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HIGH TEMPERATURE TESTS OF
STANDARD NEEDLE BEARINGS

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INTRODUCTION

Summarized herein are the results of tests of standard needle bearings. These tests were conducted with liquid metal lubrication as well as dry, in an investigation of the effects of some circumstances under which these bearings might be employed in control mechanisms.

CONCLUSION

Standard needle bearings can be run successfully to several million operations under certain conditions of poor lubrication.

Bearings tested under the following conditions were in fair operating condition after the tests described herein:

1. NaK lubrication
2. 800°F temperature
3. Oscillating motion up to 5°.

DESCRIPTION OF TEST BEARINGS AND EQUIPMENT

All the bearings tested were Torrington type NCS, made of standard bearing material, SAI 52100 steel. The initial hardness was as follows:

Needles - - - - 62 Rc
Inner Race - - - 60 Rc
Outer Race - - - 59 Rc

The races of the bearings used in tests 1.15 to 1.44 inclusive were No. 162412 (outer) and No. 121612 (inner). The outer race O.D. is 1 1/2 inches, the race I.D. is 3/4 inch. The bearing is 3/4 inch long. Those of tests 5 to 8 inclusive were No. 263516 (outer) and No. 212616 (inner). Their catalog load ratings at 50 rpm in oil are 3580 lb and 9300 lb respectively.

The liquid metal bearing tester employed in tests 1.15 to 1.44 inclusive is described in Memo EDL-24.

The dry bearing tester employed in tests 5 to 8 inclusive is described in Memo EDL-25.

DATA

SUMMARY OF TEST DATA ON NEEDLE BEARINGS
March 14, 1951

Test No.	1.15	1.22	1.25	IX 1.29a	IX 1.29b	1.33	1.36	1.42	1.43	1.44	6	7	8	9
Ambient Conditions	800°F	800°F	800°F	800°F	800°F	800°F	800°F	800°F	800°F	800°F	77°F air	77°F air	77°F air	77°F air
Lubrication	MAE	MAE	MAE	MAE	MAE	MAE	MAE	MAE	MAE	MAE	dry	dry	dry	dry
No. operations	2.5×10^6	2.5×10^6	4×10^6	3.2×10^6	4.4×10^6	2.7×10^6	2.5×10^6	2.7×10^6	2.7×10^6	2.5×10^6	2.3×10^6	2.6×10^6	360 Revs	50 Revs
Type of operation	1/2° osc.	5° osc.	5° osc.	5° osc.	5° osc.	20° osc.	5° osc.	5° osc.	5° osc.	20° osc.	1/2° osc.	1 1/2° osc.	5 rev, cool 2-3 sec.	50 Revs
Hours of operation	67 3/4	70 1/4	128 1/3	121	146	128 1/4	70	71	70	90	85	44	1 1/2	2-3 sec.
Speed, cy/min	620	606	625	438	438	350	600	600	640	470	610	1000	0-1000 RPM peak	1130 RPM
Load, Pounds	490	490	410	410	610	480	280	490	650	490	300	300	300	600
Speed, % Rated	13 1/2	13 1/2	6	6	17	11 1/2	—	13 1/2	—	13 1/2	3 1/4	3 1/4	3 1/4	6
Hardness after test														
Needles	40-43 R _c +	39 R _c +	44 R _c +		26 R _c	26 R _c	64-69 R _c	—	—	—	—	—	—	—
Inner Race	40-43 R _c	40 R _c	39-40 R _c		38 R _c	38 R _c	70 R _c	—	—	—	—	—	—	—
Outer Race	47 R _c	46-47 R _c	47 R _c		42 R _c	45 R _c	71 1/2 R _c	—	—	—	—	—	—	—
Condition after Test														
Needles	Fretting corrosion	Spalled one end	Fretting corrosion	Test continued as No. 1.29b without shut down	Fretting corrosion	Spalled	Polished. Tend. to Elastic Deform.	Trace of fretting corrosion		Spalled	Fretting corrosion	Fretting corrosion	Badly spalled	Spalled
Inner Race	"	"	"		"	"	Minute trace of fretting			Spalled	"	"	"	"
Outer Race	"	"	"		"	"	Trace of fretting corrosion			Spalled	"	"	"	"
Should test have continued?	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No

Stated load is assumed to be the catalog rating at 30 RPM.

*Converted from Vickers 1 Kg. hardness.

Results of these two tests are clouded by the fact that the MAE was carbon contaminated from an oil leak.

Wearing seized on first cycle.

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DISCUSSION OF RESULTS

LIFE

The data indicate satisfactory operation under the conditions of test, to a life of at least several million cycles. The comparison of $1/2^\circ$ and 5° oscillation with 20° oscillation shows that an increase in the arc of motion creates an increase in the rate of wear. (See photographs Figs. 1, 2, 3, and 4, page 9). Observation of the bearing that had received the 20° test leads to the conclusion that it would have been incapable of rotation to a much larger angle. Other rough tests on the dry tester have indicated no possibility of running continuously in one direction without lubrication.

The 20° motion is more than enough to move the roll from its original position to the position of the adjacent roll. The actual amount required is 17° for the design tested. It seems unlikely that the bearings will work beyond this point for very many cycles, starting new.

The data show the effect of increased arc of oscillation and increased load in increasing wear. For example, a comparison of Test 1.22 with Tests 1.25 and 1.33 indicates that increased amplitude caused a greater increase in wear than did increased load. That no bearings had failed to operate after several million operations is due to the relatively low amplitude and load. Undoubtedly, failures could have been induced at a low number of cycles by increasing the load and/or amplitude.

The loading given in Data, page 7, was applied to the bearing by an external means. Bearings tested in NaK as received were found, after test, too tight to assemble without force after once having been disassembled. This was caused by grain growth associated with microstructure transformation during the long aging period, while in test, at elevated temperature (higher than the draw temperature when the bearing was heat-treated). Since such changes require only a few hours at constant temperature, it is likely that this preload was on during most of the test. The additional apparent load caused by this is unknown.

AGING

Aging the bearing prior to mounting on any shaft, or loading in a test, stabilized the bearing so that no binding occurred. The aging cycle corresponded to the test cycle for welding described below simply because such a process was convenient. Aging was accomplished by putting the bearings in the tester while the other test was running. Tests 1.42, 1.43, and 1.44 were conducted with bearings aged in this manner. As these bearings were not sectioned after test, detailed observations on the conditions of the races are not available. Inspection of the needles and general feel of the bearing indicated slightly less wear except in the case of 20° oscillations.

WELDING

One bearing was tested in order to determine whether prolonged exposure to NaK at high temperatures, under load, would cause welding and consequent

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FIG. 1. NEEDLE BEARING ASSEMBLY
AS RECEIVED

FIG. 2. NEEDLE BEARING ASSEMBLY
RUN IN NaK AT 800°F. TEST No. 1.15
 $\frac{1}{2}^{\circ}$ OSCILLATION

FIG. 3. NEEDLE BEARING ASSEMBLY
RUN IN NaK AT 800°F. TEST No. 1.22
 5° OSCILLATION

FIG. 4. NEEDLE BEARING ASSEMBLY
RUN IN NaK AT 800°F. TEST No. 1.33
 20° OSCILLATION

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high breakaway torques. This bearing (as well as those being aged) was held at 900°F for one hour and then held at 800°F for two hours, after which the torque was measured. Torque was measured after alternate intervals of one and two weeks at rest at 800°F and 450 lb load for a total of six weeks. During this time, the torque tended to decrease at each measuring period. This is not significant, however, in view of the difficulty of measuring such low torques in the test machine being used, where seal friction is greater than the torques of the bearings. Hence, no data is presented. In no case was a measured torque higher than the initial value, and it is concluded that no significant welding of the various parts to each other takes place.

HARDNESS

The final hardness shown is to be expected from the metallurgical standpoint. It is believed that the low needle hardnesses on Tests 1.29b and 1.33 are due to the use of the Rockwell tester as compared to the Vickers tester. The smaller Vickers indent gives a truer value for surface hardness. A Rockwell test for Test 1.25 showed comparable hardness to that for Tests 1.29 and 1.33.

SPEED

Although cycling speed is supposed to affect bearing life, it was not obvious in these tests. It is probable that speed effects were swamped by the other abnormal conditions.

LUBRICANT

The value of small amounts of a lubricant better than NaK is shown by Tests 1.29a and 1.29b. During the operation of this test, a coolant oil housing failed and allowed oil to contaminate the NaK. Small amounts of carbon in a form resembling graphite were found in the bearing after test. Even though a total of 7.6 million cycles was run, about two-thirds with the highest load of any test, the resulting wear consisted of fretting corrosion only. The bearing appeared to be in better condition at the end of the test than any other bearing tested in NaK.

Several other rough tests on the dry bearing tester also provided proof of the value of even small amounts of lubricant. In one case, continuous rotation was attempted at room temperature, dry, with a 300 lb load, and with the same size bearings as were used in Tests 5 through 8. Only a few revolutions were obtained prior to seizing. The bearing could not be re-started, even in the opposite direction, under load. Two drops of machine oil were placed in the bearing, worked in by hand with no load on the bearing. The test then ran for ten minutes and was stopped, although it could have continued further. In another instance, the same size bearing with the same load ran continuously for 175,000 revolutions at 1160 rpm with water mist lubrication. The bearing was operable when the test was stopped.

MICROSTRUCTURE

Representative needles from Test 1.15 ($1/2^\circ$ oscillation) Test 1.22 (5° oscillation) and Test 1.33 (20° oscillation) were sectioned, etched, and

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FIG. 5
MAGNIFICATION OF DECARBURIZED AREA OF NEEDLE BEARING 52100 RUN IN NaK AT 800°F.
TEST No. 1.33

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examined microscopically. The microstructure from Tests 1.15 and 1.22 indicated no unusual conditions. That from Test 1.33, shown in the photograph Fig. 5, page 11 exhibited slight decarburization at the surface. It is believed that the excessive surface disturbance and operating temperature experienced in this test permitted more intermixing of the needle surface with the NaK ambient, resulting in carbon removal.

HARDNESS CURVE

Curve No. AV1088, page 13 shows the hardness radially inward from the surface of the needles, for Tests 1.15, 1.22, and 1.33. Observe that as the angle of oscillation increases, there is a decrease in surface hardness after test. The depth to which softening occurs also increases with an increased arc of oscillation. It is believed that this is caused by higher surface operating temperatures during operation at larger angles of oscillation.