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DESIGN OF A HIGH-SPEED RELIABLE BALL BEARING

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SUMMARY

A high-speed, reliable ball bearing has been designed for at least fifteen years of operation in space effectors, MWAs, and RWAs. Advance bearing concepts have been used in this design, such as: no ball retainer, which eliminates all retainer-related problems; an external lubricating system that will supply the lubricant at a specified flow rate; and a cartridge assembly that will allow the instrument user to purchase a ready-to-use bearing assembly, with lubricator. Currently, two assemblies are on life test at 12,000 RPM and have accumulated over 20,000 hours, each, with consistent low-torque losses. The paper will describe each of the salient features.

SALIENT FEATURES

Retainerless Design

The ball retainer has been eliminated to ensure no retainer-related problems, such as retainer instability (squeal). Dr. Kingsbury has shown that contrary to current theory there is a lubricant film between the balls to ensure no ball damage during operation. These tests will be described.

External Lubricator

An external lubricator, named an *oozing flow lubricator*, has been designed to give a specified flow rate of lubricant to the ball contacts. The oozing flow lubricator is shown schematically in Figure 1. The lubricant is driven through the interface by the centrifugal pressure head caused by the rotation of the lubricator. Thus, at storage conditions, no oil is lost from the lubricator.

The flow rate of the oil is controlled by the properties of the interface; for high interfacial pressures, the flow is only proportional to the cube of the flow channels' dimension. These channels can be controlled either through surface finish controls or other means. The flow is also controlled by the oil viscosity.

As the oil is lost from the lubricator, the head and the flow rate change exponentionally with running time.

Screening tests will be described to measure the flow rates from four oozing flow lubricators. See Figure 2. A correlation of flow rate with surface finish will be established.

Optimum Flow Rate Determination

Parched EHD theory was used to determine the optimum flow rate for the bearing size, a basic 100-size design, preload (10 pounds), and speed, 12,000 RPM. The tests on the counter-rotating rig will be described to show that a flow of at least 0.2 micro-grams per hour would be needed to maintain a parched EHD film.

Cartridge Bearing Design

A cartridge bearing design was selected for this bearing assembly. See Figure 1. Based on the expected loads and environment, the bearing was designed to have a pitch diameter of a 100-size bearing. There are fourteen (14) 0.1875-inch diameter balls in each bearing row. The reservoir and the ID of the outer races comprise the oozing flow lubricator. Nye 176A oil, a PAO with a kinematic viscosity of 437 CS at 100°F, is the lubricant of choice. This cartridge design with the lubricator and shaft is configured so that a competent bearing manufacturer can produce and screen the assembly. This will relieve the instrument manufacturer from handling the ball bearing.

Life Tests

Two bearing assemblies, one with a wheel and one as a cartridge only, is running at 12,000 RPM for over 20,000 hours. Torque and oil flow rates are periodically measured. The change of oil flow rate with time follows the prediction. See Figure 3. The torque losses at 12,000 RPM are around 0.4 in-oz and are consistent with time for both bearings. See Figure 4.

Figure 1.

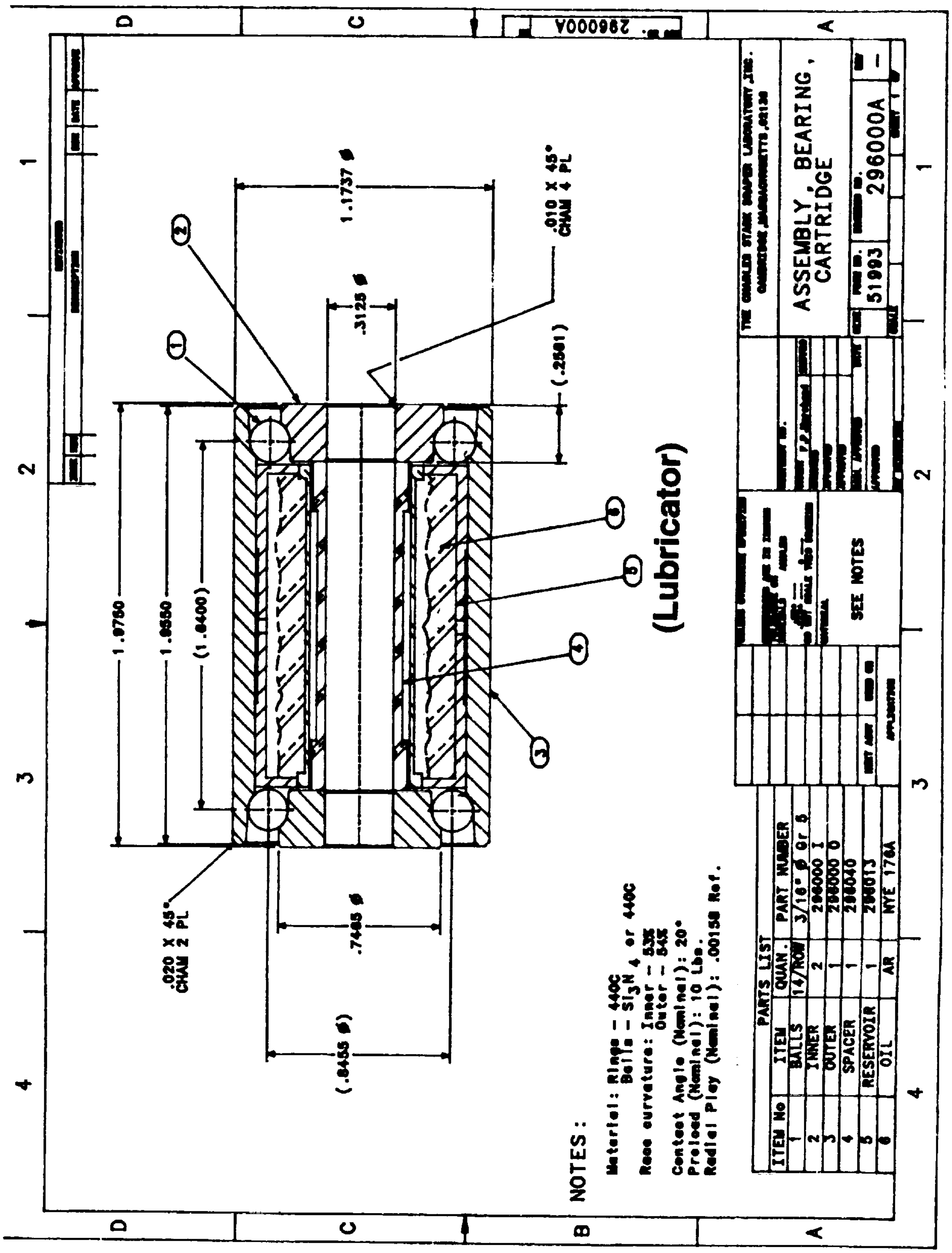
(Lubricator)
1.9750
1.8550
(1.8400)
1.1737 ø
.3125 ø
(.2581)
.7485 ø
(.8455 ø)
.010 X 45° CHAM 4 PL
.020 X 45° CHAM 2 PL
NOTES:
Material: Rings - 440C
Balls - Si_3N_4 or 440C
Race curvature: Inner - 53%
Outer - 54%
Contact Angle (Nominal): 20°
Preload (Nominal): 10 Lbs.
Radial Play (Nominal): .0015R Ref.
PARTS LIST
ITEM No | ITEM | QUAN. | PART NUMBER
1 | BALLS | 14/ROW | 3/16" ø Gr 5
2 | INNER | 2 | 296000 I
3 | OUTER | 1 | 296000 O
4 | SPACER | 1 | 296040
5 | RESERVOIR | 1 | 296013
6 | OIL | AR | NYE 179A
SEE NOTES
ASSEMBLY, BEARING, CARTRIDGE
51993
296000A

Figure 2.

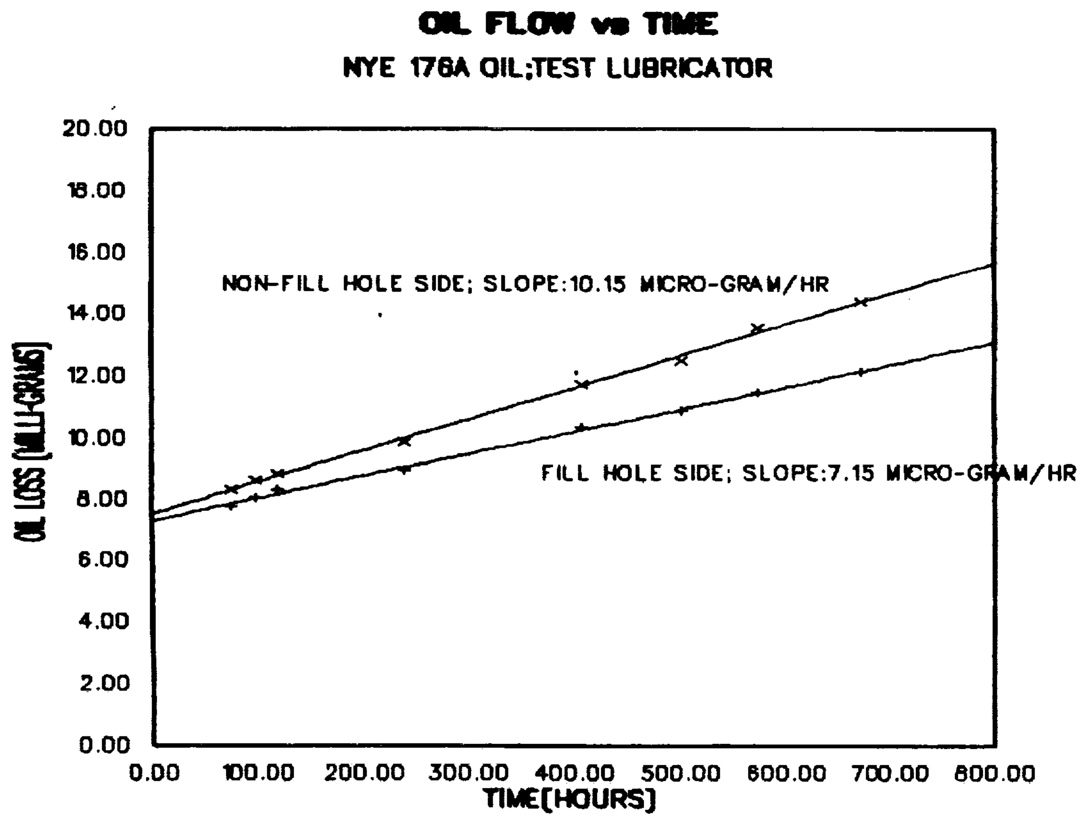

Figure 3a. Flow Rates for S/N 005

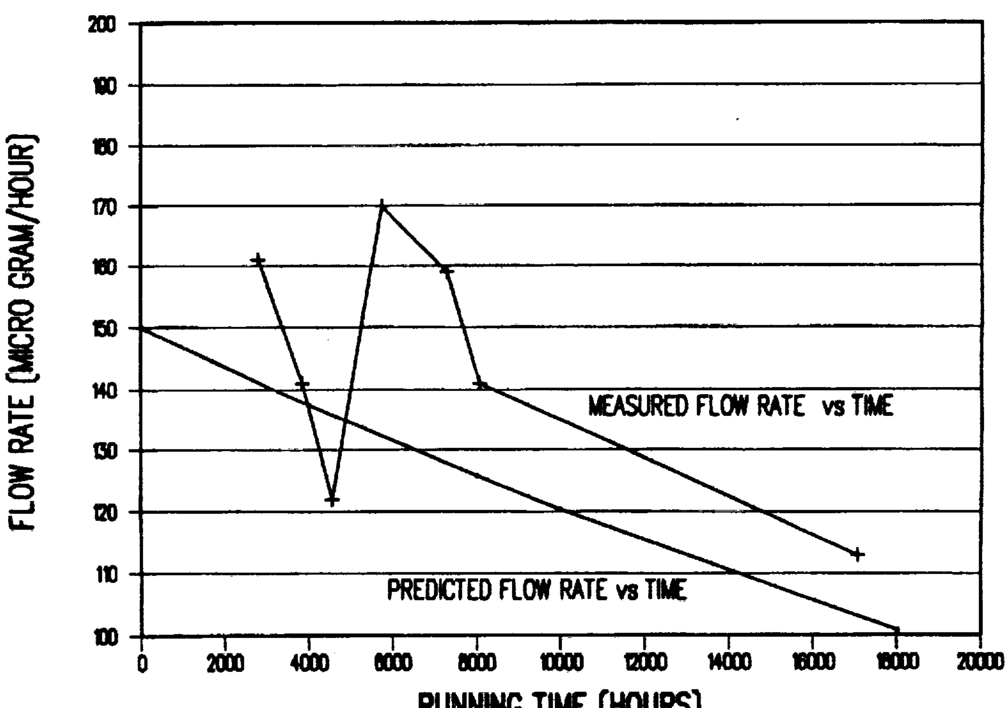

Figure 3b. Flow Rates for S/N 007

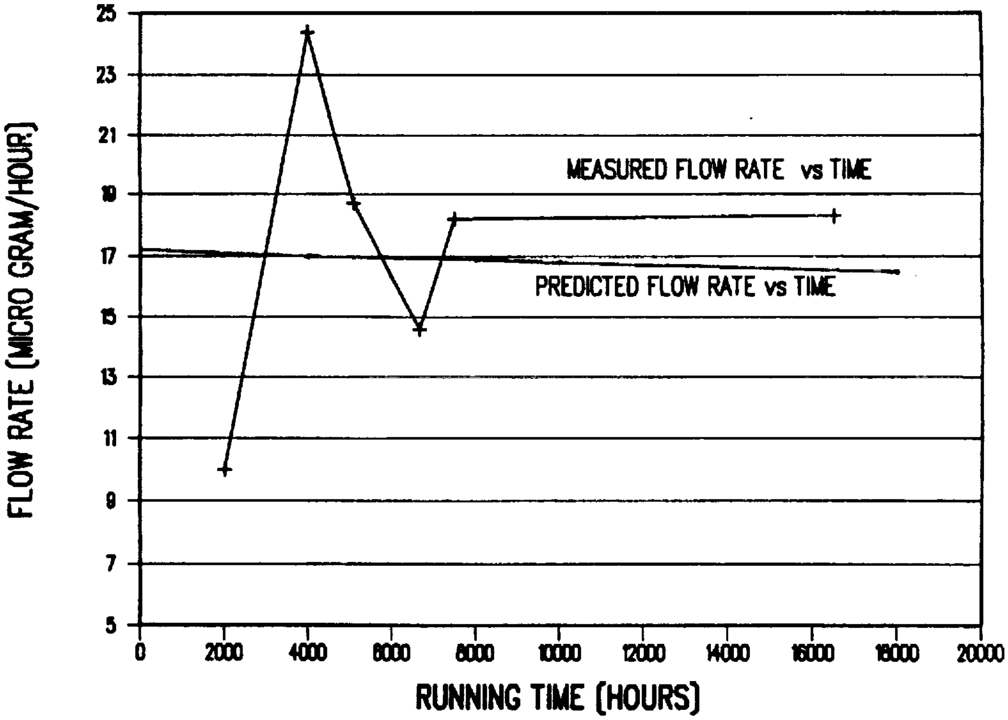

FIGURE 4. CARTRDGE BEARING LIFE TEST
TORQUE vs RUNNING TIME