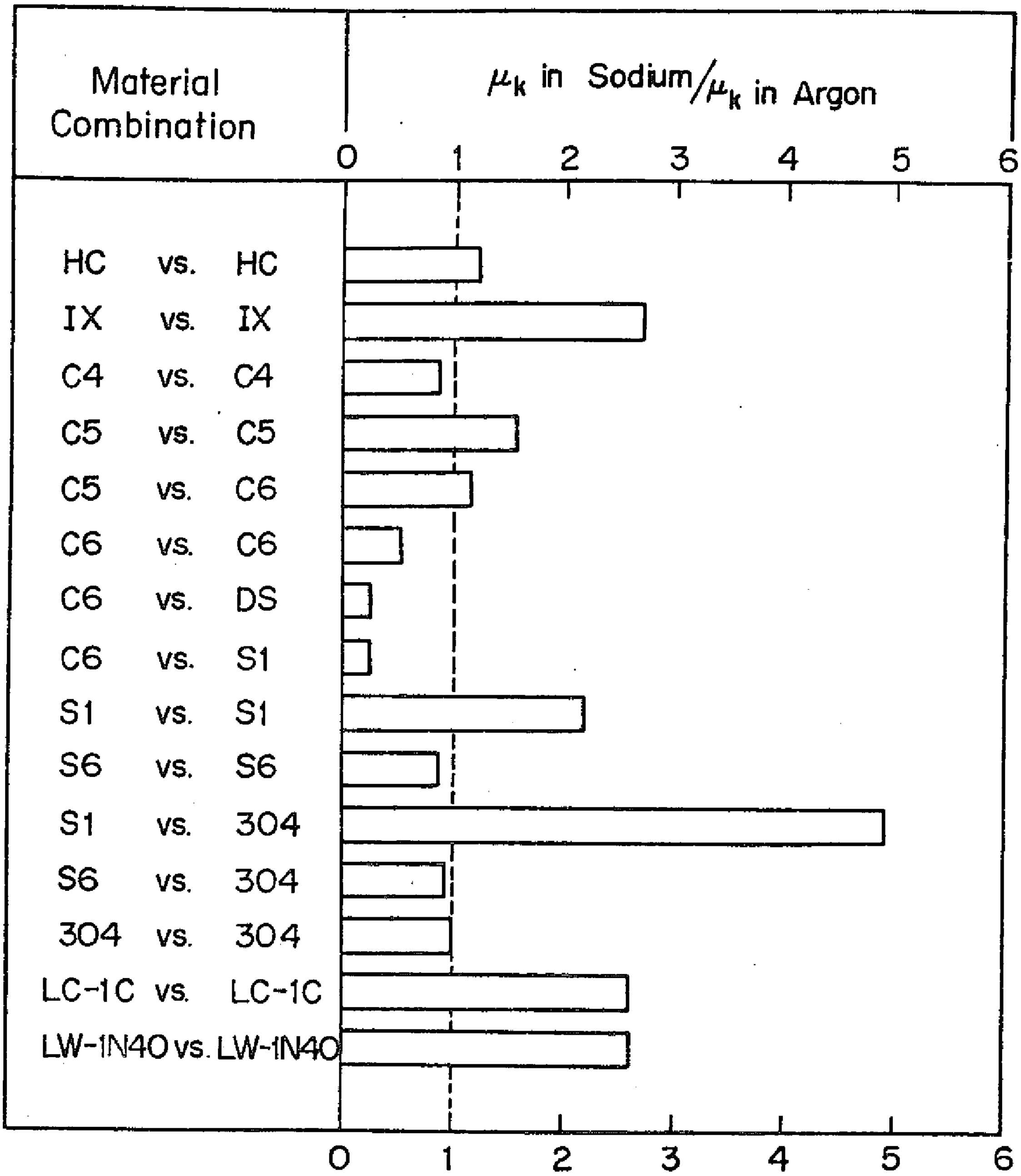


Fig. 8-2 Ratio of Kinetic Friction Coefficients in Sodium and Argon under the Load of 220 kg