FINAL REPORT

on

EVALUATION OF LOAD TRACKS AND WEAR OF TWO SETS OF BEARINGS FROM SPACE SHUTTLE MAIN ENGINE HIGH PRESSURE OXYGEN TURBOPUMPS

(Contract No. NAS8-36192, Task 118)

to

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

November 20, 1985

by

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INTRODUCTION

In an effort to qualify the Space Shuttle Main Engine (SSME) for flight service at 109 percent of full power level, certification endurance testing at this power level is being conducted by NASA and the Rocketdyne Division of Rockwell International. Problems with the bearings supporting the rotor in the high pressure oxygen turbopump (HPOTP) have been one limitation in meeting the flight certification requirements. Design improvements have been made, which have extended the bearing life, but recent engine certification tests resulted in bearing degradation on HPOTP Units No. 2317R1 and No. 4004R1 before completion of the 10-test sequence. Bearings 1 and 2 from Unit No. 2317R1 had been operated for 5044 seconds and bearings 3 and 4 (turbine end) had been operated for 3217 seconds. All four bearings on Unit No. 4004R1 had been operated for 5358 seconds. The two HPOTP's were disassembled to permit a complete inspection of the bearings.

Battelle has been assisting NASA-MSFC with SSME bearing problems under a Task Order Agreement and was requested to examine the degraded bearings and attend a review meeting at Rocketdyne. This report is a summary of the examinations and conclusions reached at the meeting

TABLE 1. SUMMARY OF BEARING EXAMINATIONS

HPOTP Unit No.	Bearing No.	General Condition	Balls	Cage		Inner Race	Outer Race		Comments
				Pocket	Land		Ball Track	Outside Surface	
2317R1	1	Acceptable	Nos. 1,2,3 Dark	1,2,3,12 High Wear Driving Direciton No Contact T-Side	Contact Band (N-Side)	Mild Uniform Wear	Mild Wear Debris Dents, Low Contact Angle	Downstream Side Coating Wear	Cage Wear in Flow Direction
	2	Degraded	Dark	Wear Fore and Aft, Contact on T-Side	Contact Band (T-Side)	Wear, Pitting Near Zero Contact Angle and at MAJ and MIN		Galling on N-Side, Evidence of Spin	Probably Insufficient Coolant, Cage Wear in Flow Direction
	3	Acceptable	Minor Banding, No. 1 Darker	Mild Wear	Circumferential Scratch	Synchronous Load, Ripple Pattern at Low Contact Angle	Minor Debris Dents, Ripple Pattern at Low Contact Angle	Mild Wear on Center of OD	
	4	Degraded	Dark, Polar Caps	High Wear Fore and Aft, Contact on T-Side	Normal	Spalls at Low Contact Angle, Synchronous Radial Load, Wear to MAJ	Wear, Ball Track to Shoulder	Major Spinning	Probably Incurred High Axial Loads and Possibly BSV Due to High Radial Loads, Cage Wear Opposite of Flow Direction
4004R1	1	Fair	Slight Wear, Polar Caps	Minor Wear Flow Direction (N-Side)	Contact Both Sides	Gold Brown Tracks, Good Condition, Synchronous Load	Debris Dents, Mild Wear at Contact Angle		Some Evidence of Unloading, Cage Wear in Flow Direciton
	2	Degraded	Dark	360° Contact Fore and Aft (T-Side Minor)	Contact Both Sides	Burr at MAJ, Pits, Synchronous Load	Pits at Low Angle, Ripples, Wear at High Angle	Mild Wear (N-Side)	Appears to be Earlier Stage of No. 2 Bearing From Unit 2317R (above) Cage Pocket Wear in Flow Direction
	3	Acceptable	Normal	Contact (T-Side) Mild Wear	Contact Both Sides	Synchronous Load, 4 Distinct Zones in Wear Track	Mild Wear	Scrubbing	Wear Probably Occurred at Different Speed Conditions
	4	Acceptable	Normal	Delamination on I.D., Wear Fore and Aft	Wear (T-Side)	Mild Ripples at Low Contact Angle	Uniform Brown Tracks	Minor Spinning	Cage Had Almost No Contact on N-Side

FOLDOUT FRAME

FOLDOUT FRAME

held on October 24, 1985. The four bearings from both HPOTP's were examined by Mr. J. W. Kannel and Mr. K. F. Dufrane from Battelle and by Mr. F. J. Dolan from NASA-MSFC.

SUMMARY AND CONCLUSIONS

The No. 1 bearings from both units were in good condition and had successfully completed 5000 seconds of operation. The No. 2 bearings, which had been in service the same length of time, were significantly degraded in the form of ball wear, race pitting, and damage from high axial loads. These bearings appeared to have been overheated and may have ceased temporarily in their housings, which subjected them to unusual axial loads. These problems appear to be the result of inadequate cooling.

The No. 3 and 4 bearings, which in previous tests have had the primary degradation, were in generally acceptable condition with the exception of bearing 4 from Unit No. 2317R1. It had been degraded as the result of high transient axial loads and synchronous radial loads.

The general conclusion from the examinations was that improved cooling on the No. 2 bearing and further improvements in controlling axial and radial loads would likely result in the HPOTP meeting the qualification test requirements. The bearing performance would also be improved with more effective transfer film lubrication on a continuing basis.

BEARING INSPECTION

Table 1 summarizes the specific observations made by the examining team. Figure 1 shows the identification nomenclature. Two bearings (2 and 4) on Unit No. 2317R1 were badly degraded. Bearing No. 2 (preburner side) had evidence of pitting (or flaking) on the inner race and evidence of wear on the outer. The outside of the outer race showed evidence of galling near the N side, which was probably the result of spinning relative to the housing. Cage pocket wear on the No. 2 bearing was fore and aft in the pocket and on the side of coolant flow, which would expected.

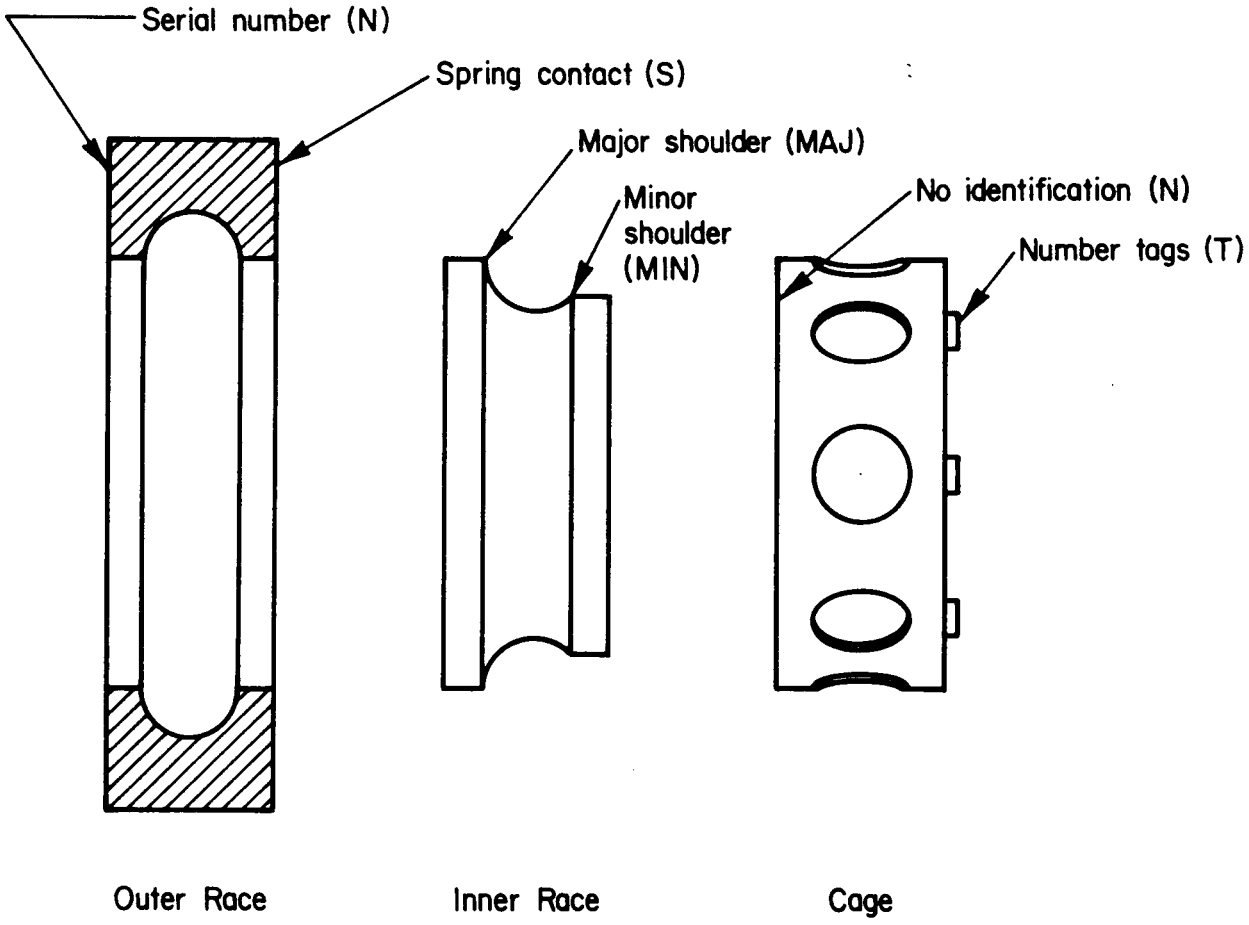

FIGURE 1. IDENTIFICATION NOMENCLATURE

Bearing No. 4 on Unit No. 2317R1 had evidence of spalls on the inner race at a low contact angle and scuffing on the outer. Cage pocket wear in bearing No. 4 was opposite to the coolant flow direction, which suggests that the cage might have been "locked" between the balls. There was some evidence of a synchronous radial load and high axial loads.

For Unit No. 4004R1, only one bearing (No. 2) was labeled as badly degraded by the examiners. The inner race of bearing No. 2 had some pitting (or flaking) and a burr at the major shoulder. The outer race had low angle pits and some axial ripples. The OD of the outer race showed evidence of spinning with contact on the N side. Cage wear was skewed toward the coolant flow direction. The condition of bearing No. 2 for Unit No. 4004R1 was similar (although less severe) than the condition of bearing No. 2 for Unit No. 2317R1.

The similarity between the condition of the two bearings from the No. 2 position of the two pumps suggests that there is a common failure mechanism. This mechanism is most likely coolant related. Possibly insufficient coolant is available to bearing No. 2, which results in bearing distress and could lead to thermal lock-up. In a cryogenic film test using a disk machine at Battelle the flow of the flow appeared to be very important in protecting the disk surfaces even though the fluid provided very little lubrication. It is quite possible that better (higher quality) coolant flow into bearing No. 2 could extend bearing life.

Bearing No. 4 from Unit No. 2317R1 appeared to have experienced both high (transient) axial loads and probably high radial loads. There is some limited evidence that the bearing No. 4 condition was similar to an earlier bearing No. 4 condition from the same unit. It is possible the better load control (axial and radial) would result in a significant improvement of the bearing No. 4 performance.

With some minor improvements to the coolant flow for bearing 2 and the loading in bearing No. 4 there is a good possibility that the HPOTP bearings can meet the qualification test. Also, improved transfer film lubrication from the bearing cage would improve the tolerance of the bearing to high or unusual transient loadings.