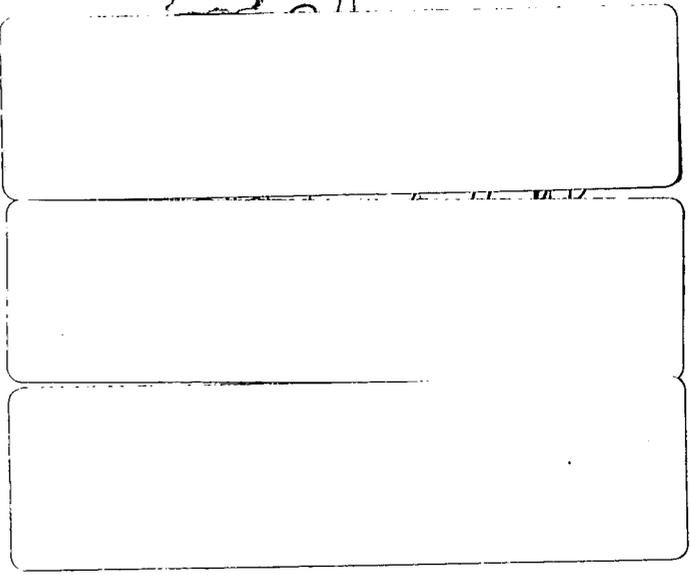


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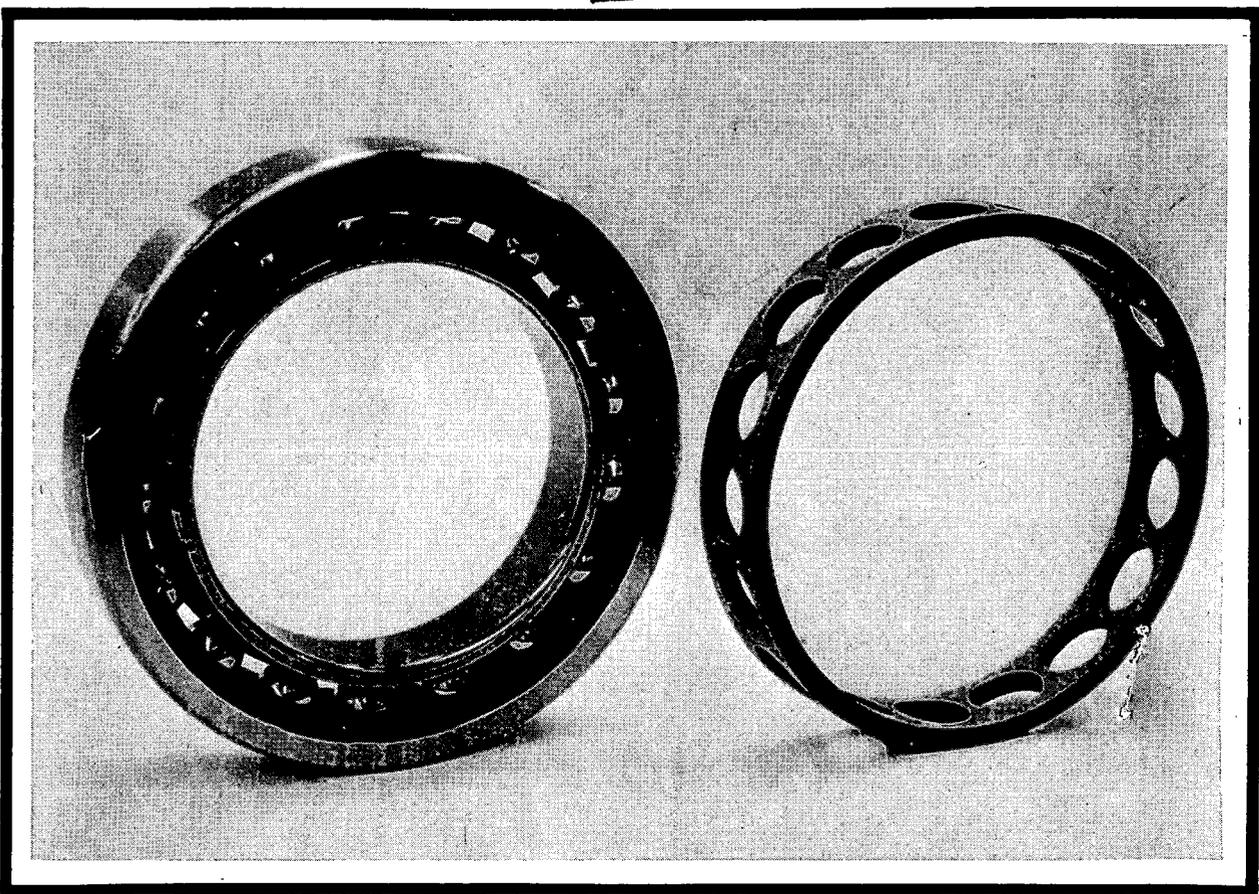
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DEC 1971  
DEC 1971 - MARCH 1972  
VOLUME III



# DESIGN & DEVELOPMENT OF LH<sub>2</sub> COOLED ROLLING ELEMENT RADIAL BEARINGS FOR THE NERVA ENGINE TURBOPUMP

NASA-CR-132229) DESIGN AND DEVELOPMENT OF LH<sub>2</sub> COOLED ROLLING ELEMENT RADIAL BEARINGS FOR THE NERVA ENGINE TURBOPUMP. VOLUME 3: (Aerojet Nuclear Systems Co., Azusa, Calif.) 328 p HC \$18.50 CSCL 13I  
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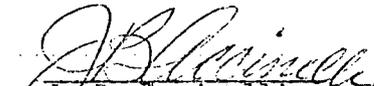
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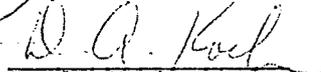
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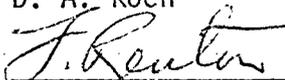
PHASE II - TESTS ON BUILD-UPS 16, 17, AND 18 AT NRDS, JACKASS FLATS, NEVADA  
DECEMBER 1971 TO MARCH 1972

PROJECT 121

MAY 1972

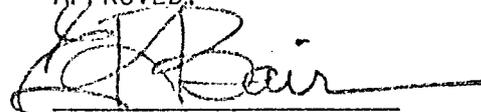
  
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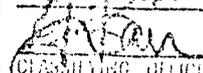
  
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ABSTRACT

The report presents LH<sub>2</sub> test results of the first three 65mm ball bearing build-ups tested in Test Cell "A", NRDS, Jackass Flats, Nevada. Each of the three build-ups completed more than 8.6 hours of accumulated duration and the final build-up successfully achieved the 15-hour target duration without bearing failure. These tests indicate a significant desirable effect on bearing life and performance of slight improvements in the bearing material, improvement in bearing retainer configuration and method of fabrication, tighter tester assembly fits, and better control of operating parameters. However, considerably more development testing needs to be done to clearly define the contributing parameters and their effect on bearing life and performance in this severe LH<sub>2</sub> environment.

*II*

TABLE OF CONTENTS

	<u>PAGE</u>
1.0 INTRODUCTION-----	1
2.0 SUMMARY-----	1
3.0 CONCLUSIONS-----	3
4.0 TECHNICAL DISCUSSION-----	4
4.1.0 65MM BEARING LH <sub>2</sub> TESTS AT NRDS, JACKASS FLATS, NEVADA-----	4
4.1.1 Facility-----	4
4.1.2 Testers and Instrumentation-----	7
4.1.3 General Test Procedure-----	7
4.1.3.1 Rotational Test Procedure-----	7
4.1.3.2 Failure Criteria for Shutdown and Target Duration-----	12
4.1.3.3 Push-Pull And Radial Play Tests in LH <sub>2</sub> -----	14
4.2.0 RESULTS OF TESTS ON BUILD-UPS 16, 17 AND 18-----	19
4.2.1 Build-Up 16-----	19
4.2.1.1 Purpose of Test and Features of Build-Up-----	19
4.2.1.2 Discussion of Test Results-----	24
4.2.1.2.1 Test Performance-----	24
4.2.1.2.2 Post-Test Condition of Test Bearing-----	31
4.2.2 Build-Up 17-----	44
4.2.2.1 Purpose of Test and Features of Build-Up-----	44
4.2.2.2 Discussion of Test Results-----	45
4.2.2.2.1 Test Performance-----	45
4.2.2.2.2 Post-Test Condition of Test Bearing-----	45

TABLE OF CONTENTS (Continued)

	<u>PAGE</u>
4.2.3 Build-Up 18-----	66
4.2.3.1 Purpose of Test and Features of Build-Up	68
4.2.3.2 Discussion of Test Results-----	69
4.2.3.2.1 Test Performance-----	69
4.2.3.2.2 Post-Test Condition of Test Bearing-----	69
4.2.4 General Comments on Build-Up 16B, 17 and 18 Test Results-----	88
4.3.0 BUILD-UP OF NEW CONFIGURATION BEARING TESTER P/N 1138990-1	92
4.3.1 Assembly Features and Procedure-----	92
5.0 APPENDICES	
APPENDIX A-----	
1. "NRDS Test Cell "A" NERVA Turbopump 65MM Bearing Testing Facility Requirements", Facility Requirements Document F004, F004-CP091295BG1, October 1971	
2. "Test Description for Facility Experimental Plan and Bearing Test Series at Test Cell "A" - Nuclear Rocket Test Operations NRT0-R-0212, R30 Issue, 12 August 1971	
3. "Standard Operating Procedure for Hot Helium or Nitrogen Dehydration Purge of the Bearing Test Article in Test Cell "A" - Nuclear Rocket Test Operations Report NRT0-SOP-0235, Final Use, 18 August 1971	
4. Basic Test Request (Revision A) dated 9-23-71 and Test Request Supplement No. 1 dated 6-23-71 which revised the original Basic Test Request.	
5. Sample "Test Operating Procedure (TOP) for Phase I Bearing Build-Up Rotational Test, Run 1190-65-016-002"	
6. Various Turbomachinery Procedures (TMP) for Tester 1138060, and Pretest preparation and Post Test Inspections of Test Bearings	

TABLE OF CONTENTS (Continued)

APPENDIX B

Turbomachinery Procedures (TMP) for LH<sub>2</sub> Dual Duplex Bearing  
Tester 1138990-1

1. Assembly Procedure, TMP-102
2. Forward Cartridge/Housing Interface Clearance Test, TMP-119
3. Aft Cartridge/Housing Interface Clearance Test, TMP-120
4. Disassembly Procedure, TMP-107

LIST OF FIGURES

<u>FIGURE NO.</u>		<u>PAGE</u>
1	Top View of 65MM Ball Bearing Tester Test Cell "A" Layout, NRDS, Jackass Flats, Nevada-----	5
2	65MM LH <sub>2</sub> Bearing Tester Installed in Test Cell "A", NRDS, Jackass Flats, Nevada-----	6
3	ANSC LH <sub>2</sub> Duplex Ball Bearing Tester 1138060-3-----	8
4	Schematic of Tester 1138060-3 in Test Cell "A", NRDS, Nevada-----	11
5	Sketch of 65mm Bearing Tester 1138060-3 showing Location of Distance Detectors-----	18
6	Sketch of Duplex Ball Bearing Assembly for Tester P/N 1138060-3 showing Critical Interfaces-----	23
7	Typical Bearing Shaft Dynamics as Related to Bearing Performance Deterioration - Build-Up 16B-----	29
8	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 16B, Test 1190-65-016-001-----	32
9	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 16B, Tests 1190-65-016-002, 003, 004-----	33
10	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 16B, Test 1190-65-016-005-----	34
11	Post-Test Photograph of Upstream Bearing Components of Build-Up 16B - General View-----	36
12	Post-Test Photograph of Upstream Bearing Metal Components of Build-Up 16B - Close-up View-----	37
13	Post-Test Photograph of Upstream Bearing Retainer I.D. - Build-Up 16B-----	38
14	Post-Test Photograph of Upstream Bearing Retainer O.D. - Build-Up 16B-----	39
15	Post-Test Photograph of Downstream Bearing Components of Build-Up 16B - General View-----	40
16	Post-Test Photograph of Downstream Bearing Metal Components of Build-Up 16B - Close-up View-----	41
17	Post-Test Photograph of Downstream Bearing Retainer I.D. - Build- Up 16B-----	42
18	Post-Test Photograph of Downstream Bearing Retainer O.D. - Build- Up 16B-----	43

LIST OF FIGURES (Continued)

<u>FIGURE NO.</u>		<u>PAGE</u>
19	Radial Play Test Results of Build-Up 17-----	48
20	Typical Bearing Shaft Dynamic as Related to Bearing Performance Deterioration - Build-Up 17-----	52
21	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 17, Test 1190-65-017-001-----	53
22	65MM Bearing Performance as a Function of Operating Time - Build- Up 17, Test 1190-65-017-002-----	54
23	65MM Bearing Performance as a Function of Operating Time - Build- Up 17, Test 1190-65-017-003-----	55
24	65MM Bearing Performance as a Function of Operating Time - Build- Up 17, Test 1190-65-017-004-----	56
25	Post-Test Photograph of Bearing Assembly Showing Severe Damage to Upstream Bearing of Build-Up 17-----	59
26	Post-Test Photograph of Upstream Bearing Components of Build-Up 17 - General View-----	60
27	Post-Test Photograph of Upstream Bearing Metal Components of Build-Up 17 - Close-up View-----	61
28	Post-Test Photograph of Downstream Bearing Components of Build-Up 17 - General View-----	62
29	Post-Test Photograph of Downstream Bearing Metal Components of Build-Up 17 - Close-up View-----	63
30	Post-Test Photograph of Downstream Bearing Retainer I.D. - Build- Up 17-----	64
31	Post-Test Photograph of Downstream Bearing Retainer O.D. - Build- Up 17-----	65
32	Radial Play Test Results of Build-up 18-----	71
33	Typical Bearing Shaft Dynamics as Related to Bearing Performance Deterioration - Build-Up 18-----	74
34	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 18, Test 1190-65-018-001-----	75
35	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 18, Test 1190-65-018-002-----	76

LIST OF FIGURES (Continued)

<u>FIGURE NO.</u>		<u>PAGE</u>
36	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 18, Test 1190-65-018-003-----	77
37	65MM Bearing Performance Parameters as a Function of Operating Time - Build-Up 18, Test 1190-65-018-004-----	78
38	Post-Test Photograph of Upstream Bearing Components of Build-Up 18 - General View-----	80
39	Post-Test Photograph of Upstream Bearing Metal Components of Build-Up 18 - Close-up View-----	81
40	Post-Test Photograph of Upstream Bearing Retainer I.D. - Build-Up 18-----	82
41	Post-Test Photograph of Upstream Bearing Retainer O.D. - Build-Up 18-----	83
42	Post-Test Photograph of Downstream Bearing Components of Build-Up 18 - General View-----	84
43	Post-Test Photograph of Downstream Bearing Metal Components of Build-Up 18 - Close-up View-----	85
44	Post-Test Photograph of Downstream Bearing Retainer I.D. - Build-Up 18-----	86
45	Post-Test Photograph of Downstream Bearing Retainer O.D. - Build-Up 18-----	87
46	Drive Motor Current (Friction) as a Function of Operating Time for Build-Ups 15, 16B, 17 and 18-----	89
47	Cross-Section of Ball Bearing Tester P/N 1138990-1A-----	93
48	Shaft Assembly, Side View - Tester 1138990-1A-----	96
49	Shaft Assembly, 3/4-Front View - Tester 1138990-1A-----	97
50	Shaft Assembly, 3/4-Rear View - Tester 1138990-1A-----	98
51	Partial Tester Assembly, 3/4-Front View - Tester 1138990-1A-----	99
52	Partial Tester Assembly, 3/4-Rear View - Tester 1138990-1A-----	100
53	Final Tester Assembly, Side View Tester 1138990-1A-----	101
54	Final Tester Assembly, 3/4-Front View Tester 1138990-1A-----	102

LIST OF TABLES

<u>TABLE NO.</u>		<u>PAGE</u>
1	Instrumentation and Required Parameters-----	9
2	65MM Ball Bearing Test Program Operating Conditions (Steady State)-	13
3	Comparison of Principal Features of Build-ups 15 and 16B-----	20
4	Bearing-Cartridge-Housing Room Temperature Fits for Bearing Tester 1138060-3 - Build-Ups 15, 16B, 17, and 18-----	21
5	Build-Up 16A, 65MM Bearing Test Results (Push-Pull Test)-----	25
6	Build-Up 16B, 65MM Bearing Test Results Summary-----	26
7	General Summary of 65MM Bearing LH <sub>2</sub> Test Results-----	27
8	Comparison of Principal Features of Build-Up 16B and 17-----	46
9	Radial Play Test Data - Build-Up 17-----	47
10	Build-Up 17, 65MM Bearing Test Results Summary-----	49
11	Comparison of Principal Features of Build-Ups 17 and 18-----	67
12	Radial Play Test Data - Build-Up 18-----	70
13	Build-Up 18, 65MM Bearing Test Results Summary-----	72
14	Summary of Ball and Retainer Post-Test Wear for Build-Ups 15, 16B, 17 and 18-----	91
15	Principal Features of Build-Up 19 (Tester P/N 1138990-1A)-----	94

## 1.0 INTRODUCTION

The NERVA Engine TPA bearing LH<sub>2</sub> test program was transferred to Test Cell "A" at NRDS, Jackass Flats, Nevada in May of 1971 and the Facility Experimental Plan (FEP) to checkout the facility and familiarize personnel with its operation was initiated and completed on November 4, 1971. Following various adjustments and some upgrading of measurement and control systems, Build-Up 16B, the first full scale 65mm ball bearing test in Test Cell A was initiated in December 1971. The test program followed the general philosophy outlined in Reference (1) and specifically the test logic of Section 5.0 of the reference. Three test series covering Build-ups 16B, 17 and 18 were successfully completed during the final 3-month period of the test program. The purpose of this report is to document and discuss the results of these tests.

## 2.0 SUMMARY

a. Completed LH<sub>2</sub> testing of three 65mm ball bearing build-ups in Test Cell "A", NRDS, Jackass Flats, Nevada. All build-ups accumulated more than 8.6 hours duration and the last build-up successfully completed the 15-hour target duration without a bearing failure.

b. Build-up 16B was set up as a duplicate of Build-up 15, the last build-up tested at the Cryogenic Laboratory in Sacramento, California, for the purpose of comparing performance at the two facilities and to provide a frame of reference for future bearing tests. The performance of the two build-ups compared favorably, especially with respect to start-up and initial operation.

## 2.0 (Continued)

c. Build-up 16B accumulated a much longer duration, 8.68 hours, compared to 4.33 hours for build-up 15, because of a change in failure shutdown criterion with Build-up 16B. On the same shutdown basis, Build-up 16B could have been terminated in about 4.0 hours, representing good agreement.

d. The 65mm ball bearings from new lot (Basic P/N 1139188-2A) representing new heat of 440C steel appeared to perform somewhat better than the 65mm bearings previously tested (Basic P/N 1138146-1). The new heat of steel seems to be somewhat better with respect to carbide size and distribution and the bearing raceways surface finish have, in general, fewer broken carbide indications. Also, the Armalon retainers for the bearings were originally fabricated with elongated pockets and did not need rework for elongation.

e. Build-up 17 with the new lot of test bearings accumulated 13.17 hours at 500 lbs radial load, 600 lbs axial preload and 27000 rpm. The upstream bearing was completely fractured but the downstream bearing was in relatively good condition.

f. Bearing fracture was not of metal fatigue origin. It appeared that inner race shoulder was first fractured by very high ball-to-raceway contact stresses resulting from high ball-to-raceway contact due to wear and loss of contact area. Chipping of inner race shoulder subsequently resulted in the gross damage observed.

g. Build-up 18, also with new lot of bearings, satisfactorily completed target duration of 15.0 hours at 500 lbs radial load, 600 axial preload and 27000 rpm. The bearings were in generally good condition although downstream bearing showed high ball and retainer pocket wear. This build-up accumulated 9.0 hours of excellent performance prior to any signs of bearing distress, the best performance so far with the 65mm ball bearings.

## 2.0 (Continued)

h. The improved performance could be attributed to the somewhat better bearing material of the new lot of bearings and improved retainer fabrication, as well as to the tighter fits at the bearing-to-cartridge and cartridge-to-housing interfaces. Also a significant contribution might have been derived from better facility control of critical parameters (pressures, load, flow rate, etc.).

i. Successfully completed assembly of dual duplex bearing tester P/N 1138990-1A.

3.0 CONCLUSIONS

a. A slight improvement in bearing material, improved retainer fabrication, tighter tester assembly fits, and better control of critical operating parameters all contributed to a significant improvement in bearing life and performance in the severe LH<sub>2</sub> environment.

b. Slight modification in the bearing geometry and use of a new configuration tester having a critical speed well above operating speed is expected to provide additional improvements in bearing performance.

c. High wear of the bearing metal components continued to be the significant failure mode, although significant reduction in wear was observed with the build-up which successfully completed the 15-hour goal.

d. Present test results indicate the need for considerably more development testing in LH<sub>2</sub> in order to more clearly identify the significant contributing factors and to define to what degree these factors affect bearing wear, life, and performance.

#### 4.0 TECHNICAL DISCUSSION

##### 4.1 65MM BEARING TESTS AT NRDS, NEVADA

###### 4.1.1 Facility

In May 1971, the NERVA Engine TPA Bearing Test Program was transferred to Test Cell "A" at NRDS, Nevada. A principal advantage of the move to NRDS was the considerably longer test duration made possible by the increased capacity of  $LH_2$  and  $GH_2$ . Improvements in piping, insulation, valving and flow and pressure control, were also achieved by some facility upgrading. Figure 1 shows a close-up photograph of the 65MM bearing test stand layout while Figure 2 shows a photograph of the test bay. The facility requirements, instrumentation requirements, all procedures pertaining to tester build-ups, basic test request, and typical test operating procedure or experimental plan (EP) are provided in Appendix A. Specific test procedures or changes in instrumentation and testing parameters are covered for each test as necessary by Test Request Supplements issued against the Basic Test Request.

The activated Test Cell "A", NRDS, Nevada, bearing test facility was capable of more than 4 hours of continuous operation at a nominal  $LH_2$  flow rate of 60 gpm at a pressure of 225 psig. This duration is made possible by the 22,000 gal  $LH_2$  run tank which is also capable of 400 psig pressurization. For comparison, the facility at the Cryogenic Laboratory at the Sacramento Plant had a maximum capability of about 2.5 hours. The Facility Experimental Plan (FEP) to check out the facility and to familiarize personnel with its operation was initiated and completed on November 4, 1971. Tester P/N 1138060-3 (Figure 3) was successfully operated for approximately 6 minutes at maximum conditions as well as at several transient and intermediate check points. The

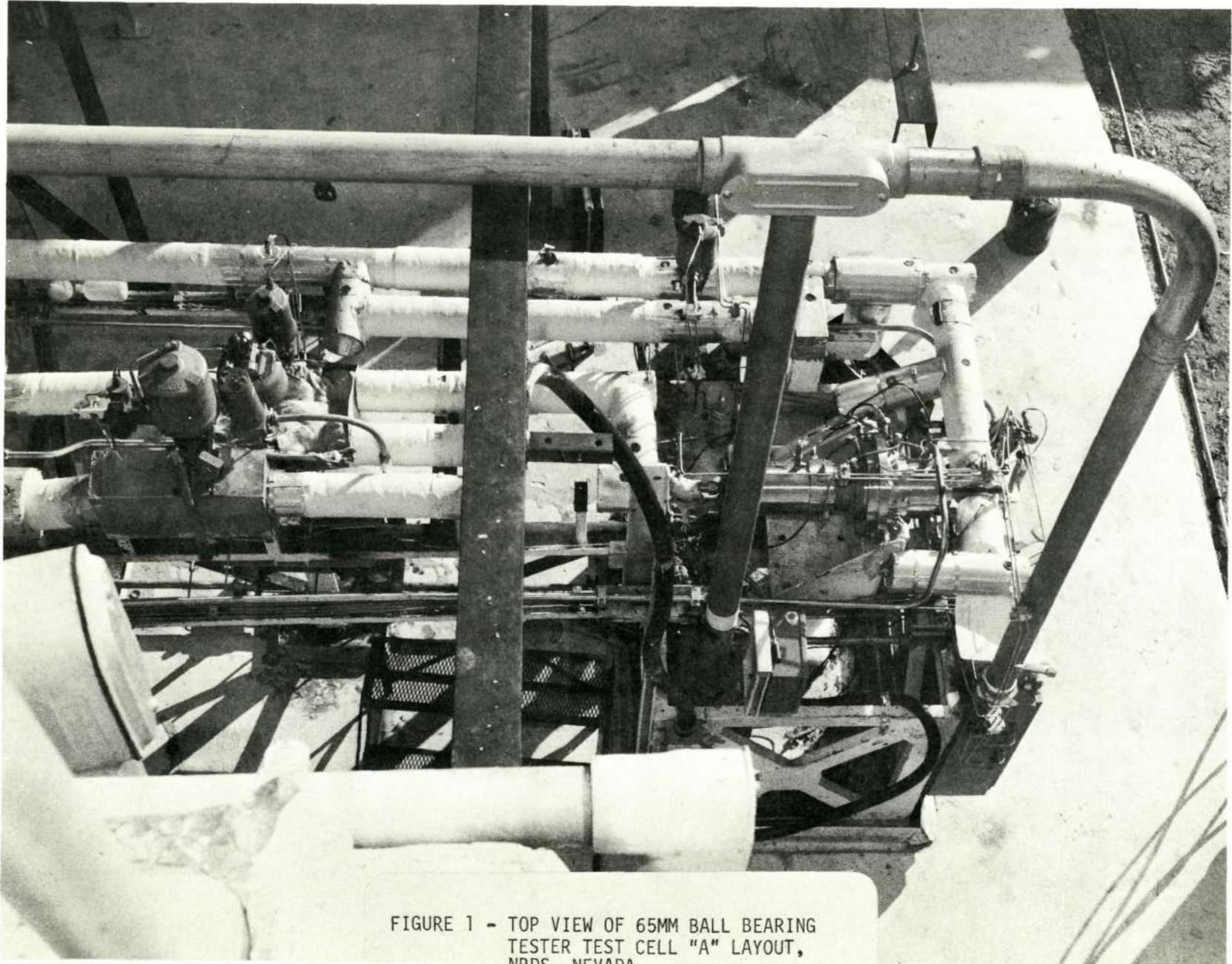


FIGURE 1 - TOP VIEW OF 65MM BALL BEARING  
TESTER TEST CELL "A" LAYOUT,  
NRDS, NEVADA

TESTER

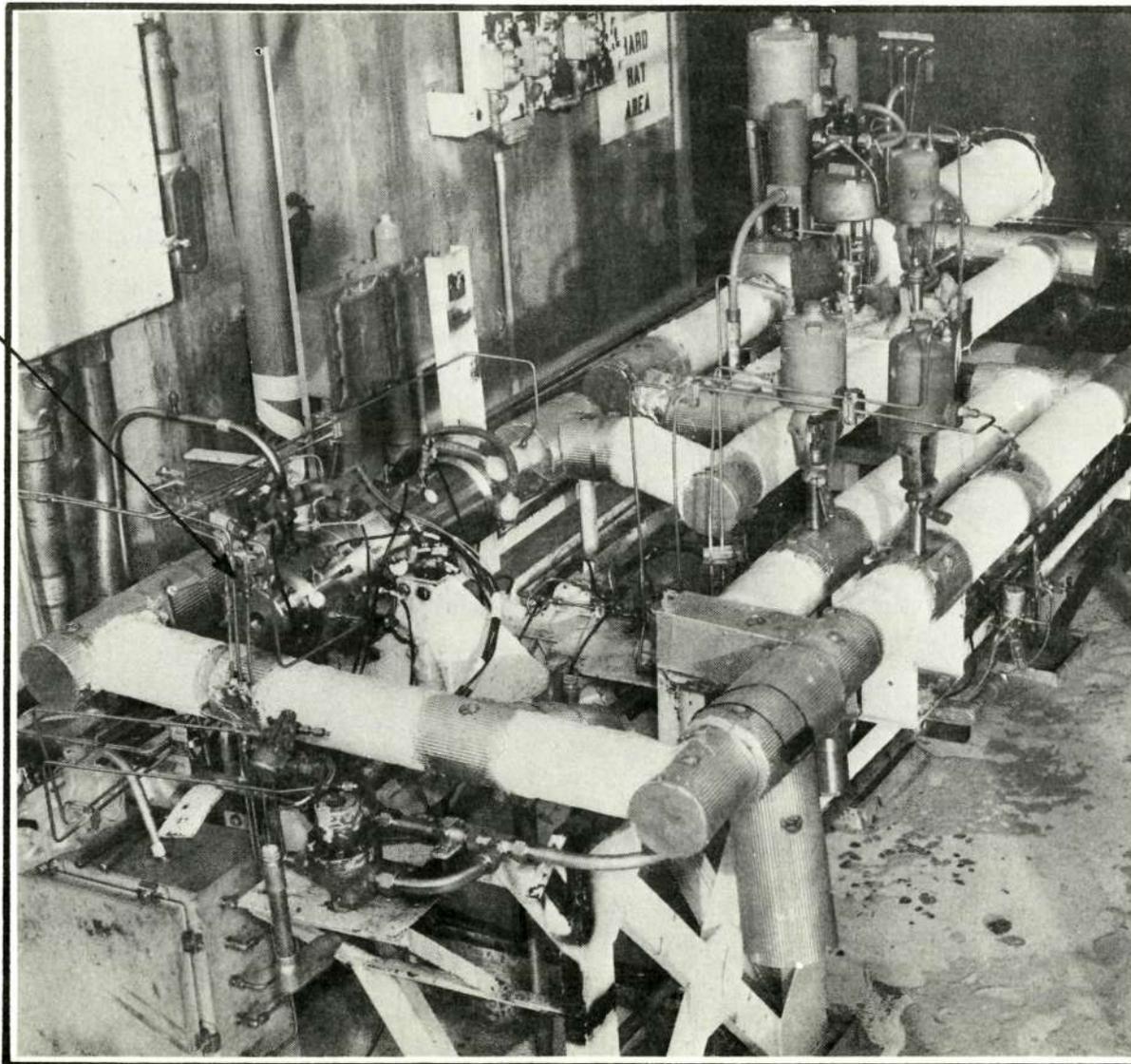


Figure 2 . 65 MM LH<sub>2</sub> Bearing Tester Installed in Test Cell "A",  
NRDS, Jackass Flats, Nevada

#### 4.1.1 (Continued)

test revealed several minor problem areas which were eliminated prior to testing of the first official bearing test, Build-up #16A and 16B.

#### 4.1.2 Testers and Instrumentation

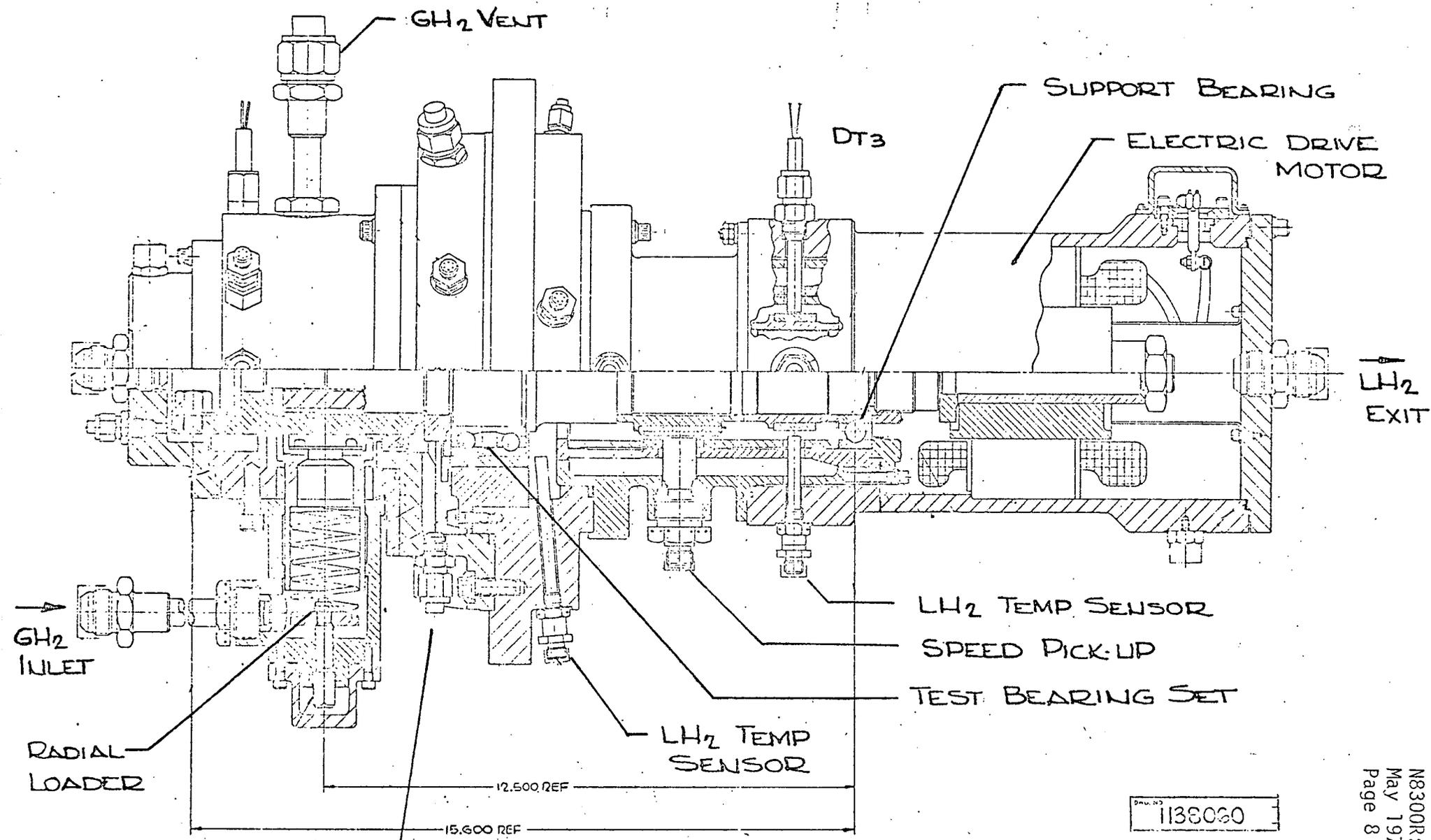
The bearing testers used in the three Build-ups under discussion were S/N's 001 and 002 of P/N 1138060-3. Figure 3 shows a drawing of this tester. Table 1 lists the instrumentation required and installed and Figure 4 shows a schematic of the bearing tester installation in the bay of Test Cell "A". A description of the tester is given in Section 4.8.9 of Reference 1.

Instrumentation for early detection of test bearing distress included distance detectors to show rotor dynamics, very sensitive RTT's (resistance thermometer) to provide temperature rise of the LH<sub>2</sub> fluid through the bearings, ammeters to give drive motor current (an indication of bearing friction), and sound pick-up to provide bearing tester noise, level and character indicative of bearing condition. These parameters were continuously monitored to provide a chronological history of bearing deterioration. Other parameters monitored verified test operating conditions and facility performance.

#### 4.1.3 General Test Procedure

##### 4.1.3.1 Rotational Test Procedure

The general test procedure used for these tests consists of a minimum 30-minute chilldown with LH<sub>2</sub> to an equilibrium maximum LH<sub>2</sub> inlet temperature of 54°R, followed by motor start and speed ramp to 12,000 rpm after adjusting bearing set radial load to value indicated by specific Test Request Supplement. (See Appendix A for typical NRT0-TOP (Test Operating Procedure)).



-3 ASSY

FIGURE 3 - ANSC LH<sub>2</sub> DUPLEX BALL BEARING TESTER

TABLE I  
INSTRUMENTATION & REQUIRED PARAMETERS

PARAMETER	NRDS CHANNEL	DESCRIPTION	RANGE	RECORDING		NOMINAL EXPECTED VALUE
				STRIP	PERMANENT	
<u>PRESSURE</u>			PSIG			PSIG
1. $P_R$	BP-106	Radial Loader	0-1000	X	X	190
2. $P_V$	BP-107	Loader Vent	0-500	X	X	25 - 100
3. $\Delta P_{RV}$	BP-110D	Radial Force	0-500	X	X	135 psi
4. $P_{FMFS}^*$	BP-101	Inlet Flowmeter	0-500	X	X	260
5. $P_{BUS}^*$	BP-102	Bearing, Upstream	0-500	X	X	225
6. $P_{BDS}^*$	BP-111	Bearing, Downstream	0-500	X	X	225
7. $P_{BH}^*$	BP-104	Bearing, Housing	0-500	X	X	225
8. $\Delta P_{BUS/BDS}$	BP-108D	$\Delta P$ across Bearings	$\pm 10$ Psi	X	X	$\pm 2$ psi
9. $P_A$	BP-105	Axial Loader	0-500	X	X	130
10. $\Delta P_{BUS/PA}$	BP-109D	Axial Force	0-500	X	X	100 psi
11. $P_{LDH}^*$	BP-112	Tester Outlet	0-500	X	X	225
12. $P_{LSH}^*$	BP-103	Tester Inlet	0-500	X	X	225
<u>TEMPERATURE</u>			$^{\circ}R$			$^{\circ}R$
1. $T_V$	BT-108	Vent	35-590	X	X	450
2. $T_{FMFS}^*$	BT-101	Flow Meter	35-80	X	X	45
3. $T_{BUS}^*$	BT-102	Bearing, Upstream	35-80	X	X	46
4. $T_{BDS}^*$	BT-106	Bearing, Downstream	35-80	X	X	51
5. $T_{MH}^*$	BT-104	Motor Housing	35-80	X	X	55
6. $T_{LDH}^*$	BT-109	Tester Outlet	35-80	X	X	55
7. $T_{LSH}$	BT-107	Tester Inlet	35-80	X	X	45
8. $T_{BH}$	BT-103	Bearing Housing	35-80		X	45
<u>FLOW</u>			GPM			GPM
$F_{FMFS}$	BF-001	Flowmeter	0-100	X	X	50 - 70

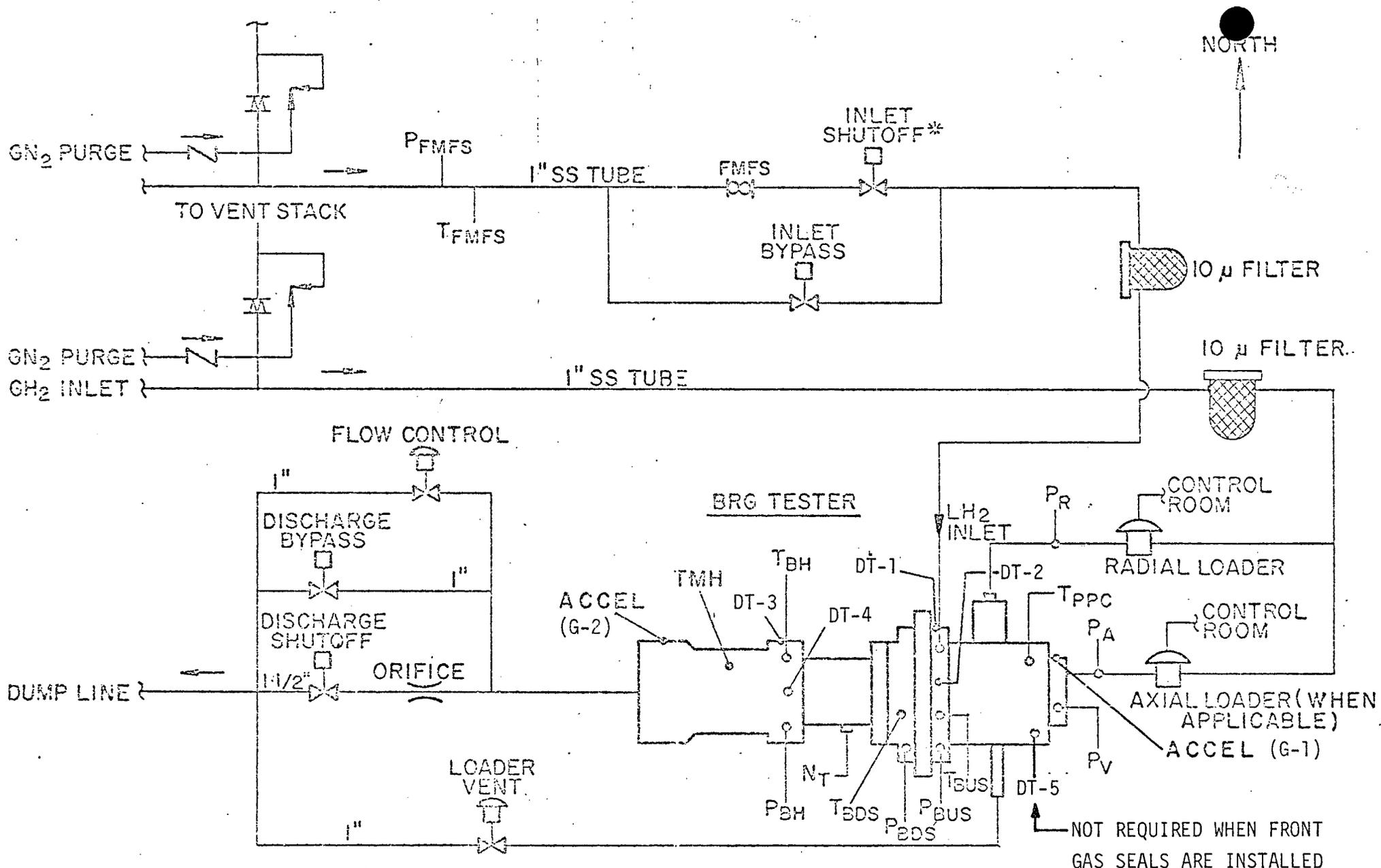
\*Fluid Pressures and Temperatures: BUS - Upstream of Test Bearing  
BDS - Downstream of Test Bearing

BH - in Bearing Housing  
MH - Motor Housing

TABLE I (Continued)  
INSTRUMENTATION & REQUIRED PARAMETERS

PARAMETER	NRDS CHANNEL	DESCRIPTION	RANGE	RECORDING		NOMINAL EXPECTED VALUE	
				STRIP	PERMANENT		
<u>SPEED</u>							
			RPM			RPM	
N-1	BQ-001	Tester Speed	0-40,000	X	X	6000-30,000	
N-2	BQ-002	Tester Speed	0-40,000	X		6000-30,000	
<u>MOTOR</u>							
V <sub>M</sub>	BH-001	Voltage	0-500 volts	X		230 volts	
I <sub>MA</sub>	BI-001	Current, Ø A	0-150 amps	X	X	45 - 70 amps	
I <sub>MB</sub>	BI-002	Current, Ø B	0-150 amps	X	X	45 - 70 amps	
I <sub>MC</sub>	BI-003	Current, Ø C	0-150 amps	X	X	45 - 70 amps	
f	BY-001	Frequency	0-700 cps	X	X	33 - 500 cps	
<u>MISCELLANEOUS</u>							
<u>SHAFT DISPLACEMENT</u>				<u>WIDE BAND</u>		<u>ΔMVMT (in.)</u>	
				(SCOPES)	(TAPE)	From Set point (SCOPE) (TAPE)	
<u>SHAFT DISPLACEMENT</u>			Inches <sup>(1)</sup>				
DT-1	BD-001	Fwd Bearing 0°	+ .00125	X	X	+ .001	+ .002
DT-2	BD-002	Fwd Bearing 90°	+ .00125	X	X	+ .001	+ .002
DT-3	BD-003	Aft Bearing 0°	+ .00125	X	X	+ .001	+ .002
DT-4	BD-004	Aft Bearing 90°	+ .00125	X	X	+ .001	+ .002
DT-5	BD-005	Loader Housing	.0025 - .0275		X		+ .010
<u>ACCELEROMETERS</u>							
G-1	BA-001	Fwd Housing	100 g's peak/peak	X	X	50 g's peak/peak	
G-2	BA-002	Aft Housing	100 g's peak/peak	X	X	50 g's peak/peak	

(1) Applies to scope ranging; tape ranging is .002 to .027 inches.



\* ELECTRICAL INTERLOCK EXISTS SO THAT WHEN SHUTOFF VALVE IS CLOSED, BYPASS VALVE COMES OPEN.

\*\* PROXIMITY PROBES (5 REQD).

FIGURE 4 LH<sub>2</sub> DUPLEX BALL BEARING TESTER, TEST STAND SCHEMATIC, NRDS, NEVADA

## 4.1.3.1 (Continued)

At an equilibrium speed of 12,000 rpm, bearing duplex set radial load may be readjusted to value specified by Test Request Supplement. Following a minimum observation period of 3 minutes, tester speed was ramped to 27,000 rpm in about 10 seconds or less. The desired steady state operating condition for these series of tests were those of operating Condition I shown in Table 2. However, in order to investigate operation at the best rotordynamics performance, Operating Condition II (Table 2) was employed during the first test of each test series of Build-Ups 16B and 17. This operating condition allowed for seeking best radial load in the range 500-1000 lbs and best speed in the range 27000-30000 rpm. Build-up 18 was operated in accordance with Operating Condition I from the beginning since there was no observable effective improvement in rotordynamic performance of Build-ups 16B and 17 at radial load and speed conditions different from those of Condition I.

## 4.1.3.2 Failure Criteria for Shutdown and Target Duration

The failure shutdown criterion in prior testing was dependent primarily on bearing performance as indicated by the various distress parameters, and on the need to investigate failure progression and cause and effect by inspecting bearings prior to on-set of very severe damage. This somewhat arbitrary failure shutdown resulted in widely varying durations and made it difficult to compare bearing performance and to evaluate the effect of various parameters from build-up to build-up. In order to obtain a more direct comparison of performance, it was decided to employ a common shutdown criterion for failure; namely, drive motor current continuously above 100 amps for 10 seconds or continuously above 115 amps for 3 seconds. All build-ups tested during the period covered by this report were shutdown on this basis.

TABLE 2

65MM BALL BEARING TEST PROGRAM OPERATING CONDITIONS (STEADY STATE)

<u>OPERATING CONDITION</u>	<u>AXIAL PRELOAD LBS</u>	<u>RADIAL LOAD ON DUPLEX SET, LBS</u>	<u>SPEED, RPM</u>	<u>LH<sub>2</sub> FLOWRATE GPM</u>	<u>LH<sub>2</sub> PRESSURE PSIG</u>	<u>LH<sub>2</sub> INLET TEMP., °R (T<sub>BUS</sub>)</u>	<u>TARGET DURATION HRS</u>
I	600	500	27,000	55-60	225	54 (max)	15
II	600	Seek Best 500-100	Seek Best 27,000-30,000	55-60	225	54 (max)	15
III	600	1000	Seek Best 27,000-30,000	55-60	225	54 (max)	15
IV	600	1000	27,000	55-60	225	54 (max)	15
V	600	500	27,000	150 <sup>(b)</sup> 73 <sup>(c)</sup>	300	70 <sup>(a)</sup>	15
VI	600	1000	27,000	150 <sup>(b)</sup> 73 <sup>(c)</sup>	300	70 <sup>(a)</sup>	15

(a) Predicted TPA Bearing Inlet Temperature

(b) Same Ht. Capacity as TPA Fluid into Bearings (70°R, 1000 psia)

(c) Same Ht. Capacity as Tester Fluid, Oper. Cond. I, II, III, IV.

## 4.1.3.2 (Continued)

The established target duration for each build-up tested was 15 hours, a duration 50% longer than the required 10-hour life of the NERVA TPA. It was decided that at this duration, the test bearings should be carefully evaluated for general condition; wear, metal fatigue, retainer wear, etc. If general operating performance prior to shut-down was satisfactory and the test bearings were found in acceptable condition after careful inspection, the test bearing set could be continued on test to accumulate additional operating time for reliability information.

4.1.3.3 Push-Pull and Radial Play Tests in LH<sub>2</sub>

There are several clearances and fits which are critical to the proper operation of the bearing duplex set. Of prime importance is the clearance existing between the bearing cartridge O.D. and housing bore. Minimum radial clearance is required (approximately .0005 inch) while allowing complete axial freedom. The determination of this value requires very careful consideration of materials, geometry, operating temperatures, speed, and preloads. Since some of these variables are not easily evaluated, it is necessary to experimentally establish that the desired freedom exists at or near the operating temperature.

Two tests have been developed and implemented to determine this information. They constitute a two phase program prior to rotational tests and have been labeled "push-pull test" and "radial play test". In essence, the push-pull test is qualitative in that it only determines that clearance does or does not exist. The radial play test follows the push-pull test and gives an indication of the actual amount of total radial clearance between bearings, cartridge and housing. The following sections discuss how each test is performed and summarizes the results relative to build-ups 16, 17 and 18.

## 4.1.3.3. (Continued)

"Push-Pull" Test - Referring to TMP-108, (Appendix A), it can be seen that the tester assembly is modified in two ways to prepare it for the LH<sub>2</sub> experiments. The object of these two modifications is to insure that the shaft assembly has limited but unrestricted axial freedom at room temperature. To accomplish this, an undersized slave bearing (50mm) is installed to prevent interference at the radial interface. Also, excess axial stack-up shims are used to permit increased shaft movement in the axial direction. The result is a shaft assembly, unrestrained in the axial direction with a total travel of approximately .125". To complete the tester set-up, an electrical sensor is positioned adjacent to and approximately .025" downstream from the cartridge.

Testing is accomplished by first establishing cryogenic conditions as follows:

- |    |                             |   |           |
|----|-----------------------------|---|-----------|
| A. | LH <sub>2</sub> Temperature | < | 54°R      |
| B. | Pressure                    | = | 225 psig  |
| C. | Flow Rate                   | = | 30-40 gpm |
| D. | Radial Load                 | = | 0 lb.     |
| E. | Axial Load                  | = | 0 lb.     |

The shaft assembly is then hydraulically unbalanced by applying a small differential axial pressure. This differential is slowly increased until the shaft moves to the aft position and the cartridge makes contact with the electrical sensor. The test is considered successful if movement is sensed with an applied axial load less than 350 lb. If the applied axial load reaches 350 lb and no movement is sensed, the cartridge is considered to be "locked" and must be modified to provide additional clearance.

#### 4.1.3.3 (Continued)

The above procedure was followed for Build-up 16 only. Shaft movement was sensed almost immediately after the first small increment of axial load was applied thus indicating adequate clearance. The push-pull test was eliminated for Build-ups 17 and 18 because a comparative analysis of actual component dimensions clearly indicated that Build-ups 17 and 18 had at least as much clearance as Build-up 16 (Table 4). Based on this, it was concluded that these shaft assemblies definitely would demonstrate complete axial freedom.

After completion of a "push-pull" test, the tester is removed from the test stand and returned to the build-up room. The tester is partially disassembled to remove both the undersized slave bearing and excess stack-up shims. The tester is then reassembled per TMP-103 (Appendix A) including installation of "radial play" hardware into the shaft housing per Section 16.0. The "Radial Play" hardware is the only deviation from a normal build-up and consists of a spring and retainer plug installed at the load sleeve end of the shaft. The spring positions the shaft at the bottom dead center location or "down" position.

Again, testing is accomplished by first establishing cryogenic conditions as follows:

- A.  $\text{LH}_2$  Temperature < 54°R
- B.  $\text{LH}_2$  Pressure = 225 psig
- C. Flow Rate = 30-40 gpm
- D. Axial Load = 100 psi = 700 lb.
- E. Radial Load = 0 lb.

## 4.1.3.3 (Continued)

Radial load on the shaft is then gradually increased in 5 psi (approximately 20 lb) increments from 0 psi to 40 psi. At some load, the "radial play" spring load will be overcome and the shaft will move to the top dead center position. Amount of movement is proportional to the total clearance present between bearings, cartridge and housing. The shaft movement is measured by distance detectors which convert a measured gap into a voltage output which in turn is recorded on strip charts. Figure 5 shows the placement of distance detectors. The forward detectors (adjacent to duplex set) is DT-1 and the rear detector is DT-3. Two additional distance detectors, DT-2 (forward) and DT-4 (rear) are at 90° and also included in the instrumentation list. These are used in conjunction with DT-1 and DT-3 for analyzing dynamic affects only.

The "radial play" test was attempted for all three build-ups. No data is available for build-up 16 due to a malfunction in the distance detector circuitry. The results from Build-ups 17 and 18 are shown in Tables 9 and 12 and in Figures 19 and 32. The data indicates in both cases that total radial clearance at the duplex set is approximately .002".

ANSC LH<sub>2</sub> DUPLEX BALL BEARING TESTER

(65 MM, P/N 1138060-3)

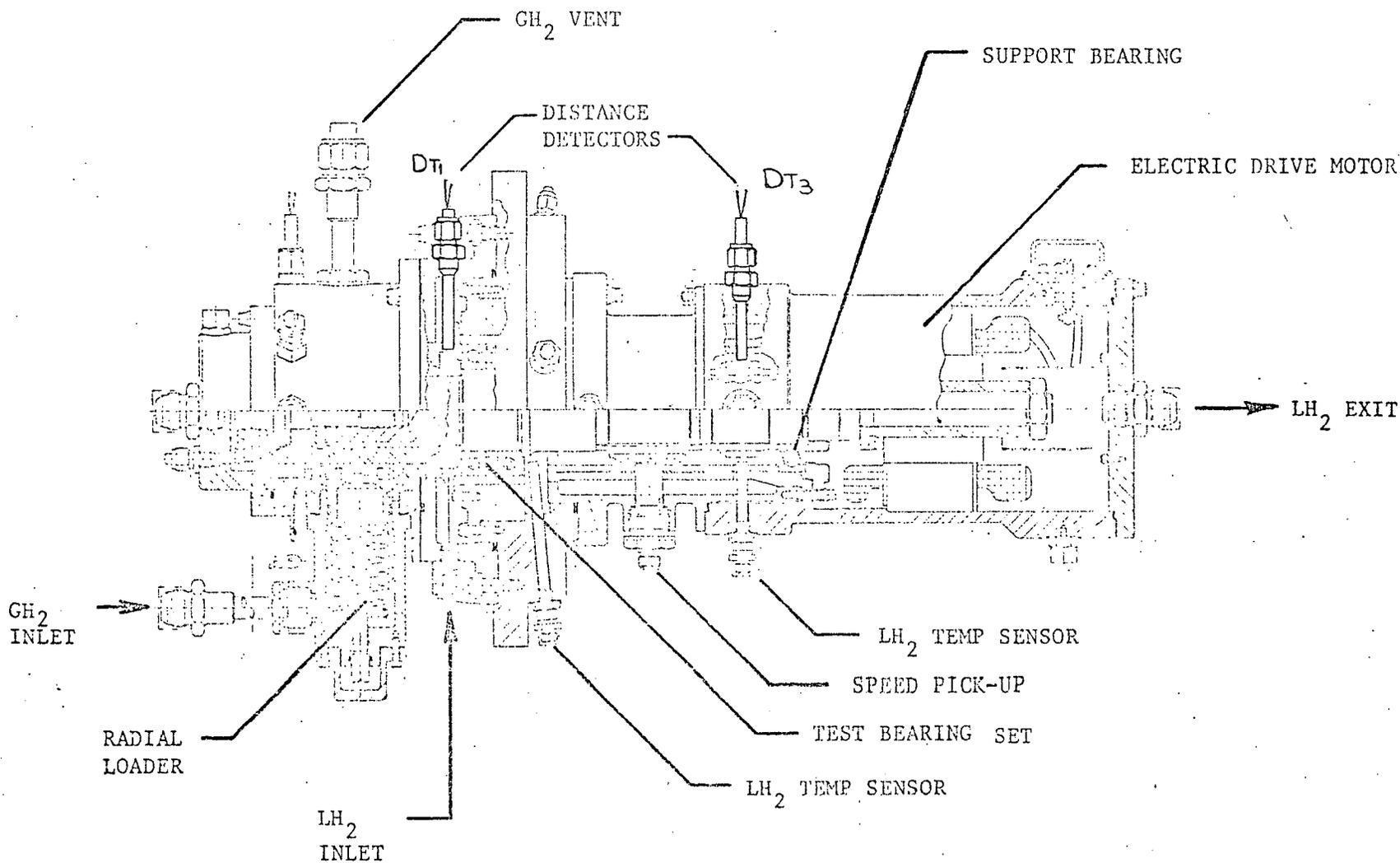


FIGURE 5 - SKETCH OF 65MM BEARING TESTER 1138060-3 SHOWING LOCATION OF DISTANCE DETECTORS, DT<sub>1</sub> & DT<sub>3</sub>

#### 4.2.0 RESULTS OF LH<sub>2</sub> TESTS ON BUILD-UPS 16, 17 AND 18

##### 4.2.1 Build-Up 16A and 16B

Build-up 16A was set up for the push-pull test in LH<sub>2</sub> to determine the axial freedom of the 440C cartridge in the operating environment. Build-up 16B was set up for the official rotational test which included the radial play check in LH<sub>2</sub> prior to rotation. Build-up 16A was tested on 12-15-71 while the rotational test series of Build-up 16B (1190-65-016-001, 002, 003, 004, and 005) covered the period 12-17-71 through 1-4-72.

##### 4.2.1.1 Purpose of Tests and General Features of Build-Up 16B

The purpose of this test series was to test a 65mm duplex bearing set similar to the set tested in Build-up #15 at the Cryogenic Lab., Sacramento, California, during May 1971 in an effort to compare the performance of the two facilities and to provide a frame of reference for future bearing testing in Test Cell A, NRDS, Nevada. The two tester build-ups were very similar with the exception that Build-up #16B had an interference fit of all shaft assembly components and minimum radial fit of bearing set cartridge, both desirable features. Both build-ups were precision dynamically balanced by a step type balancing procedure.

Table 3 shows the principal features of Build-up 16B and compares these features with those of Build-up 15. The main difference between the two build-ups is associated with the fits of some of the shaft assembly components. Build-up 16B fits are considered to be somewhat more desirable. A general comparative summary of the bearing set, shaft, bearing set cartridge, and housing fits for the last four 65mm bearing Build-ups tested is shown in Table 4. Figure 6 is a sketch of the duplex bearing assembly and shows the critical interfaces tabulated in Table 4.

TABLE 3  
COMPARISON OF PRINCIPAL FEATURES OF BUILD-UP'S 15 AND 16B

<u>TESTER ASSY CONFIGURATION</u>	<u>BU #15 Cryo Lab, Sacto</u>	<u>BU #16B TCA NRDS, Nev.</u>
Part Number/Serial Number	1138060-3/001	1138060-3/001
Shaft-Armature Coupler Fit at RT	Loose	Tight
Shaft-Armature Fit at RT	Loose	Tight
Dynamic Balancing Procedure	Step Type	Step Type
Bearing Set Cartridge	P/N 1139308-4	P/N 1139308-6 (Minimum Radial Fit)
Material	440C	440C
Actual Bearing-to-Cartridge ID Fit at RT		
Upstream Bearing	0.0011/0.0012 Loose	0.0007/0.0008 Loose
Downstream Bearing	0.0010/0.0014 Loose	0.0008 Loose
Actual Housing-to-Cartridge OD Fit at RT	.0046/.0049 Loose	.0025/.0035 Loose <sup>(a)</sup>
Bearing Assembly P/N	1138952-7	1138952-7
Basic P/N	1138146-1 (Honed Raceways)	1138146-1 (Honed Raceways)
Serial Number	880065 Upstream 880063 Downstream	880062 Upstream 880066 Downstream
Retainer:		
Material	Armalon	Armalon
Basic Configuration	From 1138146-1 (Thick-Line)	From 1138146-1 (Thick-Line)
Pockets Elongated, Ins	0.040 + .003 (Reworked)	0.040 + .003 (Reworked)
MoS <sub>2</sub> Lubricant	Raceways & Retainer	Raceways & Retainer
Shaft Rotation	C.C.W.	C.C.W.

(a) Bell-Mouth Housing

TABLE 4

BEARING-CARTRIDGE-HOUSING ROOM TEMPERATURE FITS FOR BEARING TESTER 1138060-3  
 BUILD-UPS 15, 16B, 17 AND 18

BUILD-UP	INTERFACE (SKETCH FIG. 6 )	PART NO.	MAT'L	R.T. DIA PRINT INS.	R.T. FIT PRINT INS.	BEARING LOCATION			
						UPSTREAM		DOWNSTREAM	
						R.T. DIA ACTUAL INS.	R.T. FIT ACTUAL INS.	R.T. DIA ACTUAL INS.	R.T. FIT ACTUAL INS.
						S/N 880065		S/N 880063	
15	A	1139308-4 (S/N 880002)	440C	3.9382 3.9384	0.0012 L 0.0016 L	3.9381 3.9382	0.0011 L 0.0012 L	3.9380	0.0010 L 0.0014 L
		1138146-1	440C	3.9370 3.9368		3.9370 -		3.9370 3.9368	
	B	1138199-1	INCOX	4.5000 4.5002		4.4989 <sup>(a)</sup> 4.4998			
		1139308-4 (S/N 880002)	440C	4.4953 4.4951	0.0047 L 0.0051 L		0.0036 L 0.0045 L		
						S/N 880062		S/N 880066	
16B	A	1139308-6 (S/N 880001)	440C	3.9377 3.9379		3.9376 3.9377		3.9377 -	0.0008 L
		1138146-1	440C	3.9370 3.9368	0.0007 L 0.0011 L		0.0007 L 0.0008 L	3.9369	
	B	1138199-1	INCOX	4.5000 4.5002		4.4989 <sup>(a)</sup> 4.4998			
		1139308-6 (S/N 880001)	440C	4.4963 4.4961	0.0037 L 0.0041 L		0.0025 L 0.0035 L		
						4.4964 4.4963			

TABLE 4 (Cont'd)

BEARING-CARTRIDGE-HOUSING ROOM TEMPERATURE FITS FOR BEARING TESTER 1138060-3  
BUILD-UPS 15, 16B, 17 AND 18

BUILD-UP	INTERFACE (SKETCH FIG. 6 )	PART NO.	MAT'L	R.T. DIA PRINT INS.	R.T. FIT PRINT INS.	BEARING LOCATION			
						UPSTREAM		DOWNSTREAM	
						R.T. DIA ACTUAL INS.	R.T. FIT ACTUAL INS.	R.T. DIA ACTUAL INS.	R.T. FIT ACTUAL INS.
						S/N 880070		S/N 880068	
17	A	1139308-6 (S/N 880002)	440C	3.9377 3.9379		3.9378 3.9379		3.9379	
					0.0007 L 0.0011 L		0.0008 L 0.0010 L		0.0010 L
		1139188-2	440C	3.9370 3.9368		3.9370 3.9369		3.9369	
	B	1138199-1	INCOX	4.5000 4.5002		4.4995 4.4998			
					0.0037 L 0.0041 L		0.0032 L 0.0036 L		
		1139308-6	440C	4.4963 4.4961		4.4963 4.4962			
						S/N 880067		S/N 880069	
18	A	1139733-2 (S/N 880001)	440C	3.9377 3.9379		3.9377		3.9378	
					0.0007 L 0.0011 L		0.0008 L 0.0010 L		0.0009 L 0.0011 L
		1139188-2	440C	3.9370 3.9368		3.9367 3.9369		3.9367 3.9369	
	B	1138199-1	INCOX	4.5000 4.5002		4.4989 <sup>(a)</sup> 4.4998			
					0.0037 L 0.0041 L		0.0026 L 0.0036 L		
		1139733-2 (S/N 880001)	440C	4.4963 4.4961		4.4963 4.4962			

(a) Bell-mouth toward loader side (front).

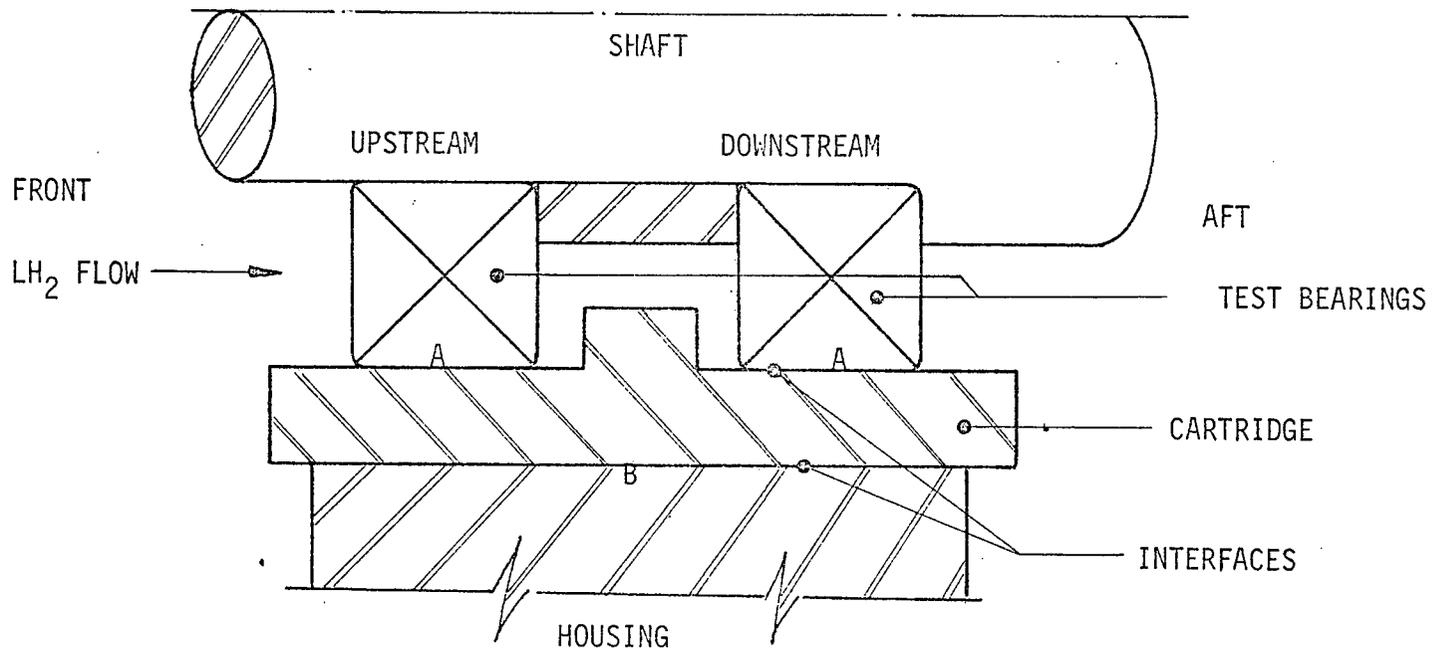


FIGURE 6 - SKETCH, DUPLEX BALL BEARING ASSEMBLY FOR TESTERS P/N 1138060-3  
SHOWING CRITICAL INTERFACES

#### 4.2.1.2 General Summary Discussion of Build-Up 16B

Radial play test in LH<sub>2</sub> for Build-up 16B were not successful since distance detector readings were subsequently found to indicate movement of shaft in opposite direction to application of load. The problem was probably associated with instrumentation circuitry which also caused the distance detectors to malfunction during the first rotational test. The problem was resolved between tests and believable distance detector scope patterns were obtained for subsequent tests.

A chronological summary discussion of the rotational tests on this build-up follows. Table 5 summarizes the results of the push-pull tests in LH<sub>2</sub>, while Table 6 is a condensed summary of the rotational test results for this build-up. An overall test results summary for Build-up 15 through 20 is shown in Table 7.

Following the prescribed chilldown in LH<sub>2</sub>, the tester was started and operated at 12,000 rpm for 19 minutes while the distance transducers were being worked on in an effort to produce meaningful oscilloscope traces. When these efforts were unsuccessful, it was decided to proceed with the test.

##### 4.2.1.2.1 General Performance History

The speed ramp from 12,000 rpm to 27,000 rpm was smooth and very similar to that experienced with BU #15. A critical speed was observed at about 22,000 rpm just as was observed with Build-up 15 and all of the previous tester build-ups. In this case, critical speed was indicated by noise level alone since displacement transducers were not operating properly at this time. Drive motor current did not overshoot as had been noted with other bearings with retainers having circular pockets with insufficient

TABLE 5

BUILD-UP 16A 65MM BEARING TEST RESULTS (PUSH-PULL TEST) (12-15-71)

PURPOSE: Push-Pull test to evaluate axial freedom of bearing support cartridge in LH<sub>2</sub> (non-rotating test).

BEARING SET: Assy P/N 1138952-7 (Basic P/N 1138146-1) S/N's 880062, 880066;retainer, Armalon from 1138146-1 "Thick-Line" elongated pockets.

BUILD-UP FEATURES:

1. Interference fit of armature-to-shaft and coupling-to-shaft.
2. Step dynamic balancing.
3. Displacement transducer calibration steps reduced to .0005/.001".
4. Bearing set cartridge P/N 1139308-6 (minimum radial fit):
 

	Room Temperature Fit
Housing-to-Cartridge OD	.0025/.0035 Loose
Bearing OD-to-Cartridge ID	.0007/.0011 Loose

OBSERVATIONS:

1. Cartridge has axial freedom in LH<sub>2</sub> at an equilibrium LH<sub>2</sub> pressure of 225 psig and temperature of 42°R.

TABLE 6

BUILD-UP 16B 65MM BEARING TEST RESULTS (12-17-71)

PURPOSE: First Bearing test in Test Cell A, NRDS, Nevada. Reference test to compare with BU #15 tested at Cryogenic Lab., Sacramento. Evaluate effect of:

1. Interference fit of all shaft assembly components.
2. Bearing cartridge with minimum radial fit.

BEARING SET: Assy P/N 1138952-7 (Basic P/N 1138146-1) S/N's 880062, 880066 with Armalong retainer from P/N 1138146-1, "Thick-Line", elongated pockets.

SPEED: 27,000 RPM (determined after searching for best speed between 27,000-30,000 RPM).

LOAD: 500/600 lbs radial/axial, (determined after searching for best radial load between 500-1000 lbs).

LH<sub>2</sub> FLOW: 55/70 GPM at 225 PSIG.

DURATION: 8.68 HRS

SHUTDOWN: Drive motor current above 100 amps (105 amps) for 10 secs, noisy, Delta T = 12/13°R DT's indicated severe shaft dynamics.

OBSERVATIONS:

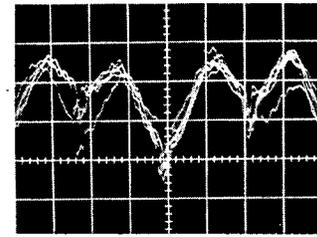
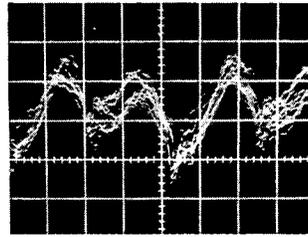
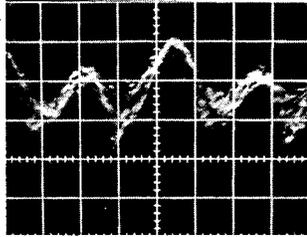
1. Excellent performance for 1.8 hrs. No initial hi amps steady state amps = 45-48, Delta T = 2.5-3.0°R.
2. Gradual Deterioriation from 1.8 hrs. Amps to 85/90, Delta T = 10°R at 3.66 hrs.
3. Motor current steady in range 80-90 amps, Delta T steady at 8-10°R, and gradual increase in shaft dynamics during subsequent 4.69 hrs.
4. Final 0.33 hrs, amps = 80-110, Delta T = 9-13°R, noisy, severe shaft dynamics.
5. Bearing inspection revealed:
  - A. Upstream bearing in visually good condition. Retainer wear moderate.
  - B. Downstream bearing in generally poor condition. Retainer broken through across retainer, very heavy OD and pocket wear. Balls and raceways frosty, some pitting, metal smearing.
  - C. 50mm support bearing in poor condition. Balls and raceways frosty. Very heavy wear of retainer pockets and OD.

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pocket clearance. Like Build-up 15, the Armalon retainers had elongated pockets and gave better initial performance. Search for best operating speed in the range 27000 to 30000 rpm and best operating radial load in the range 500 to 1000 lbs resulted in the speed and load conditions of 27000 rpm and 500 lbs, respectively. The 500 lbs radial load was the desired operating load. Motor current was initially at 45-47 amps and fluid delta T was at 2.5-3°R. Operation was very smooth, and current and delta T remained at a steady low level (less than 50 amps, and 3°R) for 1.8 hours. From this point in time to shutdown (due to LH<sub>2</sub> depletion) at 3.66 hrs, there was a gradual deterioration to a current level of 85/90 amps and delta T to about 10°R. There were several moderate excursions in vent cavity pressure (P<sub>V</sub>) which caused corresponding excursions in radial load and some momentary increase in current and delta T. It was also observed that there was a larger than previously noted delta T across the 50mm support bearing, indicating a possible problem with this bearing.

Ambient temperature breakaway torque check after 3.66 hours indicated an increase from 9 in-lbs when new to about 14 in-lbs, with some roughness.

It was interesting that current and delta T remained very steady in the range of 80-90 amps and 8-10°R, respectively, for an additional 4.69 hours. The delta T across the 50mm support increased into the range of 20+ °R, indicating that the current level observed was probably in large measure contributed by damage to this bearing. In Test 005, the displacement transducers were working and indicated a deterioration of the rotor dynamics. Figure 7 shows some of these scope traces arranged chronologically to show progressive deterioration. The scope traces had many



ACCUM. DURATION: 6.38 HRS  
DRIVE MOTOR CURRENT: 87 AMPS  
LH<sub>2</sub> ΔT: 8.0°F

7.13 HRS  
78 AMPS  
9.0°F

8.62 HRS  
100 AMPS  
12.0°F

65 MM BALL BEARING TEST SERIES 1190-65B-016 - B/U 16B  
FORWARD VERTICAL SCOPE TRACE (DT-1), SPEED: 27000 RPM

FIGURE 7-TYPICAL BEARING SHAFT DYNAMICS AS RELATED TO BEARING PERFORMANCE DETERIORATION

superimposed images which are usually indicative of unstable rotor dynamics generally associated with bearing malperformance.

Overheating of the M-G set drive motor breakers (due to high amps, time, and very warm enclosed room) caused three automatic shutdowns with tester drive motor current at about 87/90 amps. This was unusual and never experienced at the Sacramento Plant Cryo Lab. After three automatic shutdowns, each of shorter duration than the previous, it was decided to terminate and repair circuit breaker.

With circuit breaker replaced so that higher current could be tolerated (motor mfg consulted about problem, gave go ahead for motor operating at a field temperature of 265°F) test -005 was initiated. Breakaway torque of tester prior to test -005 was 22 in-lbs and moderately rough. Tester started easily and was on test at 82/85 amps and delta T of 7/9°R. Operation was very smooth with moderate noise level for 2.0 hours. At this time, a sudden change in current, delta T and noise occurred (also scope patterns), indicate a serious distress condition. LH<sub>2</sub> flow was maintained at about 65 gpm and increased to 70 gpm as a maximum. Current excursion were from 80 to 105+ amps, delta T to 13°R. Failure shutdown per established criterion occurred at 2.33 hours of this test. Shaft dynamics were severe and noise was high and erratic. MG drive motor field temperature was measured at 165°F. Total accumulated duration this build-up was 8.68 hours. The predicted expected duration was 5.0 + hours. Performance of build-up 16B was very similar to that of build-up 15 considering the added life of build-up 16B due to the more severe failure shutdown criterion. On the same shutdown basis, build-up 16B could have been shutdown in 4 hours which would have agreed quite well with 4.33 hours for build-up 15.

Plots of the various parameters of interest as a function of operating time are shown in Figures 8 through 10. The parameters plotted are speed radial load ( $\Delta P_{RV}$ ), LH<sub>2</sub> delta T, and drive motor current (Friction). These plots clearly show the bearing performance history.

#### 4.2.1.2.2 Post-Test Condition of Test Bearings

##### Microscopic bearing inspection

revealed the following conditions:

##### Upstream Bearing:

Metal Parts in generally good condition, no pitting, no cracking, light frosty texturing of raceways.

Light micropitting of surfaces most balls.

Retainer - O.D. wear slight and uniform 360°, pocket wear heavy - one pocket almost worn through at I.D.

##### Downstream Bearing:

Metal Parts in fair-poor condition - worse than upstream bearing. Some balls frosty, outer race land very fine transverse cracks caused by severe rubbing of broken retainer. Inner race in fairly good condition. Some micro pitting. O.D. of outer race fretted.

Retainer - Poor condition, failed by rupture across one pocket. Very heavy OD wear (majority of wear caused by break and probably occurred during last .33 hours), surface charred, black appearance.

##### 50mm Support Bearing:

Metal Parts - Balls slightly dull gray color, several appear to be frosted. Two balls almost in contact. Raceways appear slightly pitted or galled.

Retainer - No cracks or visible breaks but all pockets appear heavily worn. 2 pockets almost pushed through.

All preload springs in good condition.

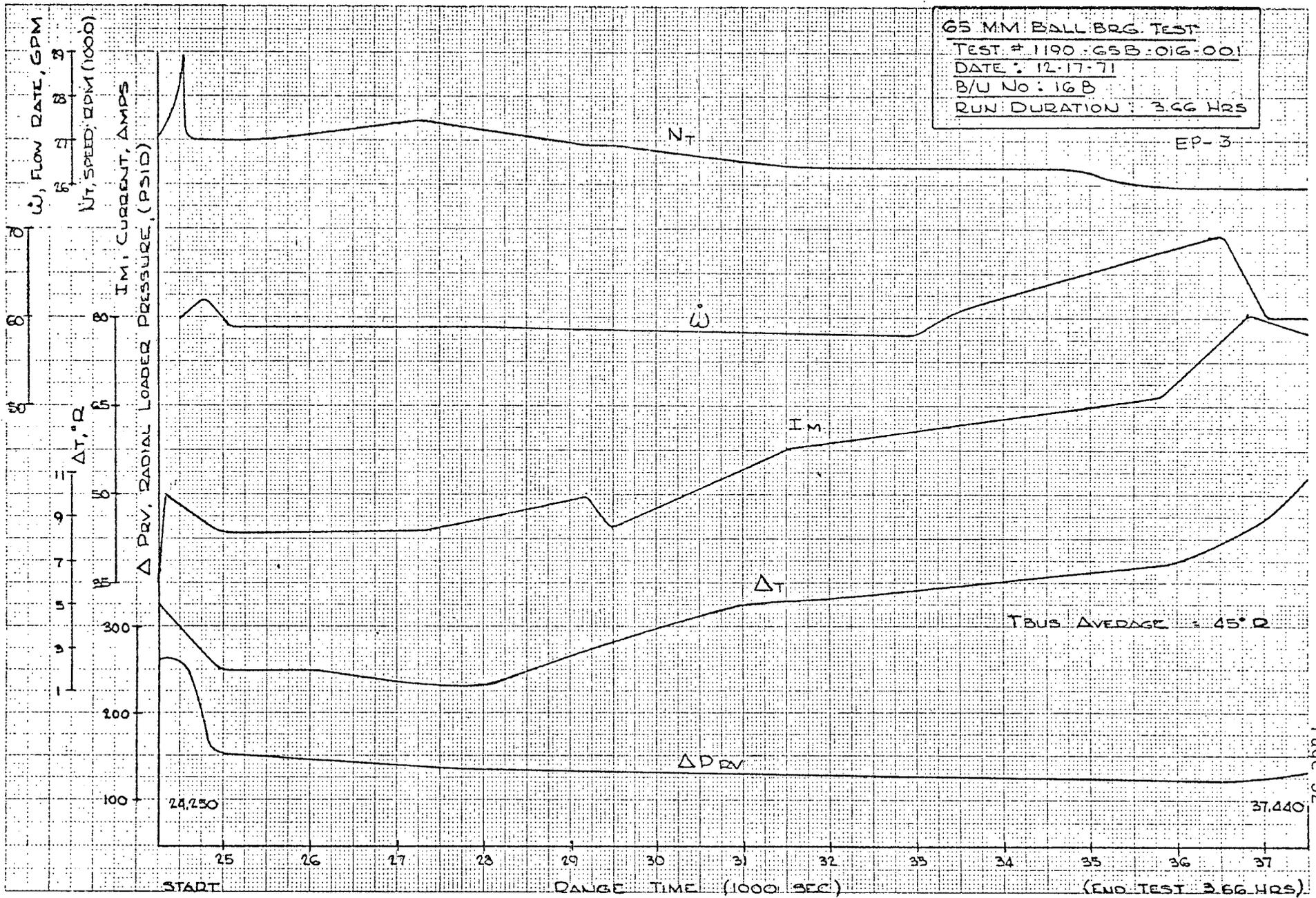
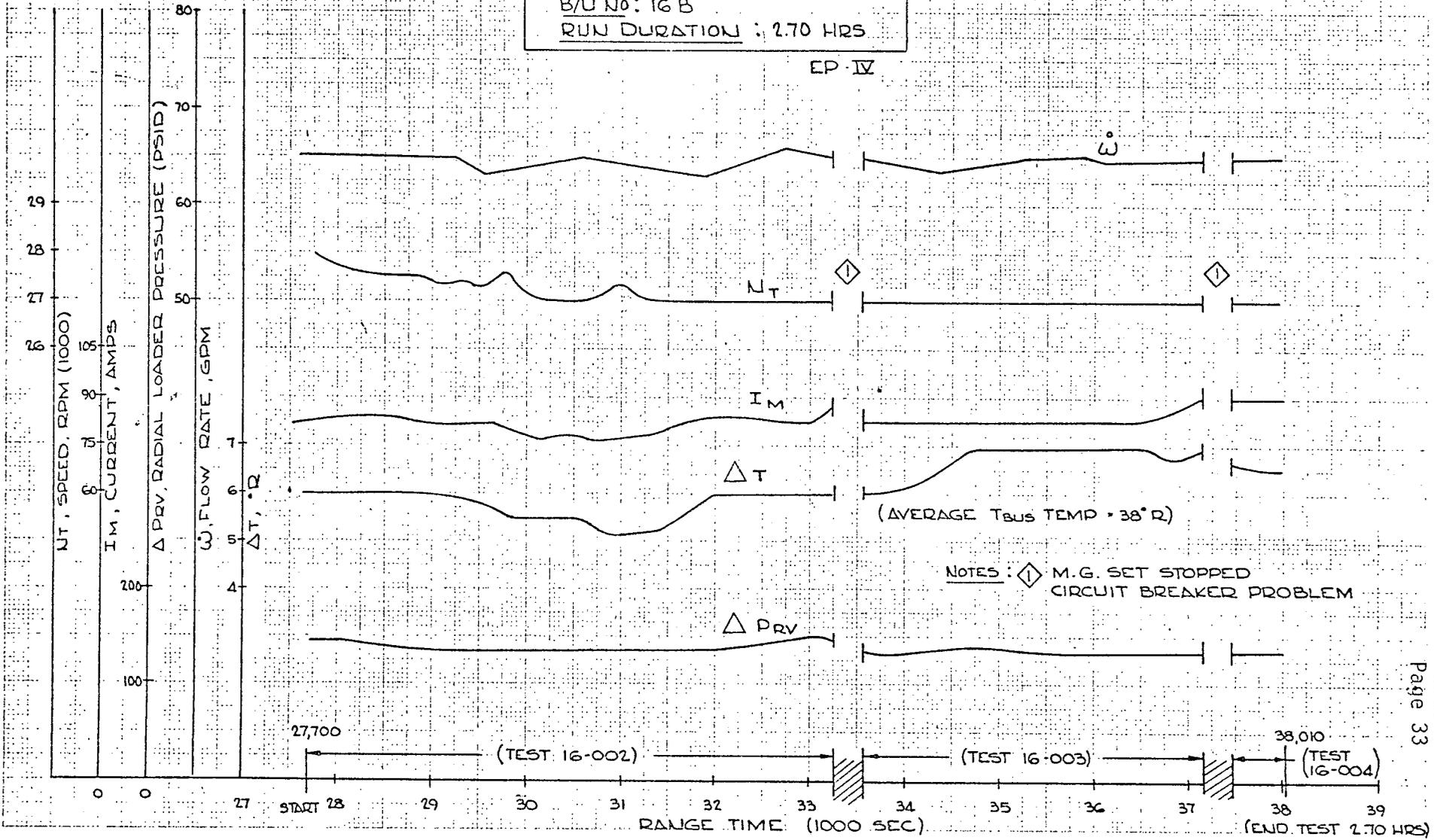


FIGURE 8 - 65MM BEARING PERFORMANCE PARAMETERS AS A FUNCTION OF OPERATING TIME - BUILD-UP 16B

65 MM BALL BRG TEST  
 TEST: 1190-65-016  
 DATE: 12-29-71  
 B/U No: 16B  
 RUN DURATION: 2.70 HRS

**65 MM BALL BRG TEST**  
 TEST: 1190-65-016  
 DATE: 12-29-71  
 B/U No: 16B  
 RUN DURATION: 2.70 HRS

EP-IV



NOTES:  $\diamond$  M.G. SET STOPPED  
CIRCUIT BREAKER PROBLEM

FIGURE 9 - 65MM BEARING PERFORMANCE PARAMETERS AS A FUNCTION OF OPERATING TIME - BUILD-UP 16B

65 MM BALL BRG TEST  
 TEST : 1190-65-016-005  
 DATE : 1-4-72  
 B/U No : 16 B  
 RUN DURATION : 2.32 HRS

EP-V

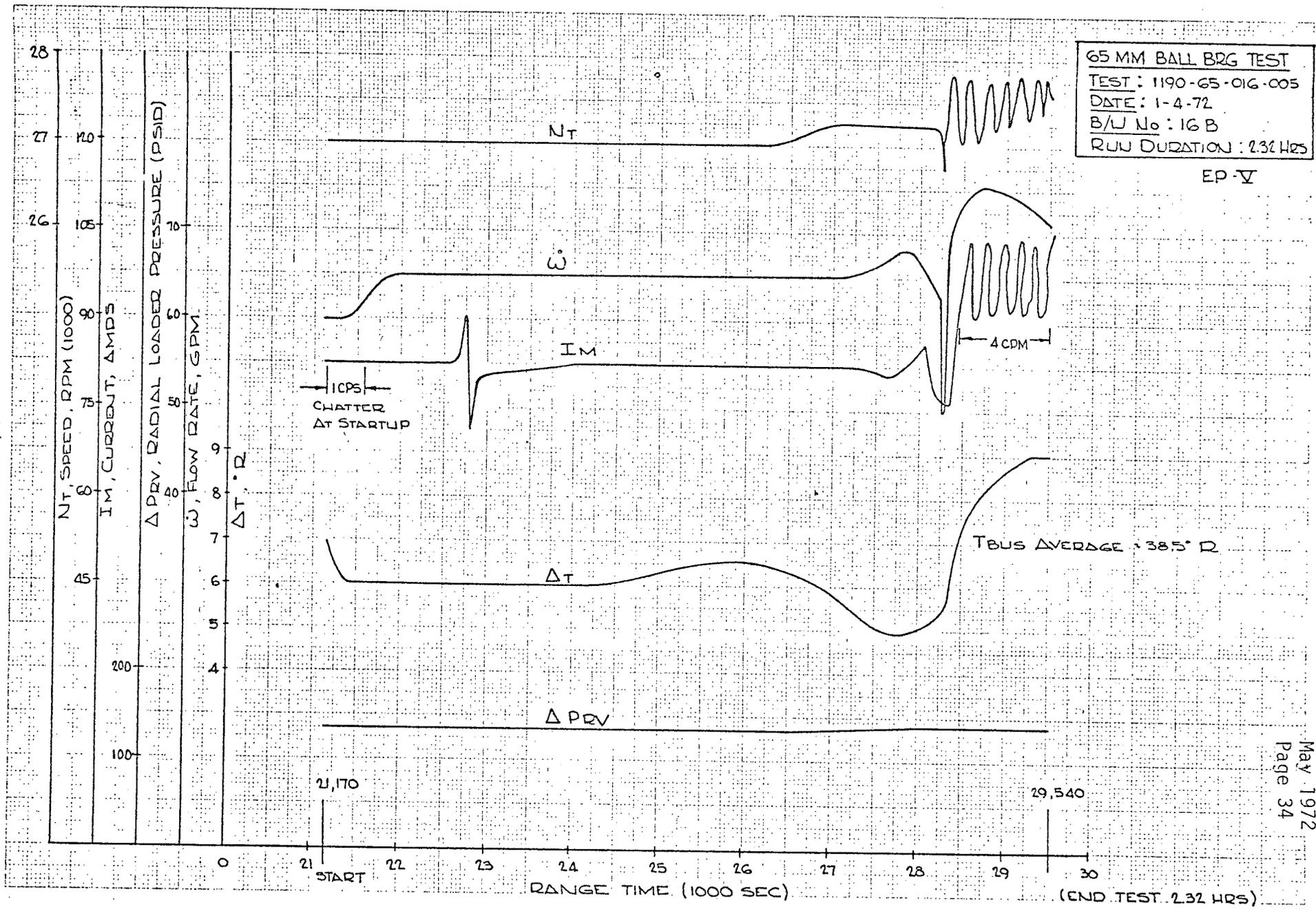


FIGURE 10 - 65MM BEARING PERFORMANCE PARAMETERS AS A FUNCTION OF OPERATING TIME - BUILD-UP 16B

The condition of the 65mm bearing set is a reversal of the usual condition observed in that the downstream bearing of this build-up is in worse condition than the upstream bearing. Generally the opposite is true. Figures 11, 12, 13 and 14 are photographs of the upstream bearing and Figures 15, 16, 17 and 18 are photographs of the downstream bearing. These photographs show the generally fair-good condition of the metal components of these bearings and visually indicate the degree of wear of the upstream bearing retainer and the wear and rupture failure of the downstream bearing retainer. Post-test measurements and weights of balls from each bearing are shown in Table 7. With respect to wear, the balls of the upstream bearing (S/N 880062) were somewhat worse than the balls of the downstream bearing (880066), although the general bearing condition of the upstream bearing was significantly superior.

It is not yet clear whether the damage to the 50mm ball bearing occurred first (delta T across this bearing was higher than normal from about 2.5 hours) and then caused the nearest bearing (the downstream 65mm bearing) to progress to failure. On the other hand, the upstream bearing, visually at least, seems as if it was not under the load normally expected (as for example, the load on the upstream bearing of build-up 15). It can be speculated that the observed condition of the 65mm bearing set was the result of using the cartridge with minimum radial fit. This cartridge fit, it may be argued, gave better bearing support but at the same time allowed a radial load distribution which favored the upstream bearing. These observations would propose a bearing load distribution in the 65mm bearing duplex set which is very sensitive to cartridge fit, an explanation which does not seem entirely logical at this time.



65mm BALL BEARING  
P/N 4135152-1  
P/N 820062 (UPSTREAM)  
4135152 P/N 410

FIGURE 11 - POST-TEST PHOTOGRAPH OF UPSTREAM  
BEARING COMPONENTS OF BUILD-UP  
16B - GENERAL VIEW



FIGURE 12 - POST-TEST PHOTOGRAPH OF UPSTREAM BEARING METAL COMPONENTS OF BUILD-UP 16B - CLOSE-UP VIEW

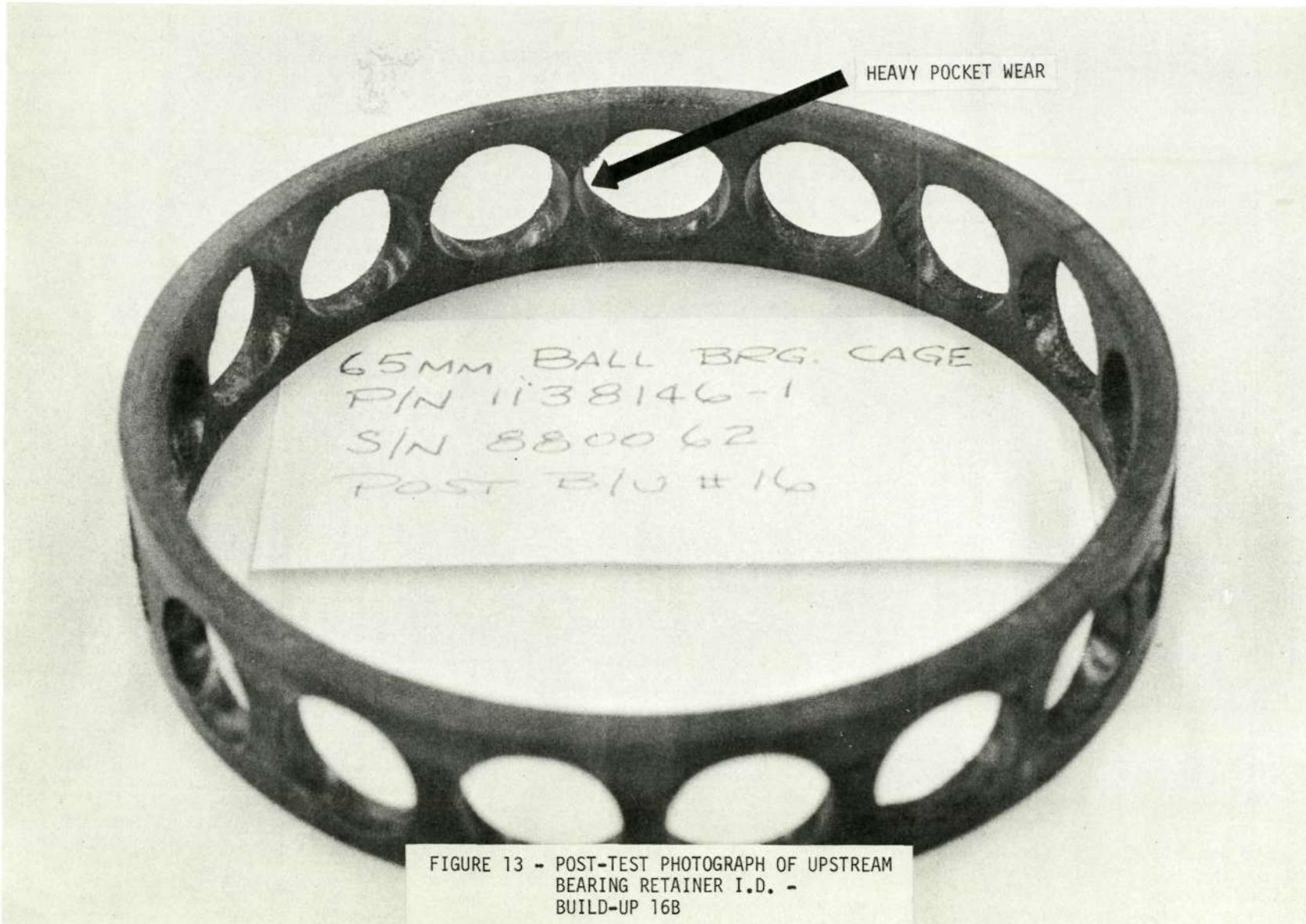
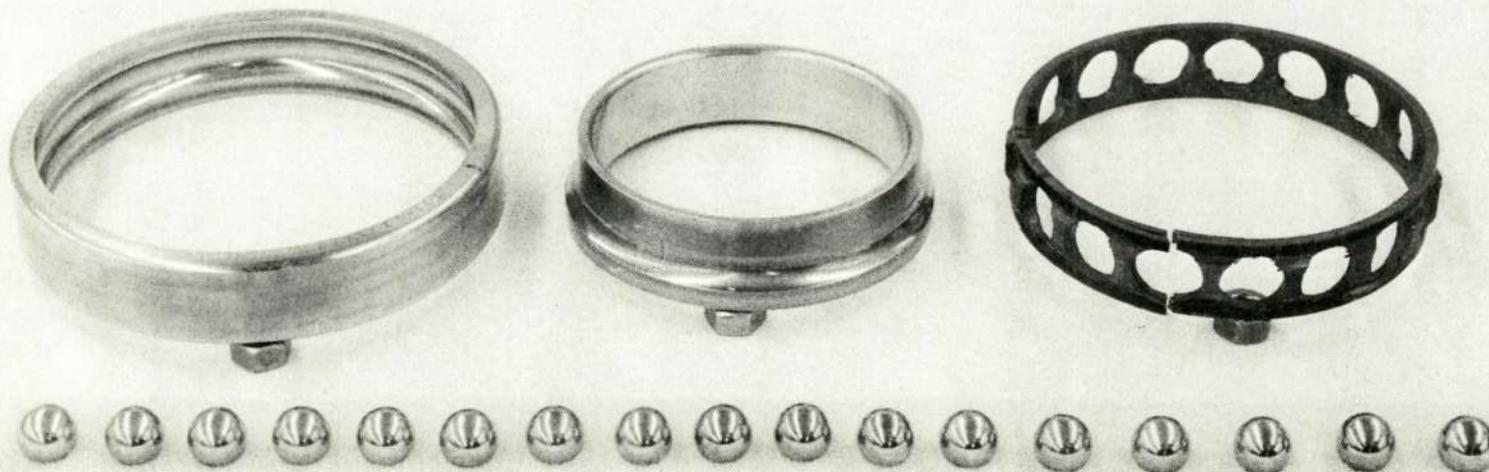


FIGURE 13 - POST-TEST PHOTOGRAPH OF UPSTREAM BEARING RETAINER I.D. - BUILD-UP 16B



65MM BALL BRG. CAGE  
P/N 1138146-1  
S/N 880062  
POST B/U #16

FIGURE 14 - POST-TEST PHOTOGRAPH OF UPSTREAM  
BEARING RETAINER O.D. -  
BUILD-UP 16B



65MM BALL BEARING  
P/N 1138952-7  
S/N 880066 (DOWNSTREAM)  
POST B/N #16

FIGURE 15 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING COMPONENTS OF BUILD-UP 16B  
GENERAL VIEW

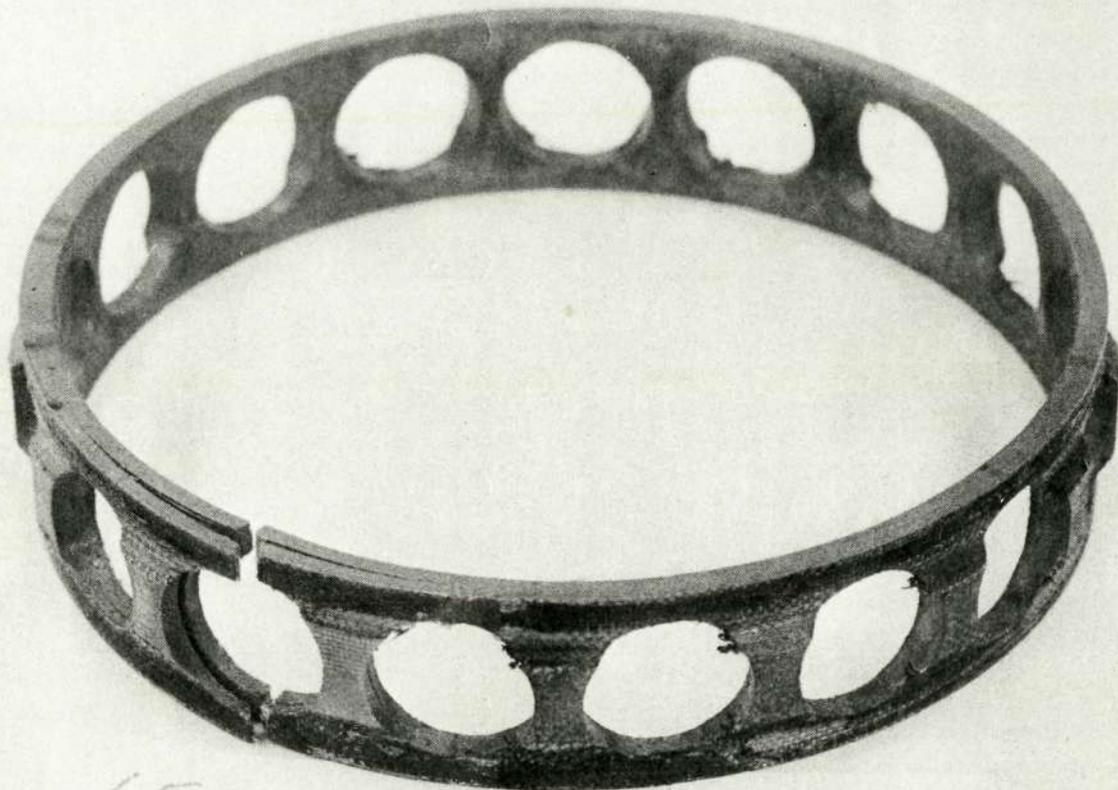


65 MM BALL BEARING  
P/N 1138952-7  
S/N 880066 (DOWNSTREAM)  
POST B/U #16

FIGURE 16 - POST-TEST PHOTOGRAPH OF DOWNSTREAM BEARING METAL COMPONENTS OF BUILD-UP 16B - CLOSE-UP VIEW



FIGURE 17 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING RETAINER I.D. - BUILD-UP  
16B



65MM BALL BRG. CAGE  
P/N 1138146-1  
S/N 880066  
POST B/O # 16

FIGURE 18 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING RETAINER O.D. - BUILD-UP  
16B

#### 4.2.2 Build-Up 17

Build-up 17 was the first test with the new lot of bearings purchased under Part No. 1139188-2A. These bearings were of the same design but from a new heat of 440C stainless steel. See Reference 1, Sections 4.6.0, 4.8.0, and 5.0.

The bearing duplex set cartridge for this build-up was of the same material and configuration as used in Build-up 16B (P/N 1139308-6), and since actual measurements of the components indicated very nearly the same ambient fits for bearing-to-cartridge and cartridge-to-housing interfaces, the LH<sub>2</sub> push-pull test was waived for this build-up. The radial play test was performed on 1-12-72 and was followed by the rotational test series (1190-65B-017-001, 002, 003, 004) starting on 1-19-72.

##### 4.2.2.1 Purpose of Tests & General Features of Build-Up 17

The purpose of this build-up was to evaluate the new lot of ITI ball bearings basic P/N 1139188-2A. These bearings were fabricated from 440C Heat #30024 (AMS 5630 CEVM). The Armalon retainers were fabricated with elongated pockets for a radial load/axial load ratio of 1.0. The pockets were broached. The 440C used in these bearings (Heat #30024) metallurgically appeared to be somewhat better than the 440C used in the previous lot of ITI bearings P/N 1138146-1. There appeared to be a little better distribution of and fewer carbides stringers. Microscopic inspection of the bearing raceways also revealed fewer frosty areas (probably sheared tips of the carbides).

Table 8 summarizes the general features of this build-up in comparison with those of build-up 16B. Three differences exist, two of which may be significant. Build-up 17 used a long load sleeve and no hydrogen gas-to-gas shaft riding carbon seal. This difference affects only the axial load control on the 50mm slave bearing. If vent cavity pressure can be maintained at a constant value, the use of a short or long load sleeve, and of a shaft riding gas-to-gas seal or no seal has no effect on performance. However, the use of the new lot of bearings (new heat of 440C steel) equipped with Armalon retainers which were fabricated (instead of reworked) with the elongated pockets is considered a significant difference that could affect performance.

#### 4.2.2.2 General Summary Discussion of Build-up 17

The data of the LH<sub>2</sub> radial play test are tabulated in Table 9 and plotted in Figure 19. The plot shows shaft radial displacement at various locations along shaft as a function of radial load at the radial loader. The total radial play at the center of the bearing duplex set at operating temperature (about 54°R max) is 0.0025 inches. As expected the cartridge has ample radial clearance to insure complete axial freedom at the operating temperature.

Table 10 presents a condensed summary of the rotational test results for this build-up. A more general summary is shown in Table 7. The chronological summary discussion for this build-up follows:

TABLE 8

COMPARISON OF PRINCIPAL FEATURES OF BUILD-UPS 16B AND 17

<u>TESTER ASSEMBLY CONFIGURATION</u>	<u>BUILD-UP 16B</u>	<u>BUILD-UP 17</u>
Tester P/N/S/N	1138060-3/001	1138060-3/002
Shaft-Armature Coupler Fit at Room Temperature	Tight	Tight
Shaft-Armature Fit at Room Temperature	Tight	Tight
Dynamic Balance Procedure	Step Type	Step Type
Hydrogen Gas/Gas Carbon Seal	Yes	No
Load Sleeve P/N/Configuration	1136636-1/Short	1136152-2/Long
Bearing Set Cartridge, P/N	1139308-6	1139308-6
Material	440C	440C
Actual Brg-to-Cartridge ID Fit at Room Temp.		
Upstream Bearing	0.0007/0.0008 Loose	0.0008/0.0010 Loose
Downstream Bearing	0.0008 Loose	0.0010 Loose
Bearing Assembly, P/N	1138952-7	1139722-4
Basic Bearing P/N	1138146-1 (Honed Raceways)	1139188-2A
Serial Numbers	880062 Upstream 880066 Downstream	880070 Upstream 880068 Downstream
Retainers		
Material	Armalon	Armalon
Basic Configuration	From 1138146-1 (Thick-Line)	From 1139188-2A (Thick-Line)
Pocket Elongation, Ins	0.040 + .003 (Reworked)	0.040 + .003 (Fabricated)
MoS <sub>2</sub> Lubricant	Raceways and Retainer	Raceways & Retainer
Shaft Rotation	Counter Clockwise	Counter Clockwise

TABLE 9  
RADIAL PLAY TEST DATA - BUILD-UP 17

Tester P/N 1138060-3 S/N 002

Bearing Set Cartridge P/N 1138308-6 S/N 002

LH<sub>2</sub> Equilibrium Inlet Temperature: 47°R

$\Delta P_{RV}$ PSI	RADIAL LOAD LBS	DISTANCE DETECTOR OUTPUT - VOLTS					
		DATA POINT #1		DATA POINT #2		DATA POINT #3	
		DT <sub>1</sub>	DT <sub>3</sub>	DT <sub>1</sub>	DT <sub>3</sub>	DT <sub>1</sub>	DT <sub>3</sub>
0	0	.446	.442	.446	.441	.446	.441
5	19.5	.446	.441	.446	.442	.446	.442
10	39.0	.447	.442	.446	.442	.447	.442
15	58.5	.449	.441	.448	.442	.448	.442
20	78.0	.450	.441	.450	.442	.450	.442
25	97.5	.451	.441	.452	.442	.453	.442
30	117.0	.455	.441	.457	.442	.460	.443
35	136.5	.560	.459	.557	.460	.560	.460
40	156.0	.562	.460	-	-	-	-
0	0	.446	.442	.446	.441	.446	.441

FIGURE 19 RADIAL PLAY TEST RESULTS OF B/U 17

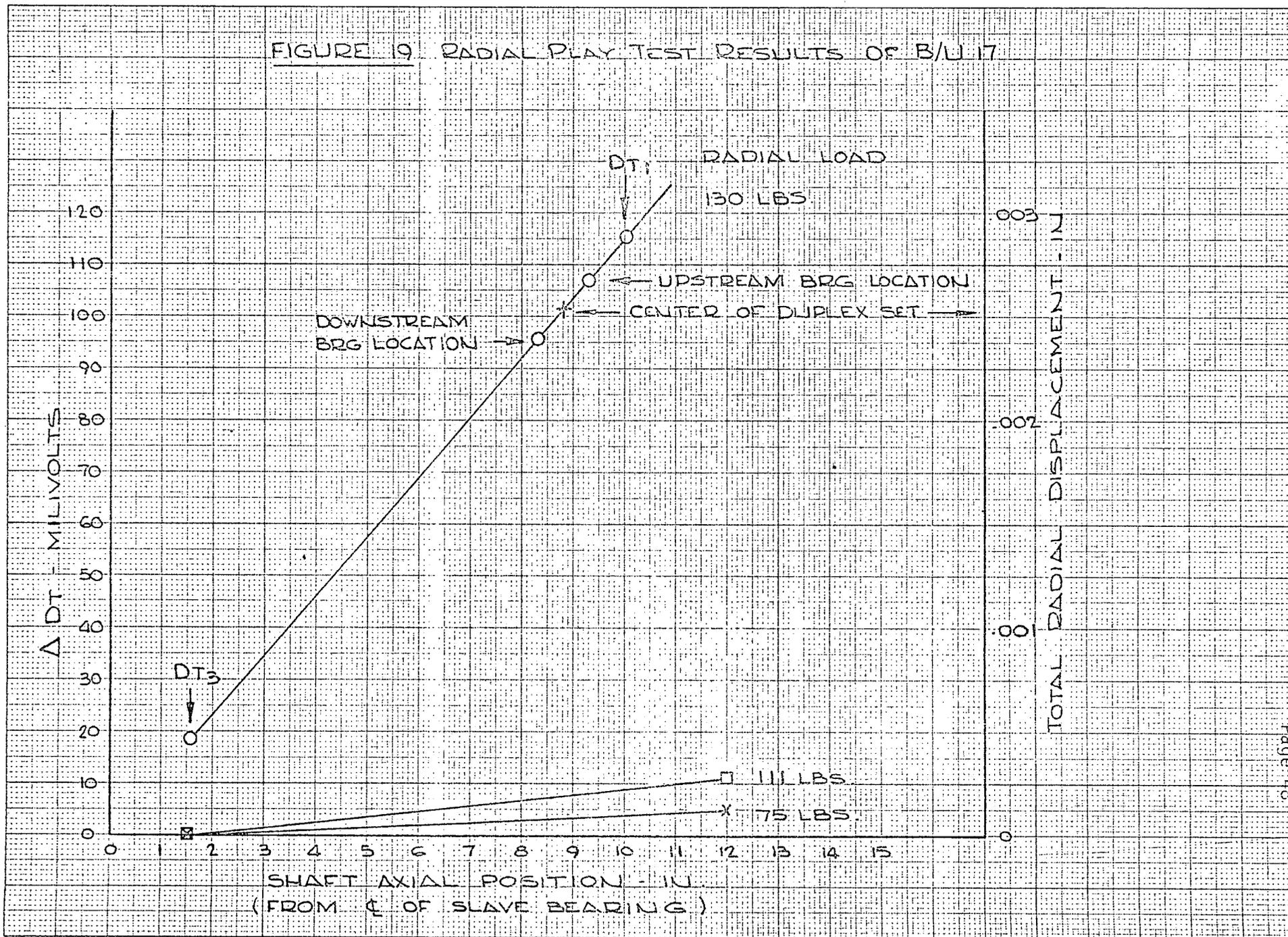


TABLE 10

BUILD-UP 17, 65MM BEARING TEST RESULTS SUMMARY (1-19-72)

PURPOSE: To evaluate performance of new lot of 65mm ball bearings Basic P/N 1139188-2A (Assy P/N 1139722-4)

BEARING DUPLEX SET: Assy P/N 1139722-4 S/N 880070 (upstream), S/N 880068 (Downstream) Armalon retainer fabricated with elongated pockets per Dwg -2 "Thick Line" configuration. Raceways and retainer MoS<sub>2</sub> coated.

SPEED: 27,000 RPM (Set after searching for best between 27,000 and 30,000 RPM)

LOAD: 500 lb radial/600 lb axial (Set after searching for best radial load between 500 and 1000 lb).

LH<sub>2</sub> FLOW: 57/70 GPM at 225 PSIG.

DURATION: 13.17 Hours

SHUTDOWN: Drive motor current to 120 amps, Delta T = 13°R, DT's indicating severe shaft dynamics. Tester very noisy.

OBSERVATIONS:

1. Excellent performance for 4.33 hours. No initial hi amps (elong pockets), steady state amps = 50-52; Delta T = 3°R.
2. Gradual deterioration from 4.33 hours. Amps to 78, Delta T = 8°R at 6.41 hours followed by moderate recovery to 66 amps and later to 59/60 amps to 12.83 hours. At this point the bearings progressed to a severe failure mode condition at 13.12 hours. Amps to 85, Delta T = 9°R and complete failure at 13.17 hours, amps to 120, Delta T = 13°R.
3. Bearing inspection revealed:
  - A. Upstream bearing completely fractured. Outer race split circumferentially, inner race land chipped off 360°. Retainer completely disintegrated except for small segment.
  - B. Downstream bearing was in visually relatively good condition. Some surface damage due to debris from failed bearing. Retainer appeared to be in excellent condition at OD and pockets.
  - C. 50mm Support Ball Bearing in visually good condition.
  - D. Armature check nut was loose and backed off but still on shaft. Probably the result of severe vibration during last several minutes of test.

TABLE 10 (Continued)

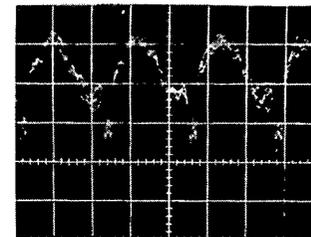
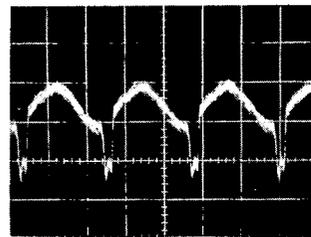
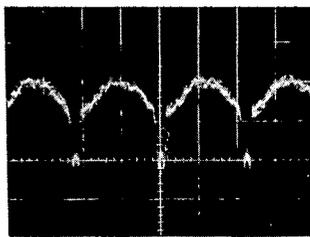
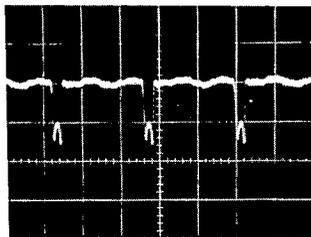
BUILD-UP 17, 65MM BEARING TEST RESULTS SUMMARY (1-19-72)

OBSERVATIONS: 4. Possible Failure Mode:  
(Continued)

Progressive wear of balls and raceways to a very high value allowed balls to run very high up on inner raceway, and probably partially beyond raceway groove. The reduced contact area increased contact stress to very high levels and caused the inner race shoulder to fracture. Large piece(s) of inner race shoulder jammed between balls and outer race groove causing the outer race to split circumferentially under the severe impact. Inspection of outer race fracture indicated that the fracture was not of the fatigue type.

Following the minimum specified chilldown of 30 minutes, tester rotation was initiated and set at 12,000 rpm. Radial load was set at 500 lbs on the duplex set. After approximately 13 minutes radial load was adjusted to 1000 lbs and speed was increased to 27,000 rpm. Search of best operating speed in the range 27,000 to 30,000 rpm and best operating radial load in the range 1000 to 500 lbs resulted in the steady state operating conditions of 27,000 rpm and 500 lbs radial load on duplex set, the desired steady state radial load. The build-up ran remarkably well for 4.1 hours---very smooth and steady with drive motor current in the range of 48-50 amps. This first test was terminated because of LH<sub>2</sub> depletion. The second test started with a drive motor current at 50 amps but in about 10 minutes started to go into a mild distress mode. Drive motor current increased gradually to 77A with  $\Delta T$  of fluid across bearings to 8°R then settled down to amps of 64/66 and  $\Delta T$  of 5°R. Again shutdown was caused by LH<sub>2</sub> depletion. In the third test series, the bearings ran well, current was in the 58-60 amps range and holding well. Sound was "louder" and somewhat more erratic as were the scope traces of shaft dynamics (considerable multiple traces). Figure 20 shows selected oscilloscope traces from this test series and how they relate to bearing performance. Note also the increased amplitude (shaft radial movement) as the bearing condition deteriorated. At the completion of this third test series (LH<sub>2</sub> depletion), the accumulated duration was 12.67 hours. On the fourth series, the drive motor current went to the same amperage at the start (60A), with  $\Delta T_1 = 5^\circ R$ , and  $\Delta T_2 = 5.0^\circ R$  (support bearing); after 30 minutes on test, drive motor amps suddenly increased to 120 and  $\Delta T_1$  jumped to 13°R, and a shutdown ensued. The total accumulated duration was 13.17 hours.

Plots of the various performance parameters are shown in Figures 21 through 24.

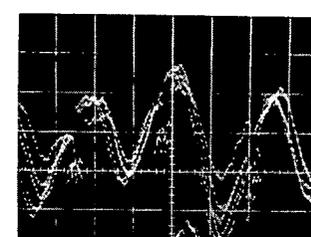
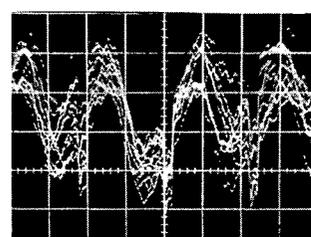
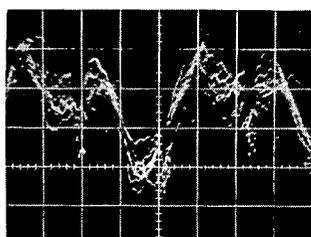
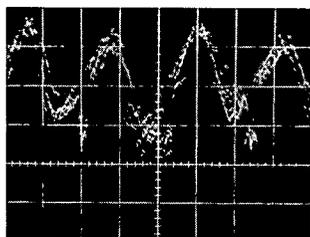


ACCUM. DURATION: START-UP (12K RPM)  
 DRIVE MOTOR CURRENT: 36 AMPS  
 LH<sub>2</sub> ΔT: 1.0 °F

.08 HRS.  
 50 AMPS  
 3.5 °F

1.94 HRS.  
 50 AMPS  
 3.0 °F

4.60 HRS.  
 55 AMPS  
 8.0 °F



ACCUM. DURATION: 5.46 HRS.  
 DRIVE MOTOR CURRENT: 58 AMPS  
 LH<sub>2</sub> ΔT: 8.0 °F

8.40 HRS.  
 63 AMPS  
 6.0 °F

12.57 HRS.  
 58 AMPS  
 4.0 °F

13.12 HRS.  
 79 AMPS  
 8.0 °F

65MM BALL BEARING TEST SERIES 1190-65B-017-B/U 17  
 FORWARD VERTICAL SCOPE TRACE (DT-1), SPEED : 27000 RPM

FIGURE 20-TYPICAL BEARING SHAFT DYNAMICS AS RELATED TO BEARING PERFORMANCE DETERIORATION

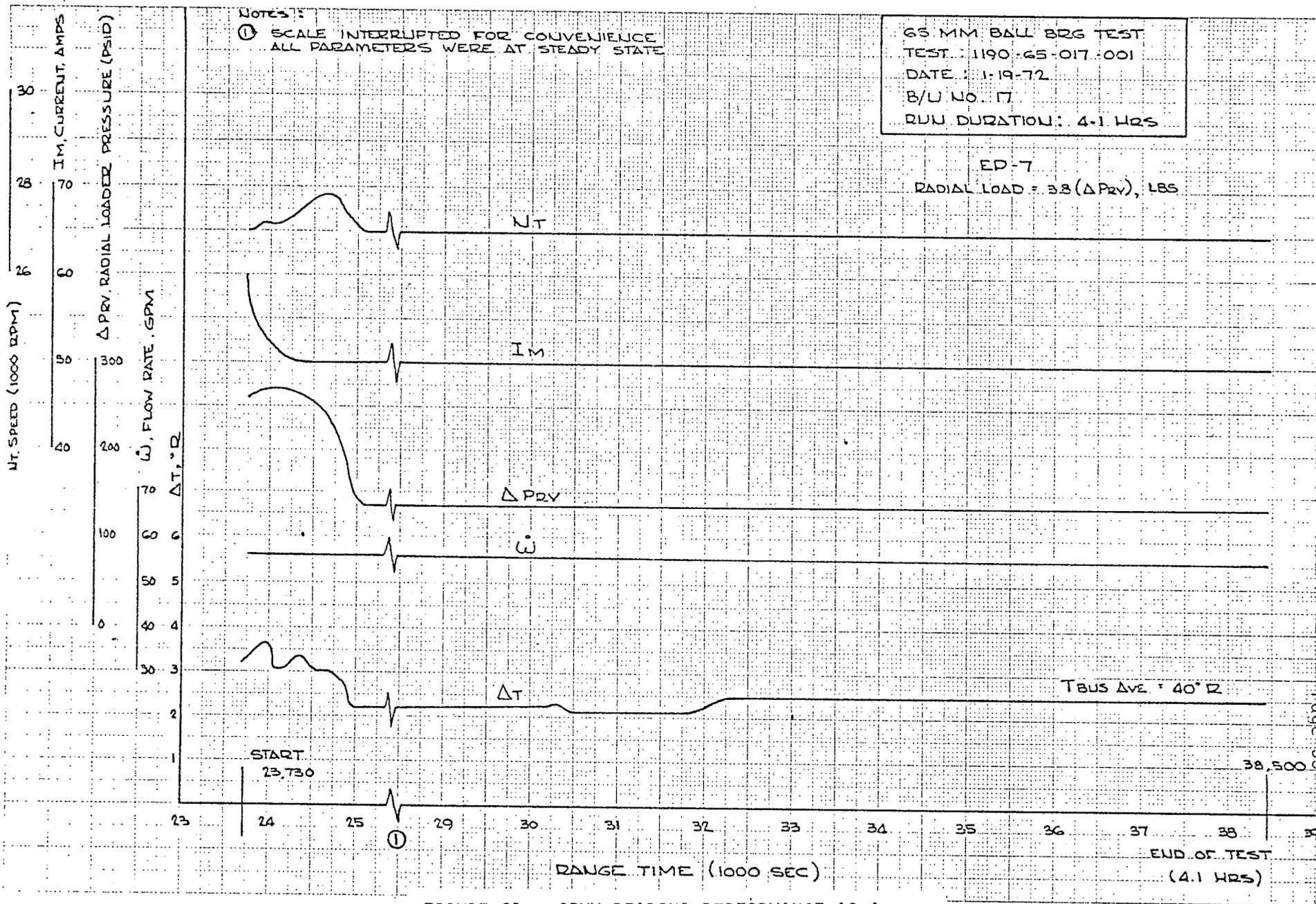


FIGURE 21 - 65MM BEARING PERFORMANCE AS A  
FUNCTION OF OPERATING TIME -  
BUILD-UP 17, TEST 1190-65-017-001

LUIGI DIETZEL CO.  
MILWAUKEE, WISCONSIN  
U.S.A.

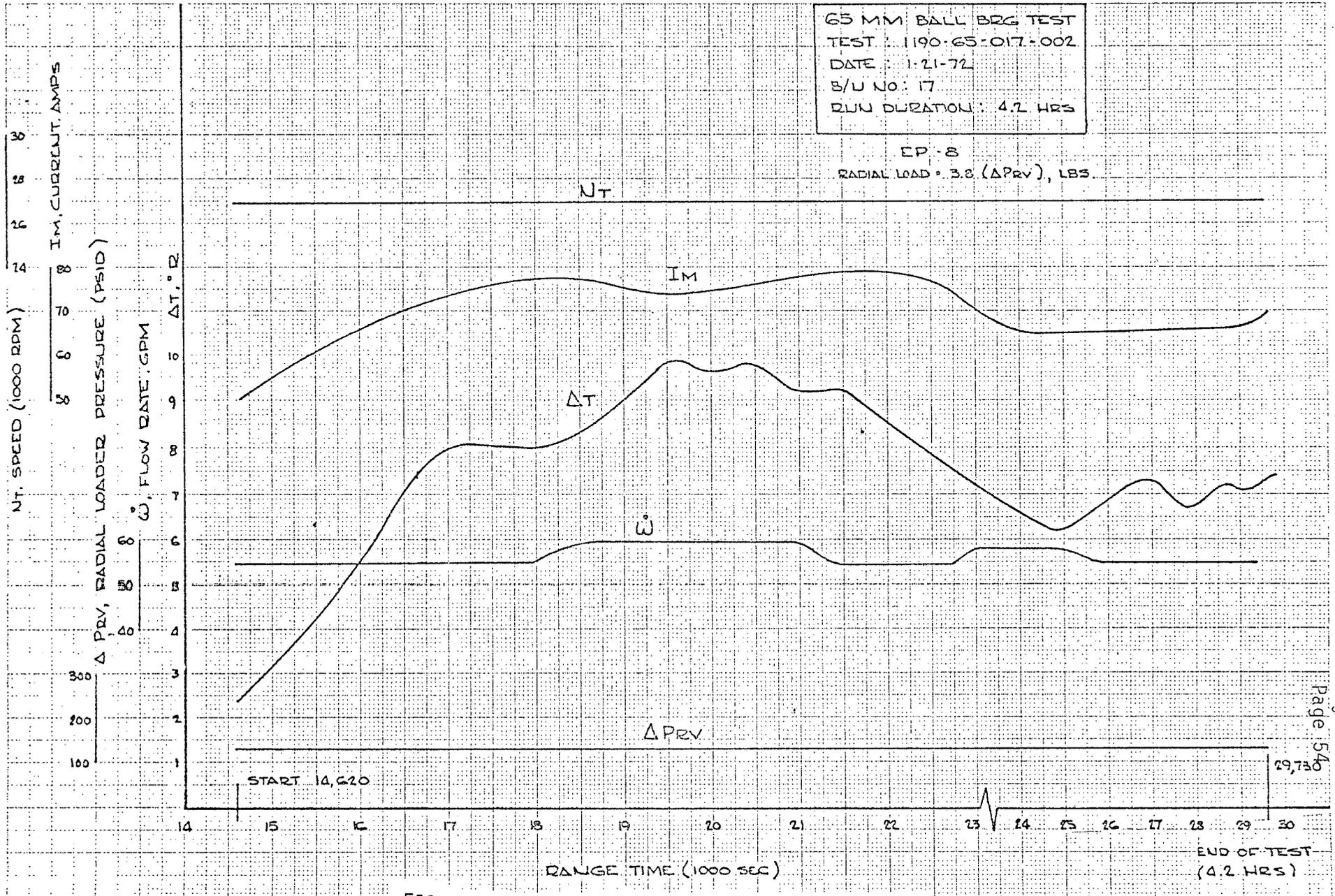


FIGURE 22 - 65MM BEARING PERFORMANCE AS A FUNCTION OF OPERATING TIME - BUILD-UP 17, TEST 1190-65-017-002

NO. 3400 10% DUTY CYCLE BEARING RATER  
EUGENE S. FRIEDEN CO.  
100 N. 10TH AVE. S.W. ALBUQUERQUE, N.M.

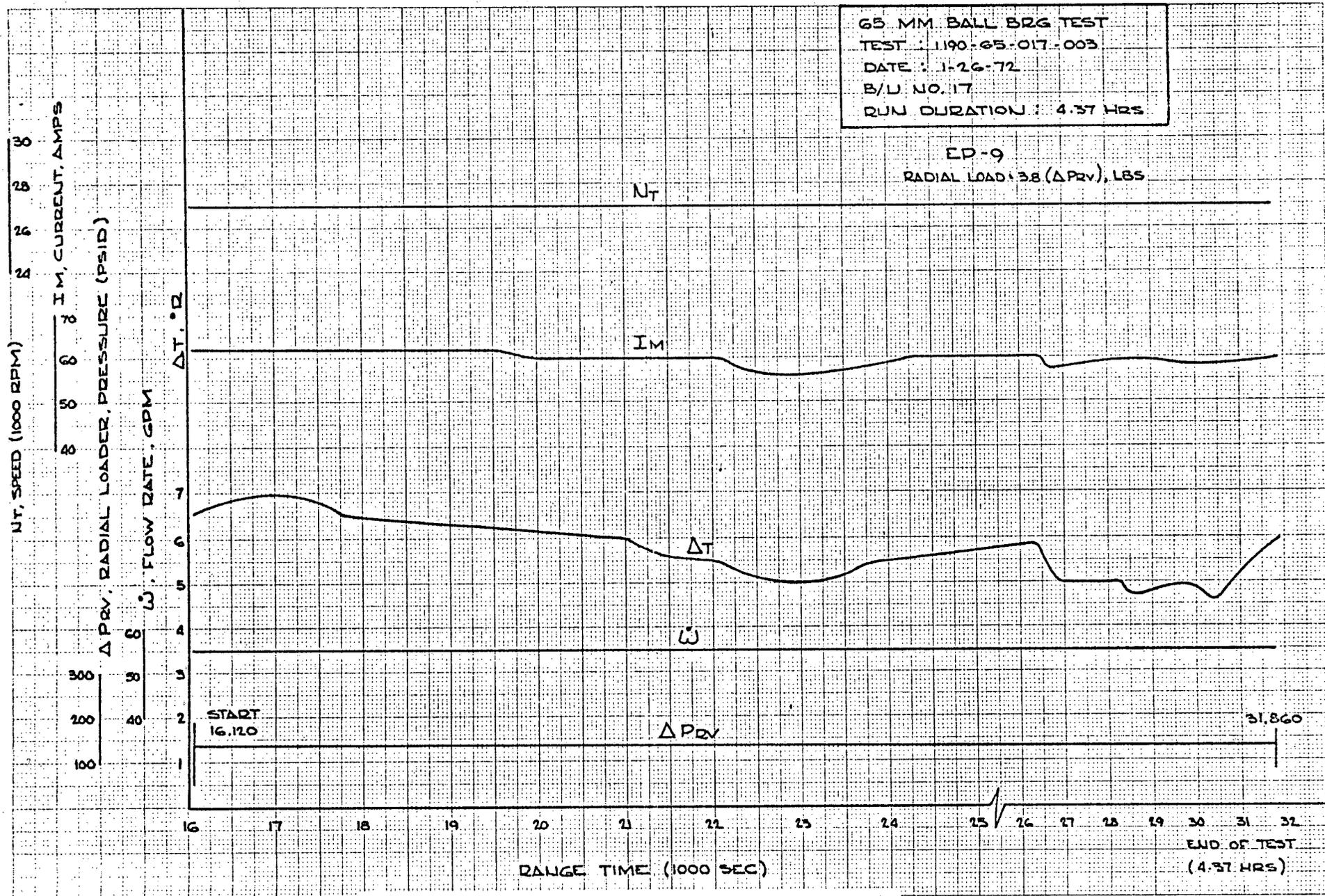
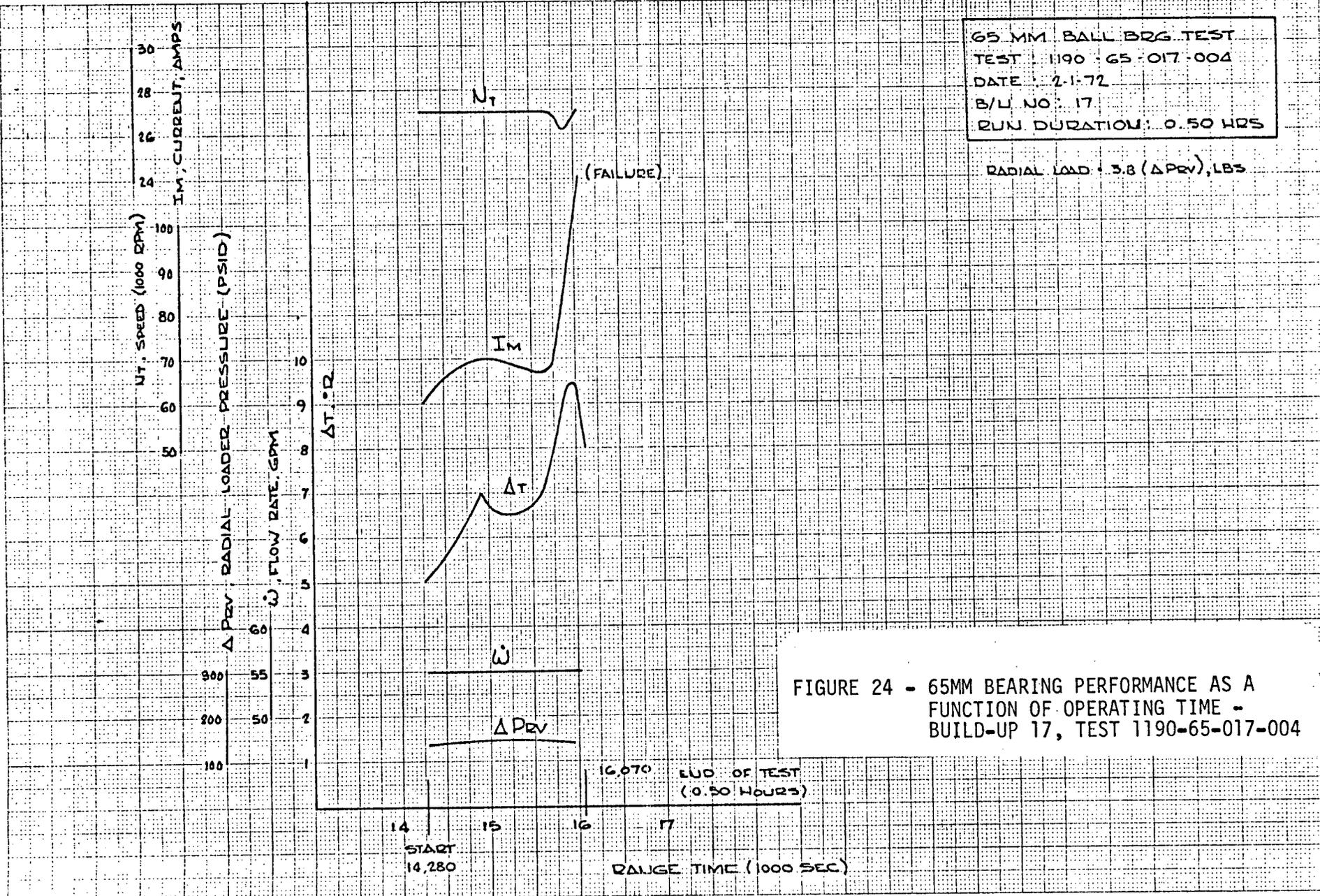


FIGURE 23 - 65MM BEARING PERFORMANCE AS A FUNCTION OF OPERATING TIME - BUILD-UP 17, TEST 1190-65-017-003



Bearing Inspection revealed the following:

Upstream Bearing (S/N 880070):

Completely fractured. Outer race was split circumferentially 360° at the smallest cross-section (bottom of raceway). The inner race shoulder was completely broken nearly 360°. All balls showed damage from fracture. Retainer was completely shattered mostly crushed and washed away.

Downstream Bearing:

In generally good condition but with some damage due to debris from upstream bearing. Inner race track ran high on shoulder indicating relatively high wear of balls and raceways. Retainer in very good condition, very light OD wear and mod wear of some pockets. Retainer edge facing upstream bearing damaged by broken pieces of upstream bearing.

50mm Support Ball Bearing:

Visually in good condition. Balls shiny, retainer does not appear to be worn.

COMMENTS: - There are three possible failure modes of the upstream bearing:

1. Retainer fracture.
2. Very high progressive wear of balls and raceways allowed balls to climb very high on inner raceway, reducing contact area, increasing contact stress to very high levels and causing inner race shoulder to fracture.
3. Fracture of outer race by some fatigue mode.

Retainer fracture is a possibility but the section of retainer which remained for inspection showed very light OD wear. Pocket wear did not seem excessive although this wear was much more difficult to assess. Also, jamming due to retainer fracture would not generally cause the type of damage observed on the inner race shoulder or outer race. The second failure mode seems more logical. Here, fracture of the inner raceway shoulder (because of high wear as stated above in 2.) caused a large piece of fractured inner race shoulder to jam between balls and outer raceway. The ensuing severe impact could cause the outer race to split circumferentially for 360° at its thinnest cross-section.

The fatigue type failure mode of 3. above is not consistent with the metallurgical inspection. There was no evidence of fatigue fracture on any part of the outer race fracture. The break appeared to be typical of impact fractures, and tends to confirm the existence of the second failure mode.

Figures 25, 26 and 27 are photographs showing the degree of damage to the upstream bearing components and the post-test condition of the bearing set cartridge assembly. Figures 28, 29, 30 and 31 are photographs of the downstream bearing components and show the relatively good condition of this bearing and the degree of damage by ingestion of debris from the upstream bearing.

65MM BALL BEARING  
DUPLEX SET  
POST B/U # 17



FIGURE 25 - POST-TEST PHOTOGRAPH OF BEARING  
ASSEMBLY SHOWING SEVERE DAMAGE  
TO UPSTREAM BEARING OF BUILD-UP 17



6.5mm BALL BEARING  
PIN 434722-4  
SIN 380076 (UPSTREAM)  
POST 3/14/17

FIGURE 26 - POST-TEST PHOTOGRAPH OF UPSTREAM  
BEARING COMPONENTS OF BUILD-UP  
17 - GENERAL VIEW



65MM BALL BEARING  
P/N 1139722-4  
S/N 880070 (UPSTREAM)  
POST B/U #17

FIGURE 27 - POST-TEST PHOTOGRAPH OF UPSTREAM BEARING METAL COMPONENTS OF BUILD-UP 17 - CLOSE-UP VIEW



FIGURE 28 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING COMPONENTS OF BUILD-UP 17  
GENERAL VIEW



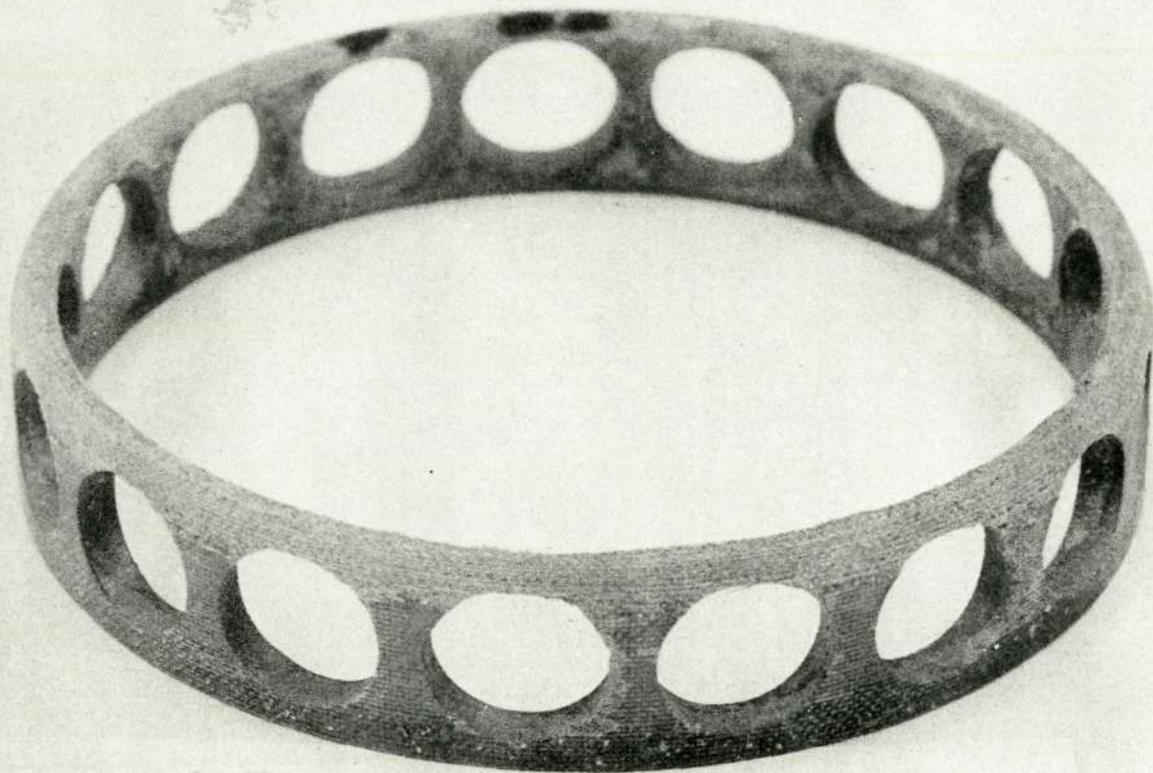
65MM BALL BEARING  
P/N 1139722-4  
S/N 880068 (DOWNSTREAM)  
POST B/U# 17

FIGURE 29 - POST-TEST PHOTOGRAPH OF DOWNSTREAM BEARING METAL COMPONENTS OF BUILD-UP 17 - CLOSE-UP VIEW



65MM BALL BRG. CAGE  
P/N 1139722-4  
S/N 880068  
POST B/U # 17

FIGURE 30 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING RETAINER ID - BUILD-UP 17



65MM BALL BRG. CAGE  
P/N 1139722-4  
S/N 880068  
POST B/U # 17

FIGURE 31 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING RETAINER OD - BUILD-UP 17

#### 4.2.3 Build-Up 18

Build-up 18 was set up in part as a duplicate of Build-up 17. The basic bearing configuration used was P/N 1139188-2A same as used in Build-up 17. However, the bearing set cartridge was of the type with minimum radial clearance (same as Build-up 17) and minimum axial clearance (less than Build-up 17; see Table 11). Tester shaft rotation was changed to clockwise rotation for this build-up, however, this change in direction of bearing rotation was not expected to influence bearing performance. A more significant change was with respect to additional "controlled" leakage at the LH<sub>2</sub>-to-gas shaft riding carbon seal. This seal modification was incorporated to provide a more stable and constant vent cavity temperature (T<sub>v</sub>). Unpredictable large variations in LH<sub>2</sub> leakage through the carbon seal caused large and sudden changes in vent cavity temperature which in turn caused large and sudden changes in vent cavity pressure. Changes in vent cavity pressure significantly affect test bearing radial load and support bearing axial load leading to bearing damage due to repeated off-specification operating conditions. With the deliberately higher leakage rates the normal leakage variations are less important and result in more constant operating conditions.

As with Build-up 17, because actual measurements of the components gave very nearly the same ambient cartridge interference fits for identical materials, no LH<sub>2</sub> push-pull tests were performed on Build-up 18. However, the radial play test in LH<sub>2</sub> was performed on 2-3-72 and followed by the rotational test series (1190-65B-018-001, 002, 003, 004) starting on 2-4-72.

TABLE 11

COMPARISON OF PRINCIPAL FEATURES OF BUILD-UP 17 AND 18

<u>TESTER ASSY CONFIGURATION</u>	<u>BUILD-UP 17</u>	<u>BUILD-UP 18</u>
Tester P/N / S/N	1138060-3/002	1138060-3/001
Shaft-Armature Coupler Fit at Room Temp.	Tight	Tight
Shaft-Armature Fit at Room Temp.	Tight	Tight
Dynamic Balance Procedure	Step Type	Step Type
Hydrogen Gas/Gas Carbon Seal	No	No
LH <sub>2</sub> /Gas Carbon Seal slotted for controlled Leakage	No	Yes
Load Sleeve, P/N/Configuration	1138152-2/Long	1136152-3/Long
Bearing Set Cartridge, P/N	1139308-6	1139733-2
Material	440C	440C
Actual Brg-to-Cartridge ID Fit at R.T. Ins.		
Upstream Bearing	0.0008/0.0010 Loose	.0008/0.0010 Loose
Downstream Bearing	0.0010 Loose	0.0009/0.0011 Loose
Actual Hsg-to-Cartridge OD Fit at R.T., Ins.	0.0032/0.0036 Loose	0.0026/0.0036 Loose <sup>(a)</sup>
Axial Clearance Brg-to-Cartridge at R.T., Ins.	0.040	0.008
Bearing Assy, P/N	1139722-4	1139722-4
Basic Brg P/N	1139188-2A	1139188-2A
Serial Numbers	880070 Upstream 880068 Downstream	880067 Upstream 880069 Downstream
Retainer		
Material	Armalon	Armalon
Basic Configuration	From 1139188-2A (Thick Line)	From 1139188-2A (Thick Line)
Pocket Elongation, Inches	0.040 + .003 (Fabricated)	0.040 + .003 (Fabricated)
MoS <sub>2</sub> Lubricant	Raceways & Retainer	Raceways & Retainer
Shaft Rotation	Counterclockwise	Clockwise

(a) Bell-Mouth Housing

#### 4.2.3.1 Purpose of Tests and General Features of Build-Up 18

The principal purpose of this build-up was to evaluate the performance of the new lot of 65mm ball bearings and confirm results of Build-up 17. Also evaluated was the effect of:

- a. Cartridge configuration with minimum axial and radial fit (MARF) P/N 1139733-2 S/N 880001.
- b. Slotting shaft riding carbon seal to provide "controlled" leakage into vent cavity in order to hold vent cavity temperature ( $T_V$ ) constant.
- c. Clockwise rotation of shaft.

The ball bearings used in this build-up were P/N 1139188-2 (basic configuration) assembled to P/N 1139722-4 (same as Build-up 17). Table 11 compares the principal assembly features of Build-ups 17 and 18. The bearing set cartridge (outer race sleeve) evaluated was the P/N 1139733-2 (S/N 880001) which gave considerably reduced axial clearance (about .008" instead of .040"), between bearing outer races and faces of spring retainer shoulder of cartridge. Room temperature radial clearance (actual) at each bearing position for the bearing-to-cartridge ID interface was nearly the same for both build-up 17 and 18. (See Tables 4 and 11).

The cartridge-to-housing interface room temperature fit for Build-up 18 was 0.0026/0.0036" loose with housing bell-mouth toward front or upstream side. (This fit is very similar to that of Build-up 16B, 0.0025/0.0035" loose which used the same housing.

#### 4.2.3.2 General Summary Discussion of Build-Up 18

Radial play test data are tabulated in Table 12 and plotted in Figure 2. The plots in Figure 32 show shaft radial displacement at various locations along the shaft as a function of radial load at the radial loader. From the plot, the total radial play at the center of the bearing duplex set, at equilibrium LH<sub>2</sub> chilldown temperature (about 43°R), is 0.0018 inches, 0.0007 inches less clearance than Build-up 17. The operating temperature clearance is sufficient to provide the desired axial freedom of the cartridge. A condensed summary of this Build-up is presented in Table 13, and a more general summary is shown in Table 7. Following the LH<sub>2</sub> chilldown, the tester was started and operated at 12,000 rpm and 500 lbs radial load for 3.5 minutes at which point the speed was increased to 27,000 rpm. Speed was held constant at 27,000 rpm and radial load at 500 lbs per Condition I of Table 2. This procedure was different from the initial tests of Build-Ups 16B and 17 (Conditions II, Table 2) in that there was no seeking of best speed and best radial load. As previously stated, experience with Build-ups 16B and 17 indicated that Condition I was ultimately the best, and also the desired operating condition, and therefore, Build-up 18 was set at this condition from the start.

The test series gave excellent performance (drive motor current 45-49 amps and delta T = 1.0 to 1.5°R) during the first two tests for an accumulated duration of 8.94 hours. Drive motor current during initial ramp-up to 27000 rpm speed at 500 lbs radial load did not overshoot as had been previously observed in tests with bearing retainer with circular ball pockets. This latter retainer configuration (circular pockets) had insufficient clearance for the required ball excursions. Elongating the

TABLE 12  
RADIAL PLAY TEST DATA - BUILD-UP 18

Tester P/N 1138060-3 S/N 001

Bearing Set Cartridge P/N 1139733-2 S/N 880001

LH<sub>2</sub> Equilibrium Inlet Temperature: 43°R

$\Delta P_{RV}$ PSI	RADIAL LOAD LBS	DISTANCE DETECTOR OUTPUT - VOLTS					
		DATA POINT #1		DATA POINT #2		DATA POINT #3	
		DT <sub>1</sub>	DT <sub>3</sub>	DT <sub>1</sub>	DT <sub>3</sub>	DT <sub>1</sub>	DT <sub>3</sub>
0	0	.472	.459	.470	.459	.470	.459
5	19.5	.472	.459	.471	.459	.471	.459
10	39.0	.474	.459	.473	.459	.474	.459
15	58.5	.480	.459	.478	.460	.478	.460
20	78.0	.489	.461	.492	.462	.489	.462
25	97.5	.560	.475	.559	.475	.557	.474
30	117.0	.563	.475	.562	.475	.562	.475
35	136.5	.564	.475	-	-	-	-
40	156.0	-	-	-	-	-	-
0	0	.470	.459	.470	.459	.470	.459

FIGURE 32 RADIAL PLAY TEST RESULTS OF B/U 18

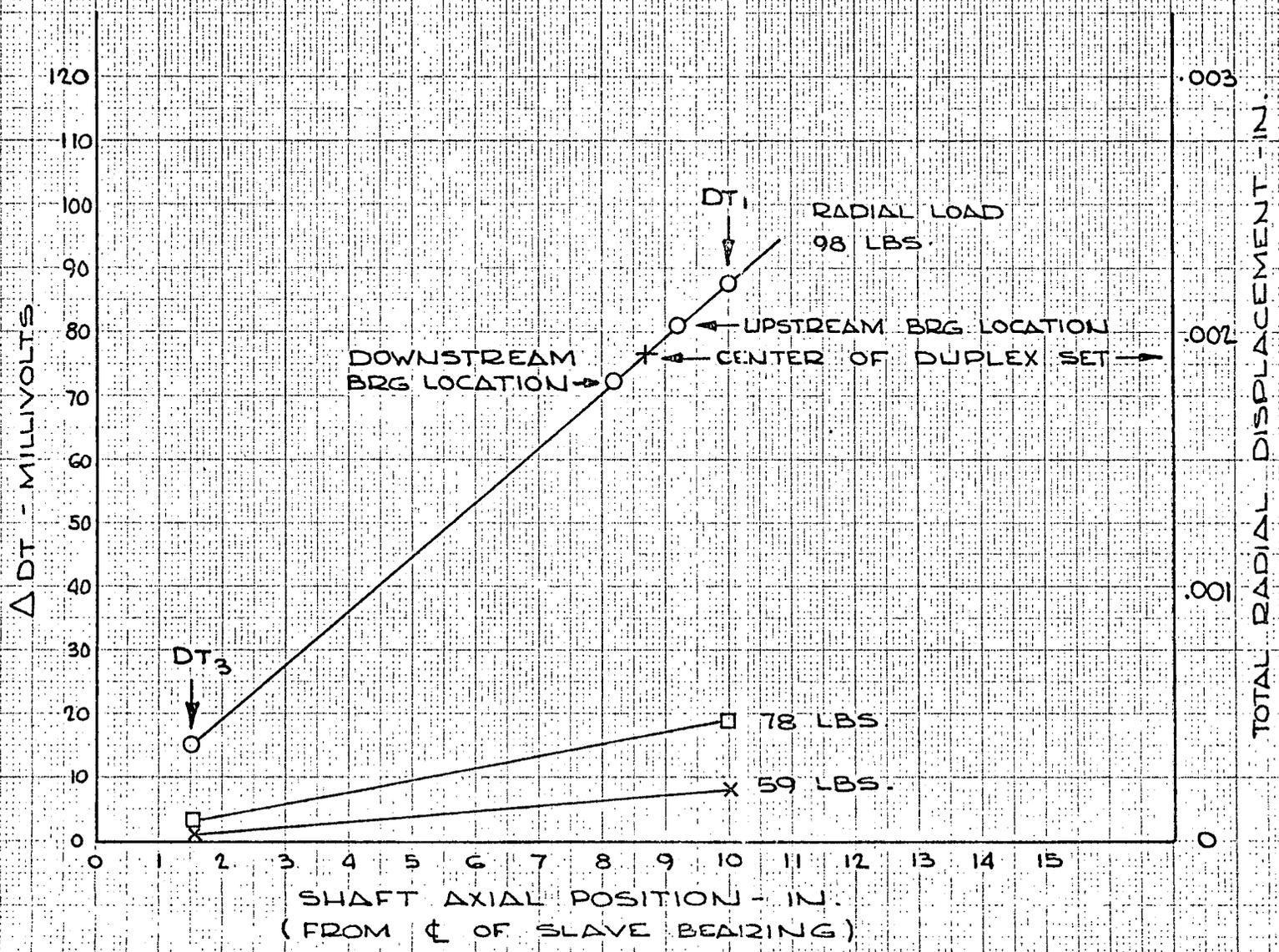


TABLE 13

BUILD-UP NO. 18, 65MM BEARING TEST RESULTS (2-4-72)

PURPOSE: To evaluate performance of new lot of 65mm ball bearings Basic P/N 1139188-2A (Assy P/N 1139722-4). New outer race sleeve (P/N 1139733-2) with minimum axial and radial fit (MARF). Controlled leakage of shaft riding seal to stabilize vent cavity temperature (press and radial load).

BEARING DUPLEX SET: Assy P/N 1139722-4, S/N 880067 (Upstream), S/N 880069 (Downstream), Armalon retainer fabricated with elong pockets per Dwg -2 configuration. Raceways and retainer MoS<sub>2</sub> coated.

SPEED: 27,000 RPM

LOAD: 500 LBS Radial, 600 LBS Axial

LH<sub>2</sub> FLOW: 57/60 GPM at 225 PSIG

DURATION: 15.1 Hours

SHUTDOWN: Achieved 15 hours target duration

OBSERVATIONS: 1. Excellent performance for 9 hours. Amps steady 46-50. No start-up high current excursions. Delta T = 1°-2°R. Steady shaft dynamics and sound. Total shaft radial movement = .001".

2. First indication of mild bearing distress at 9.04 hours, I<sub>M</sub> = 55<sup>A</sup>, Delta T = 3.5°R. Gradual deterioration to 13.04 hours, I<sub>M</sub> = 64<sup>A</sup>, Delta T = 6.5°R, somewhat unstable shaft dynamics (Multiple image on scope) and louder, slightly more erratic sound.

3. Bearing distress indications only slightly worse during last 2.06 hours. Total shaft radial movement had increased from .001" at start (zero time) to .002" at end.

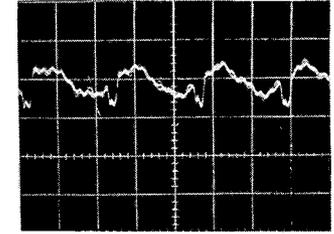
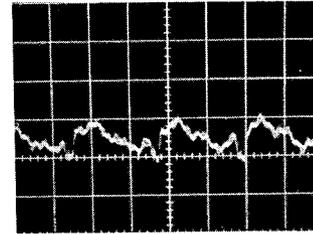
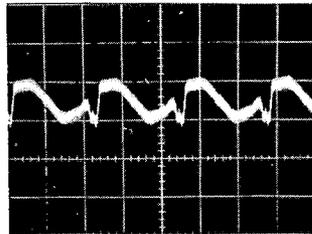
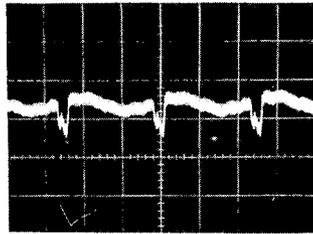
4. Upstream bearing in very good condition. Very slight OD wear and moderate pocket wear. Moderate ball wear.  
Downstream Bearing: Races and balls in good condition, high ball wear. Retainer OD slight wear, pocket mod with two very heavy wear.  
50MM Support Ball Bearing: Visually in good condition.

5. Radial load distribution between upstream and downstream bearings of duplex set appears to be more equal with downstream bearing somewhat more heavily loaded. Switch in load distribution may be related to cartridge fit.

ball pockets for adequate clearance appears to have solved the problem of initial malperformance. It seems reasonable now, that reworking the pockets to provide the proper elongation was damaging the retainer and resulted in the various cracked retainers observed. Test -003 of this series gave the first indication of distress after about 6 minutes of operation (9.04 hours accumulated duration). The drive motor current took a significant jump from 46 to 55 and  $LH_2$  delta T across the test bearings increased from  $2.0^\circ R$  to  $3.5^\circ R$ . The test showed a gradual deterioration from this point to shutdown (shutdown due to  $LH_2$  depletion) at 13.04 hours accumulated duration. At shutdown drive motor current was 64 amps and delta T =  $6.5^\circ R$ . There was also more instability in the scope traces showing unstable shaft dynamics. Figure 33 shows photographs of scope traces for this test series and indicates the effect of bearing deterioration. Toward the end of the test, tester sound was somewhat noisier with a noticeable "beat".

The test successfully completed 15.1 hours accumulated duration, the target duration. At shutdown, drive motor current was still at 65 amps with a  $LH_2$  delta T of  $2^\circ R$ , down from  $6^\circ R$  at start of last test.

From a performance viewpoint, this was the most successful test series with the 65mm ball bearings to date. The bearings ran for 9.0 hours at a drive motor current of less than 50 amps and delta T of  $LH_2$  of less than  $2^\circ R$ . For the remaining 6.1 hours drive motor current was less than 67 amps and  $LH_2$  delta T less than  $6.5^\circ R$ . Plots of the significant performance parameters are shown in Figures 34 through 37.

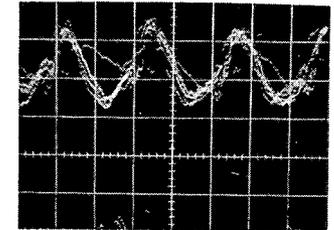
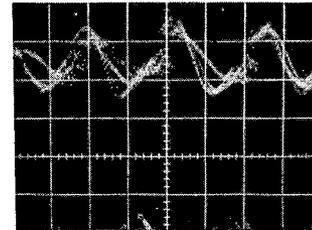
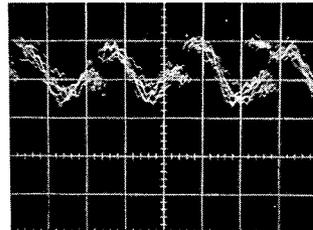
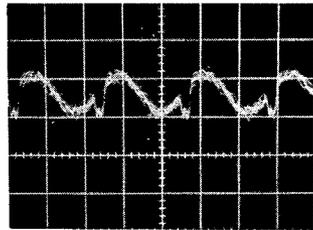


ACCUM. DURATION: START-UP (12K RPM)  
 DRIVE MOTOR CURRENT: 36 AMPS  
 LH<sub>2</sub> ΔT: 1.0°F

0.01 HRS.  
 50 AMPS  
 1.0°F

6.57 HRS.  
 46 AMPS  
 1.5°F

9.00 HRS.  
 46 AMPS  
 2.5°F



ACCUM. DURATION: 9.46 HRS.  
 DRIVE MOTOR CURRENT: 58 AMPS  
 LH<sub>2</sub> ΔT: 5.0°F

13.04 HRS.  
 64 AMPS  
 6.5°F

13.11 HRS.  
 64 AMPS  
 5.0°F

15.00 HRS.  
 65 AMPS  
 2.0°F

65MM BALL BEARING TEST SERIES 1190-65B-018-B/U 18  
 FORWARD VERTICAL SCOPE TRACE (DT-1), SPEED: 27000 RPM

FIGURE 33-TYPICAL BEARING SHAFT DYNAMICS AS RELATED TO BEARING PERFORMANCE DETERIORATION

NS 3000 REC. SYSTEM, MODEL 1000  
1000-1000-1000

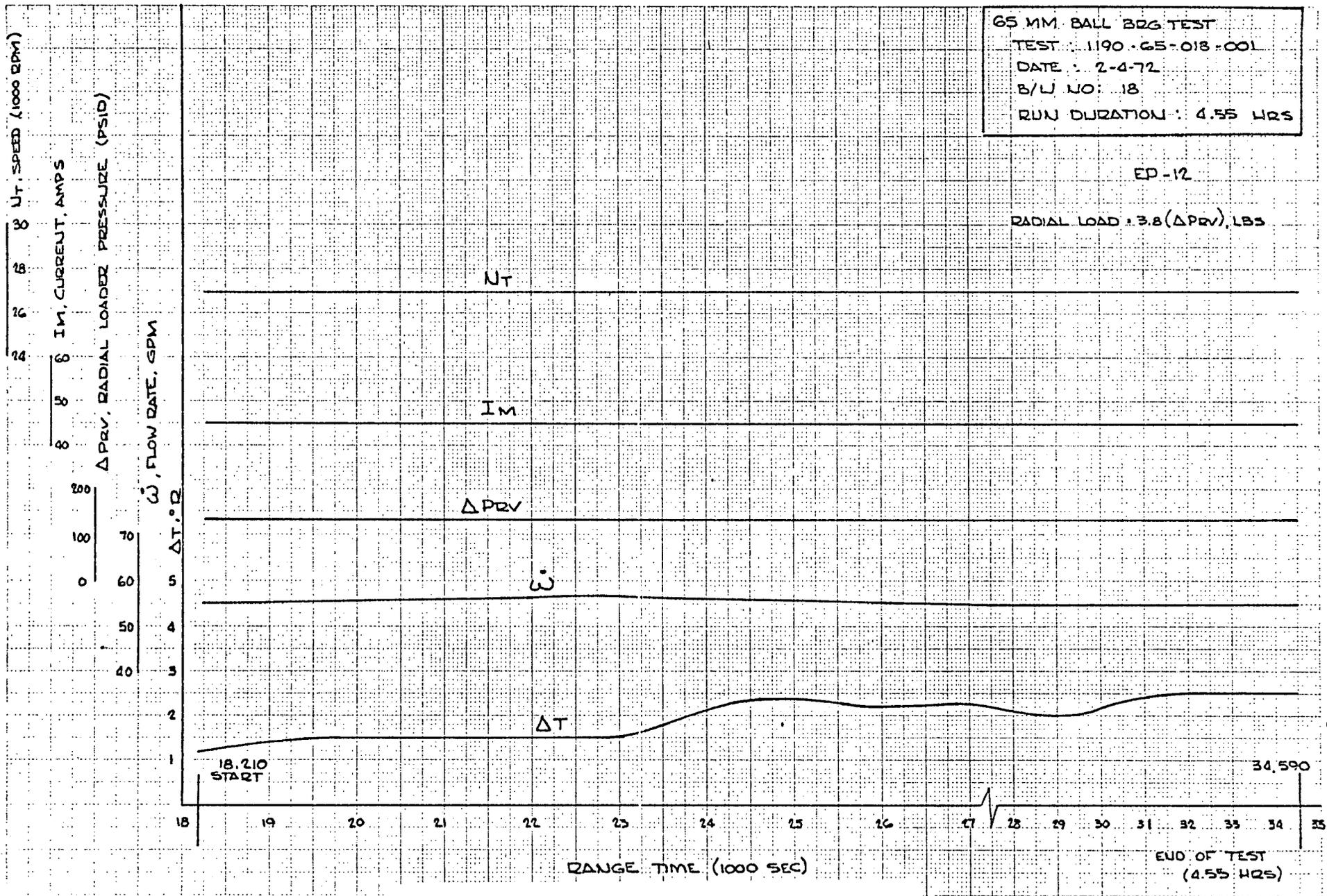


FIGURE 34 - 65MM BEARING PERFORMANCE AS A FUNCTION OF OPERATING TIME - - BUILD-UP 18, TEST 1190-65-018-001

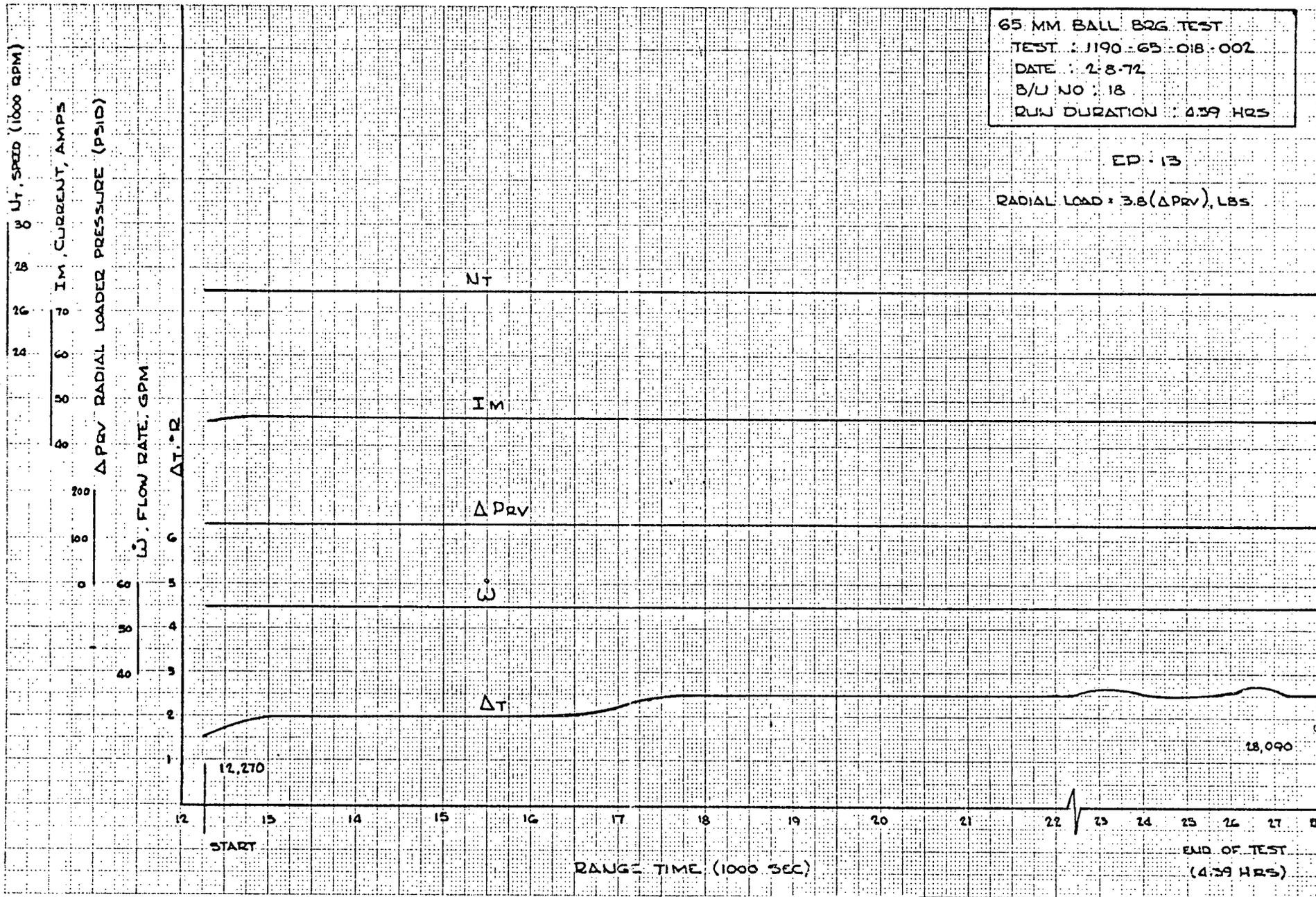


FIGURE 35 - 65MM BEARING PERFORMANCE AS A FUNCTION OF OPERATING TIME - BUILD-UP 18, TEST 1190-65-018-002

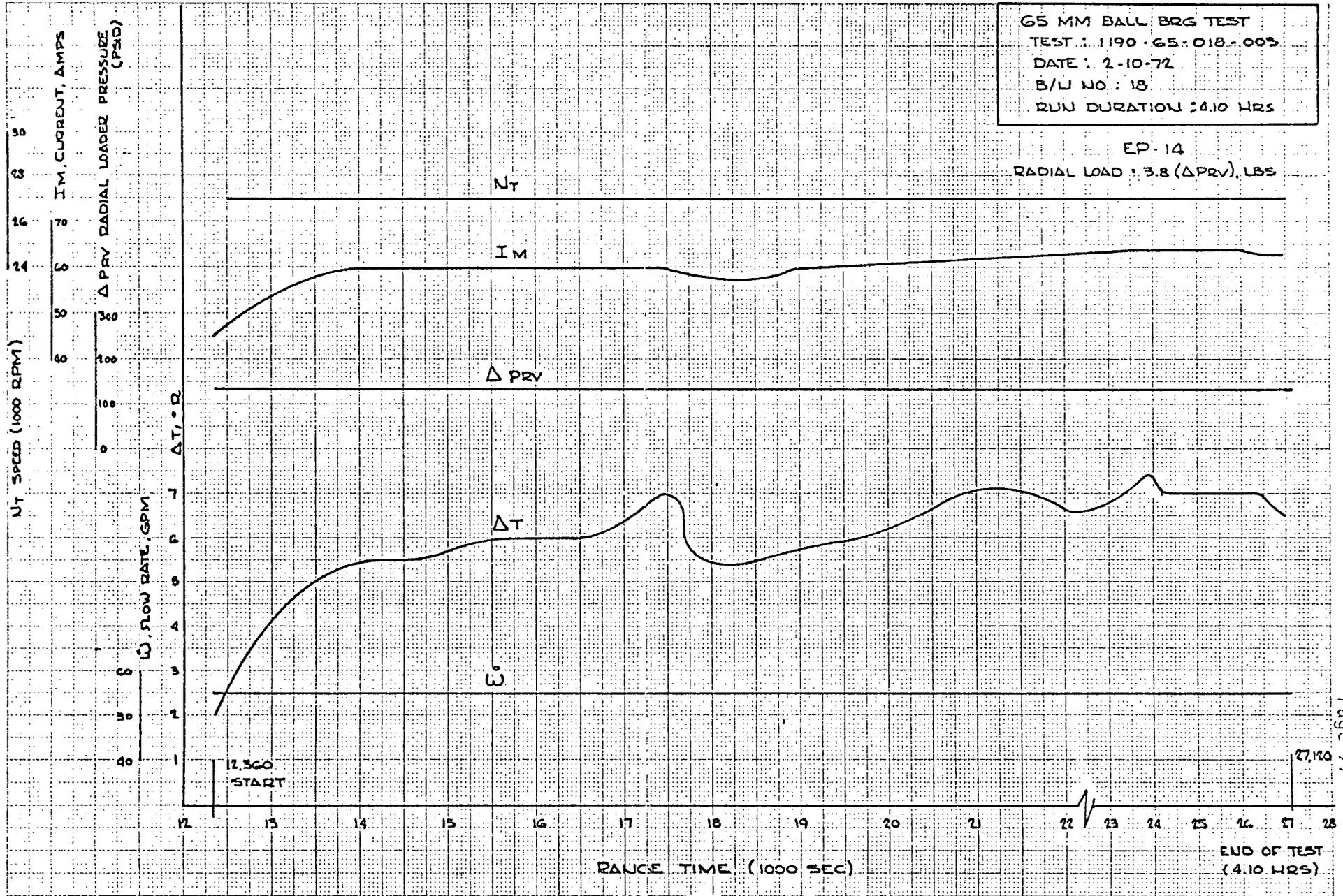


FIGURE 36 - 65MM BEARING PERFORMANCE AS A  
 FUNCTION OF OPERATING TIME -  
 BUILD-UP 18, TEST 1190-65-018-003

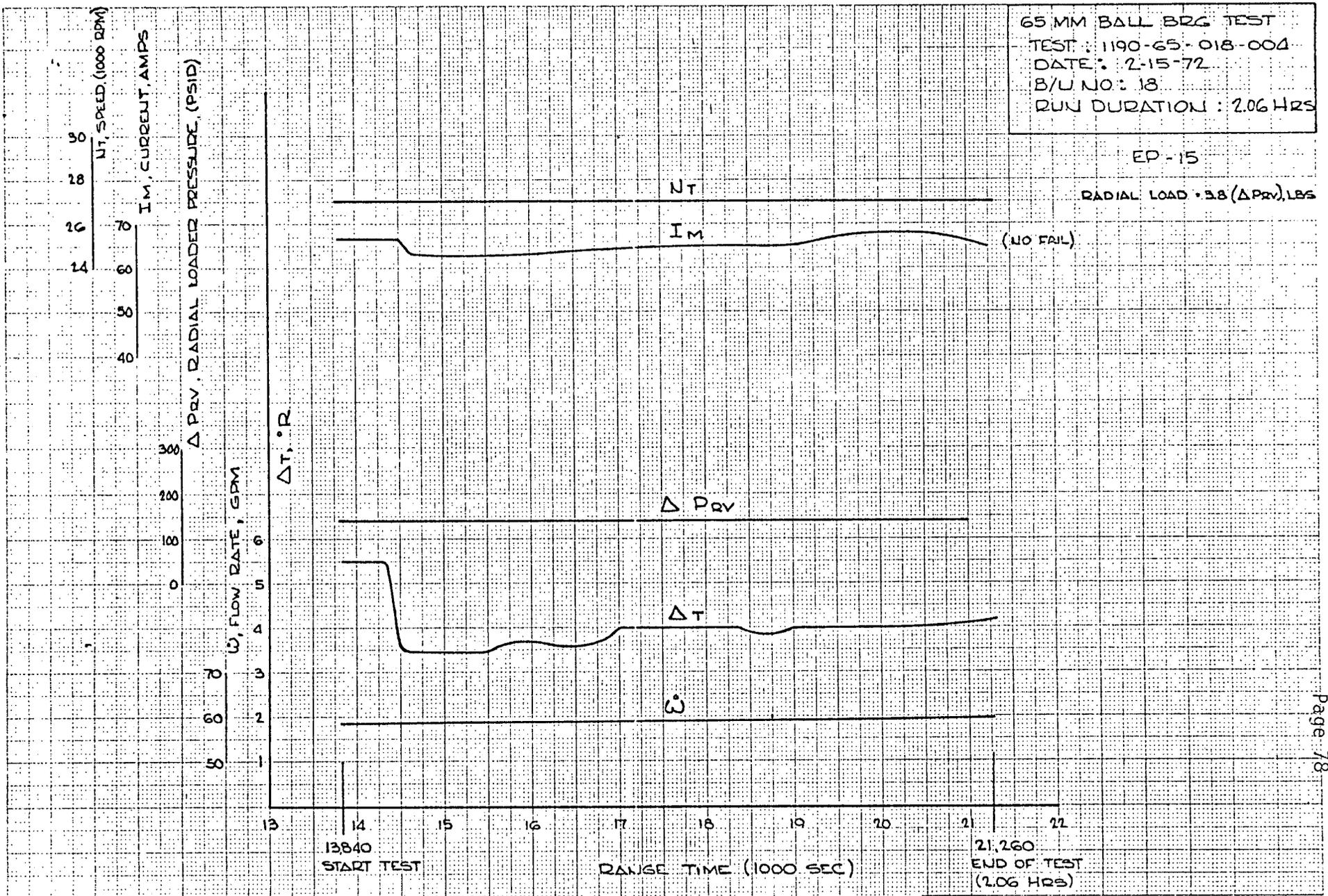


FIGURE 37 - 65MM BEARING PERFORMANCE AS A FUNCTION OF OPERATING TIME - BUILD-UP 18, TEST 1190-65-018-004

Bearing Condition:

Upstream Bearing: S/N 880067 - General condition very good. Inner raceway track nearly to top of land and moderately textured with fine micropitting. Outer race in excellent condition---evidence of some tilting. Retainer in excellent condition. OD wear very light. Pocket wear moderate. Retainer wt. loss, 3.8%.

Balls: All very shiny, no pitting, very good condition. Average wt. loss per ball: 32.1 mgs.

Downstream Bearing: S/N 880069 - General Condition fair-good. Inner raceway track very wide and to top of land. Track appears frosty (micropitting). Some slight evidence of metal movement. Outer Race: very good condition. Smooth normal track with some frosty surface characteristics.

Retainer: Fair condition. OD wear is very light but pocket wear is generally heavy with one pocket worn just through web. Retainer wt. loss, 6.8%. Balls: Generally shiny, some light bands or areas of fine micropitting on all balls. Average wt. loss per ball: 88.5 mgs.

50mm Support Bearing: P/N 290122-9 S/N 940A

Outer and Inner Raceways: Textured, frosty surfaces, light micropitting. Retainer - moderate to heavy pocket wear but light OD wear.

Balls: General somewhat dull gray surface. Areas of light micropitting all over balls. Some balls give evidence of some skidding.

There was no evidence of metal fatigue on any of the bearings.

Figures 38, 39, 40 and 41 are photographs of the upstream bearing.

Figures 42, 43, 44 and 45 show photographs of the downstream bearing. Note the relatively good condition of these bearings.



FIGURE 38 - POST-TEST PHOTOGRAPH OF UPSTREAM  
BEARING COMPONENTS OF BUILD-UP 18 -  
GENERAL VIEW



FIGURE 39 - POST-TEST PHOTOGRAPH OF UPSTREAM BEARING METAL COMPONENTS OF BUILD-UP 18 - CLOSE-UP VIEW



FIGURE 40 - POST-TEST PHOTOGRAPH OF UPSTREAM  
BEARING RETAINER ID - BUILD-UP 18



65MM BALL BRG. CAGE  
P/N 1139722-4  
S/N 880067  
POST B/U # 18

FIGURE 41 - POST-TEST PHOTOGRAPH OF UPSTREAM  
BEARING RETAINER OD - BUILD-UP 18



FIGURE 42 - POST-TEST PHOTOGRAPH OF DOWNSTREAM  
BEARING COMPONENTS OF BUILD-UP 18.  
GENERAL VIEW

C2



65MM BALL BEARING  
P/N 1139722 - 4  
S/N 880069 (DOWNSTREAM)  
POST B/U # 18

FIGURE 43 - POST-TEST PHOTOGRAPH OF DOWNSTREAM BEARING METAL COMPONENTS OF BUILD-UP 18 - CLOSE-UP VIEW

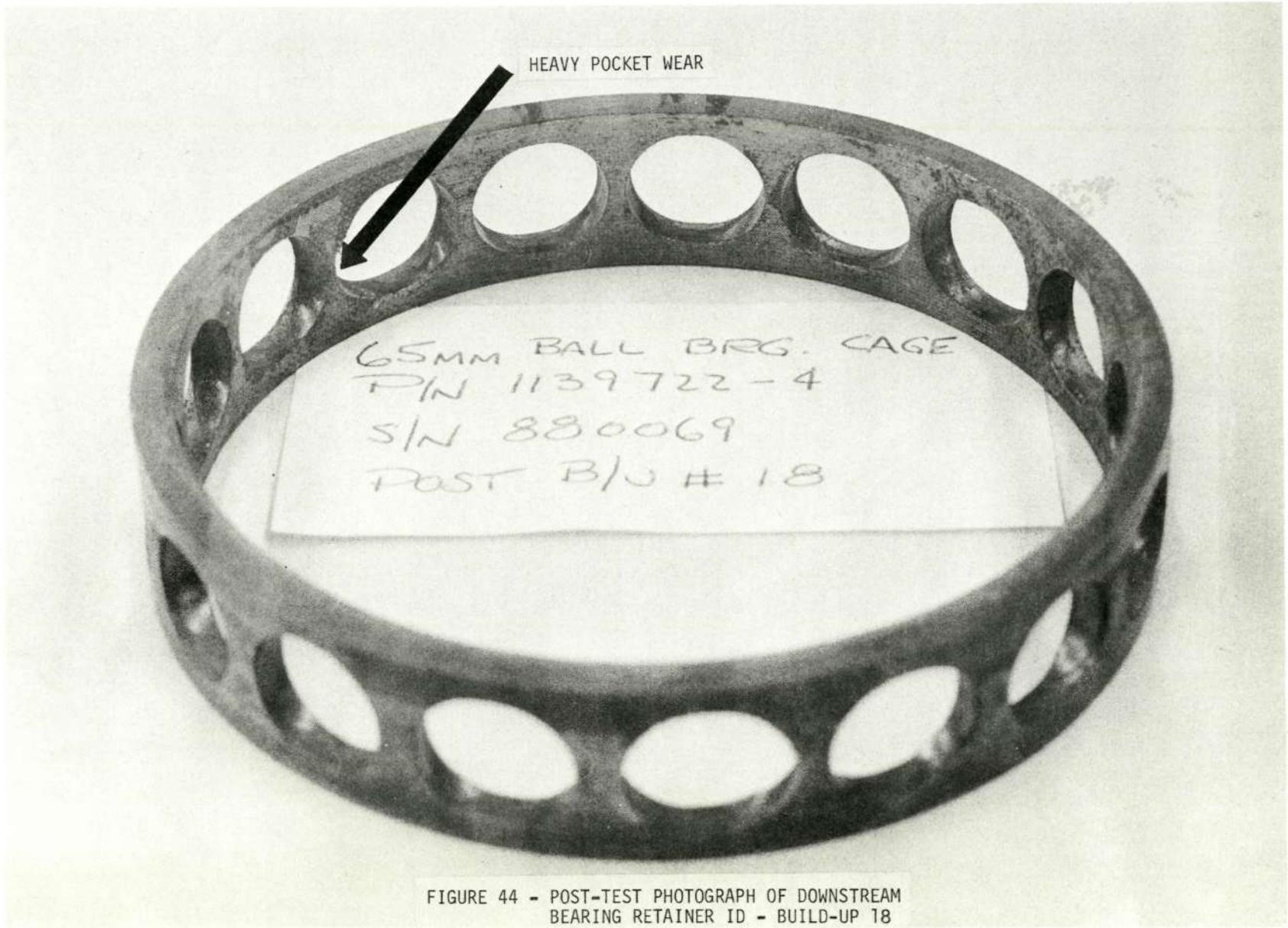
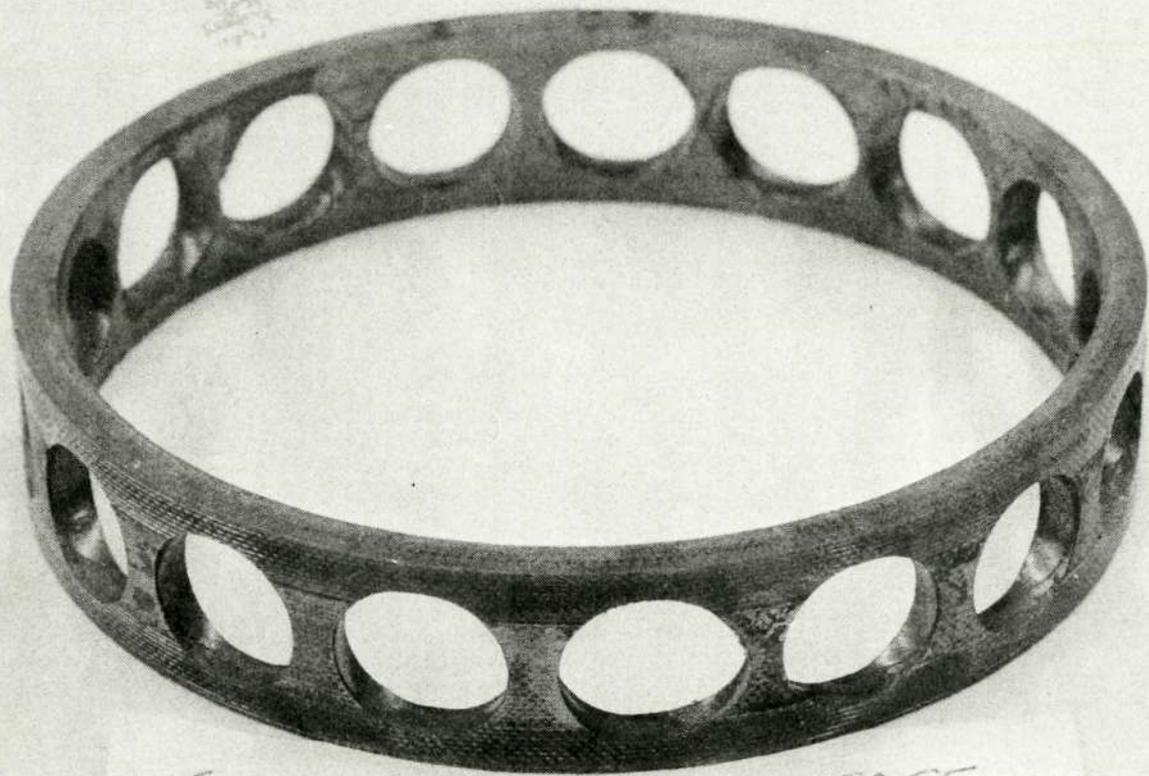


FIGURE 44 - POST-TEST PHOTOGRAPH OF DOWNSTREAM BEARING RETAINER ID - BUILD-UP 18



65MM BALL BRG. CAGE  
P/N 1139722-4  
S/N 880069  
POST B/U # 18

FIGURE 45 - POST-TEST PHOTOGRAPH OF DOWNSTREAM BEARING RETAINER OD - BUILD-UP 18

#### 4.2.4 General Comments on Build-Up 16B, 17 and 18 Test Results

A comparison of the overall performance of the various build-ups indicates that several parameters simultaneously contributed to the observed results. Figure 46 shows plots of drive motor current as a function of operating time for the four build-ups under discussion. Build-up 15 and 16B performed quite similarly if the change in shutdown criteria for build-up 16B is taken into account. This result was expected since the bearings were from the same lot and had reworked retainers for pocket elongation. Tighter bearing/cartridge/housing and shaft assembly fits were expected to improve performance, but the improvement was at best only minor. Build-up 17 showed a significant improvement in performance. Performance was excellent for 4.1 hours prior to onset of some bearing distress. This performance compared with about 1.8 hours for Build-up 16B. In Build-up 17 the new lot of bearings with slightly improved heat of 440C steel and Armalon retainers fabricated with elongated pockets, instead of rework, probably contributed significantly to the improved performance. In all tests through Build-up 17 some of the operating parameters could not be accurately controlled. An example was vent cavity temperature ( $T_V$ ) which is affected by leakage of  $LH_2$  through the shaft riding seal. Seal leakage is unpredictable and apparently has been very erratic, judging from the large variations observed for the parameter  $T_V$ . Large changes in vent cavity temperature ( $T_V$ ) cause corresponding changes in vent cavity pressure ( $P_V$ ) which, in turn, affects the test bearing radial load, and under some circumstances, the axial load on the support bearing. It was observed that changes in  $T_V$  were accompanied by changes in bearing performance (significant variations in drive current motor). In Build-up 18 the shaft riding carbon seal ( $LH_2$ /gas) was

NE 3450A M. GRIFFIN GRAPH PAPER CO. 100-10116

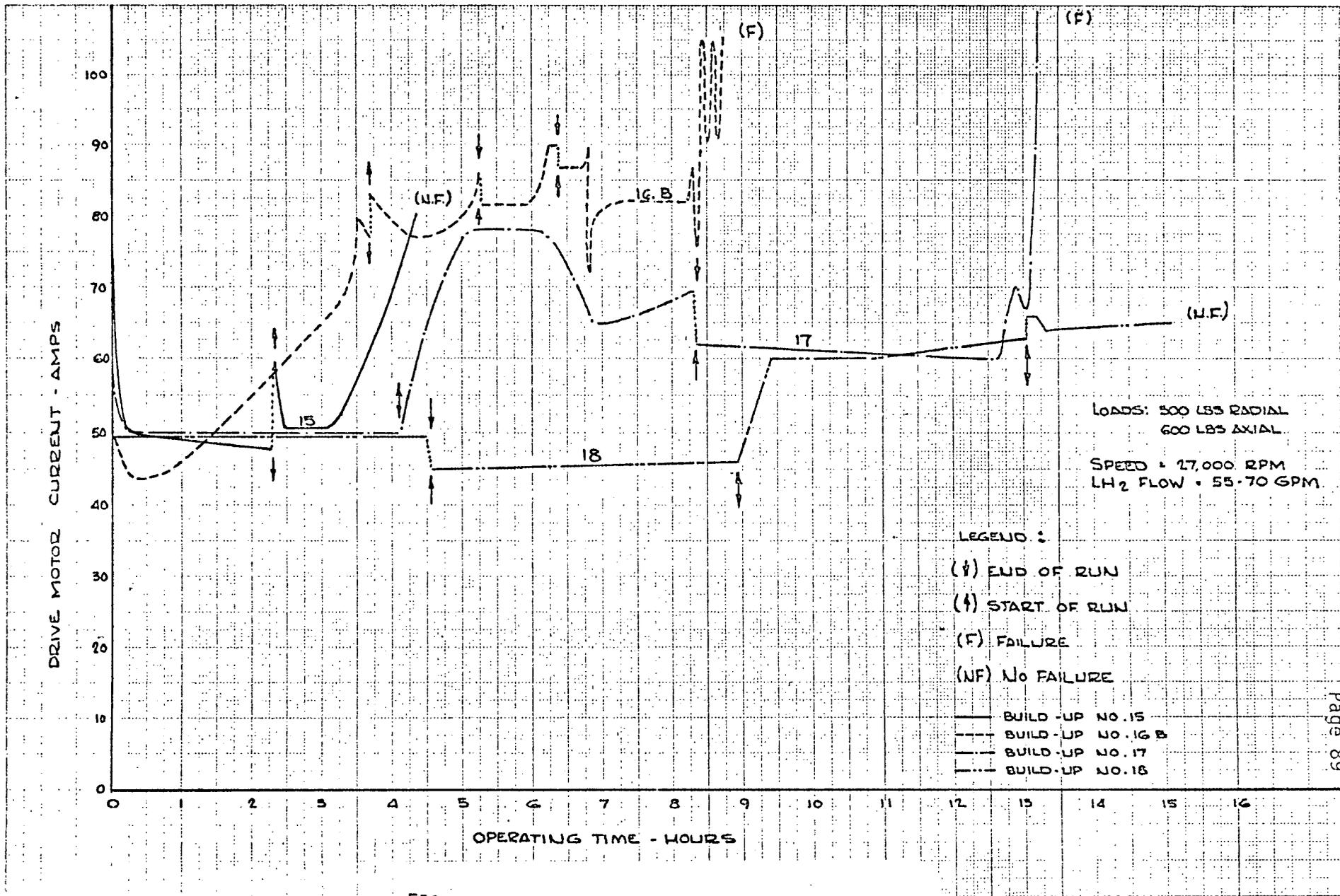


FIGURE 46 - DRIVE MOTOR CURRENT (FRICTION) AS A FUNCTION OF OPERATING TIME FOR BUILD-UPS 15, 16B, 17 & 18

experimentally slightly modified (several very small slots in sealing lip) in order to provide increased leakage of  $LH_2$  into the vent cavity. The increased, or "controlled", leakage masked the normal erratic leakage variations, as expected, and maintained a constant (and lower)  $T_V$ . Constant  $T_V$  gave constant  $P_V$  and, in turn, constant bearing loads and steadier bearing performance.

Under these conditions, Build-up 18 provided 9.04 hours of excellent performance prior to any indication of a bearing distress and this build-up completed the 15 hour target duration with only a moderate indication of distress. Post-test bearing condition was also very good in comparison to the condition of the bearings in Build-up 16B and 17. Table 14 compares the post-test wear of balls and retainers for the three build-ups under discussion. The superior performance of Build-up 18 is apparent.

It is believed that the improved performance is in large part due to the combination of the new lot of bearings and steady operating conditions. Considerable more testing is required to establish the individual contribution of the several parameters which appear to influence bearing performance in this severe environment. However, it would appear from these results that bearing/cartridge/housing fits, bearing material, bearing retainer configuration and fabrication, and stability of operating parameters (load, speed, flow rate) are all significant contributing factors. It is also possible that small changes in bearing geometry and use of the new configuration tester (P/N 1138990-1), which has a much higher critical speed, may provide additional significant improvement.

TABLE 14

SUMMARY OF BALL AND RETAINER POST-TEST WEAR FOR BUILD-UPS 15, 16B, 17, AND 18

SPEED: 27,000 RPM                      RADIAL LOAD ON DUPLEX SET: 500 LBS  
 LH<sub>2</sub> FLOW: 60 GPM @ 225 PSIG              AXIAL PRELOAD: 600 LBS

BU	TEST DURATION HRS	UPSTREAM BEARING			DOWNSTREAM BEARING		
		BALL WEAR		RETAINER	BALL WEAR		RETAINER
		WT.LOSS MGS	WEAR RATE MGS/HR	% WT.LOSS	WT.LOSS MGS.	WEAR RATE MGS/HR	% WT.LOSS
15	4.33	40.1	9.3	4.2	9.1	2.08	1.4
16B	8.68	202.8	23.3	10.4	95.5	11.0	29.4
17	13.17	(a)	(a)	(a)	46.4 <sup>(b)</sup>	3.52 <sup>(b)</sup>	17.2 <sup>(c)</sup>
18	15.1	32.1	2.13	3.8	88.5	5.85	6.8

(a) Unavailable due to severe damage (fractured) at failure.

(b) Probably invalid because of metal pick-up from upstream bearing debris.

(c) Majority of weight loss due to impact with debris from upstream bearing.

#### 4.3.0 BUILD-UP OF NEW CONFIGURATION BEARING TESTER P/N 1138990-1A

Prior to termination of the NERVA 75K Engine Program, it was decided that the new configuration (dual bearing set) tester, S/N 880001, should be assembled in order to establish component fits and accuracy of assembly procedure. Figure 47 shows a cross-section of this tester. The assembly of the tester followed the top assembly drawing 1138990-1A and TMP-102 as applicable, a sample of which is included in Appendix B along with TMP-107 which is the disassembly procedure for this tester, and TMP-119 and TMP-120, the procedure for Forward and Aft Cartridge Interface Movement. Table 15 tabulates the principal features of this build-up which was designated as Build-up 19.

The bearing tester assembly was completed without any problems. All components assembled easily as predicted by the design (one minor exception), the assembly procedure was completely valid without variations, and the assembly tooling required no modifications. The one minor exception to the component fit applies to the specified bolts (EWB-0420-TH-4) which secures the radial loader to the loader housing. The large fillet radius at the head/shank corner of the bolt does not allow the bolt to seat. A washer should be specified or the use of bolt AS 4059-06-001H, as was done in this case. Shaft breakaway torque prior to shaft seal installation was measured at 8 in-lbs. This torque (for two duplex bearing assemblies) is exactly twice the 4 in-lbs typically measured with the single duplex bearing set of the old 65mm bearing tester, (P/N 1138060-3).

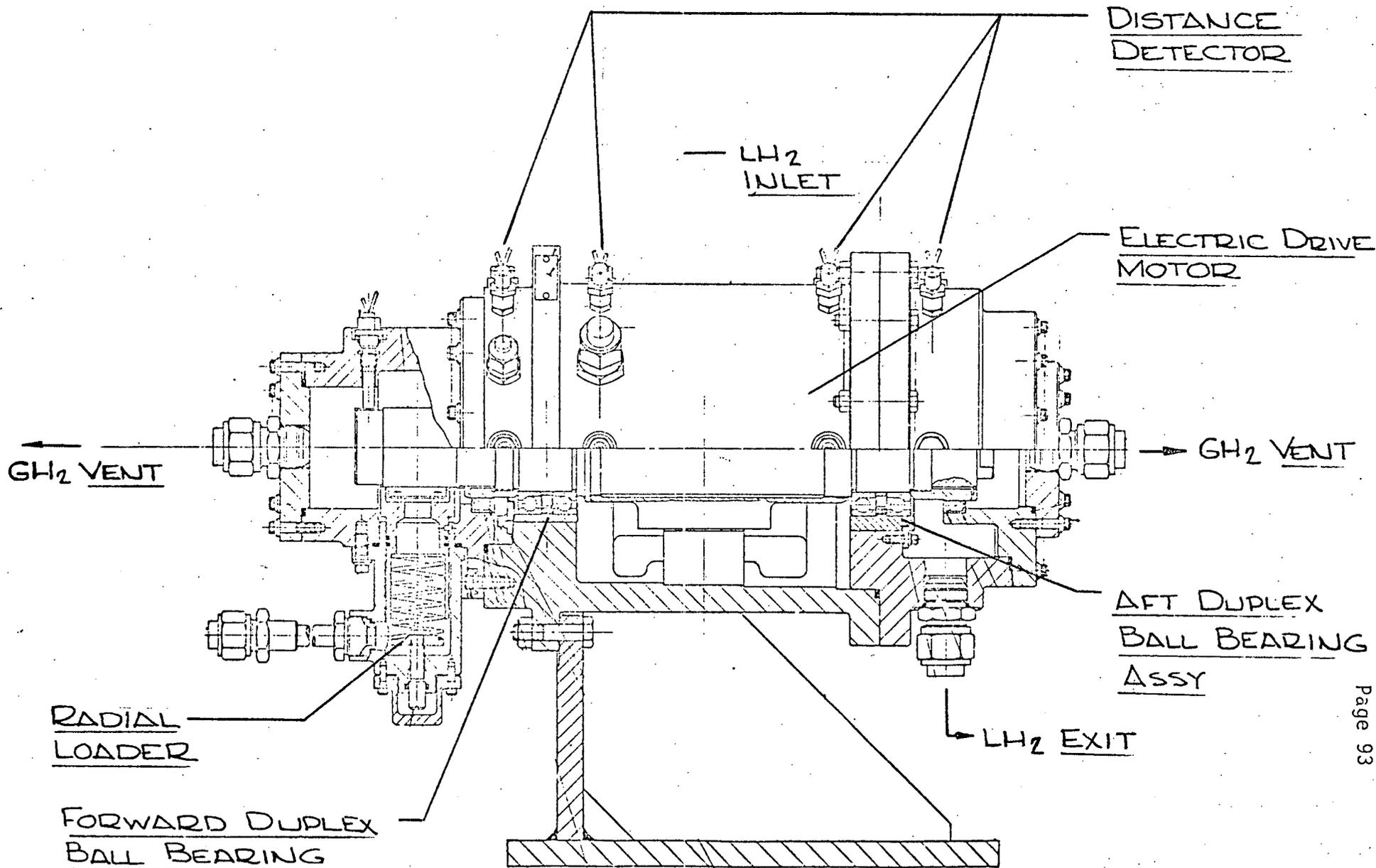


FIGURE 47 - ANSC LH<sub>2</sub> DUAL DUPLEX BALL BEARING TESTER P/N 1138990-1

TABLE 15

PRINCIPAL FEATURES OF BUILD-UP 19

DUAL DUPLEX BEARING TESTER P/N 1138990-1A, S/N 880001  
FIRST ASSEMBLY - NOT OPERATIONAL

Shaft Assy with Armature	Precision Dynamic Balancing Completed
Bearing Assemblies	P/N 1139188-2A
Basic Bearing P/N	1139188-2A
Duplex Bearing Set No. 1 (Forward Side, Near Loader)	S/N 880078 Upstream S/N 880079 Downstream
Duplex Bearing Set No. 2 (Aft Side)	S/N 880080 Upstream S/N 880081 Downstream
Retainers, All Bearings	
Material	Armalon
Pockets	Elongated as fabricated.
Axial Preload for Each Bearing Set, lbs	600
Room Temperature Radial Play, Inches	
Forward of Duplex Set No. 1	0.010+
Aft of Duplex Set No. 2	0.010+
Breakaway Torque, in-lbs	8

The photographs in Figures 48 through 54 show different views of the various stages of the tester assembly. It should be noted that this assembly is not ready for operation. There is no safety wiring of bolts, although all bolts are torqued to the specified value. Also, the tester requires a LH<sub>2</sub> push-pull test for each duplex bearing set cartridge prior to final assembly for rotational testing. If the push-pull tests in LH<sub>2</sub> indicate that there is no axial freedom of the cartridge in its housing then the cartridge OD must be reworked to provide clearance and the push-pull tests repeated. This is a one time effort if materials are not changed but is time consuming. To perform the push-pull tests the tester must be assembled in accordance with a different assembly procedure, (TMP-119 and TMP-120).

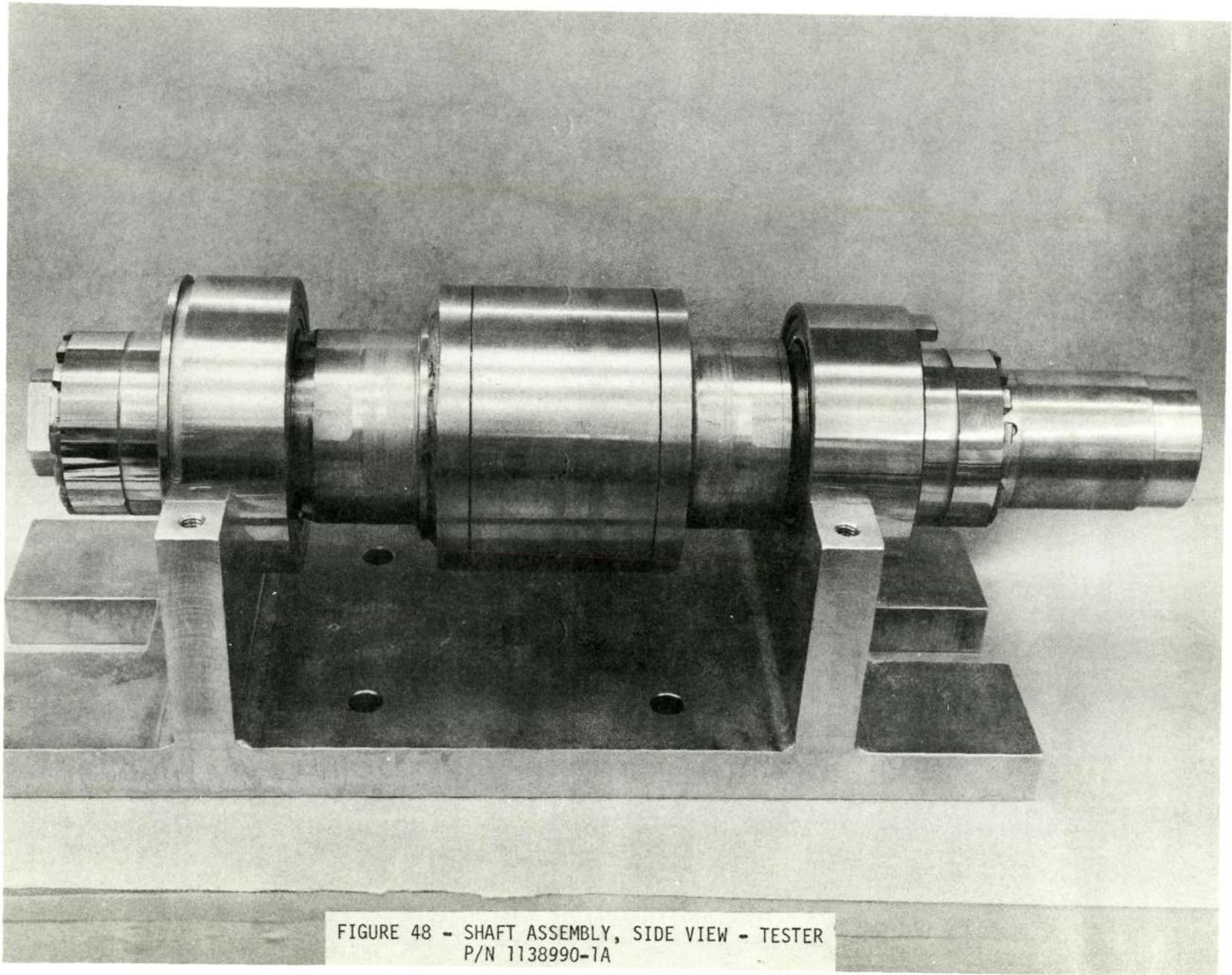
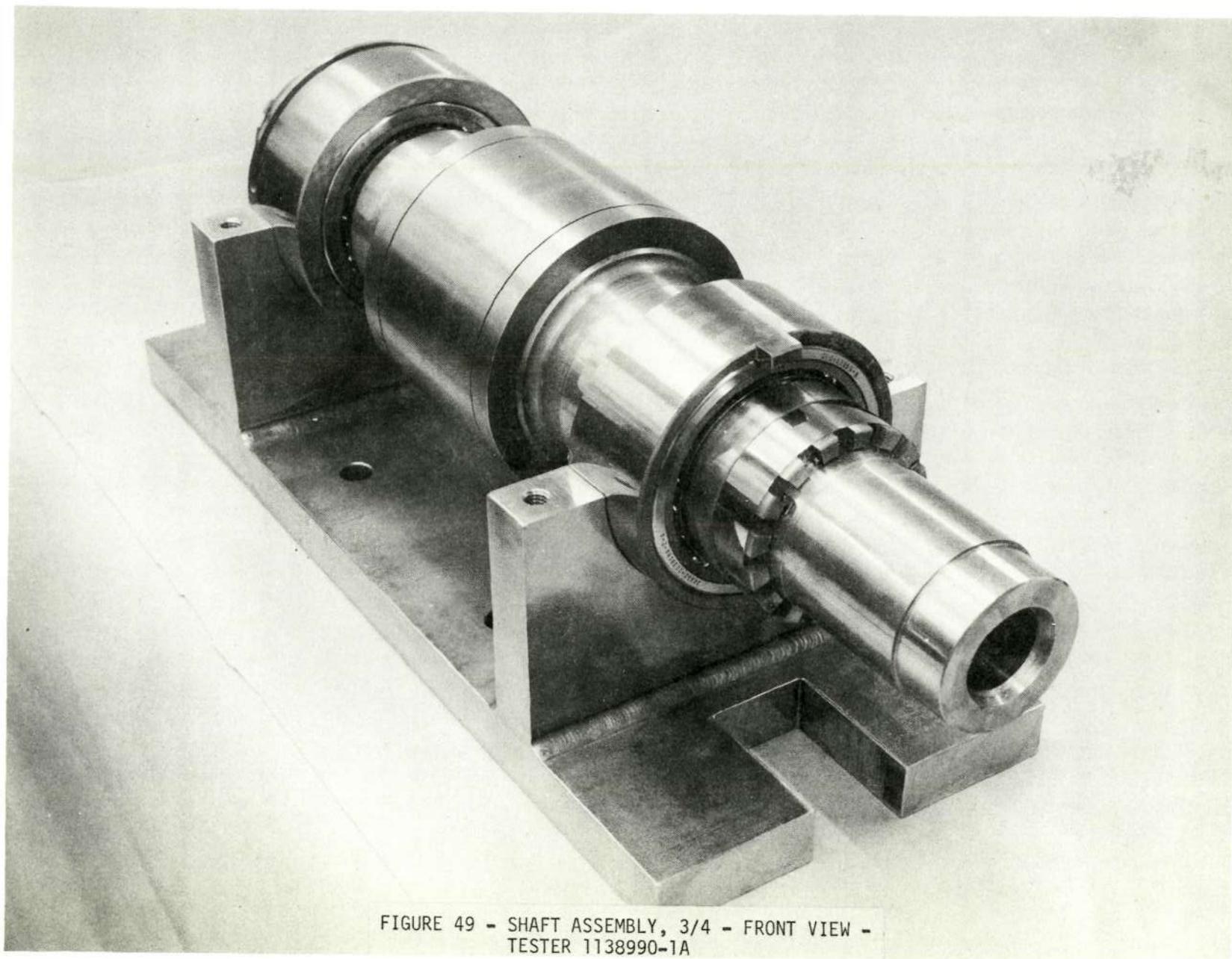


FIGURE 48 - SHAFT ASSEMBLY, SIDE VIEW - TESTER  
P/N 1138990-1A



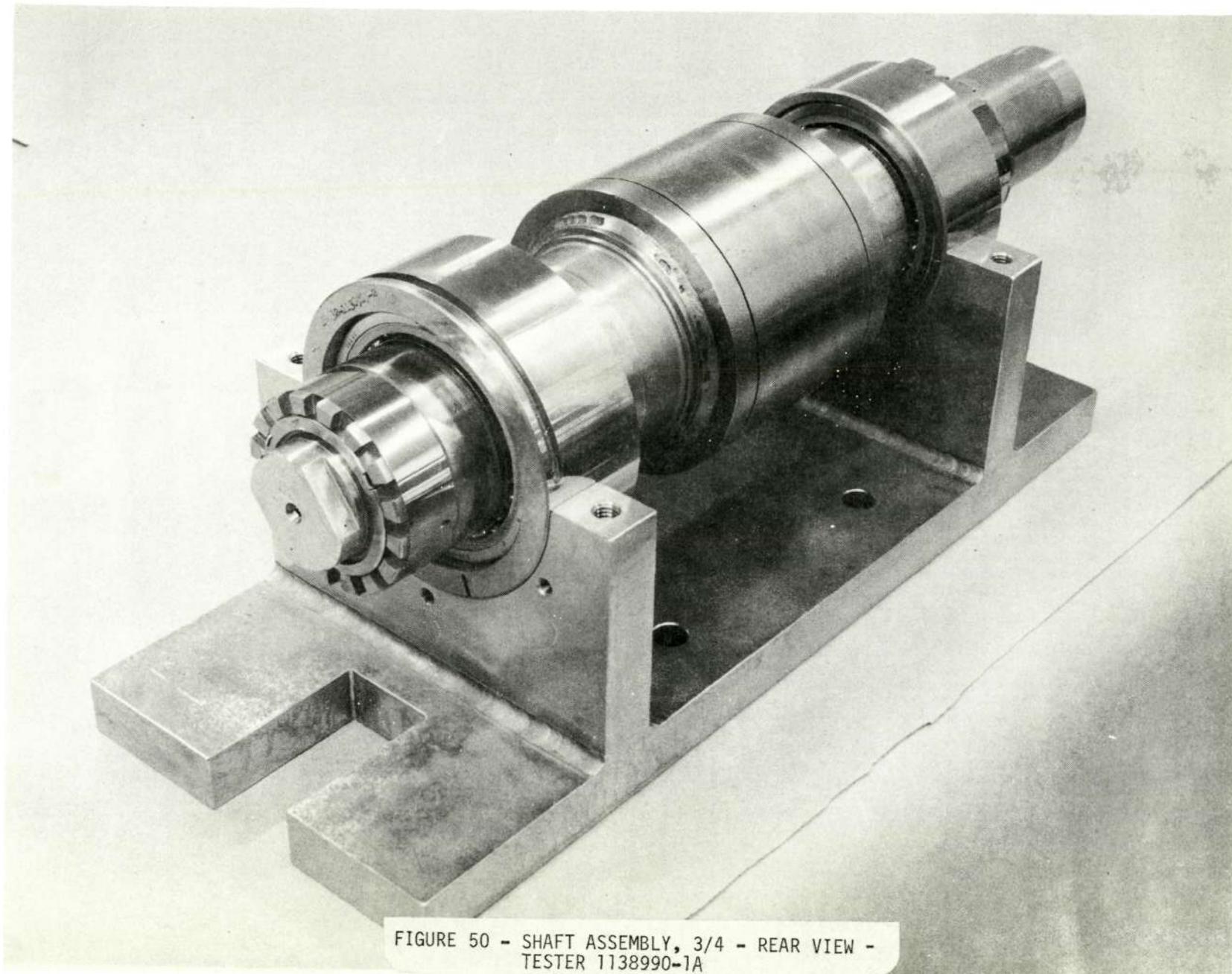


FIGURE 50 - SHAFT ASSEMBLY, 3/4 - REAR VIEW -  
TESTER 1138990-1A

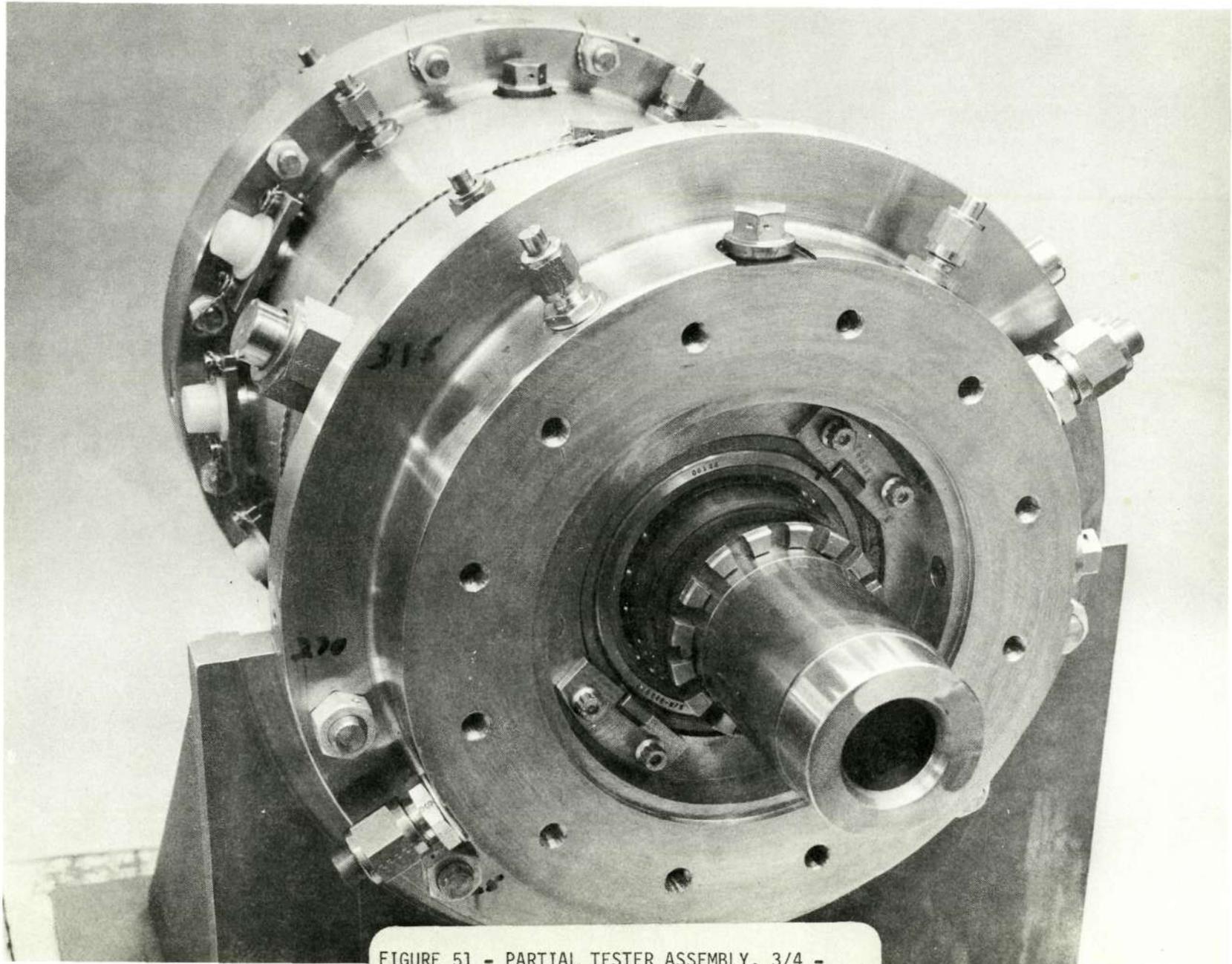


FIGURE 51 - PARTIAL TESTER ASSEMBLY, 3/4 -  
FRONT VIEW - TESTER 1138990-1A

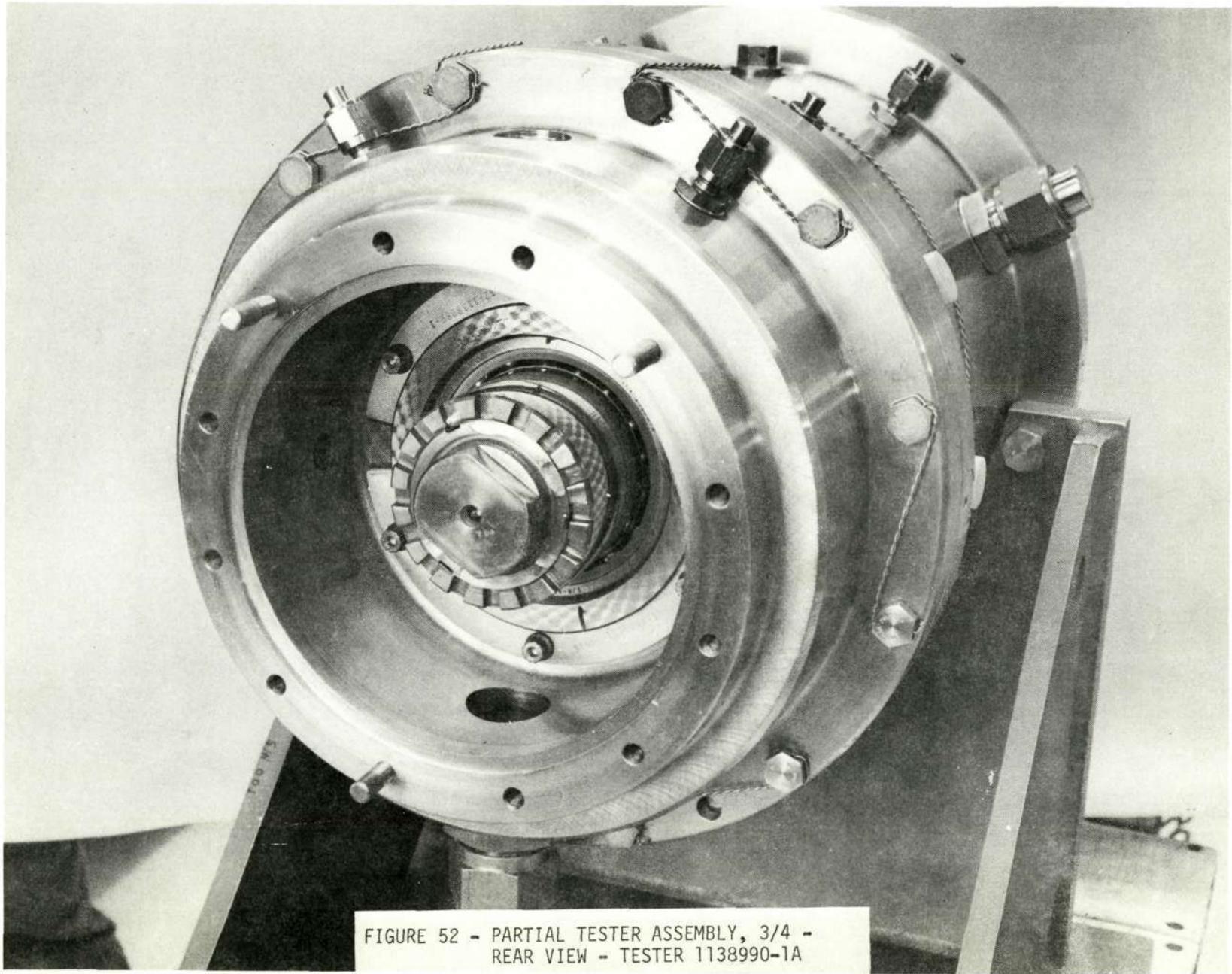


FIGURE 52 - PARTIAL TESTER ASSEMBLY, 3/4 -  
REAR VIEW - TESTER 1138990-1A

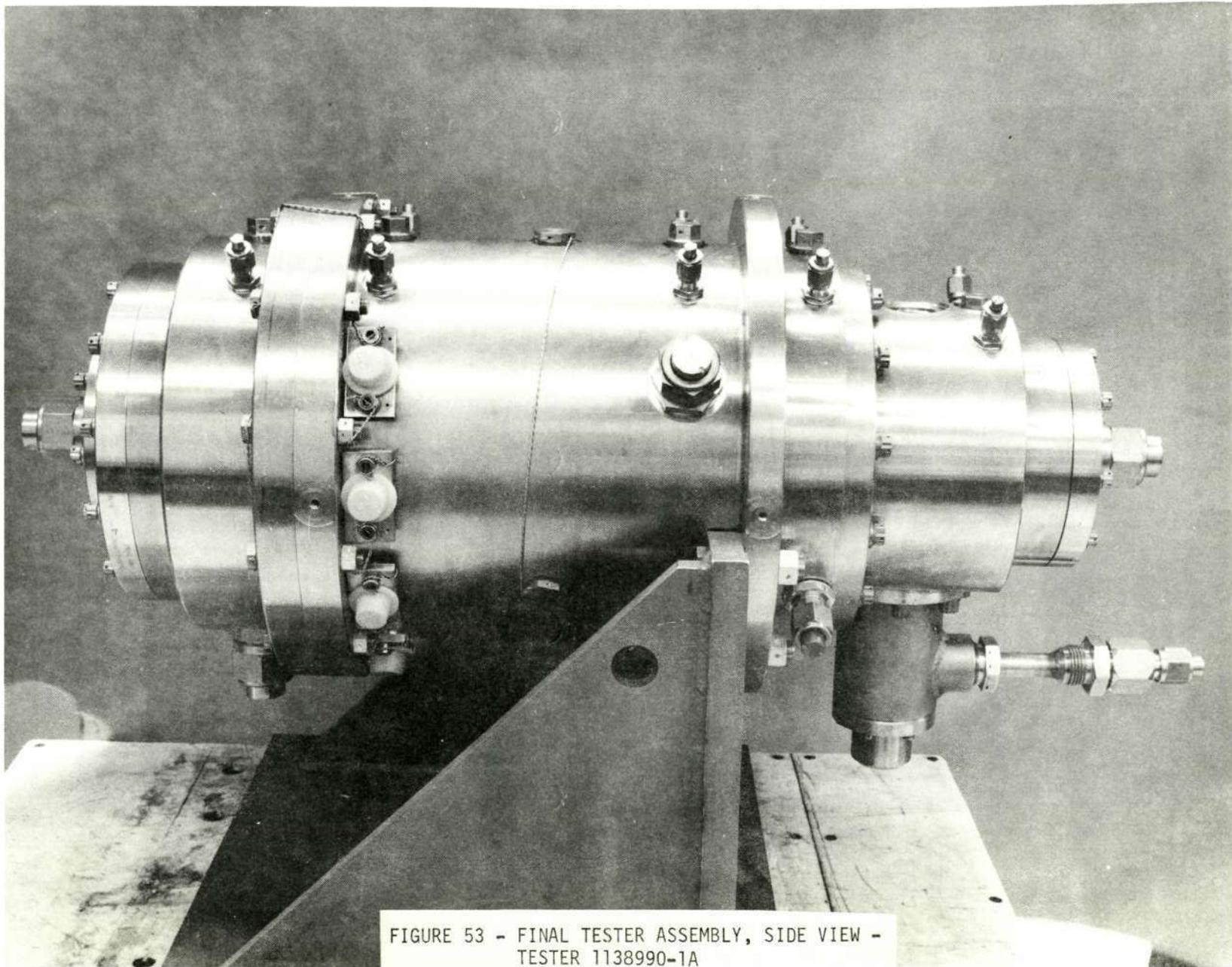


FIGURE 53 - FINAL TESTER ASSEMBLY, SIDE VIEW -  
TESTER 1138990-1A

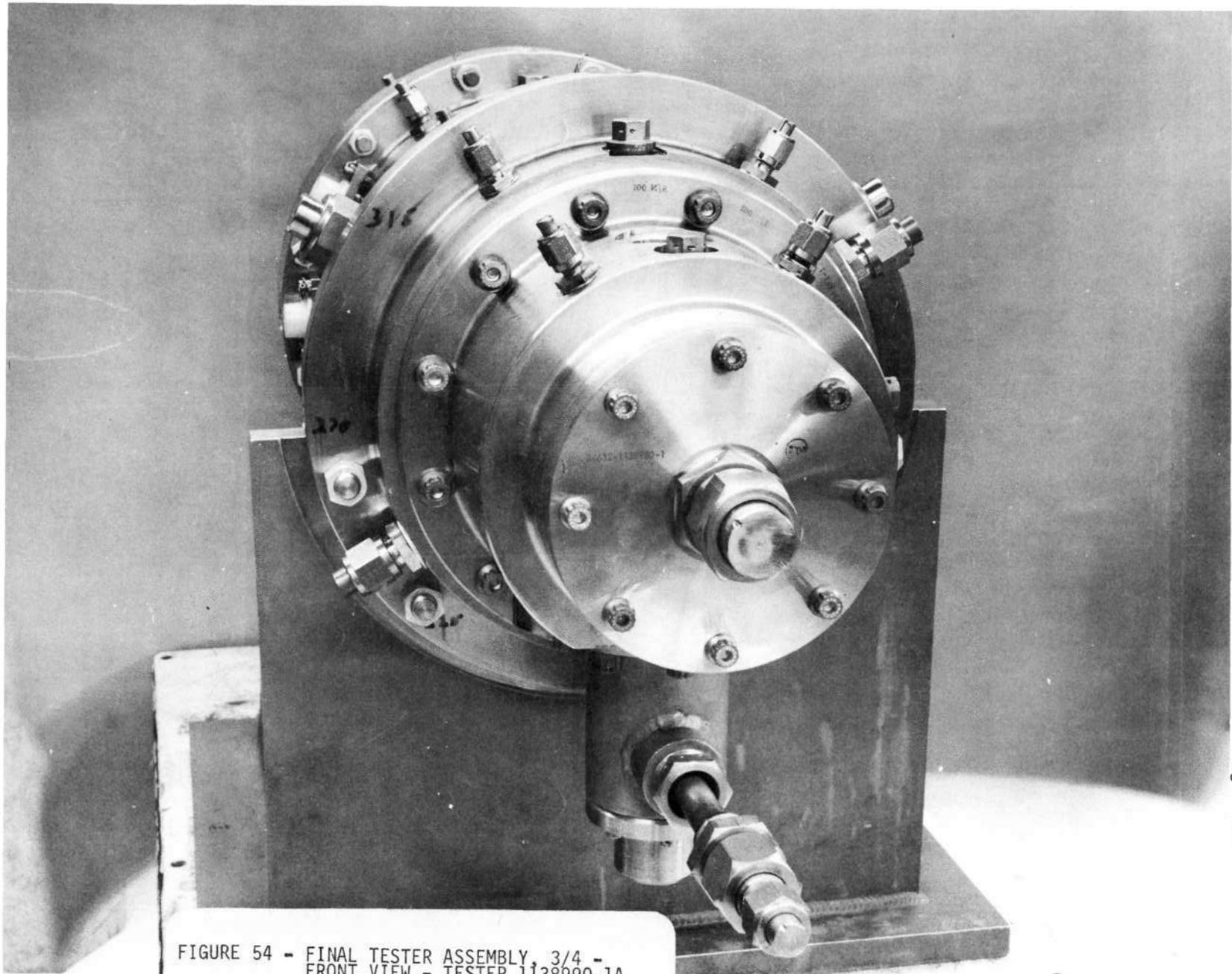


FIGURE 54 - FINAL TESTER ASSEMBLY, 3/4 -  
FRONT VIEW - TESTER 1138990-1A

LIST OF REFERENCES

1. "Design and Development of LH<sub>2</sub> Cooled Rolling Element Radial Bearings for the NERVA Engine Turbopump", N8300R:72-096 - Phase I - January 1969 - December 1971, Volumes I and II

## APPENDIX A

1. "NRDS Test Cell "A" NERVA Turbopump 65MM Bearing Testing Facility Requirements", Facility Requirements Document F004, F004-CP091295BG1, October 1971
2. "Test Description for Facility Experimental Plan and Bearing Test Series at Test Cell "A" - Nuclear Rocket Test Operations NRT0-R-0212, R30 Issue, 12 August 1971
3. "Standard Operating Procedure for Hot Helium or Nitrogen Dehydration Purge of the Bearing Test Article in Test Cell "A" - Nuclear Rocket Test Operations Report NRT0-SOP-0235, Final Use, 18 August 1971
4. Basic Test Request (Revision A) dated 9-23-71 and Test Request Supplement No. 1 dated 6-23-71 which revised the original Basic Test Request.
5. Sample "Test Operating Procedure (TOP) for Phase I Bearing Build-up 16 EP-4, Run 1190-65-016-002"
6. Various Turbomachinery Procedures (TMP) for Tester 1138060, and Pretest Preparation and Post Test Inspections of Test Bearings

*I*

F004-CP091295BG1

OCTOBER 1971

NERVA Program, Contract SNP-1

**FACILITY REQUIREMENTS**

**DOCUMENT**

**F004**

NRDS TEST CELL "A"

NERVA TURBOPUMP 65MM BEARING TESTING

FACILITY REQUIREMENTS



**AEROJET NUCLEAR SYSTEMS COMPANY**

A DIVISION OF AEROJET-GENERAL 

*II*



F004CP091295BGI

FACILITY REQUIREMENTS DOCUMENT

NRDS TEST CELL "A"  
NERVA TURBOPUMP 65MM BEARING TESTING  
FACILITY REQUIREMENTS

NERVA Program



Contract SNP-1

OCTOBER 1971

Classification Category

UNCLASSIFIED

*Haru Patman*

*2-28-71*

Classifying Officer

Date

*Milton Klein*

MILTON KLEIN, MANAGER  
SPACE NUCLEAR SYSTEMS OFFICE

*R. W. Schroeder*

R. W. SCHROEDER, CHIEF  
SPACE NUCLEAR SYSTEMS OFFICE  
CLEVELAND EXTENSION

DATA ITEM  
CHANGE NOTICE

DATA ITEM NO: F004 CP091295\*G1

DATED: October 1971

TITLE: NRDS Test Cell "A" NERVA Turbopump  
65MM Bearing Testing Facility  
Requirements

CHANGE				DESCRIPTION	AUTHORITY
REV. LTR. (*)	DATE	WAS PAGE	IS PAGE		
ORIGINAL	2/71			Original Issue dated February 1971	
A	8/30/71	3 13 14 15 16 17 18 21 22	3a 13a 14a 15a 16a 17a 18a 21a Deleted	Divide facility requirements into two phases and incorporate changes required by SNSO for approval.	Change Order 71-15
B	10/71	i ii 1 3a 4 9 12 13a 14a 15a 16a 17a 19 20 21a	ib iib 1b 3b 4b 9b 12b 13b 14b 15b 16b 17b 19b Deleted 20b	To incorporate SNSO-C approval of Engineering Change Proposal A1009.  - Page change only  <u>IV</u>	Modification No. 57 to SNP-1

TABLE OF CONTENTS

	<u>PAGE</u>
1.0 INTRODUCTION	1 b
1.1 Scope	1 b
1.2 Objective	3 b
1.3 Program Description	3 b
1.4 Test Schedule	4 b
2.0 TEST BEARINGS DESCRIPTION	5
2.1 Ball Bearings	5
2.2 Roller Bearing	6
2.3 Bearing Testers	6
2.4 Operating Characteristics	12 b
2.5 Applicable Drawings	12 b
3.0 TEST PROGRAM AND OPERATIONS	13 b
3.1 Test Program	13 b
3.2 Operations	13 b
4.0 RELIABILITY AND QUALITY ASSURANCE	14 b
4.1 Scope	14 b
4.2 Guidelines	14 b
5.0 SAFETY	14 b
6.0 STE AND FACILITY SYSTEMS	14 b
6.1 Scope	14 b
6.2 Guidelines	15a
6.3 Building and structural	16 b
6.4 Assembly and Disassembly	16 b
6.5 Measurements and Metallurgical Evaluation	16 b
6.6 Fluid Interface Requirements	17 b
6.7 Instrumentation and Controls	17 b
6.7.1 Scope	17
6.7.2 Guidelines	17
6.7.3 Instrumentation	17
6.7.4 Controls	18a
6.8 Data Acquisition	18a
7.0 SYSTEM READINESS VERIFICATION	18a

LIST OF TABLES

		<u>PAGE</u>
TABLE I	Required Instrumentation	19b
TABLE II	Bearing Tester/Facility Fluid Interface Requirements	20b

LIST OF FIGURES

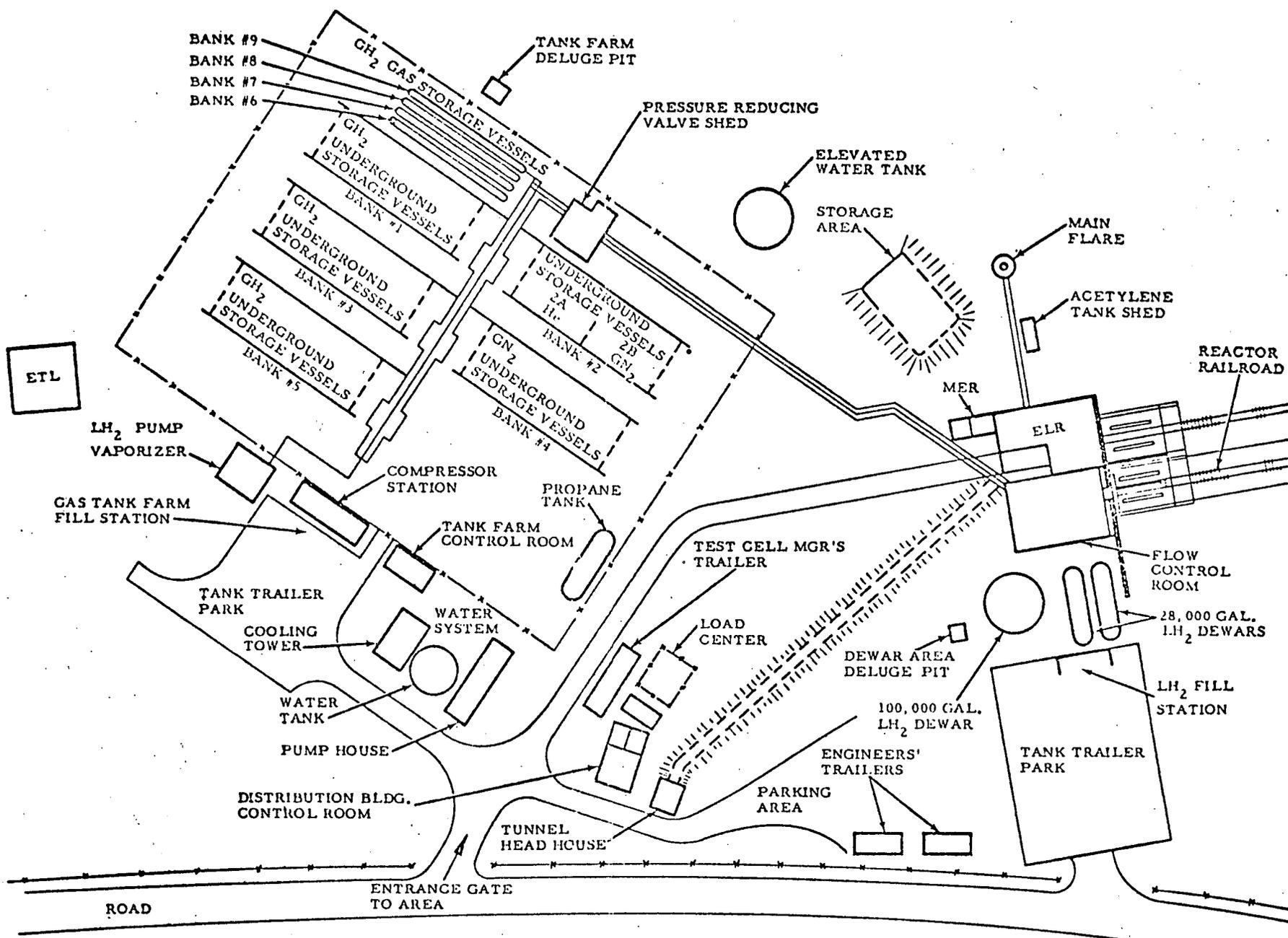
<u>FIGURE</u>		<u>PAGE</u>
1	Plot Plan Test Cell "A"	2
2	Ball Bearing Tester	7
3	Bearing Radial Load vs. Radial Loader $\Delta P$	8
4	Roller Bearing Tester	10
5	Typical Test Schematic	11

1.0 INTRODUCTION

1.1 SCOPE

This document has been prepared to present the Test Cell "A" facility and Special Test Equipment requirements necessary to support the "Evaluation Testing of LH<sub>2</sub> Cooled 65 mm Rolling Element Bearings for the NERVA Engine TPA."

The 65 mm bearing test program will be conducted at Test Cell "A", NRDS, Jackass Flats, Nevada. Figure 1 is a Plot Plan of Test Cell "A".



TEST CELL "A" PLOT PLAN

Figure 1

## 1.2      1.2      OBJECTIVE

The information presented herein is to be used in the conceptual design and definitions of facility modifications and additions to support the referenced test program, the ROM cost of these modifications, and scheduling of detailed design/construction/activation and testing. This document is intended to provide sufficient information to develop modification criteria adequate to provide capability to test 65 mm bearings.

## 1.3      PROGRAM DESCRIPTION

The objectives of the NERVA TPA Bearing Development Program are as follows:

- (a) Demonstrate feasibility of the 65 mm ball bearing duplex set at several loads for the required TPA operating durations and start/stop transients.
- (b) Evaluate several retainer materials (unirradiated and irradiated) for wear and structural strength.
- (c) Evaluate bearing failure modes, metal fatigue, metal wear, retainer wear or fracture.
- (d) Establish the metal wear characteristics at two or more loads and relate bearing wear with bearing performance and failure.
- (e) Provide a reasonable preliminary estimate of the life-load reliability.
- (f) Attempt to demonstrate the allocated reliability of the selected bearing configuration by a method of truncated testing at overload conditions for fatigue and by relating bearing wear observations, using a strength/stress reliability analogy.

(g) Evaluate the feasibility of the backup roller bearing to operate at high DN values ( $1.8 \times 10^6$ ) without roller end wear.

(h) Evaluate, as secondary objective several bearing failure detection techniques.

The primary development testing will utilize two (2) different testers as follows:

- (1) P/N 1138060-2
- (2) P/N 1138990 Dual Tester

A roller bearing tester (P/N 1138060-1) may be used to evaluate a back-up roller bearing. All testers will be installed for testing at Test Cell "A", NRDS, Nevada.

#### 1.4 TEST SCHEDULE

The anticipated bearing testing schedule for Contract Year 1971 and 1972 is given by Report M100-TTP03-W121 dated December 1970, Title: "Test and Development Plan for the Evaluation of LH<sub>2</sub> Cooled 65 mm Rolling Element Bearings for NERVA Engine TPA."

## 2.0 TEST BEARINGS DESCRIPTION

### 2.1 BALL BEARING

The test bearing of primary interest is an angular contact 65 mm ball bearing to be tested as a duplex set in an axially preloaded back-to-back mounting. The general characteristics are as follows:

P/N	1138146-1
Type	Angular Contact Ball Bearing
ABEC Class	7
Material	440C S S CEVM
Series	100
Bore, inches	2.5590 (65 mm)
O.D., Inches	3.9369 (100 mm)
Width, nom. inches	0.7062 (18 mm)
Outer Race Curvature, %	52
Inner Race Curvature, %	53
Unmounted Contact Angle, °	23
Number of Balls	17
Ball Diameter, inches	0.4375 (Grade 10)

The prototype bearing was obtained with an Armalon retainer (Teflon/glass cloth) for the initial exploratory investigation of the metal bearing components and their general feasibility. Considerably more radiation resistant retainers of polybenzimidazole polymer reinforced with graphite cloth (PBI/graphite) and glass cloth (PBI/glass), respectively, are being procured for evaluation as the prime candidate retainer. These retainers are made from materials and process specified in Dwg. 1138220. A third non-metallic retainer of high radiation resistance and reportedly of very high strength is a polyquinoxaline polymer (PQ) reinforced with a high strength graphite filament (Modmor Type I), PQ/Modmor Type I. This latter material will also be evaluated as a possible retainer candidate if laboratory tests on test specimens are encouraging.

## 2.2 ROLLER BEARING

The cylindrical roller bearing (P/N 113811401) and PBI/graphite/PBI/glass retainers (P/N 1138205) for this bearing are considered backup candidates. The retainers are made from materials and process specified in Dwg. 1138221. The general characteristics of this bearing are as follows:

P/N	1138114-1
Type	Cylindrical Roller Bearing
RBEC Class	7
Material	440C SS CEVM
Series	100
Bore, inches	2.5590 (65 mm)
O. D., inches	3.9369 (100 mm)
Width, inches	0.8636 (22 mm)
Number Rollers	19
Roller Diameters, inches	0.3937 (10 mm)
Crowned Rollers	Per Drawing
Internal Clearance, inches (Range, mounted)	+0.001 to -0.002

## 2.3 BEARING TESTERS

The ANSC LH<sub>2</sub> 65 mm Ball Bearing Tester, P/N 1138060-2, shown in Figure 2 will be used for the primary development testing in this program. Two identical testers will be in use from the initiation of testing of the 65 mm ball bearings. A second tester configuration is now in the design stage. This latter tester design will be utilized later in the program as soon as it becomes available, along with the initial testers.

The testers (p/n 1138060-2) are each capable of testing one duplex ball bearing set to radial loads of 3000 lbs. and axial preloads to 1600 lbs. The radial load is applied by a CH<sub>2</sub> pneumatic loader, while the axial preload is provided by the compression of coil springs between the outer races. Figure 3 shows a plot of bearing load as a function of

ANSC LH<sub>2</sub> 65 MM DUPLX BALL BEARING TESTER  
(P/N 1138060-2)

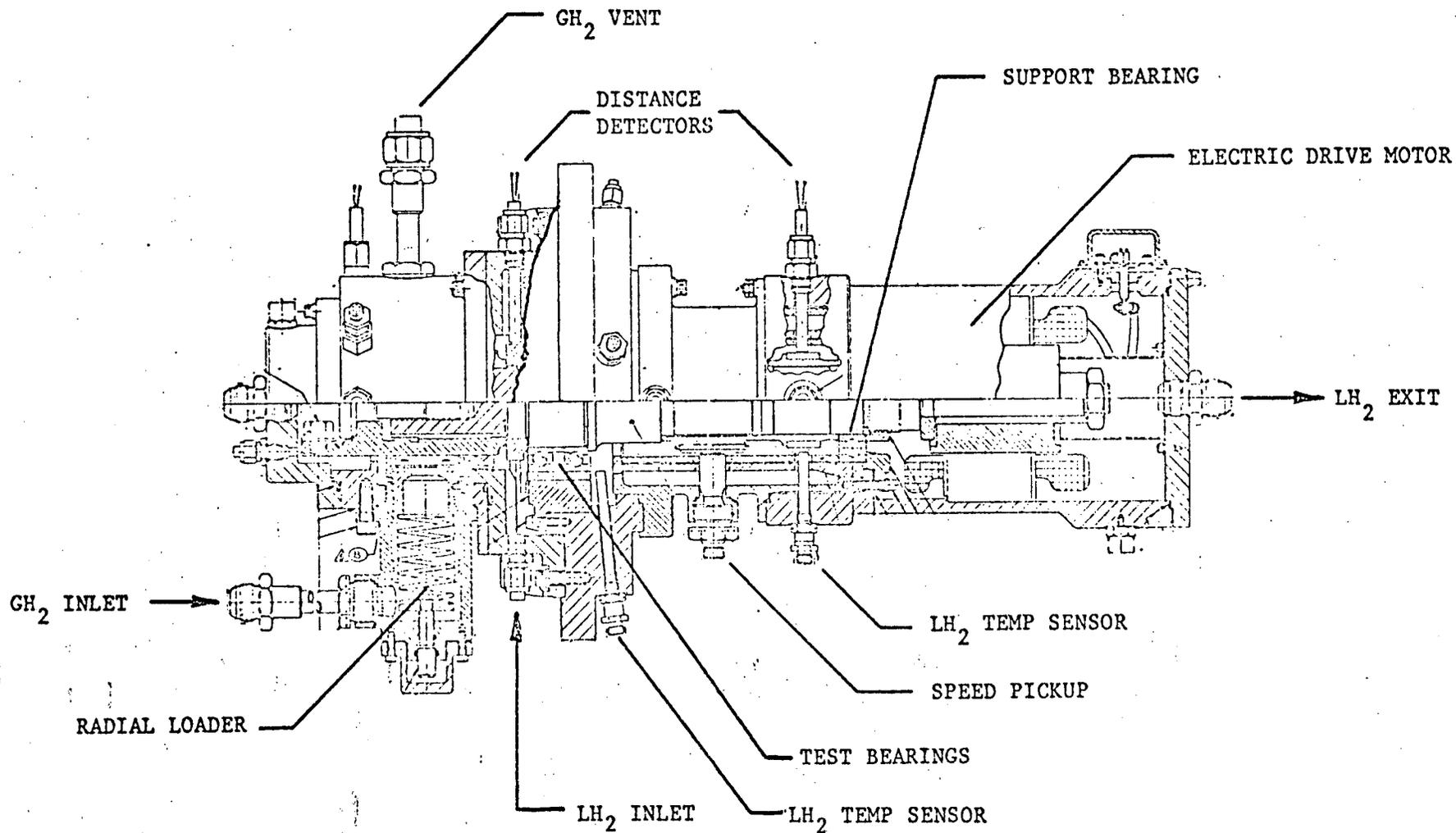


FIGURE 2

BEARING RADIAL LOAD AS A FUNCTION OF RADIAL LOADER  $\Delta P$

65MM BEARING TESTERS P/N 1138060

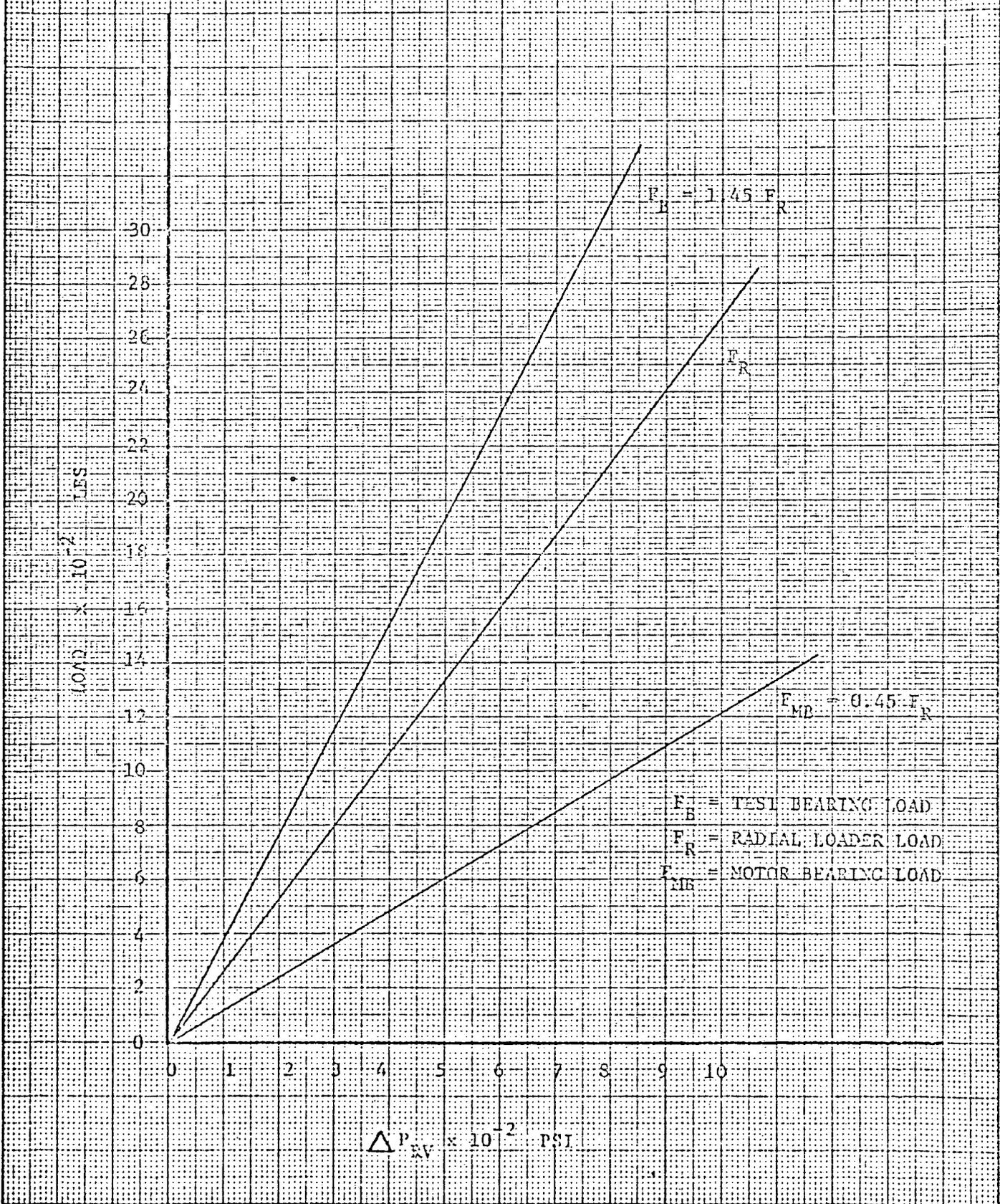


FIGURE 3

pressure drop across the loader,  $P_{RV}$ . Provisions are also available for the simultaneous application of a rotating radial load (inertia load). A  $LH_2$  cooled 2-pole induction motor can rotate the bearings to 40,000 rpm, although the test speed is presently set at 27,000 rpm for this program. A 50 mm deep groove radial ball bearing provides shaft support at the motor end.

Instrumentation pickups at the tester include various pressures ( $LH_2$  and  $GH_2$ ), temperatures, speed, vibration and shaft motion using four distance detectors at two stations. Other facility instrumentation is included for pressures, temperature, and  $LH_2$  flow rate into the tester. Table 1 lists the required instrumentation, the range, and type of recording. Pressurized (225 psig)  $LH_2$  enters the bearing tester just ahead of the upstream bearing of the duplex test bearing set, flows through the test bearings, through the support bearing, the motor and exits to vent through a control orifice and a flow control valve. Temperature of the  $LH_2$  into the bearing compartment has generally been in the range  $-403$  to  $-412^{\circ}F$  ( $52-48^{\circ}R$ ). An important parameter relative to incipient bearing failure indication has been the temperature increase of the  $LH_2$  flowing through the bearing. This is monitored by suitably ranged RTTs mounted on either side of the bearing set.

The roller bearing tester (P/N 1138060-1), shown in Figure 4 is similar to the ball bearing tester described above in nearly all respects. The principal difference is that a single cylindrical roller test bearing is located at the duplex ball bearing position.

The testers will be installed for testing at Test Cell "A", Nuclear Reactor Development Station, Nevada. A schematic of the typical installation is shown in Figure 5.

A new concept bearing tester for the 65 mm duplex ball bearing is presently in the preliminary design phase. The new improved tester will test two duplex ball bearing sets simultaneously but at different load. The two loads for a given setup (buildup) will allow simultaneous evaluation of the effect of load. However, the bearing position nearest the radial loader will be the test set. The load

ANSC LH<sub>2</sub> 65 MM ROLLER BEARING TESTER  
(P/N 1138060-1)

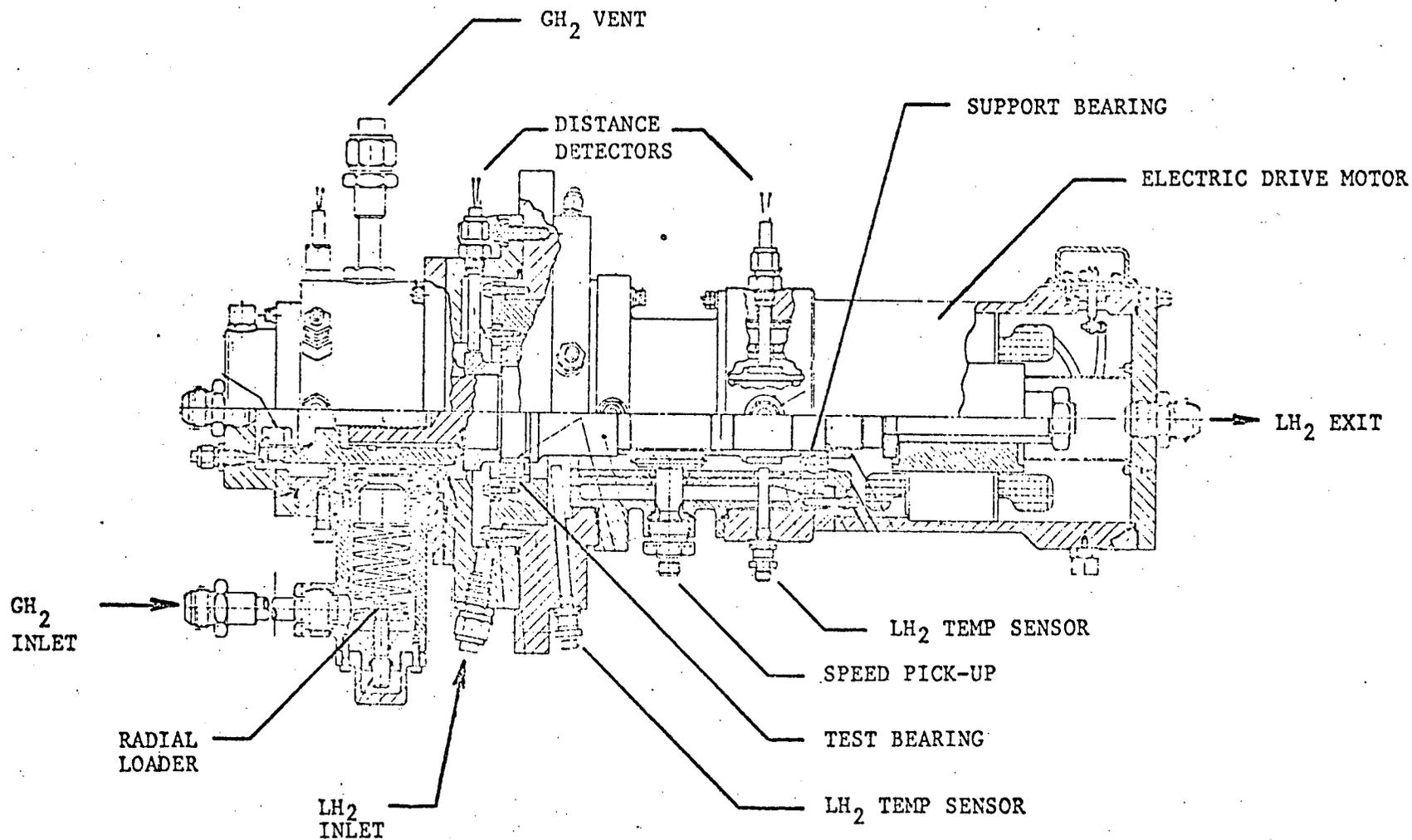
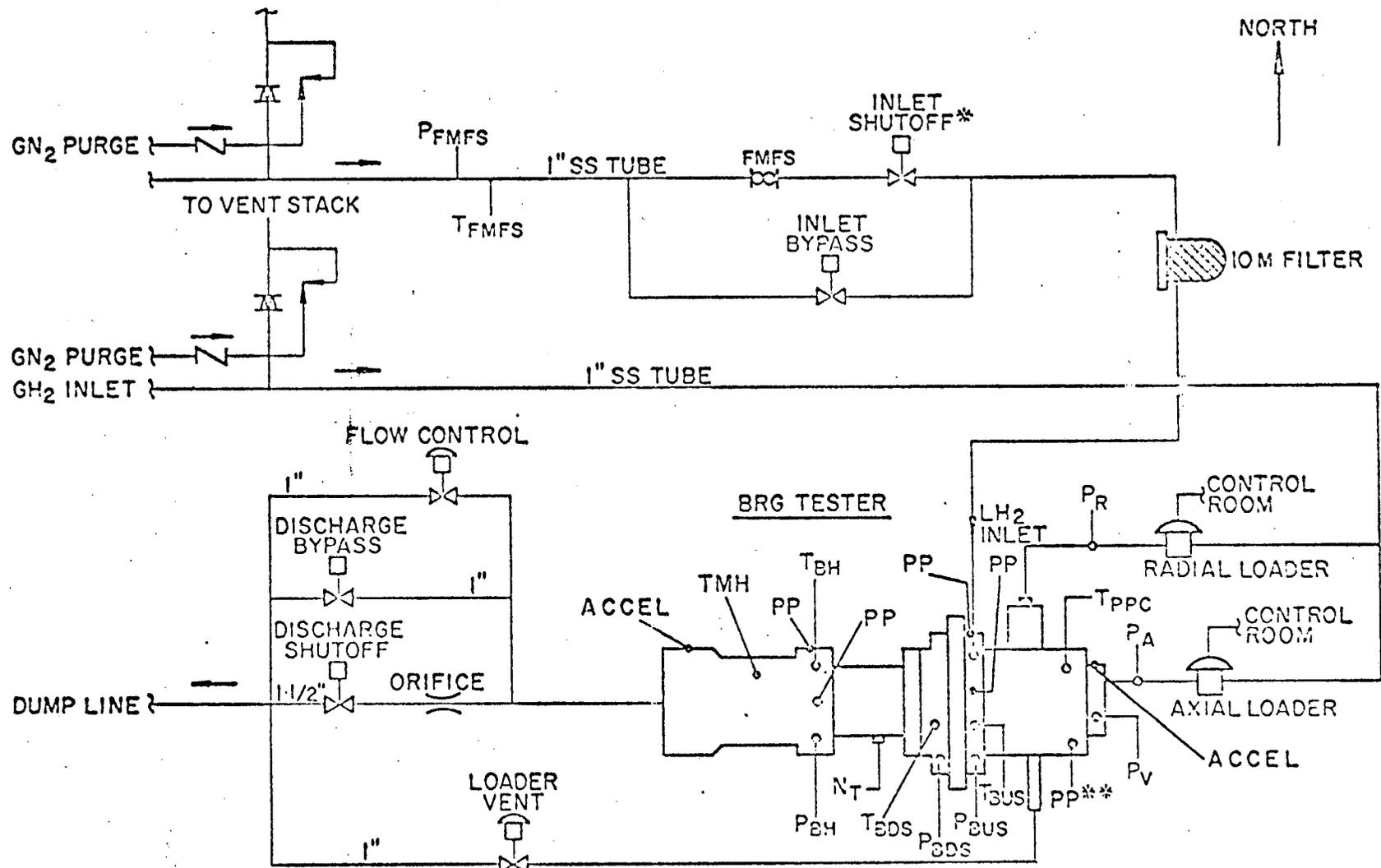


FIGURE 4

- 10 -



\* ELECTRICAL INTERLOCK EXISTS SO THAT WHEN SHUTOFF VALVE IS CLOSED, BYPASS VALVE COMES OPEN.

\*\* PROXIMITY PROBES (5 REQD).

TYPICAL TEST SCHEMATIC

LH<sub>2</sub> 65mm DUPLEX BALL BEARING AND ROLLER BEARING TESTER

FIGURE 5

- 11 -

application will be the presently used pneumatic loader with slight modifications. A similar LH<sub>2</sub> cooled electric motor will be employed to drive the tester, but shaft stiffness will be significantly improved.

#### 2.4 OPERATING CHARACTERISTICS

The bearings are LH<sub>2</sub> cooled and should be capable of providing 10 hours of accumulated duration at maximum operating conditions, with 60 start/stop transients. The NERVA Engine TPA Operating requirements relevant to the shaft radial support bearings are the following:

Nominal Malfunction Mode Shaft Speed, rpm	27,000
Short Duration Overspeed, rpm	30,000
Nominal Temperature	55°R
LH <sub>2</sub> Coolant Flow Rate, pps (duplex set)	.5
LH <sub>2</sub> Coolant Pressure, psig	>500
Life, Hours	10
Number of start/stop transients	60

#### 2.5 APPLICABLE DRAWINGS

The following drawings provide the test article description and define interfaces:

Tester Assembly No. 1138060-1	Roller Bearing
Tester Assembly No. 1138060-2	Ball Bearing
Tester Assembly No. 1138990	Ball Bearing

### 3.0 TEST PROGRAM AND OPERATIONS

The purpose of this section is to establish operational requirements in support of the NERVA TPA Bearing Test Program.

#### 3.1 TEST PROGRAM

The test and Development Plan for the NERVA bearing is contained in Report M100-TTP03-W121 dated December 1970.

#### 3.2 OPERATIONS

All facility and STE modifications shall be provided in two phases. "Phase One" modifications shall provide the capability to test a maximum of 7 bearing tester build-ups per month for 15 hours each. Assuming optimum manpower and logistics "Phase Two" modifications shall increase the facility capabilities to be able to:

- (1) test a maximum of 10 bearing tester buildups per months for 15 hours each assuming optimum manpower and logistics
- (2) provide additional data acquisition capacity (Table I), and
- (3) provide transient testing capability.

#### 4.0 RELIABILITY AND QUALITY ASSURANCE

##### 4.1 SCOPE

This section identifies the reliability, maintainability, and quality assurance requirements to be applied in the design, fabrication, installation, qualification, and testing of a maintainable and reliable facility.

##### 4.2 GUIDELINES

4.2.1 All efforts performed by Architect-Engineering firms shall be in accordance with the provisions of FEO-3 "NERVA Facilities Engineering and Design Standards" and SNPO-C-4 "Quality Assurance Requirements for Facility and Test Support Equipment."

#### 5.0 SAFETY

The design of bearing test equipment shall utilize applicable safety codes and standards; facility modifications and equipment installation at TC"A" will be done in accordance with applicable portions of the NRTO Health and Safety Manual, NRTO-A-0022, Revision 1. A pre-operational safety review of the overall bearing test systems as installed at TC"A" shall be performed, documented and transmitted to SNSO.

#### 6.0 STE AND FACILITY SYSTEMS

##### 6.1 SCOPE

This section defines the specific facility and STE performing requirements and constraints for Test Cell "A".

6.2 GUIDELINES

6.2.1 The facility shall provide normal work accessibility to the test article operations prior to testing.

6.2.2 All systems specified within this section shall have the capacity and capability of providing the required support to accomplish the test program specified in Section 3.0 for the test article described in Section 2.0.

6.2.3 Systems Maintenance

Design shall be such that maintenance requirements are minimized. Maintenance practices shall be compatible with the turn-around requirements. Access shall be provided to areas where scheduled maintenance will be required.

6.2.4 Environmental Conditions

Upon selecting equipment and components for use in the various areas, specific attention shall be given to the environment in which the equipment or component is to function.

6.2.5 Interferences

Personnel, hardware and schedular interferences with other scheduled test programs are to be avoided wherever possible.

6.2.6 The bearing tester used at the Cryogenics Laboratory, Sacramento, California shall be moved to Test Cell "A" to accomplish the testing.

6.2.7 Power

The existing electric motor drive systems shall be moved to Test Cell "A" and be used to furnish the required power to the bearing tester. This system will satisfy the requirements of all three bearing testers.

6.3 BUILDING AND STRUCTURAL

Existing buildings (Electronics Room and Recording Equipment Room) can be used for control and instrumentation. Modifications required should include only those required to install controls and instrumentation which is not already existing.

6.4 ASSEMBLY AND DISASSEMBLY

An available "white" room at E-MAD is adequate to satisfy the need for assembly and disassembly and associated functions in tester build-up. Gaseous and liquid nitrogen supplies are available in the "white" room area.

Cleanliness requirements are stated in Paragraph 6.4.2 of f004-FRC02-W223f04 "Supplemental Design Criteria-NRDS Test Cell "A" NERVA Turbopump Bearing Test Facility."

6.5 MEASUREMENTS AND METALLURGICAL EVALUATION

Pre and Post-test requirements for evaluation of each bearing will consist of visual inspection, photo inspection and documentation and will be accomplished in AGC Measurements Standard Laboratory, Sacramento. In addition, specialized tests requirements such as microscopic inspection at sufficient magnification, dynamic balancing of shaft, external geometry measurements, (O. D., I. D. and length), internal geometry measurements, and others, will be satisfied by using the Measurements and Standards Laboratory in Sacramento. Dynamic balancing may be accomplished at NRDS.

Both facilities are in operation and available for testing.

Requirement for metallurgical analysis and inspection of bearing components will be determined by cognizant engineer and existing laboratory facilities in Sacramento and/or NRTO are adequate, to support analysis requirement.

#### 6.6 FLUID INTERFACE REQUIREMENTS

The fluid interface requirements between the bearing tester and the facility are given in Table II. As indicated by Table II, the bearing test fluid requirements will vary depending upon the maturity of the test program. The first 30 sets of bearings will be tested to life conditions. The following tests will also include transient conditions as indicated.

#### 6.7 INSTRUMENTATION AND CONTROLS

##### 6.7.1 Scope

This section identifies the instrumentation and control (I&C) system requirements to monitor, record, and control the pump bearing test programs to be conducted at Test Cell "A".

##### 6.7.2 Guidelines

The existing Test Cell "A" systems, subsystems, and components shall be used as much as practical.

##### 6.7.3 Instrumentation

The instrumentation requirements for bearing testing are shown in Table 1. These are the requirements specified by the user in the Basic Test Request. The facility instrumentation requirements are in addition and shall also be provided.

Analog to digital conversion and computer processing for a minimum of 30 channels of data is required.

An analog wide band recording capability is required for 12 channels. The frequency response requirements is 10K hz. The existing capability is adequate.

The existing indicators (meters and strip charts) are adequate to satisfy the bearing test program.

#### 6.7.4 Controls

The controls requirements for the TPA bearing testing setups are 10 channels (4 - ACV's and 6 RSV's). Figure 5 and Tables I and II present information required to specify controls. Controls for facility systems are not identified because they will be a function of test facility systems design requirements. Bearing tester controls and facility controls required during bearing testing shall be remote from the test bay to insure operations personnel safety.

### 6.8 DATA ACQUISITION

Test measurement data will be acquired using transducers, signal conditioners, amplifiers, meters, and recorders. The meters and strip chart recorders will be used for operations during the conduct of the test. The wide band recorder will be used to record high frequency measurements. The digital system and strip chart recorders will be used for narrow band analog measurements. Minimum data sampling requirements are:  
10 samples per second.

### 7.0 SYSTEM READINESS VERIFICATION

At completion of the required modifications, a system checkout of all modified systems shall be performed and all problems resolved and reported prior to installation of the initial test article. Prior to such checkout, the checkout procedure shall be documented and transmitted to SNSO.

## REVISED TABLE I

BEARING DATA SYSTEM SUMMARY

<u>PARAMETER</u>	<u>PH-II CHANNELS</u>	<u>PH-I CHANNELS</u>	<u>COMMON CHANNELS</u>	<u>NEW XDCRS</u>	<u>NEW CHANNELS</u>
PRESSURE	14	12	11	3	3
TEMPERATURE	9	7	6	8	3
FLOW	3	1	1	2	2
SPEED	3	3	3	2	0
MOTOR	5	5	5	0	0
DISPLACEMENT	8	4	4	4	4
ACCELEROMETER	5	1	1	4	4
TOTALS	47	33	31	23	16

TABLE II

BEARING TESTER/FACILITY FLUID INTERFACE REQUIREMENTS

<u>Interface Parameters</u>	<u>Type of Tests</u>	
	<u>Life Tests</u> (Phase one)	<u>Transient Tests*</u> (Phase two)
LH <sub>2</sub> Supply		
Pressure	225 - 300 psig	20 to 225 psig
Temperature	54°R Maximum	150° + 4°R to 50° ± 4°R
Flowrate	40 - 100 GPM	2 - 150 GPM
GH <sub>2</sub> Supply (Axial and Radial Loader)		
Pressure	150 - 800 psig	0 to 150 psig
Temperature	Ambient	Ambient
Flowrate	450 - 1300 Scfm	0 to 450 Scfm
Purge (Pre-test hot purge)		
GN <sub>2</sub>		
Pressure	50 - 70 psig	
Temperature	120°F	
Flowrate	≈ 10 Scfm	
GH <sub>2</sub> (Sweep Purge)		
Pressure	50 psig	
Temperature	Ambient	
Flowrate	≈ 10 Scfm	
GHe (Pre-test purge and post test inert pad)		
Pressure	50 psig	
Temperature	Ambient	
Flowrate	≈ 10 Scfm	

\*Linear ramps to be generated between values shown. Ramps to be varied between 10 - 100 sec.

Transient tests will not be required until 30 sets of bearings have been tested to life conditions.

NRTO-R-0212

NUCLEAR ROCKET TEST OPERATIONS

TEST DESCRIPTION

FOR

FACILITY EXPERIMENTAL PLAN

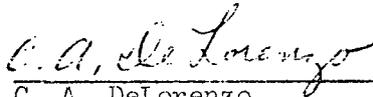
AND BEARING TEST SERIES

AT TEST CELL "A"

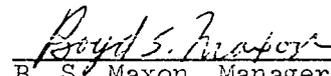
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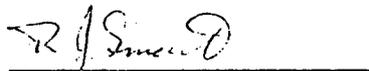
NRTO TEST ENGINEERING

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R-30 ISSUE

12 AUGUST 1971

TABLE OF CONTENTS

TEST DESCRIPTION  
 FOR  
 PHASE I  
 FACILITY EXPERIMENTAL PLAN  
 AND BEARING TEST SERIES  
 AT TEST CELL "A"

<u>PARAGRAPH</u>		<u>PAGE</u>
1.0	<u>INTRODUCTION</u> . . . . .	1
2.0	<u>TEST SYSTEM DESCRIPTION</u> . . . . .	2
2.1	TEST SYSTEM . . . . .	2
2.2	BEARING TESTER. . . . .	2
2.3	MOTOR GENERATOR SET . . . . .	5
2.4	LIQUID HYDROGEN SYSTEM. . . . .	7
2.5	VENT SYSTEM(S). . . . .	9
2.6	GASEOUS HYDROGEN SYSTEM . . . . .	10
2.7	GASEOUS NITROGEN SYSTEM . . . . .	12
2.8	GASEOUS HELIUM SYSTEM . . . . .	13
2.9	WATER SYSTEM. . . . .	14
2.10	BEARING TESTER DEHYDRATION SYSTEM . . . . .	15
2.11	ELECTRICAL POWER SYSTEM . . . . .	15
3.0	<u>TEST OBJECTIVES</u> . . . . .	16
3.1	FEP . . . . .	16
3.2	PHASE I BEARING TEST SERIES . . . . .	17
4.0	<u>TEST OPERATIONS DESCRIPTION</u> . . . . .	18
4.1	PRE-TEST OPERATIONS . . . . .	18
4.2	TEST OPERATIONS . . . . .	20
5.0	<u>TEST LIMITS</u> . . . . .	25
5.1	TEST OPERATING CRITERIA . . . . .	25
5.2	TEST OPERATING LIMITS . . . . .	25

TABLE OF CONTENTS - Cont.'d

<u>PARAGRAPH</u>		<u>PAGE</u>
6.0	<u>TEST SETUP REQUIREMENTS</u> . . . . .	27
6.1	BEARING TESTER . . . . .	27
6.2	MOTOR GENERATOR . . . . .	29
6.3	PROCESS FLUID SYSTEMS . . . . .	29
6.4	ELECTRICAL POWER SYSTEM . . . . .	30
6.5	INSTRUMENTATION AND DATA ACQUISITION SYSTEM(S). . . . .	31
6.6	CONTROLS . . . . .	32
6.7	HYDROGEN ANALYZER SYSTEM. . . . .	33
6.8	TELEVISION. . . . .	33
6.9	PHOTOGRAPHY . . . . .	33
6.10	COMMUNICATIONS. . . . .	33
7.0	<u>SAFETY REQUIREMENTS</u> . . . . .	34
7.1	SAFETY ADMINISTRATIVE DOCUMENTS . . . . .	34
7.2	EXCLUSION AREAS . . . . .	34
7.3	PERSONNEL ACCESS. . . . .	35
7.4	CONTINGENCY CHECKLIST . . . . .	35
8.0	<u>OPERATIONAL SUPPORT REQUIREMENTS</u> . . . . .	36
8.1	TEST DIRECTOR(S). . . . .	36
8.2	CONTROL ROOM OPERATOR(S). . . . .	36
8.3	TEST LIMIT MONITORS . . . . .	36
8.4	FACILITY RE-ENTRY PERSONNEL . . . . .	37
8.5	EMERGENCY RESPONSE TEAM . . . . .	37
8.6	ANSC TRE/PROJECT ENGINEER . . . . .	37
9.0	<u>DOCUMENTATION REQUIREMENTS.</u> . . . . .	38
9.1	SET-UP AND SECURE PROCEDURES. . . . .	38
9.2	TEST OPERATING PROCEDURES . . . . .	38
9.3	TEST DATA . . . . .	39
9.4	TEST CHRONOLOGY . . . . .	39
10.0	<u>REFERENCES.</u> . . . . .	40

TABLE OF CONTENTS - Cont'd

<u>TABLE NO.</u>	<u>LIST OF TABLES</u>	<u>PAGE</u>
1	BEARING TESTER/FACILITY FLUID INTERFACE REQUIREMENTS FOR PHASE I FACILITY . . . . .	41
2	TEST OPERATING LIMITS . . . . .	42
3	FLUID REQUIREMENTS . . . . .	44
4	BECKMAN PEN ASSIGNMENTS (BEARING TEST PROGRAM) . .	45
5	L&N ASSIGNMENTS (BEARING TEST PROGRAM) . . . . .	48
6	CONSOLE METER DISPLAYS (BEARING TEST PROGRAM) . .	49

<u>FIGURE NO.</u>	<u>LIST OF FIGURES</u>	
1	TEST CELL "A" BEARING TEST SYSTEM FLOW DIAGRAM. . . . .	50
2	TEST CELL "A" SITE PLAN . . . . .	51
3	TEST CELL "A" PLOT PLAN - BEARING AND SCRUBBER TEST . . . . .	52
4	65 MM BALL BEARING TESTER (P/N 1138060) . . . . .	53
5	SIMPLIFIED FLOW SCHEMATIC FOR SINGLE/DUAL DUPLIX SET BEARING TESTER . . . . .	54
6	BEARING RADIAL LOAD AS A FUNCTION OF RADIAL LOADER $\Delta P$ (P/N 1138060). . . . .	55
7	65 MM Bearing Tester (P/N 1138990) . . . . .	56
8	PNEUMATIC LOADER FORCE AND TEST BEARING LOADS (P/N 1138990). . . . .	57
9	BEARING TESTER MG SET SCHEMATIC DIAGRAM . . . . .	58
10	BEARING TESTER CTO CONSOLE LAYOUT . . . . .	59

APPENDIX A

TEST CELL "A" FACILITY MALFUNCTION ANALYSIS  
(To be supplied under separate cover.)

## 1.0

INTRODUCTION

The NERVA TPA Bearing Test Program will be performed at Test Cell "A," NRDS, Jackass Flats, Nevada to support development of LH<sub>2</sub> cooled 65 MM duplex ball bearing for the NERVA Engine TPA. The Test and Development Plan(s) for the overall bearing program are contained in references a and b. The Bearing Test Program at Test Cell "A" will utilize a Phase I facility for initial bearing tests and a Phase II facility for final bearing tests. The Phase I and Phase II facility requirements are given in reference c.

This document has been prepared by NRTO in accordance with NRTO-A-0001 to present the test setup and operational requirements for both the Facility Experimental Plan (FEP) and the Bearing Tests to be performed within the capability of the Phase I facility. The test setup and operational requirements for tests to be performed with the Phase II facility will be provided as a supplement to this document.

The Bearing Test FEP will be performed to provide an integrated check-out of the Test Cell "A" facility systems and operating procedures utilizing a modified 65 MM Bearing Tester (P/N 1138060-X) prior to the conduct of the actual Phase I Bearing Test Series. The test setup and operational requirements contained in this document for the FEP have been established to demonstrate the capability of the Phase I facility to meet the requirements given in reference c.

The Bearing Test Series will consist of steady-state life tests on candidate ball bearings within the capability of the Phase I facility utilizing either the Single Duplex Set Bearing Tester (P/N 1138060) or the Dual Duplex Set Bearing Tester (P/N 1138990). The test setup and operational requirements contained in this document for the Phase I Bearing Test Series are based on the ANSC requirements given in reference d. The Phase I Bearing Test Series will utilize different

bearing tester buildups, each consisting of a series of test runs. Test request supplements will be issued by ANSC for each Bearing Tester buildup providing specific requirements for that buildup.

2.0 TEST SYSTEM DESCRIPTION

2.1 TEST SYSTEM

The Phase I Bearing Test System consists of the Bearing Tester and those portions of the Test Cell "A" facility necessary to support the Phase I Bearing Tests.

Figure 1 is a Test Cell "A" Bearing Test System Flow Diagram showing the functional relationship between the essential flow system components, including all remote valves.

Figure 2 is a Test Cell "A" Site Plan showing the relative location between the Tank Farm, and other areas, buildings, and major equipment.

Figure 3 is a Test Cell "A" Plot Plan showing the relative location of the Liquid Hydrogen Dewar "D," Bearing Test Rig, Shield Walls, Bearing Test Control Room and the various instrumentation/control panels and consoles.

2.2 BEARING TESTER

The Phase I Bearing Test Program will utilize either the Single Duplex Set Bearing Tester (P/N 1138060-2,-3) or the Dual Duplex Set Bearing Tester (P/N 1138990) to perform tests on candidate 65 MM ball bearing sets for the NERVA Engine TPA.

The Bearing Tester/Facility Fluid Interface requirements for the Phase I facility are given in Table 1.

### 2.2.1 Test Bearings

Candidate bearings for the NERVA Engine TPA that will be tested during the Phase I Bearing Test Series consist of angular contact 65 MM ball bearings and retainer.

A detailed description of the various test bearings currently planned to be used is given in references a and b. The specific test bearings will be identified in the ANSC Test Request Supplement to be issued for each bearing test buildup.

### 2.2.2 Single Duplex Set Bearing Tester

Figure 4 is a sectional view of the ANSC LH<sub>2</sub> 65 MM Ball Bearing Tester (P/N 1138060-2,-3), showing the relative locations of the test bearing, slave bearing, Tester Motor, Radial Loader Assembly, Radial Loader inlet and vent, LH<sub>2</sub> inlet and vent. Figure 5 is a simplified schematic showing the flow paths through the essential components of the Single and Dual Duplex Set Bearing Tester, to be installed for Phase I Bearing Tests.

This Bearing Tester provides the capability to test one duplex ball bearing set, in a back-to-back mounting, to radial loads of 3000 lbs, axial pre-loads to 1600 lbs, and rotating radial loads (inertia loads) corresponding to speeds up to 40,000 rpm. The radial load is provided by a pneumatic loader while the axial pre-load is provided by compression of the coil springs between the outer races. Figure 6 shows a plot of the bearing load as a function of the pressure drop across the radial loader. The radial loader inlet and vent pressure control is provided as discussed in Section 2.6.

A LH<sub>2</sub> cooled two-pole squirrel cage induction motor provides the capability to rotate the bearings at speeds up to 40,000 rpm, although

maximum normal test speeds will be 27K-30K rpm. This Bearing Tester has a first critical speed at 22,000 rpm. The motor for the Single Duplex Set Bearing Tester (P/N 1138060) is a TASK Motor (P/N 7331-3) having a designed maximum speed of 40,000 rpm and a power rating of 50 HP at that speed. The Tester Motor supply voltage and frequency requirements at 40,000 rpm are 333 Volts and 666 Hz, respectively. The voltage-frequency characteristic is 0.5 Volts/Hz. The speed of the tester motor is controlled by the output frequency and voltage of the power supplied by the M-G set, as discussed in Section 2.3.

The Tester Motor requires a LH<sub>2</sub> coolant flow of 0.05 lb/sec minimum at 60 - 160°R. The Bearing Tester LH<sub>2</sub> coolant is provided as discussed in Section 2.4.

Additional description of the Single Duplex Set Bearing Tester is provided in Reference a.

### 2.2.3 Dual Duplex Set Bearing Tester

Figure 7 is a sectional view of the ANSC LH<sub>2</sub> 65 MM Ball Bearing Tester (P/N 1138990) showing the relative locations of the test bearings, Tester Motor, Radial Loader Assembly, Radial Loader inlet and vent. Figure 5 is a simplified schematic showing the flow paths through the essential components of the Dual Duplex Set Bearing Tester to be installed for Phase I Bearing Tests.

This Bearing Tester, unlike the Single Duplex Set Bearing Tester, provides the capability to test two duplex bearing sets simultaneously, although at different radial loads. The Dual Duplex Set Ball Bearing Tester provides the capability to test the primary duplex ball bearing set to radial loads of 3000 lbs, to axial pre-loads of 1250 lbs and rotating radial loads corresponding to speeds up to 35,000 rpm. Like the Single

Duplex Set Bearing Tester, the radial load is provided by a pneumatic loader while the axial pre-load is provided by compression springs. Figure 8 shows a plot of the bearing load as a function of the pressure drop across the radial loader.

A LH<sub>2</sub> cooled two-pole squirrel-cage induction motor provides the capability to rotate the bearings at speeds up to 35,000 rpm, although maximum normal test speeds will be 27K - 30K rpm. This Bearing Tester has a first critical speed at 49,000 rpm. The motor for the Dual Duplex Set Bearing Tester (P/N 1138990) is a Pesco (P/N 1138983) having a design maximum speed of 35,000 rpm and a power rating of 75 HP at test speed. The Tester Motor supply voltage and frequency requirements at 35,000 rpm are 292 Volts and 584 Hz, respectively. The voltage-frequency characteristic is 0.5 Volts/Hz. The Tester Motor requires an LH<sub>2</sub> coolant flow of 0.25 lb/sec minimum at 40-85°R.

A detailed description of the Dual Duplex Set Bearing Tester is provided in Reference g.

### 2.3 MOTOR GENERATOR SET

The M-G Set at Test Cell "A" consists of a 40 KW KATO Variable Frequency Motor Generator which supplies the required frequency/voltage to the Bearing Tester Motor.

Figure 9 is a simplified schematic of the Motor-Generator-Test Motor showing the relative arrangement of the Motor, exciter, electric clutch, gear box, alternator and Test Motor.

The specifications for the various M-G Set components are:

#### A. Motor

100 HP Squirrel-cage Induction 220/440 volts 230/115 amps  
 3  $\phi$  60 cycle 1750 RPM

A. Motor (Cont.)

Serial Number: ACB 7W975  
Van Alstyne and Son Electric  
Sacramento, California

B. Electric Clutch

Eaton-Dynamic Type WCS-2141  
100 HP 220 Volt D.C. 1.83 amps  
1800 RPM Maximum  
Serial Number: 39421  
Torque: 290 #-ft @ 50 RPM slip 415 #-ft @ 100 RPM slip  
Water Cooled: 15 GPM Max/Min Press. 100/35 psig  
Eaton Manufacturing Company  
Kenosha, Wisconsin

C. Gear Box

Western Frame #8103  
Ratio: 1/1.846  
HP Rating: Catalog 193.25  
Service 100  
Western Gear Corporation  
Belmont, California

D. Alternator

KATO, Model 57MPSR, synchronous  
AC Generator Type 2379  
Serial Number: 26432-52  
50 KVA .8 PF 120/208WYEV 3  $\phi$  400 Hz 139a  
1714 RPM, 11.2 Field amp, Revolving Field  
KATO Engineering Company  
Mankato, Minnesota  
Upgraded: 7/20/70 by Van Alstyne and Son Electric  
Sacramento, California  
to: 350 Volts 3  $\phi$  700 Hz 150 amps

E. Exciter

KATO Model 2BU01, Type 7823, S/N 50215-1  
1800 RPM, 2 KW  
124 VDC 16 amps 0.6 field amps  
KATO Engineering Company  
Mankato, Minnesota

The Bearing Tester motor speed depends on the frequency and voltage output of the alternator. The speed of the alternator, and thereby its output is regulated by the eddy-current clutch. The voltage and frequency output of the alternator is controlled by means of variable rheostats located on the Bearing Test Console. A voltage regulation circuit is also provided to maintain the alternator output voltage at the selected fraction of the frequency.

A circuit breaker, 150 A, shown in Figure 9, provides protection.

2.4

LIQUID HYDROGEN SYSTEM

The Liquid Hydrogen System, in conjunction with the Bearing Tester Vent System (Section 2.5), provides the capability for control of LH<sub>2</sub> flow and pressure required for the Bearing Tester.

Dewar "D" consists of a 22,000 gallon, vacuum jacket, perlite insulated dewar, having a maximum working pressure of 400 psig. A disc, BD-004, which is designed to lift at positive pressures, provides protection for the outer vessel. Dewar LH<sub>2</sub> level instrumentation consists of four platinum resistance probes at the 5, 7.5, 50 and 90 percent levels, and a 10 step carbon resistor rake with level readings at 5, 7.5, 10, 12, 20, 30, 50, 70, 80 and 90 percent.

Dewar "D" can be filled from either the Fill Station or the other liquid hydrogen Dewars at Test Cell "A," although these other Dewars will not be operational for Phase I Bearing testing. A remotely

operated binary valve, B-07, provides the capability for remote isolation between Dewar "D" and the Fill Station.

Dewar "D" is pressurized by gaseous hydrogen to provide the driving force for the liquid hydrogen. Dewar pressure is controlled by a one inch dome loaded pressure regulating valve, BR-01. The dome for this valve is loaded with helium, up to 1000 psi, through a remotely operated load-vent valve, B-51. A remote operated binary valve, B-02, located downstream of BR-01, provides the capability of isolating the Dewar from the pressurization system.

Dewar "D" venting is provided by two remotely operated binary valves, B-06 and B-04. B-06 is a two inch valve which discharges to the main vent system. Check valve BC-006, set at 5 psig, downstream of B-06 prevents backflow to the Dewar. In parallel with B-06 is a Fike two inch burst disc (BD-005) and a Ladewig 2 x 3 spring loaded relief valve (BS-005). The burst pressure of BD-005 is 480 psig and the set pressure of BS-005 is 440 psig. B-04 is a one inch valve which discharges directly to the atmosphere. A spring loaded check valve (BC-005) downstream of B-04 maintains a minimum vented back pressure of two psig on the Dewar.

The LH<sub>2</sub> supply line to the Bearing Tester is vacuum jacketed and foam insulated and includes remote operated binary valves (B-10, B-11, B-19, B-13, B-14, B-18, B-15), burst disc (BD-040), relief valves (BS-019, BS-040), LH<sub>2</sub> flowmeter (BF-001), terminal filter (BM-015), and associated pressure and temperature instrumentation.

B-10 provides the main remote isolation capability between the Dewar and the LH<sub>2</sub> supply line. B-11 provides isolation capability between the upstream LH<sub>2</sub> supply line and flowmeter. The vent valve, B-19, provides the capability to vent the LH<sub>2</sub> supply line upstream of B-11 during initial line chilldown and secure operations. The relief valve,

BS-019, provides thermal relief protection for the LH<sub>2</sub> supply line between B-10, B-11 and B-19 in the event these valves are closed with LH<sub>2</sub> in the line. BS-019 is set to relieve at pressure of 480 psig.

B-13 and B-14 provide the capability to chill down and purge the LH<sub>2</sub> supply line without overspeed of the flowmeter. B-13 and B-14 are interlocked so that when one valve is commanded closed, the other is commanded open. B-15 and B-18 provide the additional capability to isolate the Bearing Tester from the LH<sub>2</sub> supply line. B-15 and B-18 are commanded open or close together by a single switch. During test operations these two valves will be mechanically blocked open.

A burst disc, BD-040, and relief valve, BS-040, provide thermal relief protection for the LH<sub>2</sub> supply line between B-11, B-15 and B-18, in the event these valves are closed with LH<sub>2</sub> in the line. The LH<sub>2</sub> supply line terminal filter (BM-015) has a 10 micron nominal rating and filters the LH<sub>2</sub> supplied to the Bearing Tester through B-15 and B-18.

## 2.5

### VENT SYSTEM(S)

The Main Vent System provides for the safe discharge to atmosphere of hydrogen from the Bearing Tester LH<sub>2</sub> and GH<sub>2</sub> outlets, Dewar "D" Vent Valve (B-006), Dewar "D" Burst Disc (BD-005), Dewar "D" Relief Valve (BS-005), LH<sub>2</sub> Supply Line Vent Valve (B-19), LH<sub>2</sub> Supply Line Relief Valve (BS-019, 040), and LH<sub>2</sub> Supply Line Burst Disc (BD-040). The Main Vent System includes an unflared vent stack which discharges above the Test Cell "A" control room building.

The Bearing Tester LH<sub>2</sub> flow and back pressure is controlled by two valves in parallel, BR-32 and B-33. Another parallel remote operated binary valve (B-31) provides the capability for initial chilldown. B-33 is a remote operated binary valve which, in conjunction with BR-32, is used to manually control the total Bearing Tester LH<sub>2</sub> flow. BR-32

is a remote operated pneumatic analog valve which provides capability to manually trim the Bearing Tester LH<sub>2</sub> flow rate for a constant Dewar pressure. A remote operated binary valve, B-30, provides the capability to isolate all the Bearing Tester Vents (B-31, BR-32, B-33 and BR-34) from the Main Vent Line.

The Bearing Tester GH<sub>2</sub> Loader back pressure is manually controlled by BR-34 which is a remote operated pneumatic analog valve. This valve, in conjunction with BR-83/82 (discussed in Section 2.6) is used to vary radial/axial bearing loads.

## 2.6

### GASEOUS HYDROGEN SYSTEM

Gaseous hydrogen is used during Bearing Testing for Dewar pressurization, Bearing Tester loader application, Bearing Tester H<sub>2</sub> purge, and LH<sub>2</sub> supply line purge.

Gaseous hydrogen is stored in a number of high pressure bottles, located in the Tank Farm at Test Cell "A," which are manifolded together into Banks 1, 3 and 5. Although these vessels have a maximum working pressure of 3500 psig and have been pneumatically proof tested to 3850 psig, they will be operated at maximum pressure of 2500 psig for the Bearing Test Program. At 2500 psig, Banks 1, 3 and 5 provide a total hydrogen inventory capability of 874 KSCF.

The hydrogen banks are filled by converting liquid hydrogen to gaseous hydrogen. The converter is supplied with LH<sub>2</sub> from either Dewar "D" or LH<sub>2</sub> tank trucks. The converter is located adjacent to the LH<sub>2</sub> Fill Station, as shown in Figure 3. The converter capability (max-rated) is  $7.5 \times 10^4$  SCF/hr.

Gaseous hydrogen is supplied from the Test Cell "A" storage and distributing system through a common header to a reducing station. A remote operated binary valve, OBV-82, located upstream of the reducing station in the main header line provides the capability

for remote isolation of the gaseous hydrogen header from the distribution system. The reducing station consists of a flow restriction orifice (BO-201), in-line filter (BM-201), a pressure regulating valve (BR-201), and two relief valves (BS-201 and BS-202) in parallel downstream of BR-201.

The flow restriction orifice, BO-201, located upstream of BR-201, in conjunction with relief valves BS-201 and BS-202, provides protection against overpressurization of the system downstream of BR-201 in the event of an open failure of BR-201. The flow restriction orifice is a sharp edged orifice ( $d = 0.42$ " ) sized to flow 1.5 lb/sec of  $\text{GH}_2$  at a header pressure of 2500 psig. The relief valves, BS-201 and BS-202, are Ladewig 1 x 1 spring loaded set to relieve at 1100 psig. The pressure regulating valve (BR-201) is a hand loaded pressure regulating valve which is set to reduce the header pressure to 1000 psig for Bearing Testing. The filter, BM-201, located upstream of BR-201 provides filtration of the gaseous hydrogen supply.

The gaseous hydrogen system divides into three separate sub-systems downstream of BR-201 to serve the Dewar "D" pressurization, the Radial and Axial Loaders, and the  $\text{LH}_2$  supply line purge.

The Dewar "D" pressurization subsystem, which is discussed in Section 2.4, can be isolated from the reducing station by a hand valve, B-001.

The Axial and Radial Loader subsystem consists of a local isolation valve (B-080), a remote operated valve (B-81), a terminal filter (BM-081), and two remote dome-loaded pressure regulating valves (BR-82 and BR-83). The remote operated binary valve (B-81) provides capability for remote isolation of both the Axial and Radial Loaders pressure regulation valves from the reducing station. The terminal filter, BM-081, has a 10 micron nominal rating which filters the gaseous hydrogen before being supplied to the Radial/Axial Loader control valves. The remote dome-loaded pressure regulating valves (BR-82 and BR-83) provide capability

for remote control of the pressure to the Bearing Tester Radial and Axial Loaders, respectively.

The LH<sub>2</sub> supply line gaseous hydrogen purge subsystem consists of a hand isolation valve (B-010), a hand loaded pressure regulating valve (BR-011), and a hand isolation valve (B-016). This gaseous hydrogen purge system provides the capability to purge the LH<sub>2</sub> supply line and the Bearing Tester LH<sub>2</sub> flow paths with gaseous hydrogen.

## 2.7

### GASEOUS NITROGEN SYSTEM

Gaseous nitrogen is used during Bearing Testing for pneumatic valve actuation, facility purges, and Bearing Tester purges.

Gaseous nitrogen is stored in a number of high pressure bottles, located in the Tank Farm at Test Cell "A," which are manifolded together into Banks 2, 4, and 10. These vessels have a maximum working pressure of 3500 psig and have been pneumatically proof tested to 3850 psig. At 3500 psig, Banks 2, 4, and 10 provide a total nitrogen inventory capability of 1092 KSCF. The nitrogen banks are filled by converting LN<sub>2</sub> from trailers. The GN<sub>2</sub> Fill Station is located adjacent to the Tank Farm Area, as shown in Figure 2.

Gaseous nitrogen is supplied from the Test Cell "A" Distribution System through a common header to a reducing station. The reducing station consists of a local dome-loaded pressure regulating valve (PCV-104) which is set to reduce the header pressure to 1500 psig for Bearing testing. Gaseous nitrogen is supplied downstream of the reduction station through the local shut-off and by-pass valves, B-060 and B-061.

Downstream of the header shut-off valve, 1500 psig nitrogen is routed: 1) through hand valves B-040 and B-041 to the Dewar "D" vent purge system, the main vent purge system, and other facility purge systems, and 2) from filter, BM-060, to BR-067.

The hand loaded pressure regulating valve, BR-067, reduces the 1500 psi nitrogen supply pressure to 500 psi, which is then supplied to the 500 psi valve actuation system, to BR-070, and to BR-063. Filter, BM-060, provides initial filtering of the gaseous nitrogen supplied to BR-067. A relief valve, BS-069, set to relieve at 550 psig, protects the system downstream of BR-067 against over-pressurization.

The hand loaded pressure regulating valve, BR-063, reduces the 500 psi nitrogen supply pressure to 150 psi which is then supplied to the 150 psi valve actuation system. A relief valve (BS-066) set to relieve at 165 psig protects the system downstream of BR-063 against over-pressurization.

The hand loaded pressure regulating valve, BR-070, reduces the 500 psi nitrogen supply pressure to 70 psi which is then supplied to the Bearing Tester Dehydrating System (Section 2.10) through hand valve B-070. A relief valve, BS-072, set to relieve at 77 psig protects the system downstream of BR-072 against over-pressurization.

## 2.8

### GASEOUS HELIUM SYSTEM

Gaseous helium is used during Bearing testing for Bearing Tester and facility line purging and loading hydrogen dome-regulated valves.

Gaseous helium for Bearing testing is supplied from a tube trailer connected to the Test Cell "A" helium distribution system. The tube trailer to be used for Bearing testing, when fully pressurized to 2400 psig, provides a total helium storage capability of 41,400 SCF.

Gaseous helium is supplied for Bearing testing from the Test Cell "A" helium distribution system through a local shut-off valve (B-050) and a filter (BM-051). The filter, BM-051, provides first filtration of the trailer stored helium.

The gaseous helium header divides into two subsystems downstream of BM-051. One system reduces the pressure in two stages from 2400 to 1000 to 50 psia, using hand loaded pressure regulating valves, BR-052 and BR-054, respectively. Part of the 1000 psig is routed to B-51 as actuation pressure for BR-01. The 50 psia gas is routed through several hand valves (B-103, B-101, B-110, B-108, B-085, B-107, B-056 and B-057) to supply purge gas for all facility gaseous hydrogen lines, Dewar "D" fill line, and the Bearing Tester Dehydration System (Section 2.10).

The other helium system consists of shutoff valve, B-053, and a dome loaded regulating valve, BR-053. The loading pressure is supplied by a hand loader, BR-051. This system provides purge helium for the LH<sub>2</sub> supply line downstream of B-11, through a remote operated binary valve, B-50; and the Bearing Test Axial/Radial loader supply line downstream of B-81, through a hand valve, B-054.

## 2.9

### WATER SYSTEM

Water stored in the Test Cell "A" 50,000 gallon elevated water tank is required during Bearing testing to provide emergency deluge water for the Bearing Test Rig and Dewar "D," cooling water for the M-G Set electric clutch, and other facility uses.

Water is supplied to the Bearing Test Rig spray heads through remote operated valve BW-98. Bearing Tester Rig deluge water will be provided only during emergency operations, as directed by the Test Director during Test Operations.

Water is supplied to the Dewar "D" spray heads through remote operated valve BW-99 which can be activated by heat sensors, manually at the Fill Station or from the console. Dewar "D" deluge water will be provided as directed by the Test Director during Test Operations.

Water is supplied to the M-G Set through hand valve B-130.

## 2.10 BEARING TESTER DEHYDRATION SYSTEM

The Bearing Tester will be dehydrated using either gaseous nitrogen or helium at  $120^{\circ}\text{F} \pm 20^{\circ}$  as required.

The Bearing Tester Dehydration System consists of an electric heater which heats either ambient gaseous nitrogen supplied at 70 psig through B-070, by pressure regulating valve BR-070, or ambient gaseous helium supplied at 50 psi through B-057/056 by pressure regulating valve BR-054. The electric heater has the capability to heat either ambient temperature nitrogen or helium at 10 Scfm to  $120^{\circ}\text{F} \pm 20^{\circ}$ .

The heated  $\text{GN}_2$  or  $\text{GHe}$  is supplied to: 1) the Bearing Tester Axial/Radial supply line downstream of B-81 through hand valve B-073, and a filter, BM-073, and/or 2) the Bearing Tester  $\text{LH}_2$  supply line downstream of B-11 through hand valve B-072 and a filter, BM-072. The filters, BM-073/072 provide intermediate filtering of the supplied gases.

The Bearing Tester Dehydration System will be used and then isolated prior to remote test operations.

## 2.11 ELECTRICAL POWER SYSTEM

The Electrical Power System at Test Cell "A" consists of both Commercial and Emergency power.

Commercial power is supplied from the NRDS power distribution system which is stepped down through a Test Cell "A" transformer providing 1000 KVA of 480 Volt, 3  $\phi$  power.

28 volt DC power is supplied by two parallel banks of 13 series-connected batteries. The battery banks are continuously charged from commercial power by use of two on-line rectifiers. In the event there is a loss of commercial power, the battery charging capability is lost and the batteries will continue to provide 28 VDC power to within the capacity of the batteries (560 amp-hrs).

The remotely operated valves and their associated indicator lights are on the 28 VDC system. There are no other provisions for emergency power other than battery pack emergency lighting throughout the facility.

3.0 TEST OBJECTIVES

3.1 FEP

The Bearing Test FEP will be performed to provide an integrated checkout of the Test Cell "A" facility systems, operating procedures, and test operational personnel using hydrogen fluids for the first time in the complete test setup prior to the conduct of the Phase I Bearing Test Series.

The tests to be performed during the FEP are discussed in Section 4.0. The FEP will utilize a modified Single Duplex Set Bearing Tester (P/N 1138060) which will allow operation of all Test Cell "A" facility systems except for the Axial Loader System in a manner required to conduct Phase I Bearing Test Series.

The specific test objectives for the FEP are: To perform normal startup, mapping, and normal shutdown operations in order to demonstrate adequate system control, operational capability, and system integrity required for the Phase I Bearing Test Series.

3.2 BEARING PHASE I TEST SERIES

The Phase I Bearing Test Series will be performed to develop 65 MM duplex ball bearings which will meet the steady-state load life-reliability requirements for the NERVA Engine TPA.

The tests to be performed on the candidate 65 MM Duplex Ball Bearings during the Phase I Bearing Test Series will utilize either the Single Duplex Set Bearing Tester (P/N 1138060) or the Dual Duplex Set Bearing Tester (P/N 1138990), and will be performed under test operating conditions that are within the capability of the Phase I facility.

The specific test objective for each Bearing Tester buildup will be provided in the applicable Test Operating Procedure (TOP) based on the Test Request Supplement issued by ANSC for that test.

4.0 TEST OPERATIONS DESCRIPTION

The following section provides a description of those operations that will be performed for the FEP and the Phase I Bearing Tests. Unless otherwise noted, the operations to be performed as discussed in the following sections will be the same for the FEP and the Phase I Bearing Tests.

Control Room operation will be performed in accordance with the applicable TOP. The applicable TOP will be the controlling document if differences exist in the specific operating condition and procedures given in the following sections. The Test Operating Limits are given in Section 5.0.

The system setup requirements before initiation of operations described in the following section are given in Section 6.0.

4.1 PRE-TEST OPERATIONS

The activities to be performed during this phase include in sequence: (1) setup checklist review, (2) communication net check, (3) valve exercise, (4) voltage calibration, and (5) final area sweep of all personnel.

These activities are described below:

4.1.1 Setup Checklist Review

The setup checklists including the console setup checklist will be reviewed by the Acting Facility Manager (AFM) and Test Director (TD) in order to verify that the test system has been set up in accordance with the specific requirements, and that any discrepancies have been satisfactorily resolved.

4.1.2 Communications Net Check

The communications nets required for the conduct of control room operations will be checked with all test operating personnel, at their corresponding stations in order to insure readiness of the test operating personnel and communications systems.

4.1.3 Valve Exercise

Those valves that are operable from the control room but which do not release deluge water, high pressure gas, or hydrogen into the lines not containing hydrogen will be cycled in order to verify proper operation prior to start of test operations in accordance with section 4.2. The valves to be exercised will be exercised in a manner or sequence which will minimize fluid consumption and not release hydrogen into lines that have not previously contained hydrogen.

The final valve setup positions will be the same as those at the start of the valve exercise.

4.1.4 Voltage Calibration

A voltage calibration of all applicable data and control channels will be performed. The data channels calibration will consist of a 10 point calibration. The applicable data recorders will be operated and the console/panel displays monitored during the voltage calibration.

4.1.5 Final Area Sweep

An area sweep will be conducted to clear all personnel not on the access list from the applicable areas in preparation for the test operation to be performed.

## 4.2 TEST OPERATIONS

4.2.1 Dewar Pressurization, System Chillover, Loader and M-G Setup for Initial Operation Conditions

Dewar "D" will be pressurized, the Bearing Tester LH<sub>2</sub> system will be chilled down, the initial M-G frequency/voltage outputs will be set, the initial Bearing Tester radial/axial loader and vent pressures will be set, and the initial Bearing Tester total flow will be set during those operations for the FEP and Bearing Tests.

## a. FEP:

Dewar "D" will be initially pressurized and initial chillover initiated. During the initial chillover, B-31, BR-32, and B-33 will be cycled to insure chill of each parallel flow path. The BF-001 LH<sub>2</sub> flow meter will be chilled in a manner which will prevent over-speed of the flow meter.

After initial chillover operations are complete, Dewar "D", the LH<sub>2</sub> supply line and the Bearing Tester LH<sub>2</sub> system will be checked under pressurized LH<sub>2</sub> conditions up to 400 psig, and total LH<sub>2</sub> flow conditions up to 100 gpm. Dewar "D" will then be vented to obtain 225 psig at BP-102/104 (PBUS) and the flow throttling capability of BR-32 determined. BR-32 will then be adjusted as required to maintain 55 gpm at BF-001 and less than 54<sup>0</sup>R at BT-102/106. Concurrent with these operations, the radial/vent differential pressure will be adjusted to 35 psid.

The motor generator will be started, with the circuits to the Bearing Tester motor open, and an initial frequency of 200 Hz and voltage of 100 volts set.

During the above operations, the data recorders will be operated as indicated in the TOP.

## b. Bearing Tests:

During Bearing Tests, Dewar "D" will be pressurized and initial chilldown accomplished using procedures developed during FEP tests. Dewar "D" will then be pressurized to obtain 225 psig at BP-102/106 (PBUS), BR-32 adjusted to obtain 55 gpm at BF-001 (FMFS), BR-82 adjusted to obtain 210 psig at BP-106 (P<sub>R</sub>), BR-34 adjusted to obtain 135 psid at BP-110D, and the motor generator started with initial frequency/voltage settings of 200 Hz/100 volts.

The above initial conditions for Bearing Tester, without forward seal, will be specified in the applicable ANSC Test Request Supplement, and will appear in the applicable TOP. Comparable values for Tester with forward seal are shown in 4.2.2.

4.2.2 Initial operations will be performed during the FEP and Bearing Tests, as discussed below, after those operations discussed in Section 4.2.1 are completed.

The data recorders will be started a minimum of 30 seconds prior to applying power to the Bearing Tester motor.

The circuit to the Bearing Tester motor will be closed to start the Bearing Tester motor when the following nominal conditions are achieved:

<u>Parameter</u>	<u>Value W/O Forward Seal</u>	<u>Value With Forward Seal</u>
BP-106 (P <sub>R</sub> )	210 psig	135 psig
BP-107 (P <sub>V</sub> )	175 psig	100 psig
BP-102/104 (PBUS)	225 psig	225 psig
BP-110D ( $\Delta$ P <sub>RV</sub> )	35 psid	35 psid
BH-001	100 v	100 v
BY-001	200 cps	200 cps
BT-102 (TBUS)	Below 54 <sup>o</sup> R	Below 54 <sup>o</sup> R
BT-106 (TBDS)	Below 54 <sup>o</sup> R	Below 54 <sup>o</sup> R
BF-001 (FMFS)	55 gpm	55 gpm
BP-105 (P <sub>A</sub> )	175 psig	175 psig

BR-34 and BR-82 will be used to establish 125 psig at BP-107 ( $P_V$ ) and 135 psid at BP-110D after Bearing Tester speed is indicated.

The above initial operating conditions are nominal for the FEP and Bearing Tests. The specific operating conditions will appear in the applicable TOP.

#### 4.2.3 Normal Operations

Normal operations will be performed during the FEP and Bearing Tests as discussed below, after the 4.2.2 operations have been completed.

##### a. FEP:

The normal operating conditions for the FEP will be established to demonstrate the capability of the Phase I facility.

At the initial conditions established in Section 4.2.2, BR-82 and BR-34 will be used to establish steady-state pressure up to 300 psig at BP-110D ( $\Delta P_{RV}$ ). After these pressure conditions have been achieved, 135 psid will be re-established at BP-110D.

The M-G set frequency and voltage controls will then be used to establish steady-state Bearing Tester motor speed conditions of 18, 25 and 30 KRPM. After steady-state speed conditions have been obtained, the motor speed will be reduced to 27 KRPM.

A normal shutdown will then be performed as discussed in Section 4.2.4.

##### b. Bearing Tests:

The normal operating conditions for a specific Bearing Test will be specified in the applicable ANSC Test Request Supplement and appear in the applicable TOP. The following values are for nominal run conditions:

Nominal Run Conditions

<u>Parameter</u>	<u>Value with Forward Seal</u>	<u>Value W/O Forward Seal</u>
$P_A$	125 psig	( = $P_V$ )
$P_V$	100 psig	125 psig
$P_R$	235 psig	260 psig
$\Delta P_{RV}$	135 psid	135 psid
$P_{BUS}$	225 psig	225 psig
$V$	225 v	225 v
$f$	27,000	27,000
$T_{BUS}$	$\leq 54^\circ R$	$\leq 54^\circ R$
$F_{mfs}$	55 gpm	55 gpm

The nominal normal operating conditions for Phase I Bearing Tests in each buildup will be at Bearing Tester motor speeds of up to 27,000 RPM,  $LH_2$  flow rates of 55 - 60 gpm, Bearing Tester inlet pressure (BP-102) at 225 psig, Bearing Tester  $LH_2$  inlet temperature (BT-102) at  $48^\circ R$ , and various radial differential pressures of up to 270 psid, for target durations of 15 hours. Since the Phase I facility fluid storage systems are not adequate to perform a continuous run time of 15 hours, repeated normal test cycles will be required. At the end of each test cycle, normal shutdown will be performed, as discussed in Section 4.2.4.

4.2.4 Normal Shutdown Operations

A normal shutdown will be performed at the completion of the normal operations as discussed in Section 4.2.3 for the FEP and Bearing Tests.

Normal shutdown will be accomplished by opening the Bearing Tester motor power supply line, and stopping the M-7 set. When the motor speed (BQ-001) reaches Zero, the loader pressures will be reduced to Zero and then the  $LH_2$  flow will be stopped. The data recorders will be shut off only after the bearing motor reaches Zero speed.

4.2.5 Normal Secure Operations

Normal secure operations will be performed under the direction of the AFM in accordance with applicable secure checklists.

5.0 TEST LIMITS

5.1 TEST OPERATING CRITERIA

The FEP and Bearing Test operations will be conducted under the direction of the TD in accordance with normal and contingency test operating procedures approved by ANSC and NRTO. Minor adjustment in test operating conditions or other necessary corrective actions will be taken by the test operator under the direction of the TD in order to continue Bearing Test operations unless anomalous events occur which could present an unsafe condition to the test system or personnel.

Test operations will be terminated when the test operating limits given in Section 5.2 are exceeded, or in event anomalies (i.e., fires, hydrogen leakage, loss of test limit instrumentation, loss of facility safety system capabilities, etc.) occur which at the discretion of the TD would result in unsafe conditions to either the test system facility or personnel.

The cognizant ANSC TRE/Project Engineer may also call for test termination or test operating condition adjustment depending on test bearing performance. The means of test termination, or test operating condition adjustment, will be at the discretion of the TD.

5.2 TEST OPERATING LIMITS

The test operating limits and the associated nominal corrective actions to be taken during the FEP and Bearing Test Series are given in Table 2. The nominal corrective

actions given in Table 2 must be taken under the direction of the TD. The method used to accomplish the nominal corrective action given in Table 2, and the subsequent actions, will be at the discretion of the TD depending on the severity and rate at which the limit is exceeded.

The cognizant ANSC TRE/Project Engineer may authorize continuation of test operations and/or change in test operating limit value if a test article operating limit has been exceeded. The test operating limit values given in Table 2 are the maximum values for the entire Phase I Bearing Test Series. The test operating limits applicable to a specific bearing test, which may be equal to or less than those given Table 2, will be contained in the applicable Test Operating Procedure.

## 6.0 TEST SETUP REQUIREMENTS

This section presents the setup requirements for the FEP and the Phase I Bearing Test Series to support Control Room operations in accordance with the applicable Test Operating Procedure (TOP).

The systems will be set up in accordance with the requirements of this section, unless otherwise specified in the applicable TOP.

The Bearing Tester will be installed and checked out under the direction of ANSC personnel and in accordance with ANSC procedures. The AFM will be responsible for facility system setup during Bearing Tester installation and checkout.

All work performed during test setup operations will be coordinated by the AFM, Test Cell "A". Completed test setup checklists will be transmitted to and received by the TD before beginning Control Room operations.

### 6.1 BEARING TESTER

The Bearing Tester will be set up for the FEP and the Phase I Bearing Tests in accordance with NRTO-SOP-0233, "Bearing Tester Pre-Fire Checkout and Secure", based on the following requirements:

#### 6.1.1 Bearing Tester Hardware

The Single Duplex Set Bearing Tester, P/N 1138060-X (modified) S/N 002 including components and instrumentation, specified in ANSC Test Request Supplement No. 3, dated July 9, 1971, will be installed for the FEP.

The Bearing Tester(s) to be installed for Phase I Bearing Test Series will be specified in the applicable Test Request Supplement to be issued by ANSC for each buildup. The Bearing Tester buildup will be identified in the applicable TOP.

6.1.2 Bearing Tester Purge

The Bearing Tester will be dehydrated and maintained in a static purge condition before the start of Control Room operations in accordance with the following requirements.

The Bearing Tester will be dehydrated by use of a continuous purge of gaseous helium or nitrogen at  $120 \pm 20^{\circ}\text{F}$  through the bearing  $\text{LH}_2$  supply line for a minimum of 20 minutes (1) after initial installation of the Bearing Tester, or (2) after re-connecting any facility interface piping which has been disconnected under conditions wherein neither a continuous purge of ambient temperature nitrogen or helium has not been maintained. Nitrogen will not be used for any Bearing Tester purging until the system has been warmed to a minimum temperature of  $200^{\circ}\text{R}$ .

A static or continuous purge of ambient temperature helium, at or less than 50 psig, will be established and maintained through the bearing  $\text{LH}_2$  supply line, the axial loader supply line (if applicable), and the radial loader supply line after accomplishment of the dehydration purge until the start of Hydrogen Flow operations.

6.1.3 Bearing Tester Shaft Rotation

The Bearing Test shaft shall not be rotated except as specified in ANSC test request or by the ANSC TRE/Project Engineer and then only in accordance with applicable procedures.

Breakaway torque measurements will be made (1) after initial installation of the Bearing Tester in the test stand and before rotation with the Bearing Tester motor during Control Room operations, (2) prior to subsequent rotation with the Bearing Tester motor during Control Room operation if the bearings have been allowed to warm up to ambient temperatures, and (3) at other times as specifically requested by ANSC Test Request Supplement or by direction of the ANSC TRE/Project Engineer.

6.2 MOTOR GENERATOR

The motor generator will be set up in accordance with NRTO-SOP-0232, "TCA I&C and Electrical Pre-Test Setup and Post-Test Secure for the Bearing Program."

6.3 PROCESS FLUID SYSTEMS

The Process Fluid Systems will be set up in accordance with NRTO-SOP-0231, "TCA Facility Pre-Test Setup and Post-Test Secure for the Bearing Program" and in accordance with the following requirements.

6.3.1 Fluids

The Test Cell "A" fluid storage vessels will be set up for the first test on each Bearing Tester buildup in accordance with Table 3, unless otherwise specified by the TD.

Fluids will be replenished as required during repeat tests on the same Bearing Tester buildup. Fluid vessel setup requirements for repeat tests, if different than given in Table 3, will be given in the applicable TOP. Fluids will be replenished in accordance with the applicable SOP.

6.3.2 Valves

The final setup conditions for the valves required for the Phase I FEP and Bearing Tests before the start of Control Room operations will be in accordance with the setup conditions given in the applicable TOP.

The valve final setup conditions will satisfy the following requirements unless otherwise specified in the applicable TOP.

- a. Bearing Tester Fluid Interface Lines.- The Bearing Tester fluid interface lines between B-11, B-81, and B-30 will be

maintained with a helium purge as specified in Section 6.1.2.

- b. LH<sub>2</sub> System.- Dewar "D" will be filled with LH<sub>2</sub> to the required level and vented. Dewar "D" will be isolated from the LH<sub>2</sub> supply line downstream B-10, from the gaseous hydrogen pressurization line upstream B-02, and from the Dewar fill system.

The LH<sub>2</sub> supply line between B-10, B-11, and B-19 will be inerted and either a static or continuous purge of ambient temperature helium at 50 psig or less maintained.

- c. GH<sub>2</sub> System.- The GH<sub>2</sub> System will be set up to supply 1000 psig (nominal) gaseous hydrogen downstream BR-201 to BR-01 and B-81.
- d. GHe System.- The GHe System will be set up to supply 50 psi (nominal) gaseous helium downstream from BR-011, BR-054, and BR-053, and 1000 psi (nominal) gaseous helium downstream BR-052.
- e. GN<sub>2</sub> System.- The GN<sub>2</sub> System will be set up to supply 1500 psi (nominal) gaseous nitrogen downstream PCV-104, to supply 500 psi (nominal) gaseous nitrogen downstream BR-067, and to supply 150 psi (nominal) gaseous nitrogen downstream BR-063.

The GN<sub>2</sub> heater and associated GN<sub>2</sub> purge lines will be isolated from the Bearing Tester LH<sub>2</sub> and Loader supply lines.

- f. Facility Vents.- All facility vents into which hydrogen will be discharged during Control Room operations will be inerted with either ambient temperature gaseous helium or gaseous nitrogen.

#### 6.4 ELECTRICAL POWER SYSTEM

The commercial and 28 VDC power system will be set up before the start of Control Room operations in accordance with NRTO-SOP-0232, "TCA I&C and Electrical Pre-Test Setup and Post-Test Secure for the Bearing Program."

6.5 INSTRUMENTATION AND DATA ACQUISITION SYSTEM(S)

The Instrumentation and Data Acquisition System(s) will be set up and checked out before the start of Control Room operations in accordance with NRTO-SOP-0232, "TCA I&C and Electrical System Pre-Test Setup and Post-Test Secure for Bearing Program" and in accordance with the following requirements.

6.5.1 Instrumentation

The instrumentation required for the tests will be as given in the applicable Channel List Document to be issued by EG&G on R-3 for each Bearing Tester buildup. A master copy of Channel List Document for each Bearing Tester buildup will be "red-lined" and maintained by the AFM if changes are required after the R-3 issue until the completion of tests on the specific buildup.

Instrumentation change requirements will be transmitted to EG&G by Channel Change Requests.

6.5.2 Data Recording and Display

The Narrow Band (Multiplex), Wide Band, Beckman, L&N, and console/panel meter recording and display will be in accordance with the applicable Channel List Document identified in Section 6.5.1.

The Beckman Recorder, L&N Recorder, Bearing Test Console Meter, and Oscilloscope displays will be in accordance with the Channel List Document. The following establishes the initial assignments and is presented on an "Information Only" basis.

- a. Beckman Recorders.- Five 8-channel Beckman Strip Chart Recorders will be required. The initial recorder pen assignments are given in Table 4. Channel identification and scaling shall be provided for each recorder and pen. Beckman records may be removed upon TD's request for analysis during holds.

- b. L&N Recorders.- Twelve single channel Leeds and Northrup (L&N) strip chart recorders will be required. The initial recorder assignments are given in Table 5. Channel identification and scaling shall be provided for each strip chart.
- c. Bearing Tester Console Meters.- The initial Bearing Test Console Meter displays are given in Table 6.
- d. Oscilloscope.- Any two of the following five Kaman distance detectors and the bearing accelerometer shall be co-ax patched to the mobile oscilloscope display upon TD request.

<u>Channel</u>	<u>Title</u>
BA-001	Upstream Bearing Acceleration
BD-001	Motor Bearing Displacement
BD-002	Motor Bearing Displacement
BD-003	Test Bearing Displacement
BD-004	Test Bearing Displacement
BQ-003	Vent Cavity Displacement

NOTE: The oscilloscope and displays will not be required for the FEP.

## 6.6 CONTROLS

The valve, Bearing Test motor, and motor generator controls will be set up before the start of Control Room operations in accordance with NRTO-SOP-0232, "TCA I&C and Electrical System Pre-Test Setup and Post-Test Secure for Bearing Program."

The valve, Bearing Tester motor, and motor generator controls will be in accordance with the applicable Channel List Document identified in Section 6.5.1.

Figure 10 shows the Bearing Test console layout (for information only).

6.7 HYDROGEN ANALYZER SYSTEM

The hydrogen detectors located in the Control Room, Electronics Room and Penthouse will be set up in accordance with NRTO-SOP-0232.

6.8 TELEVISION

Television cameras and monitors will be set up and operational for Control Room operations, in accordance with the TD requirements.

6.9 PHOTOGRAPHY

Still photographic coverage will be provided of the test setup in accordance with directions provided by the ANSC TRE/Project Engineer.

6.10 COMMUNICATIONS

Communications systems will be set up and operational to support setup and Control Room operations. The communication system will be set up in accordance with NRTO-SOP-0232.

7.0 SAFETY REQUIREMENTS

## 7.1 SAFETY ADMINISTRATIVE DOCUMENTS

The Test Cell "A" operations performed during the preparation and conduct of the FEP and Bearing Tests will be in accordance with the following safety related NRTO and Test Cell "A" Administrative Documents:

- a. NRTO-A-0022 NRTO Health and Safety Manual
- b. NRTO-A-0090:001 Test Cell "A" Emergency Plan
- c. NRTO-A-0090:002 Test Cell "A" Exclusion Area Guide
- d. NRTO-A-0090:004 Test Cell "A" Lock and Tag Procedure
- e. NRTO-A-0090:006 Test Cell "A" Re-entries and Stand-by and Re-entry Crews
- f. NRTO-A-0090:007 Test Cell "A" Safe Work Permits

## 7.2 EXCLUSION AREAS

Exclusion areas for the protection of personnel during the preparation and conduct of the FEP and Bearing Tests will be established in accordance with the requirements of NRTO-A-0090:002, "Test Cell 'A' Exclusion Area Guide."

Exclusion areas will be established by the AFM during non-test operations or by the TD during test operations.

Exclusion Area shall be all of Test Cell "A" and the ETL. The Test Cell "A" and ETL entrance gates shall be closed. The road from R-MAD to Test Cell "A" (Road 'F') shall be barricaded by means of the security gate provided. An Exclusion Area Guard shall be posted on the Test Cell "A" entrance road, 500 feet toward Test Cell "C" from the Test Cell "A" main gate. The Guard will be equipped with a portable radio and will be in contact with and under the direction of the TD.

7.3 PERSONNEL ACCESS

Personnel access into Test Cell "A" and defined exclusion areas will require the approval of either the AFM during non-test operations or the TD during test operations, in accordance with approved access lists.

Personnel re-entry shall be in accordance with the requirements given in NRTO-A-0090:006, "Test Cell 'A' Re-entries and Stand-by and Re-entry Crews."

The test system secure operations performed prior to planned personnel re-entry will be in accordance with the applicable TOP.

7.4 CONTINGENCY CHECKLIST

The TOP for the FEP and Bearing Tests will contain contingency checklists which will be prepared to perform emergency operations in the event of pre-determined emergencies occurring during test operations.

8.0 OPERATIONAL SUPPORT REQUIREMENTS

This section presents the minimum requirements for the operational personnel required to support the conduct of the FEP and Phase I Bearing Tests. No special requirements for support services such as security, housing, cafeteria, exist for these tests.

8.1 TEST DIRECTOR(S)

The TD and ATD will be assigned by and responsible to the Manager, NRTO, for the subject test.

The TD/ATD will be named in the applicable Test Operating Procedure and will have been qualified in accordance with NRTO-SOP-0203, "NRTO Test Director Qualification Program."

8.2 CONTROL ROOM OPERATOR(S)

The Control Room Operators who will be assigned by and responsible to the TD during test operations will be required for the following operating positions:

- a. Chief Test Operator (CTO)
- b. Assistant Chief Test Operator (ACTO)
- c. Facility Operator (FO)
- d. Instrumentation Control & Power Operator (ICPO)

The selected Control Room Operator personnel will be named in the applicable TOP. The selected Control Room Operators will have been trained and qualified in accordance with NRTO-R-0200, Rev. 1, "Operator Training and Qualification Program."

8.3 TEST LIMIT MONITORS

The Test Limit Monitors required for the subject test will be assigned by and responsible to the TD during test operations. The selected Test Limit Monitors will be named in the applicable TOP.

8.4 FACILITY RE-ENTRY PERSONNEL

Facility Re-entry Personnel, as required for the subject test, will be assigned by and responsible to the TD during test operations. Facility Re-entry Personnel will be familiar with NRTO-A-0090:006, "TCA Re-entries and Stand-by and Re-entry Crews."

8.5 EMERGENCY RESPONSE TEAM

The NRDS Site Emergency Response Team who may be called upon to supplement the Facility Emergency Response Team will be advised of the time and date of the subject tests no later than R-1 by the TD. The NRDS Site Emergency Response Team will respond as necessary to a request by the TD.

8.6 ANSC TRE/PROJECT ENGINEER

An ANSC TRE/Project Engineer will be required on-site to support test operations. The appropriate ANSC TRE/Project Engineer for the subject tests and their responsibilities and authorities are given in Reference d.

9.0 DOCUMENTATION REQUIREMENTS

This section presents the Pre- and Post-Test Procedures/Reports to be prepared by NRTO for the FEP and the Phase I Bearing Tests.

9.1 SET-UP AND SECURE PROCEDURES

The Set-up and Secure procedures required to support the conduct of test operations are identified in the following sections. These Procedures will be prepared in accordance with requirements given in NRTO-A-0001, the Test Requests issued by ANSC, and Section 6.0 of this document.

- A. NRTO-SOP-0231 - Test Cell "A" Facility Pre-Test Setup and Post-Test Secure for Bearing Program.
- B. NRTO-SOP-0232 - Test Cell "A" I&C and Electrical Pre-Test Setup and Post-Test Secure for Bearing Program.
- C. NRTO-SOP-0233 - Bearing Tester Pre-fire Checkout and Secure.
- D. NRTO-SOP-0235 - Bearing Dehydration Purge, Test Cell "A".

9.2 TEST OPERATING PROCEDURE (TOP)

The Test Operating Procedure (TOP) will be prepared jointly by the assigned Test Director, CTO, and the NRTO Test Engineering Group, in accordance with NRTO-A-0001, based on test requirements contained in Sections 3.0, 4.0 and 6.0 of this document.

A review issue of the TOP for the FEP (Category III) will be released on R-14. The Run Day TOP will be issued on R-1. The Master Run Day TOP will be approved for use by the Test Director on Run Day morning.

A review issue of the TOP for the Phase I Bearing Tests will be released for the first buildup on R-14. The Run Day TOP will be issued on R-1 for the first test on each buildup. Changes to the

Run Day TOP for subsequent tests on the same buildup will be included in the Master R-Day copy only. The Master R-Day copy and changes for each Run Days' operation will be approved by the Test Director and the appropriate ANSC TRE/Project Engineer.

9.3 TEST DATA

9.3.1 Strip Charts, Original

The original L&N and Beckman strip charts will be transmitted directly to the ANSC TRE/Project Engineer following each run-day operation. Distribution of the original strip charts will be coordinated by the NRTO Bearing Project Coordinator.

9.3.2 Oscillograph Wide Band Playback

Selected wide band data will be provided on oscillograms and transmitted to the ANSC TRE/Project Engineer upon his specific request. Wide band data playback and distribution will be coordinated by the NRTO Bearing Project Coordinator.

9.3.3 CAL-COMP Plots and DDP-116 Listings

The DDP-116 will be programmed to process the raw narrow band tapes to CAL-COMP plots and/or DDP-116 listings in engineering units for the Bearing Test Series. CAL-COMP plots and/or DDP-116 listings will be transmitted to the ANSC TRE/Project Engineer within five days following run day. The ANSC TRE/Project Engineer shall prepare a Data Request to detail requirements for CAL-COMP plots and/or DDP-116 listings. CAL-COMP plots and/or DDP-116 listings will be coordinated by the NRTO Bearing Project Coordinator.

9.4 TEST CHRONOLOGY

A chronology of the test operations will be prepared and issued, under responsibility of the Test Director, following each run day operation. A copy of this Test Chronology will be transmitted to the ANSC TRE/Project Engineer.

10.0

REFERENCES

- a. Report M-100-TTPO3-W121, Test and Development Plan for the Evaluation of LH<sub>2</sub> Cooled 65 MM Roller Element Bearings for NERVA Engine TPA, dated 5 November 1970.
- b. Report N8300R:71-064, Near Term Test and Development Plan for 65 MM Bearings. (Supplement to 65 MM Bearing Test and Development Plan, Report M-100-TTPO3-W121) Dated 2 July 1971.
- c. NRDS TC"A" NERVA Turbopump 65 MM Bearing Testing, Supplemental Facility Design Criteria, July 1971.
- d. Basic Test Request for 65 MM Bearing Tests at NRDS, Test Request Series 1190-65-XXX-X, dated 3 May 1971.
- e. Test Request Supplement No. 1 to Basic Test Request 1190-65-XXX, dated 23 July 1971.
- f. NERVA Bearing Tester Usage and Testing Specifications, 774OR-70-029, Project 121.
- g. "Design Description of Bearing Tester, Dwg. #1138990, for use in the Development of 65 MM Angular Contact Duplex Ball Bearings Operating in LH<sub>2</sub> Environment." N8300R:71-056.
- h. NRTO Quality Assurance Program Plan, NRTO-M-30775, dated 24 May 1971
- i. Quality Assurance Requirements for the Testing of 65 MM Bearings at NRTO, N7000:2072, dated 8 June 1971.

NRTO-R-0212

TABLE 1  
BEARING TESTER/FACILITY FLUID INTERFACE  
REQUIREMENTS FOR PHASE I FACILITY

FUNCTION	FLUID	PARAMETER	CONDITION
Bearing Tester Coolant Supply	LH <sub>2</sub>	Pressure Temperature Flow Rate	225 - 300 psig 54°R (Max) 40 - 100 gpm
Bearing Tester Coolant Vent	LH <sub>2</sub>	Pressure	225 - 300 psig
Bearing Tester Radial/Axial Loader Supply	GH <sub>2</sub>	Pressure Temperature Flow Rate	150 - 950 psig Ambient 450 - 1300 Scfm
Bearing Tester Radial/Axial Loader Vent	GH <sub>2</sub>	Pressure	0 - 150 psig
Bearing Tester Hot Inert Purge	GHe & GN <sub>2</sub>	Pressure Temperature Flow Rate	50 - 70 psig 120 ± 20°F ~ 10 Scfm
Bearing Tester Ambient Inert Purge	GHe	Pressure Temperature Flow Rate	50 psig ± 10 Ambient ~ 10 Scfm
Bearing Tester Ambient Purge	GH <sub>2</sub>	Pressure Temperature Flow Rate	50 ± 10 psig Ambient ~ 10 Scfm

TABLE 2  
TEST OPERATING LIMITS

PARAMETER	CHANNEL	DISPLAY TYPE/LOCATION	LIMIT TYPE	LIMIT VALUE	NOMINAL EXPECTED OPERATING CONDITION	ALARM TYPE/SETTING	CORRECTIVE ACTION
Run Tank Pressure	BP-003	Meter/RO05-A	High	400 psig	250 psig		Decrease Dewar pressure
Run Tank Level	BT-004	Meter/RO05-A	Low	5%	7.5% - 90%		Normal Shutdown
Test Bearing Upstream Press.	BP-102	Meter/RO06-A	Low	190* psig for more than 10 sec.	225 psig		Decrease Bearing Tester Motor Speed to Zero
Test Bearing Upstream Temp.	BT-102	L&N/RO03	High	54°R	46°R		As above
LH <sub>2</sub> Flow	BF-001	Meter/RO06-A L&N/RO01	Low	50 gpm	55 to 60 gpm		As above
Bearing Test Speed	BQ-001/002	Beckman/RO81 L&N/RO04	High	31,000 RPM	6,000-30,000 RPM		As above
Bearing Test Speed	BQ-001/002	Beckman/RO81 L&N/RO04	Low	3,000 RPM at greater than MS+5 sec or 12,000 RPM for greater than MS+20 sec	6,000-30,000 RPM		Shut down MG Set
Electric Drive Motor Current	BI-001/002/003	Beckman/RO81 L&N/RO04	High	100 amps at greater than MS + 5 sec	45 to 70 amps		As above
Electric Drive Motor Voltage	BH-001	Meter/RO05-B	High	258 Volts	230 Volts		As above
Test Bearing Temp. Rise	BT-106 - BT-102	Beckman/RO81 L&N/RO03	High	10°R	5°R		Normal Shutdown
Slave Bearing Temp. Rise	BT-103 - BT-102	Beckman/RO80 Beckman/RO81	High	10°R	4°R		Normal Shutdown
Seal Differential Pressure	BP-100D ▲PBUS/PA	Meter/RO06-A	Low	25 psid			Decrease Loader Vent Press.
Radial/Vent Differential Pressure	BP-110D	L&N/RO03 Meter/RO05-A	High	300 psid	35 - 270 psid		Decrease Loader Press.
Axial Loader Pressure	BP-105	Beckman/RO79 Meter/RO06-A	High	300 psig	130 psig		Decrease Axial Loader Press.
H <sub>2</sub> Concentration	N/A	Flashing Light/RO04	High	2%	0%	Visual/1% Audible/2%	Normal Shutdown

\* - 180 psig instantaneous (pressure "spike")

TABLE 2 - Cont'd  
TEST OPERATING LIMITS

PARAMETER	CHANNEL	DISPLAY TYPE/LOCATION	LIMIT TYPE	LIMIT VALUE	NOMINAL EXPECTED OPERATING CONDITION	ALARM TYPE/SETTING	CORRECTIVE ACTION
Seal Differential Pressure	BP-1C 9D Δ P <sub>BUS/PA</sub>	Meter/R006-A	High	150* psid			Normal Shutdown
Helium Pressure	BP-050	Meter/R005-A	Low	500 psig			Normal Shutdown
Hydrogen Pressure	BP-010	Beckman/R082 Meter/R005-A	Low	500 psig			Normal Shutdown
Nitrogen Pressure	BP-060	Beckman/R082	Low	500 psig			Normal Shutdown
Control Room Press.	N/A		Low	Loss	(.2" H <sub>2</sub> O)		Normal Shutdown

\*Not Applicable with Forward Seal in Place

TABLE 3FLUID REQUIREMENTS

<u>STORAGE VESSEL</u>	<u>FLUID</u>	<u>NOMINAL SETUP CONDITION</u>	<u>FLUID INVENTORY</u>
Banks 2, 4 and 10	N <sub>2</sub>	3500 psig	1092 Kscf
Banks 1, 3 and 5	H <sub>2</sub>	2500 psig	828 Kscf
Tube Trailer	He	2400 psig	41.4 Kscf
Dewar "D"	LH <sub>2</sub>	90%	20,000 gal
Elevated Water Tank	H <sub>2</sub> O	N/A	50,000 gal

TABLE 4  
 BECKMAN PEN ASSIGNMENTS  
 BEARING TEST PROGRAM

RECORDER #1  
RACK A1-R078

	<u>TITLE</u>	<u>RANGE</u>
1. * BD-001	Motor Bearing Displacement Forward Bearing, 0°	± .002 in.
2.		
3. * BD-003	Test Bearing Displacement Aft Bearing, 0°	± .002 in.
4.		
5.		
6.		
7.		
8. BP-101	Flowmeter Inlet Pressure	0 - 500 psig

RECORDER #2  
RACK A1-R079

	<u>TITLE</u>	<u>RANGE</u>
1. BP-103	Tester LH <sub>2</sub> Inlet Pressure	0 - 500 psig
2. BP-104	Bearing Housing Pressure	0 - 500 psig
3. BP-108D	Bearing Upstream/Downstream Differential Pressure	± 10 psid
4. BP-111	Test Bearing Downstream Pressure	0 - 500 psig
5. BP-102	Test Bearing Upstream Pressure	0 - 500 psig
6. BP-109D	Upstream/Vent Cavity Differential Pressure	0 - 500 psid
7. * BP-105	Axial Loader Pressure	0 - 500 psig
8. BP-110D	Radial/Axial Differential Pressure	0 - 500 psid

NOTE: Those channels and displays indicated by \* will not be required for the FEP.

TABLE 4 (continued)  
 BECKMAN PEN ASSIGNMENTS  
 BEARING TEST PROGRAM

RECORDER #3  
RACK A1-R080

	<u>TITLE</u>	<u>RANGE</u>
1.	BP-106 Radial Loader Line Pressure	0 - 1000 psig
2.	BP-107 Loader Vent Pressure	0 - 500 psig
3.	BT-101 Flowmeter Inlet Temperature	35 - 80°R
4.	BT-107 Test LH <sub>2</sub> Inlet Temperature	35 - 80°R
5.	BT-108 Loader Vent Temperature	0 - 535°R
6.	BT-105 Proximity Probe Cavity Temperature, Loader Housing	35 - 530°R
7.	BT-103 Slave Bearing Housing Temperature	35 - 80°R
8.	BT-104 Motor Housing Temperature	35 - 130°R

RECORDER #4  
RACK A1-081

	<u>TITLE</u>	<u>RANGE</u>
1.	BT-102 Test Bearing Upstream Temperature	35 - 80°R
2.	BT-106 Test Bearing Downstream Temperature	35 - 80°R
3.	BF-001 LH <sub>2</sub> Flowmeter	0 - 100 gpm
4.	BQ-001 Bearing Tester Speed #1	0 - 40K RPM
5.	BQ-002 Bearing Tester Speed #2	0 - 40K RPM
6.	BI-001 Electric Drive Motor Current #1	0 - 150 a
7.	BI-002 Electric Drive Motor Current #2	0 - 150 a
8.	BI-003 Electric Drive Motor Current #3	0 - 150 a

TABLE 4 (continued)  
 BECKMAN PEN ASSIGNMENTS  
 BEARING TEST PROGRAM

<u>RECORDER #5</u> <u>RACK A1-082</u>	<u>TITLE</u>	<u>RANGE</u>
1. BP-060	GN <sub>2</sub> Supply Manifold Pressure	0 - 400 psig
2. BP-004	Run Tank Pressure, Line Pressure, Dome	0 - 1000 psig
3.		
4. BT-004	Run Dewar 5% Level Temperature	35 - 100°R
5. BT-005	Run Dewar 7.5% Level Temperature	35 - 100°R
6. BT-006	Run Dewar 50% Level Temperature	35 - 100°R
7. BT-007	Run Dewar 90% Level Temperature	35 - 100°R
8. BP-010	GH <sub>2</sub> Supply Manifold Pressure	0 - 3500 psig

TABLE 5  
L & N ASSIGNMENTS  
BEARING TEST PROGRAM

<u>L &amp; N BAY</u>	<u>TITLE</u>	<u>RANGE</u>
Al-RO01:		
BT-104	Motor Housing Temperature	35 to 140°R
BT-108	Loader Vent Temperature	35 to 530°R
BF-001	LH <sub>2</sub> Flowmeter	0 to 100 gpm
Al-RO02:		
BT-010	LH <sub>2</sub> Run Line Temperature	35 to 80°R
BT-011	LH <sub>2</sub> Run Line Temperature	35 to 80°R
BT-101	Flowmeter Inlet Temperature	35 to 80°R
Al-RO03:		
BT-102	Test Bearing Upstream Temperature	35 to 80°R
BT-106	Test Bearing Downstream Temperature	35 to 80°R
BP-110D	Radial/Axial Differential Pressure	0 to 500 psid
Al-RO04:		
BI-001	Electric Drive Motor Current #1	0 - 150 a
BQ-001	Bearing Tester Speed #1	0 - 40K RPM
BQ-002	Bearing Tester Speed #2	0 - 40K RPM

3

TABLE 6  
 CONSOLE METER DISPLAYS  
 BEARING TEST PROGRAM

<u>AI-R005</u>	<u>TITLE</u>	<u>RANGE</u>
1. BP-001	Run Tank Pressure Line	0 - 1000 psig
2. BP-003	Run Tank Pressure	0 - 500 psig
3. BP-011	LH <sub>2</sub> Run Line Pressure	0 - 500 psig
4. BT-004	Run Dewar 5% Level Temperature	5%
5. BT-005	Run Dewar 7.5% Level Temperature	7.5%
6. BP-050	GH <sub>2</sub> Supply Manifold Pressure	0 - 5000 psig
7. BP-010	GH <sub>2</sub> Supply Manifold Pressure	0 - 5000 psig
8. BP-090	Run Tank Pressure Line Primary Pressure	0 - 5000 psig
9. BP-080	GH <sub>2</sub> Load Gas Line	0 - 1000 psig
10. BT-006	Run Dewar 50% Level Temperature	50%
 <u>AI-R006</u>		
1. BX-001	Run Dewar Carbon Resistor Rake	5 - 90%
2. BP-109D	Upstream/Vent Cavity Differential Pressure	0 - 500 psid
3. BP-102	Test Bearing Upstream Pressure	0 - 500 psig
4. BP-104	Bearing Housing Pressure	0 - 500 psig
5. BF-001	LH <sub>2</sub> Flowmeter	0 - 100 gpm
6. BT-007	Run Dewar 90% Level Temperature	90%
7. BP-110D	Radial/Axial Differential Pressure	0 - 500 psid
8. BP-107	Loader Vent Pressure	0 - 500 psig
9. BP-106	Radial Loader Line Pressure	0 - 1000 psig
10. * BP-105	Axial Loader Pressure	0 - 500 psig

NOTE: Those channels and displays indicated by \* will not be required for the FEP.

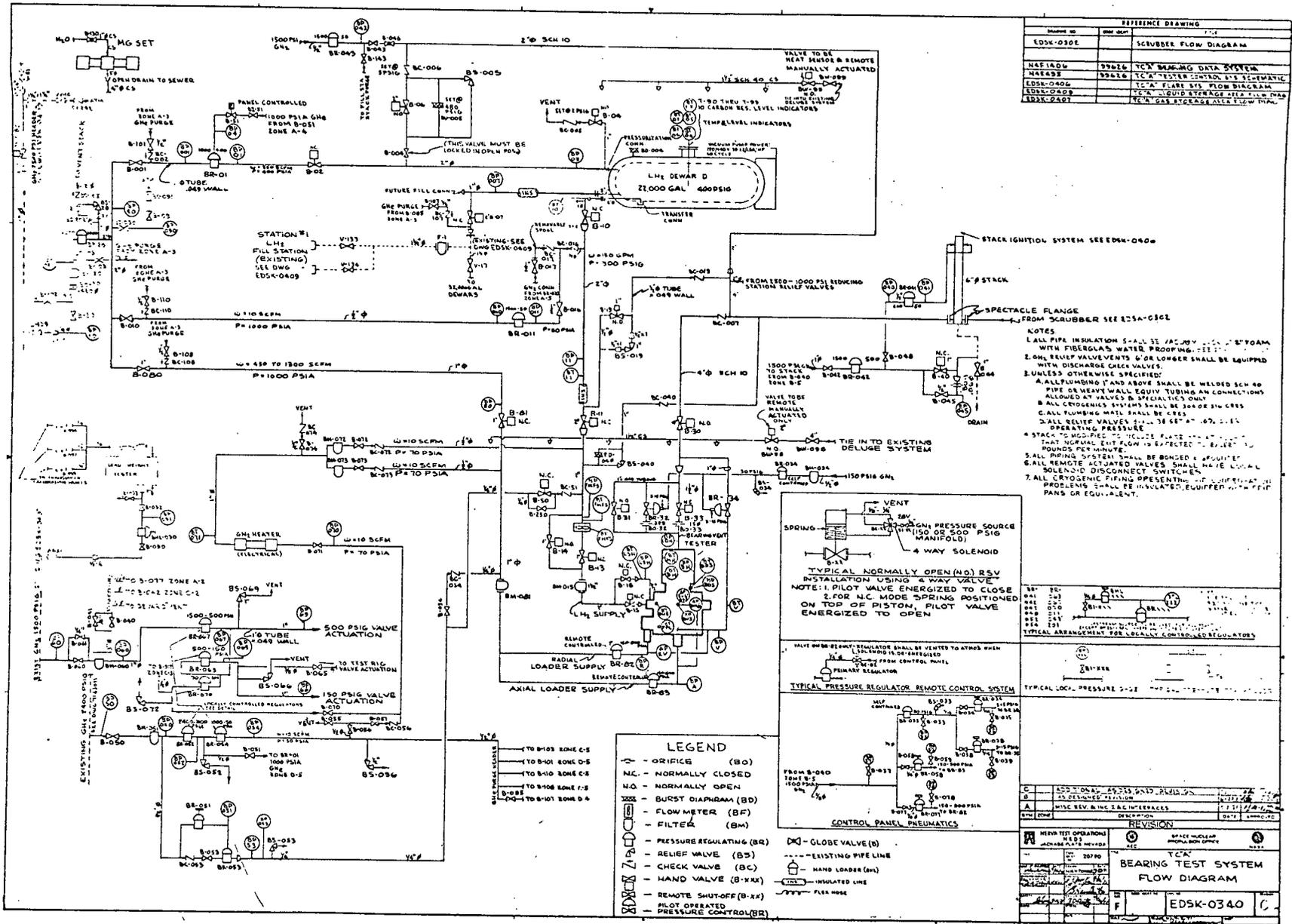
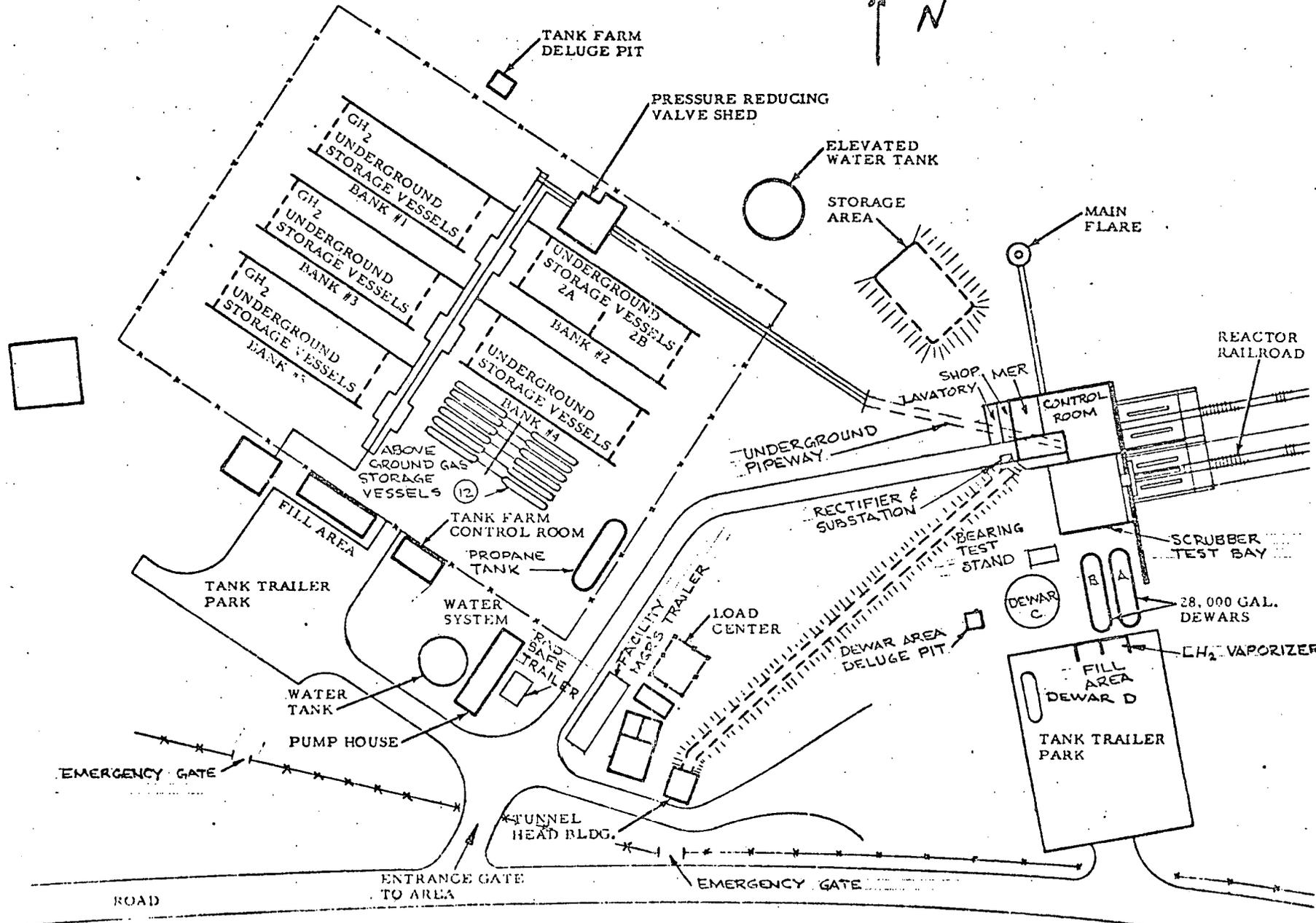


Figure 1  
Page 50

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NRTO-R-0212  
FIGURE 2

TEST CELL A SITE PLAN

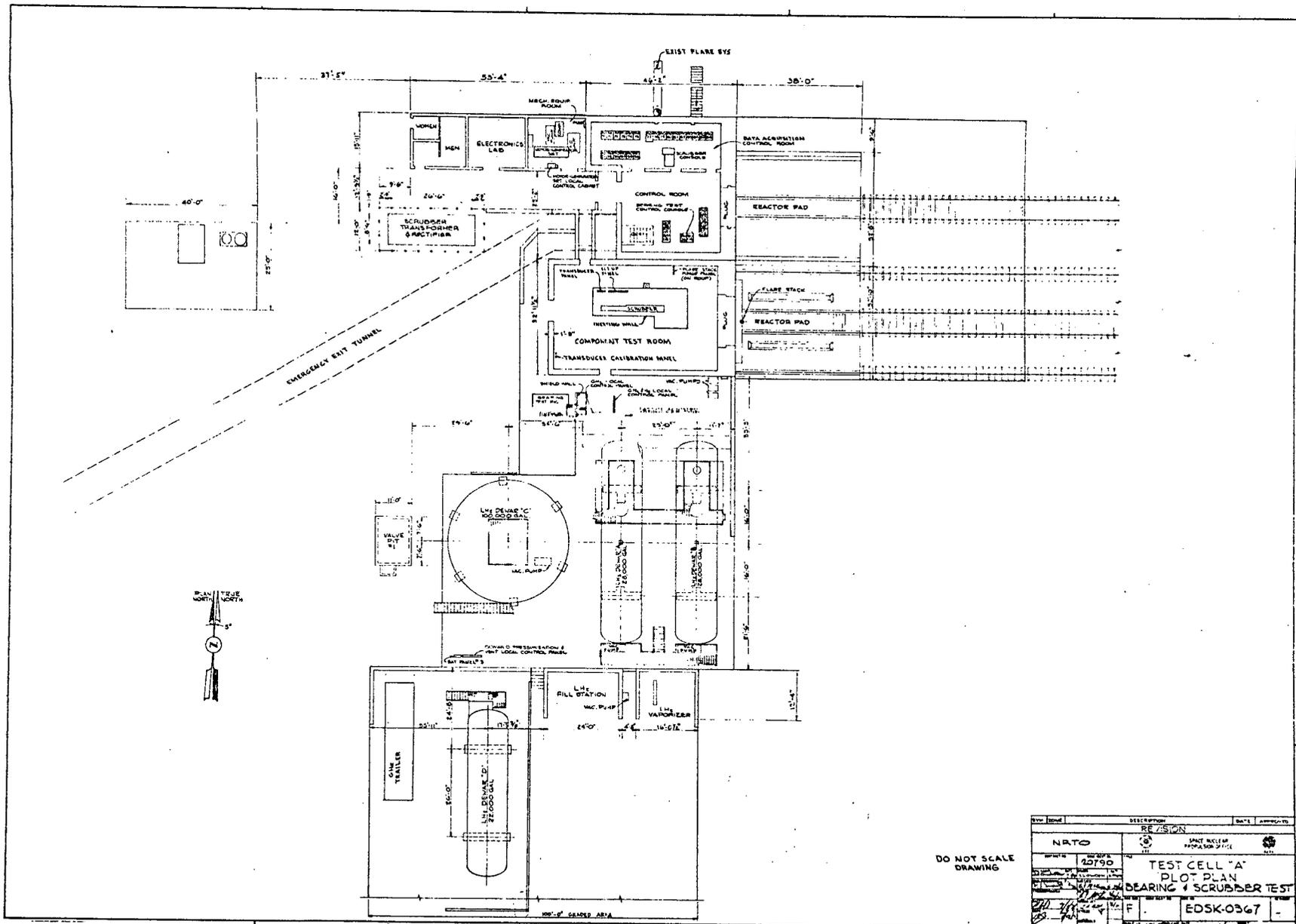


Figure 3  
Page 52

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best available copy.

DESCRIPTION		DATE	APPROVED BY
REVISION			
NATO	SAFETY REVIEW		
42790	TEST CELL 'A'		
	PLOT PLAN		
	BEARING & SCRUBBER TEST		
F	EDSK-0367		

# ANSC LH<sub>2</sub> 65MM BALL BEARING TESTER

GH<sub>2</sub> VENT

DISTANCE DETECTORS

ELECTRIC DRIVE MOTOR

PA INLET (GH<sub>2</sub>)

LH<sub>2</sub> EXIT

- 53 -

NRFO-R-0212

GH<sub>2</sub> INLET

SUPPORT BEARING

LH<sub>2</sub> TEMP SENSOR

SPEED PICKUP

TEST BEARINGS

RADIAL LOADER

LH<sub>2</sub> INLET (2 PLACES)

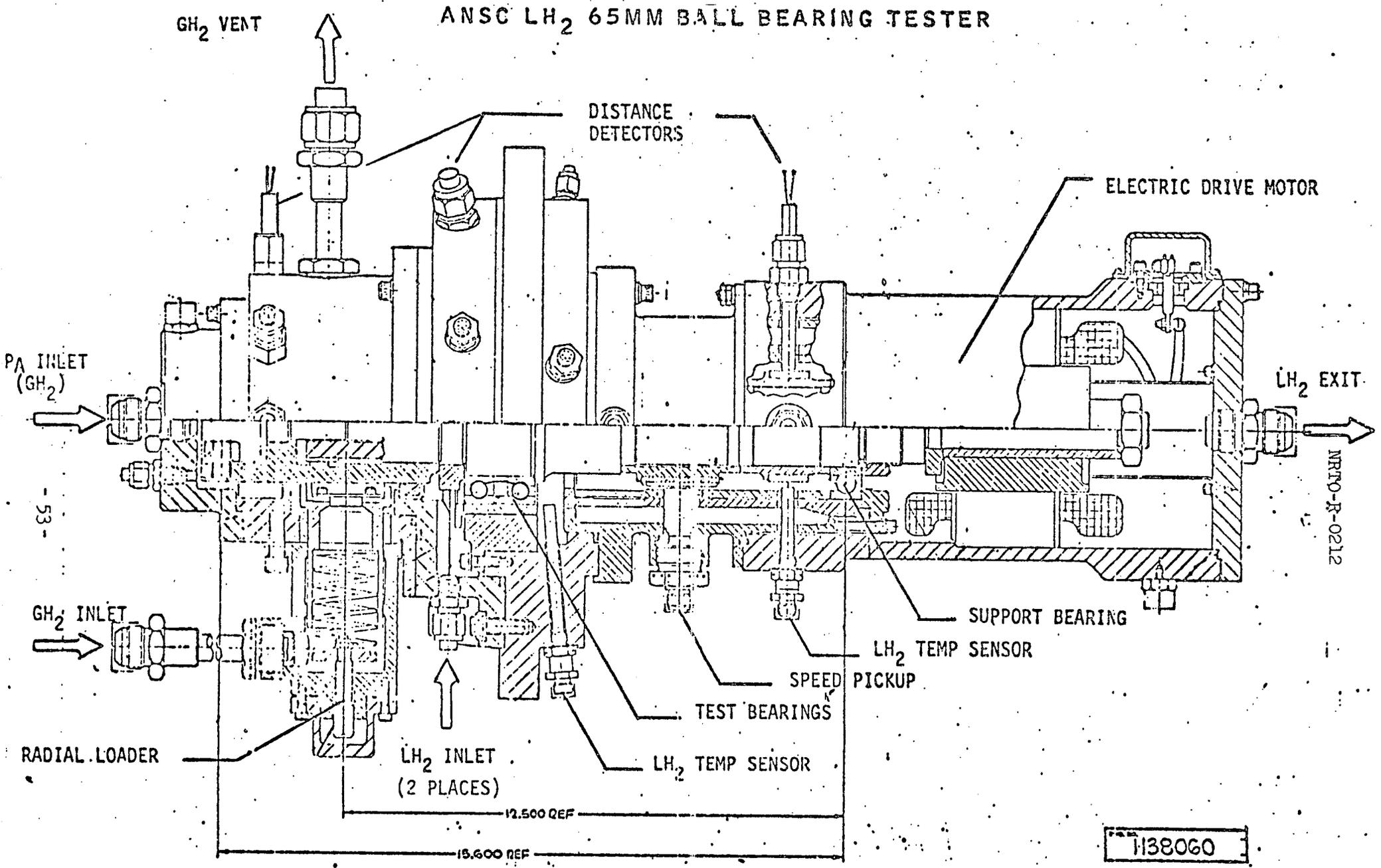
LH<sub>2</sub> TEMP SENSOR

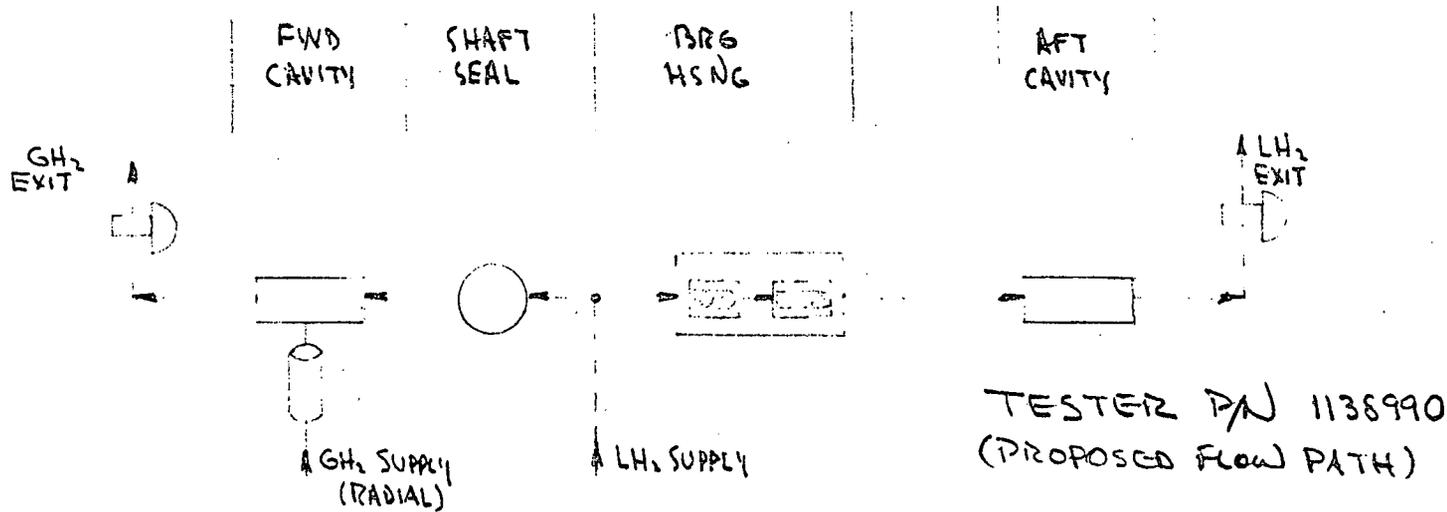
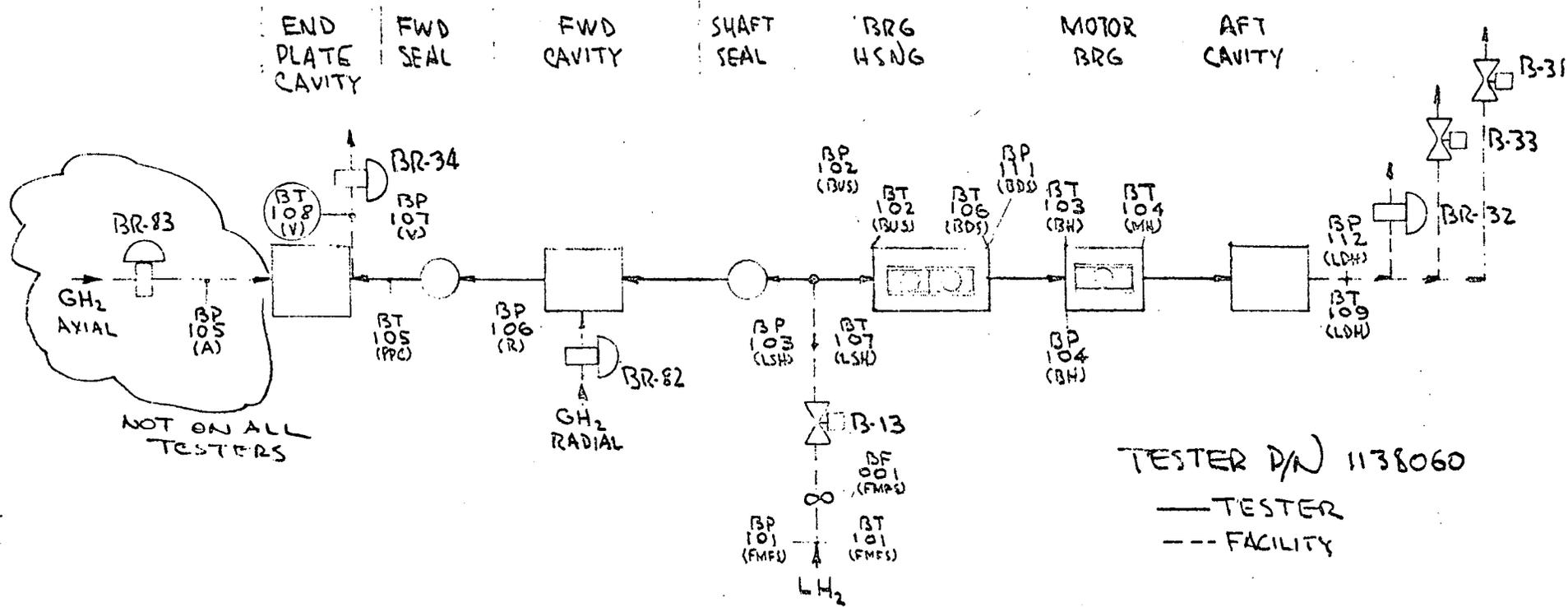
12.500 REF

15.600 REF

1138060

FIGURE 4





SIMPLIFIED FLOW SCHEMATIC  
 FOR

SINGLE/DUAL DUPLEX SET BEARING TESTER

FIGURE 5

EUGENE DIETZGEN CO.  
MADE IN U. S. A.

NO. 340-MP DIETZGEN GRAPH PAPER  
MILLIMETER

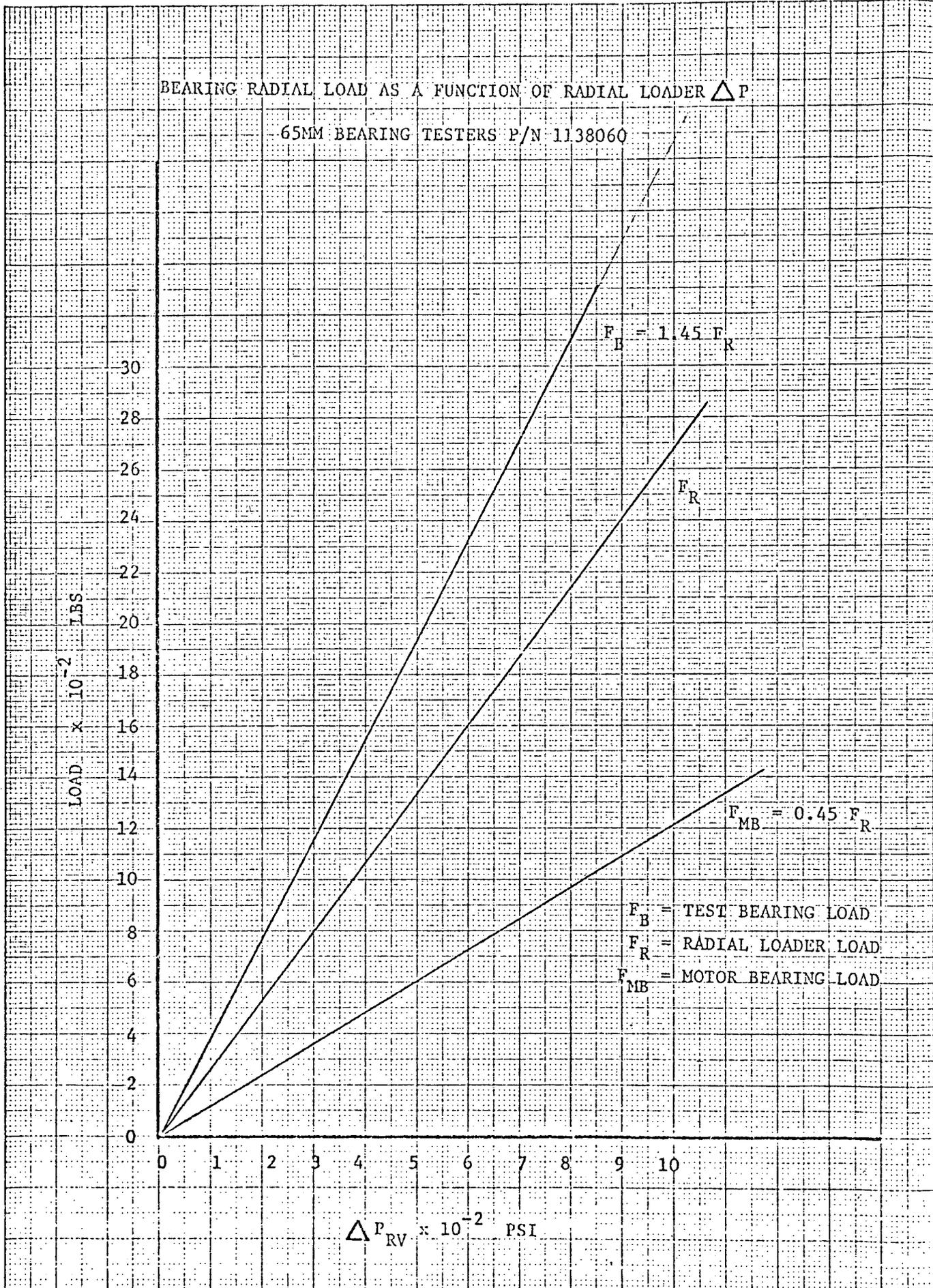
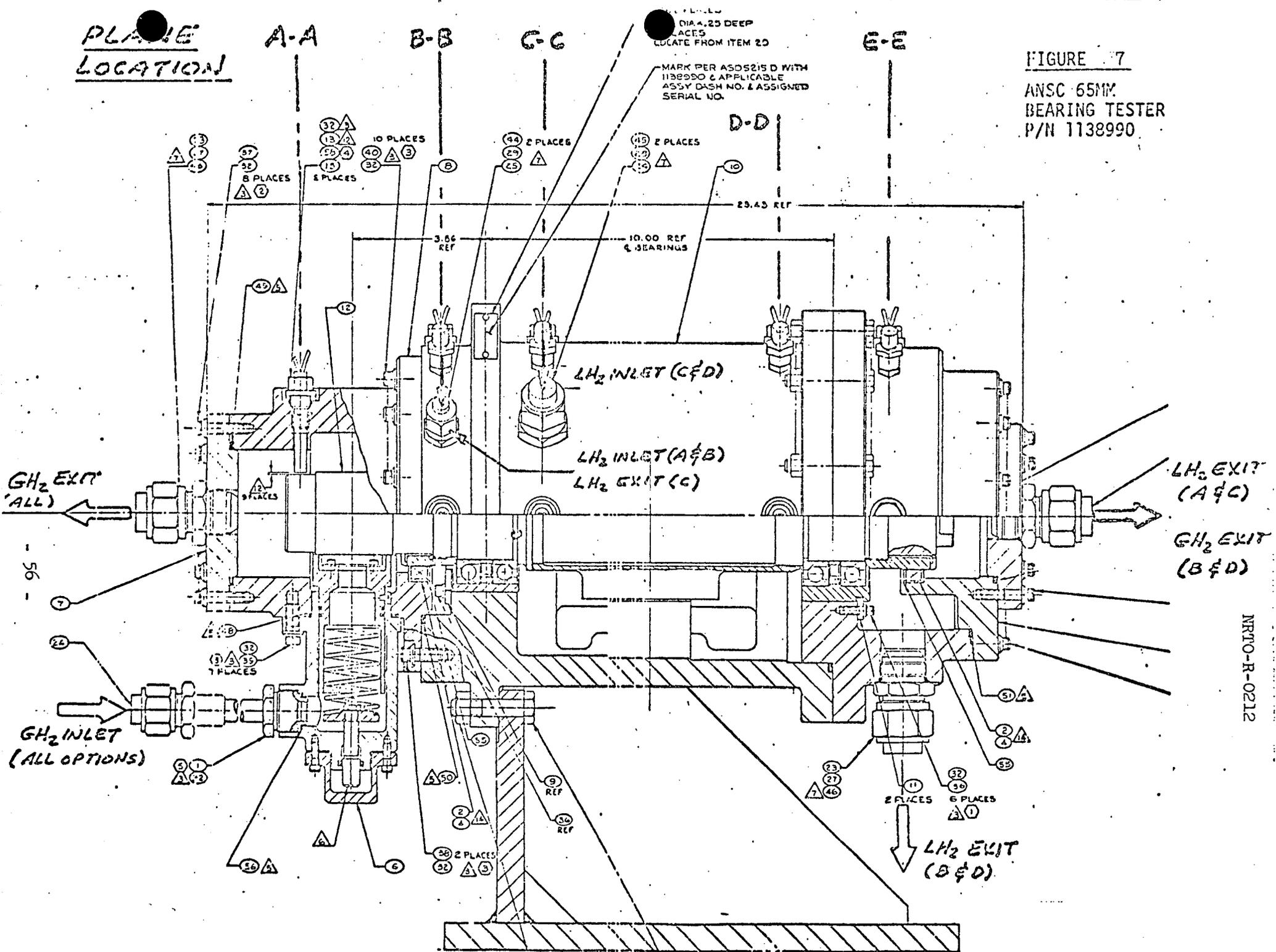


PLATE  
LOCATION

FIGURE 7

ANSC 65MM  
BEARING TESTER  
P/N 1138990



- 56 -

NRTO-R-0212

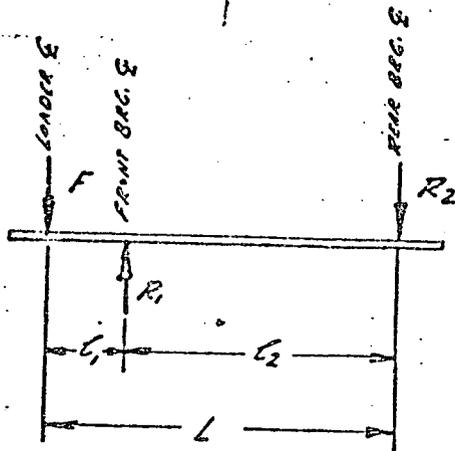
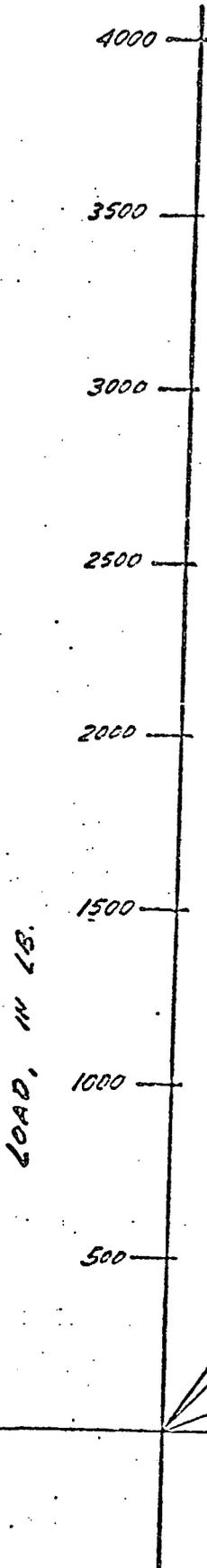
PNEUMATIC LOADER FORCE AND TEST BEARING LOADS :

P/N 1138990

$l_1 = 3.860$  INCH

$l_2 = 10.000$  INCH

$L = l_1 + l_2 = 13.860$  INCH



$$F \times L = R_1 \times l_2$$

$$F = R_1 \left( \frac{l_2}{L} \right) = R_1 \left( \frac{10.000}{13.860} \right) = 0.7215 R_1$$

$$R_1 = F \left( \frac{L}{l_2} \right) = F \left( \frac{13.860}{10.000} \right) = 1.386 F$$

$$R_2 = F \left( \frac{l_1}{l_2} \right) = F \left( \frac{3.860}{10.000} \right) = 0.386 F$$

PNEUMATIC LOADER  $\Delta P$ , IN PSI.

FIGURE 8

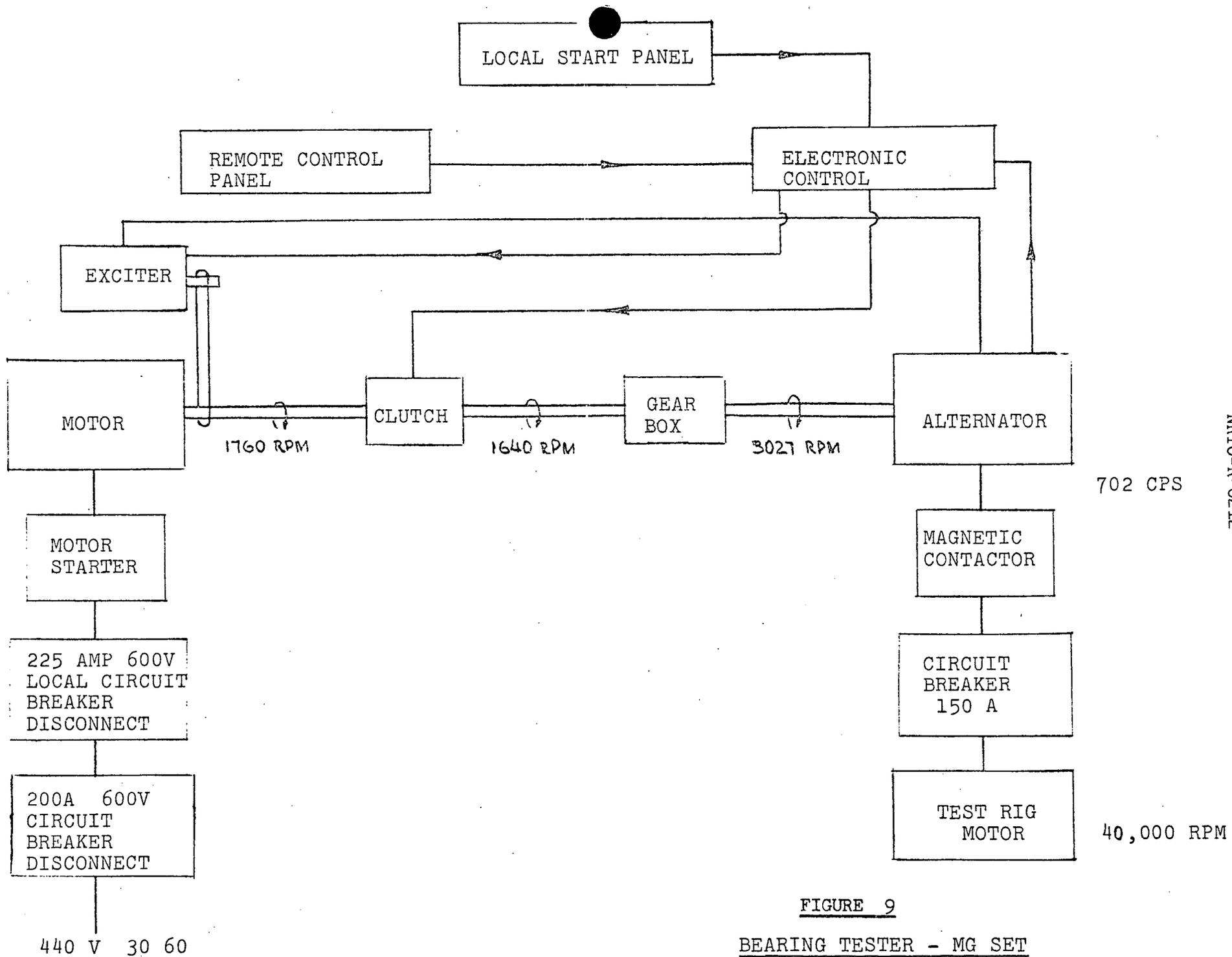
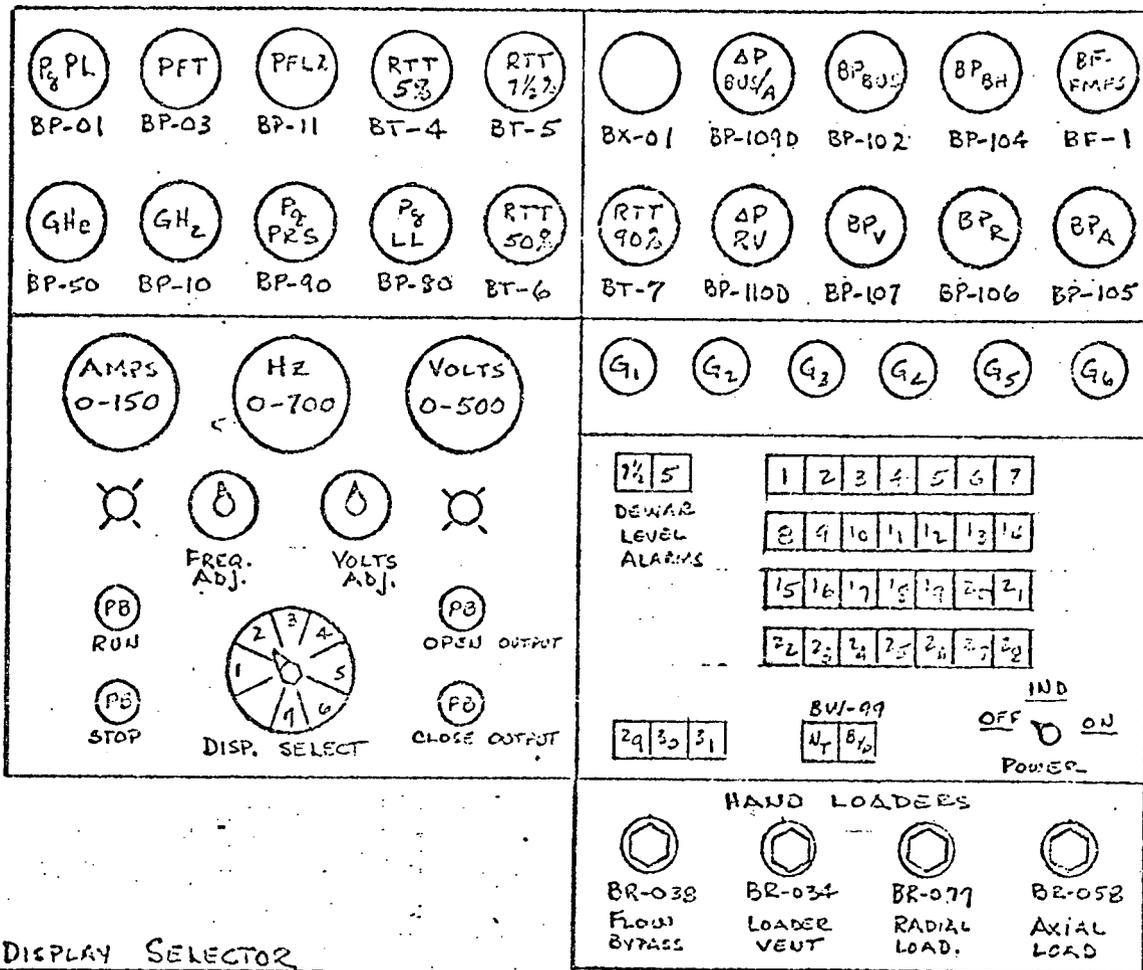


FIGURE 9  
BEARING TESTER - MG SET  
SCHEMATIC DIAGRAM

# BEARING TESTER CTO CONSOLE LAYOUT



### DISPLAY SELECTOR

1. OFF
2. Volts  $\phi A - \phi B$   
AMP  $\phi A$
3. V.  $\phi B - \phi C$   
A.  $\phi B$
4. V.  $\phi C - \phi A$   
A.  $\phi C$
5. V.  $\phi A - N$
6. V.  $\phi B - N$
7. V.  $\phi C - N$

### PRESSURE GAUGES

- |                |         |        |
|----------------|---------|--------|
| G <sub>1</sub> | - BP-33 | 0-60   |
| G <sub>2</sub> | - BP-37 | 0-2000 |
| G <sub>3</sub> | - BP-39 | 0-30   |
| G <sub>4</sub> | - BP-35 | 0-30   |
| G <sub>5</sub> | - BP-78 | 0-1500 |
| G <sub>6</sub> | - BP-59 | 0-1000 |

### SWITCHES

- |            |                           |                |
|------------|---------------------------|----------------|
| 1. B-22    | 15.                       | 29. SLESU      |
| 2. B-21    | 16. BW-98                 | 30. RIG Lites  |
| 3. B-10    | 17. BW-99                 | 31. AREA Lites |
| 4. B-19    | 18. B-40                  |                |
| 5. B-11    | 19. B-50                  |                |
| 6.         | 20. B-47                  |                |
| 7.         | 21. B-43                  |                |
| 8. B-13/14 | 22. B-51 P <sub>MAX</sub> |                |
| 9. B-15/18 | 23. B-51 V <sub>MAX</sub> |                |
| 10. B-31   | 24. B-51 V <sub>AA</sub>  |                |
| 11. B-33   | 25. B-2                   |                |
| 12. B-30   | 26. B-4                   |                |
| 13.        | 27. B-6                   |                |
| 14.        | 28. B-7                   |                |

FIGURE 10

LOGAN - 7/20/7

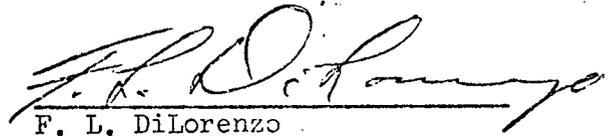
NUCLEAR ROCKET TEST OPERATIONS

STANDARD OPERATING PROCEDURE

FOR

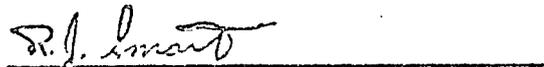
HOT HELIUM OR NITROGEN DEHYDRATION PURGE  
OF THE BEARING TEST ARTICLE  
IN TEST CELL "A"

Prepared by:

  
F. L. DiLorenzo

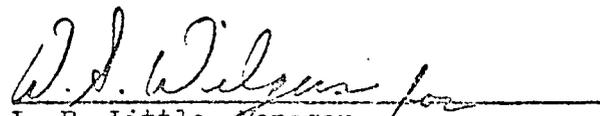
Reviewed by:

  
C. A. DeLorenzo, Manager  
NRTO Health and Safety

  
R. J. Smart  
NRTO Quality Assurance

Approved by:

  
D. D. Vander Meer, Manager  
Test Cell "A"

  
L. E. Little, Manager  
Nuclear Rocket Test Operations

CATEGORY IV

FINAL ISSUE  
18 August 1971

1.0 PURPOSE

The purpose of this procedure is to perform the dehydration of the Bearing Test Article prior to the admission of cryogenic fluids through the system.

2.0 GUIDELINES

2.1 This procedure will be performed only with the approval of the Acting Facility Manager (AFM).

2.2 The AFM is responsible for scheduling the work covered by this procedure. He will monitor the operation for compliance with the established safety and operational requirements.

2.3 The responsible NRTO Facility Operations Engineer will direct the work in accordance with the approved checklist, Section 5.0, and will maintain communication with the Console Operator during valve cycle operations.

2.4 All personnel connected with the performance of this procedure will be knowledgeable of the provisions and safety requirements of this document. A briefing shall be held to acquaint operations personnel with the operation and to emphasize proper emergency actions in case of an incident.

2.5 The Checklist, Section 5.0, can be modified only with the approval of both the responsible Facility Operations Engineer and the AFM (two persons) or higher authority. Any modifications, including items marked "N/A", must in no way violate the requirements, limits, purposes, safety considerations, or intent of this document. Modifications, including items marked "N/A", shall be clearly marked on the executed copy, together with a briefly stated reason for each; and shall be individually initialed by the AFM.

2.6 Discrepancies noted during the performance of this procedure shall be noted adjacent to the applicable paragraph by the System Engineer. NRTO Quality Assurance shall be notified, if applicable, for the purpose of documenting discrepancies (QRDR).

2.7 The operations covered by this document will be classified as Category IV in accordance with NRTO-A-0001.

3.0 GENERAL INSTRUCTIONS

3.1 SAFETY REQUIREMENTS AND EMERGENCY ACTIONS

The Exclusion Area for the conduct of this operation shall be the Bearing Test Stand.

3.1.1 In the event a GHe or GN<sub>2</sub> leak develops, the responsible Facility Operations Engineer personally supervising the operation, shall evaluate the significance of the leak, and:

- a. Direct corrective action, such as closing appropriate valves or venting the system, and then tightening appropriate fittings to stop the leak and notify the AFM, or,
- b. Direct the immediate evacuation of the area in the safest manner and notify the AFM.

3.1.2 In the event of a facility emergency signaled by sirens or PA announcement, the procedure shall be terminated and personnel evacuated in accordance with Reference A., of Section 4.0. If the emergency occurs during the flow phase of this operation, the pneumatic supply valve and heater power will be secured at the discretion of the Cognizant Engineer prior to the evacuation of the area. No other securing operations are anticipated due to the nature of conducting this procedure.

3.2 OPERATING LIMITS AND REQUIREMENTS

3.2.1 BP-071 maximum pressure, 75 psig.

3.2.2 BTMH maximum temperature, 135<sup>o</sup>F.

3.2.3 BTMH must be maintained at 120 ± 15<sup>o</sup>F for at least 20 minutes.

3.2.4 After the dehydration purge is completed a low pressure purge must be maintained on the Test Article.

3.2.5 If a condition exists such that the purge maintenance is questionable on the Test Article System, a dehydration purge must be performed prior to cryogenic operation.

4.0

REFERENCES

- A. NRTO-A-0090:001 - Test Cell "A" Emergency Plan
- B. NRTO-A-0090:004 - Test Cell "A" Lock and Tag Procedure
- C. Engineering Dwg. - EDSK-0340, Rev. C
- D. 774OR-70-29 - Bearing Tester Usage and Testing Specification, dated November 5, 1970

DATE/INITIAL

5.0 CHECKLIST OPERATIONS

5.1 SAFETY CHECKS

1. Instruct operating crew on sequence of operation for completion of this procedure. \_\_\_\_\_
2. Purge pressure and flow is to be initiated slowly. \_\_\_\_\_
3. Notify AFM of the intent to start Checklist Operations. \_\_\_\_\_

5.2 INITIAL CONDITIONS

1. The following parameters must be operational:

BTMH \_\_\_\_\_  
 BT-071 \_\_\_\_\_  
 BP-071 \_\_\_\_\_  
 BT-FMFS \_\_\_\_\_

2. 500 psig actuation pressure operational for supply of GN<sub>2</sub> to BR-070 or 100 psig helium supply to BR-054. \_\_\_\_\_

5.3 OPERATIONS

- 5.3.1 1. Verify the position of the following valves:

B-30	OPEN	_____	B-14	OPEN	_____
B-31	OPEN	_____	B-11	CLOSED	_____
BR-82	OPEN	_____	B-81	CLOSED	_____
BR-83	OPEN	_____	B-072	OPEN	_____
B-15	OPEN	_____	B-073	OPEN	_____
B-18	OPEN	_____	B-074	CLOSED	_____
			B-071	OPEN	_____

DATE/INITIAL

NOTE: Either a Nitrogen or a Helium purge will be performed. If a Nitrogen purge is performed, proceed with Step 5.3.2, omit Step 5.3.3 and proceed to Step 5.4

If a Helium purge is performed, proceed directly to Step 5.3.3.

5.3.2 Nitrogen Purge

1. OPEN B-070. \_\_\_\_\_
2. Slowly regulate BR-070 to provide 70 psig on BP-071. \_\_\_\_\_

5.3.3 Helium Purge

1. Check B-070 CLOSED. \_\_\_\_\_
2. OPEN B-057 and B-056. \_\_\_\_\_
3. CLOSE the following valves:
 

B-103 _____	B-055 _____
B-101 _____	B-108 _____
B-110 _____	B-085 _____
	B-051 _____
4. Verify the following:
 

BR-054 - Vented _____	BR-051 - Vented _____
BR-052 - Vented _____	B-053 - CLOSED _____
5. OPEN B-050 slowly and establish helium pressure at BP-050. \_\_\_\_\_

DATE/INITIAL

6. Using BR-052, establish 200 psig minimum at BP-052.

\_\_\_\_\_

7. Using BR-054, establish 70 psig at BP-071.

\_\_\_\_\_

5.4

DEHYDRATION PHASE

1. Verify heater Stop/Start switch is in STOP position.

\_\_\_\_\_

2. CLOSE circuit breaker TCA-10.

\_\_\_\_\_

3. CLOSE heater local circuit breaker.

\_\_\_\_\_

4. Switch the heater Start/Stop switch to START.

\_\_\_\_\_

5. Monitor BTMH to maintain 120 ± 15°F for 20 minutes.

\_\_\_\_\_

6. Cycle B-31, BR-32, B-33 and BR-34 alternately OPEN and CLOSED during Dehydration Phase to assure flow of dehydrating gas through all legs of plumbing system.

\_\_\_\_\_

5.5.

SECURE PHASE

1. Upon meeting the purge requirements, switch the Start/Stop switch to STOP.

\_\_\_\_\_

2. Upon a decrease in BT-071 temperature, CLOSE the following valves in the order shown to lock up the inert purge pressure on the Test Article.

B-30 CLOSED \_\_\_\_\_

B-15 and B-18 CLOSED \_\_\_\_\_

Verify B-81 CLOSED \_\_\_\_\_

\_\_\_\_\_

DATE/INITIAL

3. Position the following valves:

- B-070 CLOSED \_\_\_\_\_ B-073 CLOSED \_\_\_\_\_
- B-056 CLOSED \_\_\_\_\_ B-071 CLOSED \_\_\_\_\_
- B-057 CLOSED \_\_\_\_\_ B-074 OPEN \_\_\_\_\_
- B-055 OPEN \_\_\_\_\_ BR-82 Vented \_\_\_\_\_
- B-072 CLOSED \_\_\_\_\_ BR-83 Vented \_\_\_\_\_

4. If helium was used as the dehydrating gas, perform the following: \*

- BR-054 Vented \_\_\_\_\_
- BR-052 Vented \_\_\_\_\_
- B-50 CLOSED \_\_\_\_\_

NOTE: \*These Steps should not be accomplished if GHe is required for B-51 loader or purging purposes.

5. OPEN the heater local circuit breaker. \_\_\_\_\_

6. OPEN circuit breaker TCA-10. \_\_\_\_\_

7. If dehydration is not to be immediately followed by bearing testing, tag out the following, per Reference B.:

- Console Power Switch ON. \_\_\_\_\_
- B-30 commanded CLOSED. \_\_\_\_\_
- B-30 Safe/Operate switch in OPERATE. \_\_\_\_\_
- B-30 Actuation Pressure ON. \_\_\_\_\_
- B-080 CLOSED. \_\_\_\_\_

8. Notify the AFM of the completion of this procedure. \_\_\_\_\_

\_\_\_\_\_  
NRTO Signature

\_\_\_\_\_  
Date / Time

<input checked="" type="checkbox"/> BASIC TEST REQUEST		SECURITY CLASSIFICATION			
		<input checked="" type="checkbox"/> UNCLASSIFIED	<input type="checkbox"/> CONFIDENTIAL	<input type="checkbox"/> SECRET	<input type="checkbox"/> OTHER (EXPLAIN)
SUPPLEMENT NO.	ST NUMBER	TEST SERIES NO.	WORK CHARGE NO.	GWA REFERENCE TP.	
		1190-65-XXX-X			
G. D. Westcot			BLDG. 2019A	DEPT. N5300	
REQUESTED BY:		BLDG. 2019A	DEPT. N8300	EXT. 4661	DATE 9-23-71
ACTION APPROVAL		DATE	ESTIMATED COMPLETION DATE		
MANHOURS	INSPECTION REQUIREMENTS				

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

1.0 General Discussion:

1.1 This test request provides information for the tests on NERVA Engine TPA prototype bearings to be tested in the single duplex set bearing tester (P/N 1138060-2, & -3.) For each specific test in this series, a Test Request Supplement will be issued that will define specific start-up and run conditions or other unusual test needs (e.g. Bearing Spring Rate Determination, etc.).

1.2 Test Request Supplements for the new dual duplex set tester (P/N 1138990) will be published when this hardware is available to the test program.

1.3 Test run kill parameters are listed in this document as a guide to the Test Director. However, the assessment of bearing performance and the decision to terminate or continue testing shall be the responsibility of the designated cognizant Project Engineer that particular test. Bearing performance is evaluated on several parameters which involve run duration, friction torque as indicated by drive motor current, LH<sub>2</sub> temperature rise across the bearings, and flow rate required to maintain good performance. Shaft dynamics, noise level and accelerometers are also used to assess bearing performance. The Test Director has total responsibility for termination of test operations for facility or other safety considerations.

2.0 References:

- (a) Report M100-TTP03-W121, Test and Development Plan for the Evaluation of LH<sub>2</sub> Cooled 65MM Roller Element Bearings for NERVA Engine TPA, dated December 1970
- (b) Report 7740R-70-029, NERVA Bearing Tester Usage and Testing Specifications, dated 5 November 1970 (where applicable)
- (c) Tester Assembly Drawing, P/N 1138060-2, -3 (Duplex Ball Bearing).
- (d) ANSC Test Operations "Data Handling Plan", dated May 14, 1971
- (e) ANSC Memo N7000:2072, QA Requirements for Testing 65MM Bearings, dated 6-8-71
- (f) ANSC Memo N8300:M0702, Near-Term Test Plan for Development of 65MM Ball Bearings, dated 7-12-71
- (g) F004-FRC02-W223F04, Supplemental Design Criteria, July 1971

DISTRIBUTION

NRTO: J. B. Accinelli, C. S. Boncore, F. B. Damerval, D. H. Duke, N. A. Edlebeck, H. D. Greenwood, D. A. Koch, F. E. Porter, F. Reuter, G. A. Thorsen, M. W. Young, H. Dudzinski, J. Smart, W. P. Hollowell, D. C. Durrill (3), L. E. Little, D. Vandermeer (3), F. DiLorenzo (3)

### Object of Tests:

- 3.1 To develop 65mm rolling element bearings (duplex ball) which will operate successfully in LH<sub>2</sub> for the required NERVA Engine TPA duration at representative loads and speed. To demonstrate with the prototype bearings the load-life-reliability relationship.
- 3.2 To determine the bearing radial spring rate at speed.
- 3.3 To investigate the application and performance of failure detection devices.
- 3.4 To investigate the effect of gamma radiation on several retainer materials.

### 4.0 Test Article:

- 4.1 Two (2) 65mm Bearing Testers (P/N 1138060-2, -3) with associated hardware will be alternately delivered to TC "A" fully assembled and inspected. The assembly will house one 65mm duplex set of angular contact ball bearings (P/N 1138952) and the required transducers for measurement of temperatures and pressures within the tester, shaft radial movement acceleration and tester motor speed.
- 4.2 For the initial test series, bearings with an Armalon retainer (Teflon/glass cloth) will be tested to investigate the design feasibility of the bearing components. A detail description of the development plan appears in References (a) and (f).

### 5.0 Schedule:

The current test program using one test stand requires the testing of an average of three build-ups per month, with the goal of 15 hours test duration per build-up.

### 6.0 Test Setup and Suggested Procedures:

6.1 The test will be conducted at a speed of 27,000 rpm for a target duration of 15 hours at an initial LH<sub>2</sub> flow rate of 55-60 gpm (inlet temperature (T<sub>BUS</sub>) nominally 48°R at a pressure of 225 psig) and at several radial loads. The general test plan, and procedures, are as outlined in Reference (a). The initial test program is outlined in detail in Table 1 of Reference (f). The tester is to be installed in the Bearing Tester Facility at TC "A" and the general test setup as shown in Figure 1 (attached).

### 6.2 Instrumentation:

6.2.1 Requirements are shown in Table I.

6.2.2 Critical parameters should be displayed at the control console to evaluate the performance of the test bearings during Phase I testing. These data are used for test control. The parameters, nominal expected values, and resolutions are noted below.

CRITICAL PARAMETERS REQUIRED FOR OPERATION  
(PHASE I)

<u>MEASUREMENT</u>	<u>FUNCTION</u>	<u>RANGE</u>	<u>NOMINAL EXPECTED VALUE</u>	<u>RESOLUTION</u>
$T_{BUS}$ (1)	Temp Brg Upstream	35-80°R	46°R	1°R
$T_{BDS}$ (1)	Temp Brg Downstream	35-80°R	51°R	1°R
$T_{MH}$	Temp Motor Housing	35-80°R	55°R	1°R
$P_{BUS}$	Press Brg Upstream	500 psig	225 psig	5 psig
$P_V$	Press Vent Cavity	500 psig	25-100 psig	5 psig
$\left. \begin{array}{l} P_{BUS}/P_A \\ \text{or} \\ P_{BUS}/P_V \end{array} \right\}$	Diff Press Brg Upstream vs Fwd Cavity Pressure	500 psi	100 psi	5 psi
$F_{FMFS}$ (1)	LH <sub>2</sub> Flow Rate	100 gpm	50-70 gpm	2 gpm
$\Delta P_{RV}$ (1)	Radial Force	500 psi	135 psi	5 psi
● 1	Test Motor Speed	40,000 rpm	6000-30,000 rpm	500 rpm
$I_M$	Test Motor Current	150 amps	45-70 amps	2 amps
$T_V$	Vent Temperature	35-590°R	450°R	10°R

(1) To be displayed on Dual Pen Brown Recorders.

6.3. Detail test requirements for each buildup will be defined in the Test Request Supplement to be published for each specific test. Reference (b), NERVA Bearing Tester Usage and Testing Specification describes general test information. Specific details of testing shall be defined in the basic test request and supplements.

6.4. Nominal startup and run conditions are listed here for information but will be specified in the Test Request Supplement for each test. The listing shows test conditions for the tester configured with and without the forward gas/gas seal (P/N 700977-9).

6.4.1 Nominal Start-Up Conditions: (Before Motor Start, MS)

<u>PARAMETER</u>	<u>WITH GAS/GAS SEAL INSTALLED</u>	<u>W/O GAS/GAS SEAL INSTALLED</u>
$P_A$	175 psig	( = $P_V$ )
$P_V$	100 psig	175 psig
$P_R$	135 psig	210 psig
$\Delta P_{RV}$	35 psid	35 psid
$P_{BUS}$	225 psig	225 psig
$T_{BUS}$	$\bar{\leq}$ 54°R	$\bar{\leq}$ 54°R
$F_{FMFS}$	55 gpm	55 gpm

6.4.2 Recorders:

Start recorders 30 seconds before MS.

6.4.3 Motor Start:

(a) After establishing above conditions, close the circuit to the bearing tester motor. This time is referenced as MS (motor start) + 0 seconds. Motor speed required is  $N > 3000$  rpm at MS + 5 seconds and  $N = 12,000$  rpm at MS + 20 seconds.

(b) Maintain  $N = 12,000$  rpm for  $3 \pm 0.5$  Minutes.

(c) Voltage: 100 Volts  
Frequency: 200 Hz

6.4.4 Nominal Run Conditions:

<u>PARAMETER</u>	<u>WITH GAS/GAS SEAL INSTALLED</u>	<u>W/O GAS/GAS SEAL INSTALLED</u>
$P_A$	125 psig	( = $P_V$ )
$P_V$	100 psig	125 psig
$P_R$	235 psig	260 psig
$\Delta P_{RV}$	135 psid	135 psid
$P_{BUS}$	225 psig	225 psig
$T_{BUS}$	$\bar{< 54^\circ R$	$\bar{< 54^\circ R$
$F_{FMFS}$	55 gpm	55 gpm

6.4.5 After establishing the above conditions increase motor speed to:

$N_T$  27,000 rpm

Voltage 225 Volts

Frequency 450 Hz

6.5 Normal Shutdown Operations:

6.5.1 Stop bearing tester motor by opening supply line contactor switch at control console.

6.5.2 When  $N_T$  (motor speed) = 0 rpm, decrease  $P_R$  &  $P_A$  to 0 psig (by closing BR-82 and BR-83 or by closing B-81).

6.5.3 Reduce flow to 0 gpm (close B-11)

6.5.4 Start post test purge operations.

6.6 Between test runs on each buildup, test motor breakaway and running torques shall be measured and witnessed by the cognizant Project Engineer.

7.0 Operating Limits:

7.1 The following limits are not to be exceeded during any test:

$P_A$	300 psig (when applicable)
$\Delta P_{RV}$	300 psid
$P_{BUS}$	190 to 440 psig (not below 190 for more than 10 seconds)
$T_{FMFS}, T_{BUS}$	54°R (upper limit)
$F_{FMFS}$	Not below 50 gpm
$I$	100 amps (after motor start plus 5 seconds)
$V$	258 volts
$N$ (rpm)	31,000 (RPM rate from 12,000 rpm to run speed shall be in the range of 2000 to 4000 rpm/sec)

7.2 In addition to the limits indicated above, and during the test run, the following parameters shall be used as a guide for test termination.

Speed: If motor speed is not indicated ( $N$  above 3000 rpm), within five seconds after power is applied to the motor, the test is to be killed.

Current: After MS + 5 seconds, the current shall not be greater than 100 amps. If after MS + 5 seconds, the current is greater than 100 amps, the test is to be terminated. (MS = motor start)

Coolant Pressure: At no time is  $\Delta P_{BUS}/P_V$  (coolant pressure ( $P_{BUS}$ ) to vent pressure ( $P_V$ )) to be less than 25 psi or more than 150 psid. If this condition should occur, decrease  $P_V$  to correct it. At no time during the test is  $P_{BUS}$  allowed to drop below 190 psig.

Bearing Coolant Temperature: At no time shall the temperature difference across the test bearings ( $T_{BDS} - T_{BUS}$ ) or the slave bearing ( $T_{MH} - T_{BDS}$ ) exceed 10°R.

Operating Sound: The cognizant Project Engineer listening over the microphone at the tester shall have the prerogative to command a kill.

Flow Rate: A flow rate indication of less than 50 gpm at  $F_{FMFS}$  shall constitute cause to terminate the test.

Coolant Inlet Temperature: If  $T_{BUS}$  exceeds 54°R, the test is to be terminated unless authorized by Test Request Supplement.

## 8.0 Data Reduction:

8.1 Test Operations "Data Handling Plan", (Reference d) defines the data acquisition and handling plan for the Bearing Test Program and shall be implemented to process the necessary data. Figure 1 of Reference (d) displays the data acquisition flow path and Figure 2 details the data processing plan for Bearing Test Displacement Transducers (Figures 1 and 2 are attached for reference).

8.2 Data listings (in E.U.) and plots are required for the startup and shutdown transient periods (200 seconds) at one sample/second intervals. For the steady state period, data listings and plots are required at one minute intervals.

8.3 Subsequent to each test run, the designated Project Engineer shall prepare a Data Request form defining in detail other data reduction requirements, time slices, etc. for each test run.

## 9.0 General Remarks:

9.1 Test Request Supplements (TRS) will be issued as necessary to outline specific procedures, or changes in operating parameters.

9.2 At least one of the following project engineers will witness, in detail, the bearing tests, and maintain an appropriate documentation log.

D. A. Koch  
D. H. Duke  
J. B. Accinelli  
F. Reuter

9.3 Evaluation of test results will be performed by the Project Engineers who also will maintain a detail summary of the test results.

9.4 Follow Q/A requirements of ANSC Memo N7000:2072 dated 6-8-71, "Q.A. Requirements for testing 65mm Bearings".

9.5 Applicable Turbomachinery Procedures for assembly, disassembly, installation and removal are listed below for reference.

TMP-102	Buildup Procedure (65MM) Duplex Ball Bearing Tester, Dwg. No. 1138990
TMP-103	NERVA Bearing Tester Assembly (65mm) P/N 1138060-2 Ball Bearing Rev.B.
TMP-105	NERVA Bearing Tester Disassembly (65mm) P/N 1138060-2 & 3, Ball Bearing Check List
TMP-107	Disassembly Procedure for 65mm Duplex Ball Bearing Tester per Dwg 1138990
TMP-108	Cartridge/Housing Interface Clearance Tester - 65mm Ball Bearing Tester P/N 1138060
TMP-110	Installation - Bearing Tester Assy (65mm) Rev. A
TMP-111	Removal - Bearing Tester Assy

TMP-112 NERVA Bearing Tester (65mm) P/N 1138060-2 & -3 Pre- and Post-  
test Conditioning Requirements

TMP-113 NERVA Bearing Tester (65mm) P/N 1138060-2 & -3 Rotational Direction  
Procedure

TABLE I  
INSTRUMENTATION & REQUIRED PARAMETERS

PARAMETER	NRDS CHANNEL	DESCRIPTION	RANGE	RECORDING		NOMINAL EXPECTED VALUE
				STRIP	PERMANENT	
<u>PRESSURE</u>			PSIG			PSIG
1. $P_R$	BP-106	Radial Loader	0-1000	X	X	190
2. $P_V$	BP-107	Loader Vent	0-500	X	X	25 - 100
3. $\Delta P_{RV}$	BP-110D	Radial Force	0-500	X	X	135 psi
4. $P_{FMFS}^*$	BP-101	Inlet Flowmeter	0-500	X	X	260
5. $P_{BUS}^*$	BP-102	Bearing, Upstream	0-500	X	X	225
6. $P_{BDS}^*$	BP-111	Bearing, Downstream	0-500	X	X	225
7. $P_{BH}^*$	BP-104	Bearing, Housing	0-500	X	X	225
8. $\Delta P_{BUS/BDS}$	BP-108D	$\Delta P$ across Bearings	$\pm 10$ Psi	X	X	$\pm 2$ psi
9. $P_A$	BP-105	Axial Loader	0-500	X	X	130
10. $\Delta P_{BUS/PA}$	BP-109D	Axial Force	0-500	X	X	100 psi
11. $P_{LDH}^*$	BP-112	Tester Outlet	0-500	X	X	225
12. $P_{LSH}^*$	BP-103	Tester Inlet	0-500	X	X	225
<u>TEMPERATURE</u>			$^{\circ}R$			$^{\circ}R$
1. $T_V$	BT-108	Vent	35-590	X	X	450
2. $T_{FMFS}^*$	BT-101	Flow Meter	35-80	X	X	45
3. $T_{BUS}^*$	BT-102	Bearing, Upstream	35-80	X	X	46
4. $T_{BDS}^*$	BT-106	Bearing, Downstream	35-80	X	X	51
5. $T_{MH}^*$	BT-104	Motor Housing	35-80	X	X	55
6. $T_{LDH}^*$	BT-109	Tester Outlet	35-80	X	X	55
7. $T_{LSH}$	BT-107	Tester Inlet	35-80	X	X	45
8. $T_{BH}$	BT-103	Bearing Housing	35-80		X	45
<u>FLOW</u>			GPM			GPM
$F_{FMFS}$	BF-001	Flowmeter	0-100	X	X	50 - 70

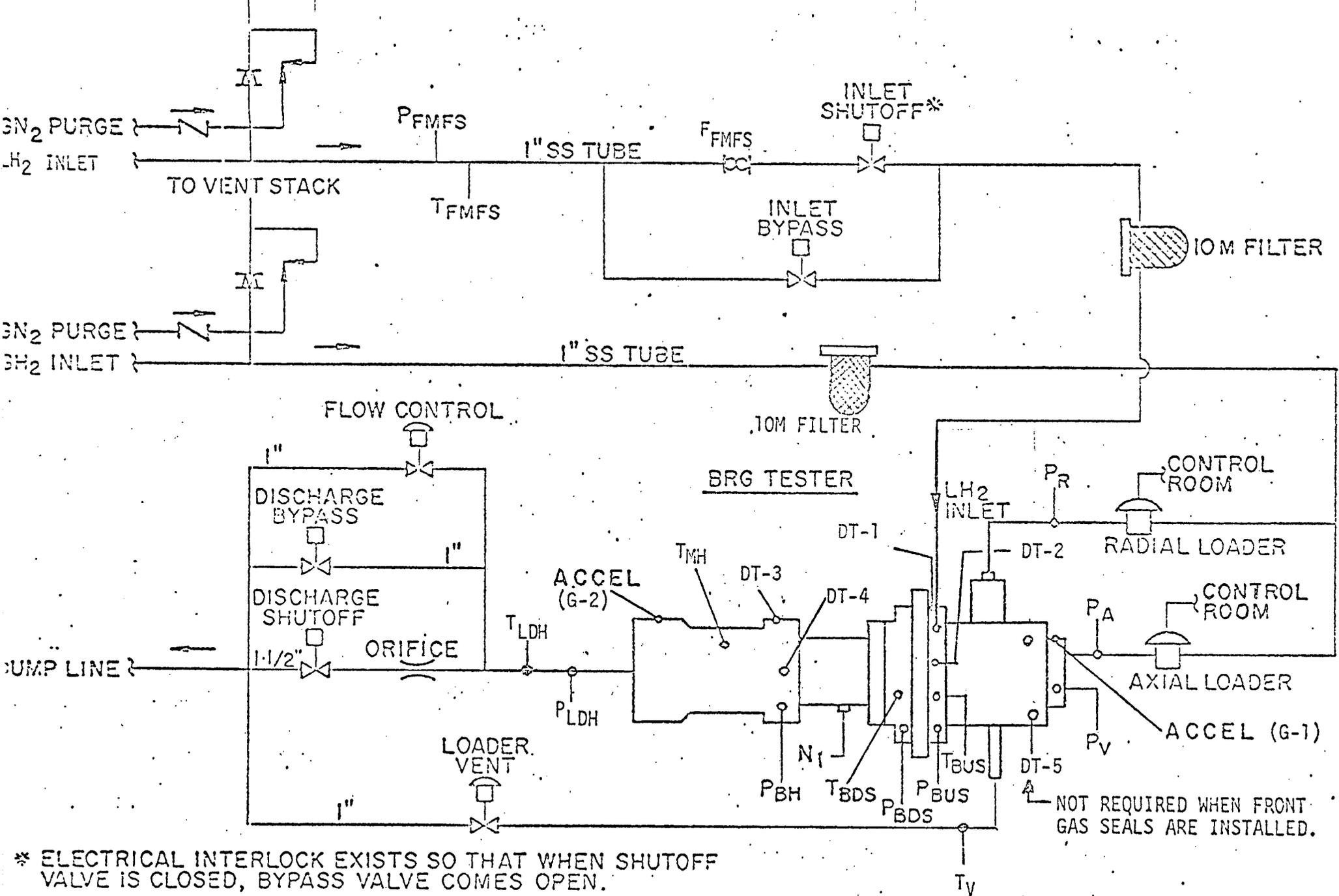
\*Fluid Pressures and Temperatures: BUS - Upstream of Test Bearing.  
BDS - Downstream of Test Bearing

BH - in Bearing Housing  
MH - Motor Housing

TABLE I (Continued)  
INSTRUMENTATION & REQUIRED PARAMETERS

PARAMETER	NRDS CHANNEL	DESCRIPTION	RANGE	RECORDING		NOMINAL EXPECTED VALUE	
				STRIP	PERMANENT		
<u>SPEED</u>							
			RPM			RPM	
N-1	BQ-001	Tester Speed	0-40,000	X	X	6000-30,000	
N-2	BQ-002	Tester Speed	0-40,000	X		6000-30,000	
<u>MOTOR</u>							
V <sub>M</sub>	BH-001	Voltage	0-500 volts	X		230 volts	
I <sub>MA</sub>	BI-001	Current, ∅ A	0-150 amps	X	X	45 - 70 amps	
I <sub>MB</sub>	BI-002	Current, ∅ B	0-150 amps	X	X	45 - 70 amps	
I <sub>MC</sub>	BI-003	Current, ∅ C	0-150 amps	X	X	45 - 70 amps	
f	BY-001	Frequency	0-700 cps	X	X	33 - 500 cps	
<u>MISCELLANEOUS</u>							
<u>SHAFT DISPLACEMENT</u>				<u>WIDE BAND</u>		<u>ΔMVT (in.)</u>	
				(SCOPES)	(TAPE)	From Set point	(SCOPE) (TAPE)
<u>SHAFT DISPLACEMENT</u>			Inches <sup>(1)</sup>				
DT-1	BD-001	Fwd Bearing 0°	±.00125	X	X	± .001	± .002
DT-2	BD-002	Fwd Bearing 90°	±.00125	X	X	± .001	± .002
DT-3	BD-003	Aft Bearing 0°	±.00125	X	X	± .001	± .002
DT-4	BD-004	Aft Bearing 90°	± .00125	X	X	± .001	± .002
DT-5	BD-005	Loader Housing	.0025 - .0275		X		± .010
<u>ACCELEROMETERS</u>							
G-1	BA-001	Fwd Housing	100 g's peak/peak	X	X	50 g's peak/peak	
G-2	BA-002	Aft Housing	100 g's peak/peak	X	X	50 g's peak/peak	

(1) Applies to scope ranging; tape ranging is .002 to .027 inches.

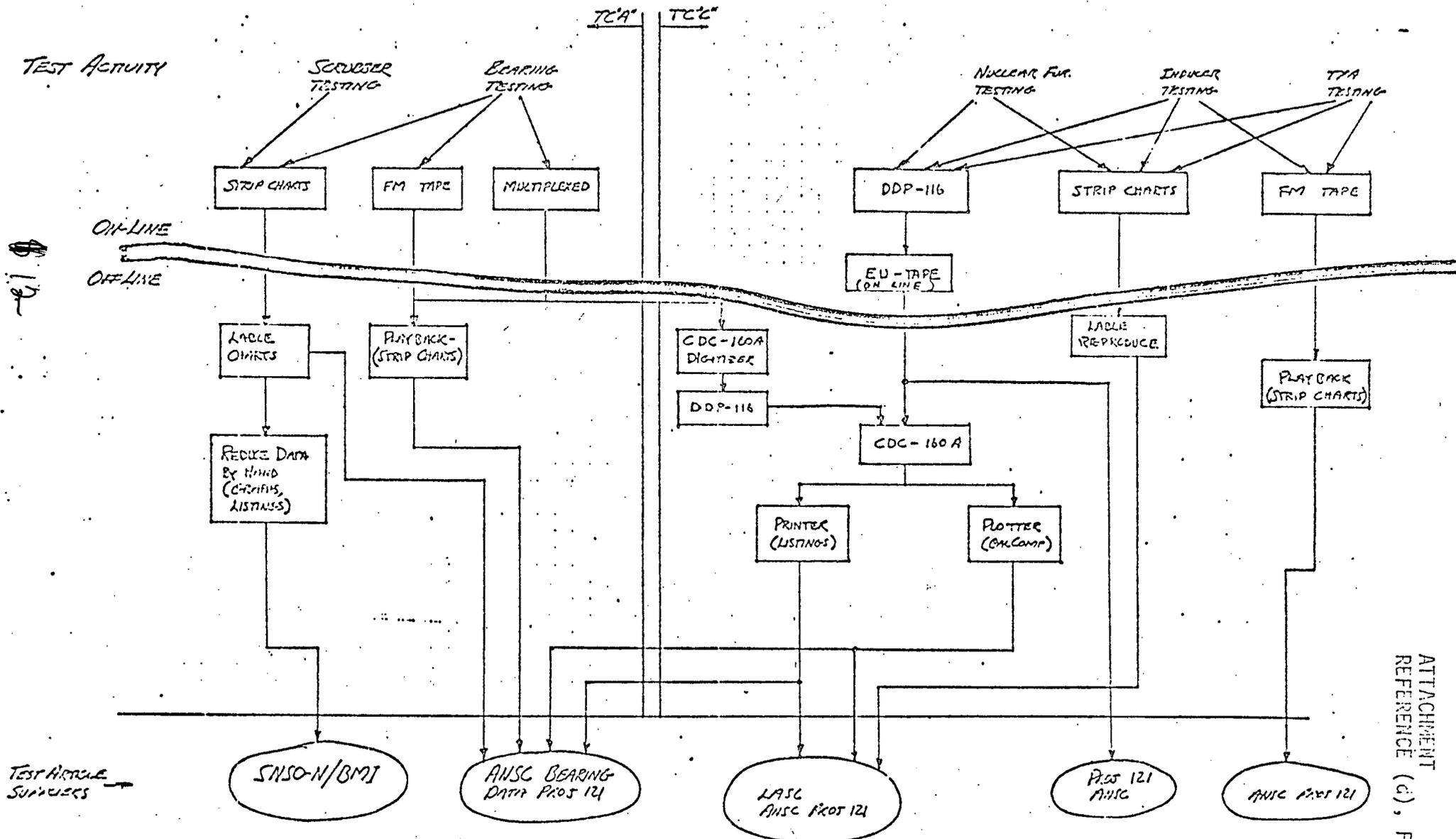


TEST STAND SCHEMATIC

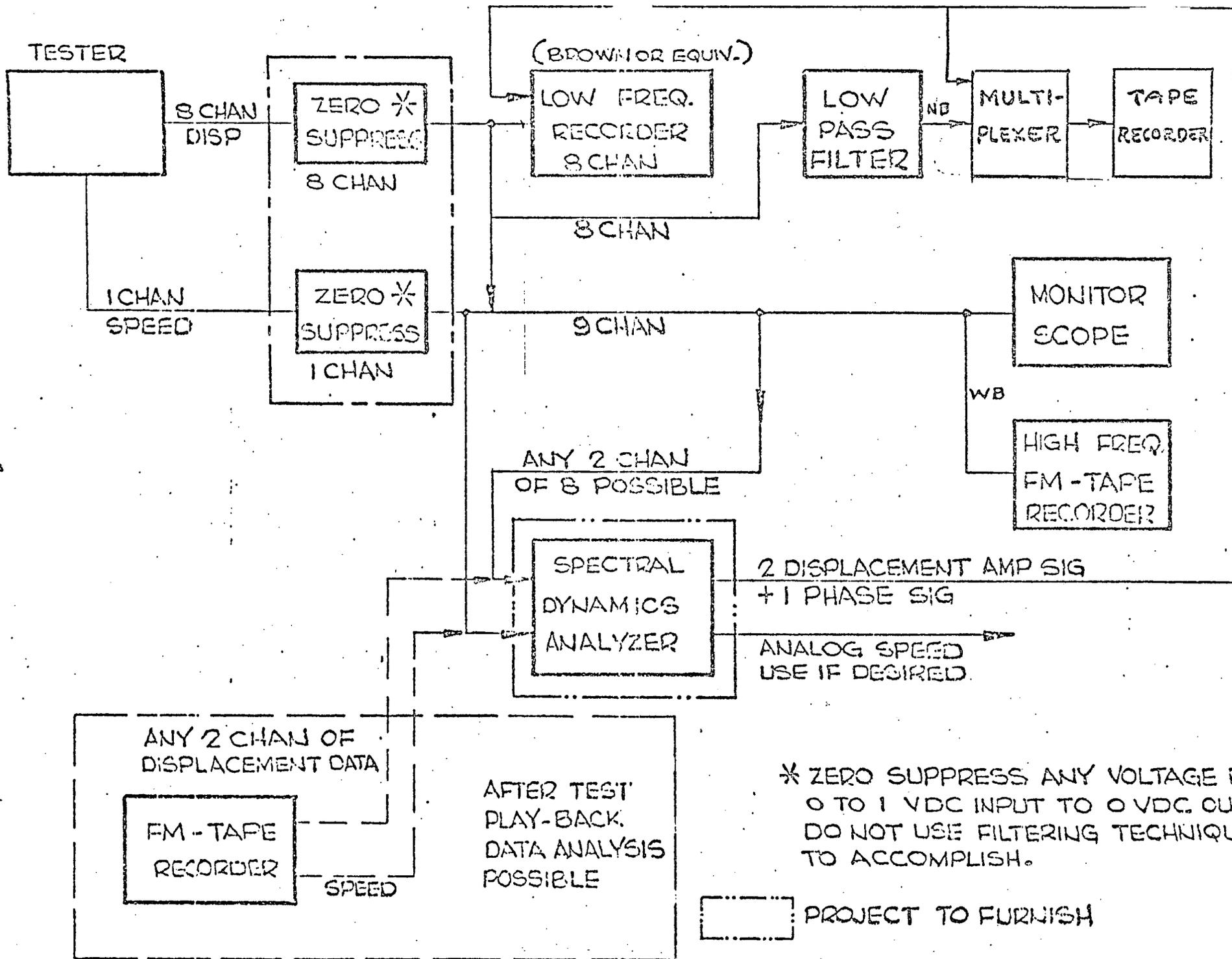
LH<sub>2</sub> 65mm DUPLEX BALL BEARING AND ROLLER BEARING TESTER

FIGURE 1

- DATA ACQUISITION & HANDLING FLOW PATH -



ATTACHMENT  
REFERENCE (C), FIGURE 1



\* ZERO SUPPRESS ANY VOLTAGE FROM 0 TO 1 VDC INPUT TO 0 VDC. OUTPUT. DO NOT USE FILTERING TECHNIQUES TO ACCOMPLISH.

PROJECT TO FURNISH

PROJECT CAN FURNISH IF DESIRED

<input type="checkbox"/> BASIC TEST REQUEST	SECURITY CLASSIFICATION			
	<input checked="" type="checkbox"/> UNCLASSIFIED	<input type="checkbox"/> CONFIDENTIAL	<input type="checkbox"/> SECRET	<input type="checkbox"/> OTHER (EXPLAIN)
<input checked="" type="checkbox"/> SUPPLEMENT NO. 1	S T NUMBER	TEST SERIES NO.	WORK CHARGE NO.	GWA REFERENCE TP.
G. D. Westcot		1190-65-XXX		
			BLDG. 2019A	DEPT. N5300
REQUESTED BY:		BLDG.	DEPT.	EXT.
M. W. Young/W. A. Edlebeck		2019A	N8300	4661
				DATE
				23 June 1971
ACTION APPROVAL		DATE	ESTIMATED COMPLETION DATE	
MANHOURS	INSPECTION REQUIREMENTS			

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

This Supplement revises and adds the following sections to the Basic Test Request (1190-65-XXX) dated 3 May 1971.

SECTION 9: TEST ARTICLE RESPONSIBILITIES (REVISED)

SECTION 10: QUALITY ASSURANCE REQUIREMENTS (ADD)

DISTRIBUTION

B. Accinelli, C. S. Boncore, F. B. Damerval, D. H. Duke, N. A. Edlebeck, H. D. Greenwood, D. A. Koch, M. J. Margetts, F. E. Porter, F. Reuter, M. W. Young

9.0 TEST ARTICLE RESPONSIBILITIES:9.1 Test Requirement Engineer (TRE)

F. Reuter, Phone (916) 355-3649, ANSC will be the TRE and the Senior TAS Representative. All correspondence pertaining to the test article or tests to be conducted shall be directed to him.

Other Bearing Project Engineers acting as TRE will be assigned to each buildup and shall be responsible for that particular test article from initiation of the Test Request Supplement to Buildup Summary Report. These activities will include responsibility for specific instrumentation requests, assembly and disassembly instructions, witnessing the tests and maintaining appropriate documentation logs. At least one of the following Bearing Project Engineers will witness in detail the bearing tests and act as TRE:

D. A. Koch, D. H. Duke, J. B. Accinelli

The designated TRE for each buildup shall be responsible for the assessment of bearing performance during the conduct of the test as well as the decision to terminate or continue testing. In concurrence with the Test Director, he shall have the liberty to change operating parameters during the test as long as they are within the scope of the Test Request Supplement.

9.2 Test Request Supplements

Test Request Supplements (TRS) shall be prepared by the TRE. All instructions to NRTO will be via TRS for each buildup and these will outline specific procedures, data requests, or changes in operating parameters.

9.3 Receiving and Inspection

Receiving and pretest inspection of ball bearings shall be performed at the AGC Measurements Standards Laboratory (MSL), Sacramento. Bearing Tester hardware shall have traceability system consistent with procedures outlined in "Quality Assurance Requirements for the 65MM Bearing Test Program" (Appendix B).

9.4 Assembly

NRTO shall assemble each buildup of the Bearing Testers in accordance with instructions from TRE via a TRS. Assembly shall be performed in the E-MAD clean room under the cognizance of the designated TRE. The Assembly Procedure for Bearing Testers P/N 1138060-2 & 3 (TMP-103A) appear in Appendix A. The assembly procedure checklist shall be maintained by the designated TRE and become part of the individual log books maintained for each buildup. Assembly shall be under the surveillance of the Quality engineer.

### 9.5 Disassembly

E-MAD personnel shall disassemble each buildup of the bearing testers upon termination of the test series. Disassembly will be in accordance with instructions from the designated TRE and shall be performed in the E-MAD clean room using the Disassembly Procedure Checklist (TMP-105A) which will be transmitted later. The Disassembly Procedure Checklist shall be maintained by the designated TRE and become part of the individual log book for that buildup.

### 9.6 Installation and Removal of Test Article

E-MAD assembly personnel under TRE cognizance, will be responsible for transfer of the assembled tester to Test Cell A, installation of the tester in the test stand, hook-up of instrumentation and piping, and checkout to an interface patch panel. After installation, hook-up and checkout, Test Operations shall assume responsibility for operations. Upon termination of the test, E-MAD personnel will assume responsibility for disconnect of instrumentation and piping, and the removal and transfer of the tester to E-MAD for disassembly. Transfer of test articles shall be in the shock-insulated crates provided by the TAS.

### 9.7 Maintenance and Storage

Bearing testers will be stored at E-MAD clean room and maintained in accordance with TRE instructions.

### 9.8 Test Planning

Detailed test planning is the responsibility of NRT0. The Test Operating Procedure (TOP) shall be approved by the TRE prior to conduct of the test.

## 10.0 QUALITY ASSURANCE REQUIREMENTS

Quality Assurance provisions for the 65MM Bearing Test Program at NRDS have been established in enclosure to ANSC Memo N7000:2072, F. E. Porter to Distribution and dated 8 June 1971. The enclosure appears in Appendix B.

## 11.0 TEST SERIES IDENTIFICATION

Project plans to use the following test numbering scheme for general test information and specific buildup-test identification.

11.1 Basic Test Request and General Information Supplements will bear the following identification:

Basic Test Request: 1190-65-XXX

Test Request Supplement: 1190-65-XXX Supplement No. 1

(General Information)

No. 2

etc.

11.2 Buildup-Test Identification

1st Buildup, Run 1:	1190-65-016-001
1st Buildup, Run 2:	-016-002
1st Buildup, Run 3:	-016-003 etc.
2nd Buildup, Run 1:	1190-65-017-001
2nd Buildup, Run 2:	-017-002 etc.
3rd Buildup, Run 1:	1190-65-018-001 etc.

QUALITY ASSURANCE REQUIREMENTS FOR THE TESTING  
OF 65MM BEARINGS AT NRTO

8 June 1971

This is the quality control requirements supplement to the Test Plan for the Evaluation of LH<sub>2</sub> Cooled 65MM Rolling Element Bearings for the NERVA Engine. TPA (Report M100-TTFO3-W121) and defines quality assurance provisions for operations at NRTO. The quality control requirements supplement, issued as enclosure (1) to memorandum W7CCO:1107, is limited to operations performed by ANSC at Sacramento.

### 1.0 General Requirements

1.1 The M100-TTFO3-W121, data item, dated December 1970 is the basic controlling document. Supplementary instructions, assembly and disassembly procedures, test requests and test procedures will be issued by or in coordination with ANSC project engineering. The project engineer provides program direction to quality assurance and has engineering authority including decisions related to hardware acceptance and use. He provides support in the performance of quality assurance tasks and resolution of quality problems.

1.2 This quality assurance supplement to the test plan is the basic document defining the quality assurance provisions for bearing testing phase conducted at NRTO. The ANSC project quality engineer provides quality assurance direction and support to the test program.

1.3 The NRTO quality assurance representative is responsible for quality assurance support for NRTO operations.

NRTO quality assurance responsibility includes:

- a) Review NRTO procedures for test article installation, and test check-out for completeness and accuracy.
- b) Verification of test article installation, instrumentation, pre-test check-out, and monitor dry runs and testing at Test Cell A.
- c) Assurance that all discrepancies related to NRTO test operations are documented and resolved.

1.4 The Test Operations Directive (TOD) initiates conduct of tests on ANSC supplied test articles, at NRTO, and sets forth the methods by which NRTO responds to ANSC component engineering requirements. These quality assurance provisions take into consideration NRTO-A-0001 and the controlling documents referenced therein.

1.5 All material transported between ANSC and NRTO will be covered with a ANSC shipper. NRTO will be contacted for shipments of ANSC material from NRDS. Shipment of test articles from NRTO to ANSC will be covered by a NRTO shipper.

## 2.0 Design and Development Controls

### 2.1 Drawings

Drawings and drawing changes for test article (bearings, bearing testers and equipment) will be prepared by ANSC project engineering at Sacramento.

### 2.2 Test Program Plans

2.2.1 Test program plans and revisions shall be submitted to ANSC quality assurance for review and comment.

2.2.2 Quality control requirement supplements shall be revised, as required, to complement revised test program plans.

## 3.0 Control of ANSC Procured Material

The preparation of requisitions and purchase orders shall be performed at ANSC Sacramento. The verification of the quality requirements will be provided for by ANSC quality assurance at source, or Sacramento receiving, or at destination.

## 4.0 Control of ANSC Fabricated Articles

4.1 In general, fabrication will be performed at Sacramento using inter-division orders (IDOs).

4.2 Items other than shop aids fabricated at NRTO shall be authorized and released through a system that provides for quality engineering review of work scope definition, manufacturing and processing controls and requirements for inspection and verification.

## 5.0 Control of ANSC Assembly and Disassembly Operations

### 5.1 Assembly/Disassembly Area

5.1.1 The assembly and disassembly of the test article, (bearings and bearing tester), will be accomplished in the plastic cleanroom at E-MAD to approved assembly/disassembly procedures. This area shall be maintained at a particle count level that will maintain test article and tester hardware to the cleanliness requirements of AGC-STD 9007, Level II.

5.1.2 Bearing tester assemblies will be retained in the cleanroom when not being used.

5.1.3 Spare parts and seals for the bearing testers will be maintained within the cleanroom. Obsolete bearing testers or used test equipment may be stored in the storage room off the receiving area within E-MAD. Accountability logs will be maintained for these items.

## 5.2 Assembly/Disassembly Procedures

The assembly procedures and checklists for installing the test article in the test equipment and set-up in the test facility shall be prepared by engineering, in accordance with the Test Request Supplements, and reviewed by quality engineering to insure incorporation of quality assurance verification points. Planning shall, as a minimum include:

5.2.1 Identification of the article.

5.2.2 Identification of specialized test or measuring equipment.

5.2.3 Identification of the inspection and test to be performed, with sufficient instructions to insure that the requirements are understood.

5.2.4 Criteria for passing or failing the inspection or test (usually the tolerance or criteria expressed on the drawing or in the specification).

5.2.5 The recording forms, when they are required.

5.2.6 The inspection status identification requirements.

Configuration shall be based upon assembly parts lists (APL) of the as-built configuration conforming to a basic parts list representative of a released drawing or an engineering parts list representative of a test set-up. Configuration of reassembly after disassembly shall be maintained to the APL, as further defined by the assembly check-off-list for the respective build-ups or by a new APL.

5.3 The work authorizing documents to perform assembly operations or to specify instrumentation shall be the Test Request supplements with appropriate review by ANSC quality engineering representative.

## 6.0 Control of Test Operations

### 6.1 Test Request

The Test Request detailing all technical requirements of the test, prepared by the project engineer, shall be submitted to ANSC quality engineering for review and comments.

### 6.2 Test Operation Directive (TOD)

Test Operations Planning shall provide copies of TODs to ANSC quality assurance for information and record.

### 6.3 Detailed Test Planning

6.3.1 The NRTO prepared detailed test procedure and process, prepared in accordance with NRTO-A-0001, shall be submitted to the NRTO quality

assurance representative for review and comments. Copies of NRTO QA review comments shall be provided to ANSC quality assurance for information and record.

6.3.2 ANSC quality engineering will provide the project engineer with review and comments for consideration in the design organization review/approval cycle.

#### 6.4 Installation of Test Article

E-MAD assembly personnel under ANSC surveillance as the test article supplier, will be responsible for transfer of the assembled tester to Test Cell A, installation of the tester in the test stand, hook-up of instrumentation, and check-out to an interface patch panel. After installation and instrumentation hook-up and check-out, NRTO shall assume responsibility for operations. Upon termination of the test, E-MAD personnel will assume responsibility for disconnect of instrumentation and the removal and transfer of the tester to E-MAD area for disassembly. ANSC quality assurance is responsible for verification that these operations are performed according to plan and that any unanticipated degradation of quality, discrepancies and failures that are observed, during the test and disassembly, are documented and resolved.

#### 6.5 Testing

NRTO quality assurance is responsible for verification that testing is performed in accordance with the test request and detailed test planning. He shall assure that all departures, discrepancies and nonconformances are accurately documented in the test record and on ANSC furnished inspection reports (IRs). He shall assure that copies of completed checklists and test procedures, reduced test data and other test records, with dispositioned copies of inspection reports, are available for ANSC review and subsequently delivered for insertion into the test article log book.

### 7.0 Control of Test Article (Bearings) Hardware

#### 7.1 Test Article Hardware

Bearings scheduled for test will be furnished (1) by ANSC and delivered to ANSC personnel at NRTO on an ANSC shipping memorandum or (2) direct from supplier on the supplier's shipping order, with copies of ANSC documentation evidencing verification of product quality and any pre-test data that may be required. All documentation will be maintained in the test article (bearing) log book at NRTO, E-MAD.

#### 7.2 Test Article Storage

All bearings will be stored in adequate containers in the E-MAD cleanroom. A log will be maintained in or near the container to account for bearings received for testing and removed for assembly into a tester. The log will provide an entry for each part number, change letter, serial number, purchase order and shipping

order, for each bearing. Upon removal, the number of the bearing tester into which it will be assembled and the build-up number will be entered on the same line as the receiving entry. The log shall provide accountability from receipt at NRDS to final disposition to ANSC, Sacramento.

### 7.3 Test Article Modification

Requests for modification to test article, bearings, shall be initiated by use of an Inspection Report and accomplished in accordance with the ERB disposition.

### 7.4 Post-Test Evaluation

Post-test evaluation of the tested bearings performed at NRDS will be conducted within the E-MAD cleanroom, in accordance with ANSC approved procedures. The equipment for this evaluation will be located available to the operation.

All nonconformances, defects and failures will be recorded on an ANSC Inspection Report, IR, for each serial numbered bearing. The IRs will be dispositioned at NRTO, including shipping bearings and bearing components to ANSC for subsequent examination. In the absence of a ANSC quality assurance representative, NRTO quality assurance may sign for quality assurance on the IR. Such assistance by NRTO quality assurance will be on a noninterference basis with his other work assignments.

### 7.5 Hardware Acceptance

7.5.1 New Hardware - Based on compliance to drawing requirements. Provision for conditional acceptance of instrumentation or equipment when compliance to requirements are not verified by ANSC.

7.5.2 Used Hardware - Based on designated use and provision on prepared parts lists.

7.5.3 Commercial Hardware - As a minimum, shall be inspected for identification and condition. More extensive inspection requirements shall be coordinated with the quality engineer.

7.5.4 Nonconforming Hardware - Nonconformances shall, as applicable be reported on Inspection Reports (IRs).

7.5.5 ERB, with primary responsibility for decision of usability assigned to engineering, shall be used to determine hardware acceptance. Quality engineering shall consider the need for discrepancy/failure analysis for cause and for corrective action.

7.5.6 Lack of traceability or evidence of acceptance shall be reported for disposition/decision.

## 7.6 Residual Hardware

When testing is completed, engineering and quality engineering shall jointly disposition the tested bearings. This disposition shall indicate the area of storage and responsibility of the person or area assuming custody of this hardware.

## 8.0 Documentation

8.1 Procurement documentation evidencing product acceptance shall be retained in the quality assurance documentation center.

8.2 Copies of all test plans, test requests, and procedures shall be directed to the project quality engineer for information and file in the quality assurance documentation center.

8.3 Assembly planning, including parts lists and nonconforming documentation shall be directed to the project quality engineer for filing in the quality assurance documentation center.

8.4 A preliminary summary of test results shall be prepared by engineering after each disassembly on a prepared form, which will provide for the information required before test and after test and will become a traceable document identified by part number and serial number.

NUCLEAR ROCKET TEST OPERATIONS

TEST OPERATING PROCEDURE

FOR

PHASE I BEARING

BUILDUP \_\_\_\_\_ EP \_\_\_\_\_

ROTATIONAL TESTS

RUN 1190-65 \_\_\_\_\_

Prepared by:

*P. E. Ortstadt*  
P. E. Ortstadt  
Chief Test Operator  
Bearing Program

Reviewed by:

Approved by:

*C. A. DeLorenzo*  
C. A. DeLorenzo  
NRTO Health and Safety

*D. D. Vander Meer*  
D. D. Vander Meer, Test Director  
Bearing Program

*R. J. Smart*  
R. J. Smart  
NRTO Quality Assurance

*F. L. DiLorenzo*  
F. L. DiLorenzo, Project Coordinator  
Bearing Program

TAS Agreement:

*L. E. Little*  
L. E. Little, Manager  
Nuclear Rocket Test Operations

\_\_\_\_\_  
ANSC/TRE/PE

CATEGORY II

RUN DAY ISSUE

\_\_\_\_\_  
Date

1.0

INTRODUCTION AND TEST SUMMARY

The NERVA TPA Bearing Test Program will be performed at Test Cell "A," NRDS, Jackass Flats, Nevada, to support development of LH<sub>2</sub> cooled 65 MM duplex ball bearing for the NERVA Engine TPA. The Bearing Test Program at Test Cell "A" will utilize a Phase I facility for initial bearing tests and a Phase II facility for final bearing tests. This document has been prepared in accordance with NRTO-A-0001 to present the checklist operations for the Rotational Test of Bearing Test Assembly \_\_\_\_\_ as required by ANSC Bearing Test Request Supplement No. \_\_\_\_\_.

A single Duplex Set Bearing Tester will be used. This EP is "rotational"; hence, the MG set will be used. A detailed description of the test hardware and facility will be found in NRTO-R-0212, "Test Description for Facility Experimental Plan and Bearing Test Series at Test Cell 'A'".

The pre-test operations, e.g., setup checklist review, communications check and voltage calibration, will be conducted preparatory to the test operations. During the Test Operations phase, Dewar D will be pressurized and the system will be chilled. Following chilldown, dewar pressure will be increased to establish pre-start conditions after the radial and axial loads for start will be set. The tester motor will be started and speed to 12,000 rpm obtained. After a hold period, the tester motor and tester loads will be adjusted to the optimum values for the duration of test.

2.0 PRE-TEST OPERATIONS

The activities to be performed during this phase include: Setup checklist review, communications check, voltage calibration, operator readiness check, system readiness check and final area sweep of all personnel.

2.1 TEST AUTHORIZATION/APPROVAL RECEIVED

NRTO Manager \_\_\_\_\_

2.2 TEST NOTIFICATION COMPLETE

NRTO Health and Safety \_\_\_\_\_

NRDS Emergency Response Team \_\_\_\_\_

NRDS Security (Wackenhut) \_\_\_\_\_

NRTO Manager \_\_\_\_\_

2.3 VERIFY SETUP CHECKLIST COMPLETE

NRTO-SOP-0231, "TCA Facility Setup and Secure for Bearing Program"

NRTO-SOP-0232, "TCA I&C and Electrical Pre-test and Post-test Secure for Bearing Program"  
(with the exception of MG startup)

NRTO-SOP-0233, "Bearing Tester Prefire Checkout and Secure"

NRTO-SOP-0235, "Bearing Dehydration Purge, TCA"

2.4 VERIFY EXCLUSION AREA (FIG 1) ESTABLISHED AND ALL PERSONNEL, EXCEPT THOSE ON ACCESS LIST, CLEAR OF AREA. \_\_\_\_\_

(TD Make P.A. Announcement)

2.5

VERIFY COMMUNICATIONS SYSTEM READY

Check Setup Team Communications.

\_\_\_\_\_

Check Emergency Call Station (Net 22).

\_\_\_\_\_

Check Control Room Net.

\_\_\_\_\_

	<u>PRIMARY</u>		<u>BACKUP</u>
TD	_____	TD	_____
CTO	_____	CTO	_____
ACTO	_____	ACTO	_____
FO	_____	FO	_____
ICPO	_____	ICPO	_____
TLM	_____	TLM	_____
TVC	_____	TVC	_____
TRE	_____	TRE	_____
SCOPE	_____	SCOPE	_____

2.6

ICPO/CTO: PERFORM VOLTAGE CALIBRATION.

\_\_\_\_\_

2.7

ICPO: START M.G. SET.

\_\_\_\_\_

2.8

CLEAR TEST AREA OF ALL PERSONNEL.

\_\_\_\_\_

2.9

VERIFY ALL OPERATORS READY AT STATIONS. \_\_\_\_\_

	<u>PRIMARY</u>		<u>BACKUP</u>
TD	_____	TD	_____
CTO	_____	CTO	_____
ACTO	_____	ACTO	_____
FO	_____	FO	_____
ICPO	_____	ICPO	_____
TLM	_____	TLM	_____
TVC	_____	TVC	_____
TRE	_____	TRE	_____
SCOPE	_____	SCOPE	_____

2.10

VERIFY SYSTEM READINESS

Bearing Tester Console

- a. Master Power ON. \_\_\_\_\_
- b. BR-32/BR-34 Enable Switch ON. \_\_\_\_\_

Instrumentation \_\_\_\_\_

Power System \_\_\_\_\_

Data Recorders

- a. Beckman\*
- b. L&N\*
- c. Tape

Television \_\_\_\_\_

Hydrogen Analyzers \_\_\_\_\_

Control Room Pressurization

Area Warning

Deluge System

- a. Verify "DEL AP" switch in "T" Mode.
- b. Verify B-99BP switch in "SENS" Mode.

Fluid Inventory

GN<sub>2</sub> PgN<sub>2</sub>S (BP-60)

GHe PgHeS (BP-50)

GH<sub>2</sub> PgH<sub>2</sub>S (BP-10)

LH<sub>2</sub>

H<sub>2</sub>O

\*NOTE: Verify that test limits have been appropriately marked.

2.11 TLM ASSIGNMENT SHEET COMPLETED AND MONITORS BRIEFED.

3.0 TEST OPERATIONS

Initially, Dewar D will be pressurized to 50 psig and system chilldown established (3.1 and 3.3).

When stable LH<sub>2</sub> temperatures have been obtained, Dewar D will be pressurized to obtain 225 psig at P<sub>BUS</sub>. The gas load systems will be set up to obtain pretest run

conditions of PV at 175 psig and  $\Delta P_{RV}$  at 35 psid (3.4 to 3.6). The motor will be started and  $N_T$  brought to 12,000 rpm at which time tester parameters will be observed. The motor speed and bearing loads will be set to values desired for duration run as predicted by previous run data and cognizant TRE and TD decision.

3.1 \_\_\_\_\_ ICPO: Start "Bleed-In" data recorders:

- a. L&N            6 ipm
- b. Beckman        1 mm/s
- c. Brown           6 ipm

3.2 \_\_\_\_\_ CTO: Pressurize dewar and perform system chilldown.

1. \_\_\_\_\_ Verify the following valves CLOSED:

B-10 \_\_\_\_\_ B-19 \_\_\_\_\_

2. \_\_\_\_\_ Verify  $P_A$  and  $P_R$  handloaders vented.

3. \_\_\_\_\_ Verify B-31 OPEN.

4. \_\_\_\_\_ Verify B-13/B-14 in "BP" mode.

5. \_\_\_\_\_ OPEN or verify OPEN the following valves:

B-11 \_\_\_\_\_ BR-32 \_\_\_\_\_ B-30 \_\_\_\_\_

B-33 \_\_\_\_\_ B-19 \_\_\_\_\_ B-10 \_\_\_\_\_

6. \_\_\_\_\_ CLOSE B-04 and B-06.

7. \_\_\_\_\_ Set 50 psig on  $P_g$  PRD.

8. \_\_\_\_\_ OPEN B-02. Range Time \_\_\_\_\_ seconds.

9. \_\_\_\_\_ Report when  $P_{FT}$  stable.

NOTE: Monitor TV for system leaks.

10. \_\_\_\_\_ When  $T_{FMFS}$  indicates less than  $80^{\circ}R$ , CLOSE B-19.
11. \_\_\_\_\_ When  $T_{FMFS}$  indicates  $53^{\circ}R$ , continue chill-in for another 10 minutes; then CLOSE B-33.
12. \_\_\_\_\_ Position BR-32 at 10% OPEN.
13. \_\_\_\_\_ Intermittently cycle B-13/B-14 to "FM" mode (Note: Do not exceed 100 gpm on FMFS) until 5 additional minutes of chillover is achieved.
14. \_\_\_\_\_ When FMFS stabilizes, perform the following operations:
  - a. \_\_\_\_\_ Place B-13/B-14 in "FM" mode.
  - b. \_\_\_\_\_ Verify B-33 CLOSED
  - c. \_\_\_\_\_ OPEN BR-32 to maintain chill-in and CLOSE B-31.
15. \_\_\_\_\_ Report when  $T_{BUS}$  indicates  $<54^{\circ}R$ . Range time \_\_\_\_\_ sec.

3.3

.....  
 CTO: Pressurize dewar.

1. \_\_\_\_\_ Start all recorders except  $N_T$  and I and tape.  
 Range Time \_\_\_\_\_
2. \_\_\_\_\_ Verify the following valves OPEN:
  - B-10 \_\_\_\_\_
  - B-11 \_\_\_\_\_ BR-32 \_\_\_\_\_ controlling at \_\_\_\_\_ % OPEN
3. \_\_\_\_\_ Verify the following valves CLOSED:
  - B-19 \_\_\_\_\_
  - B-31 \_\_\_\_\_
  - B-33 \_\_\_\_\_

4. \_\_\_\_\_ Verify B-13/B-14 in "FM" mode.

NOTE: During dewar pressurization, use BR-34 to maintain  $\Delta P_{BUS}/P_V$  at 25 to 150 psid. If necessary, hold pressurization to establish load gas pressures by Paras. 3.4 and 3.5.

5. \_\_\_\_\_ Set dewar pressure to establish 225 psig at  $P_{BUS}$ .

6. \_\_\_\_\_ Use BR-32 to maintain 55 gpm at FMFS.

7. \_\_\_\_\_ Report  $T_{BUS}$  when stable (\_\_\_\_\_°R) and  $P_{ft}$  (\_\_\_\_\_psig).

3.4 \_\_\_\_\_ CTO: Set radial loader pressure.

1. \_\_\_\_\_ Verify BR-34 CLOSED or in control, and  $P_V$  less than 135 psig.

2. \_\_\_\_\_ Verify B-81 OPEN.

3. \_\_\_\_\_ CLOSE BE-82.

4. \_\_\_\_\_ Set 210 psig on  $P_R$  and use BR-34 to maintain 175 psig at  $P_V$  ( $\Delta P_{RV} = 35$  psid).

3.5 \_\_\_\_\_ ICPO: Start  $N_T$  and I recorders and tape.

3.6 \_\_\_\_\_ CTO/TLM: Report or establish the following pre-test parameters:

\_\_\_\_\_ FMFS 55 gpm

\_\_\_\_\_  $P_{BUS}$  225 psig  $\pm$  10 psig

\_\_\_\_\_  $P_V$  175 psig  $\pm$  5 psig

\_\_\_\_\_  $\Delta P_{RV}$  35 psid

\_\_\_\_\_  $T_{BUS}$   $<54^{\circ}R$

\_\_\_\_\_ Range time for D.P. #1

\_\_\_\_\_ Motor frequency set for 200 Hz

\_\_\_\_\_ Motor voltage set for 100V

NOTE: FO monitor the following during motor start and be prepared to shut down motor if conditions are not met:

- a. \_\_\_\_\_ 3,000 rpm minimum at M.S. + 5 sec.
- b. \_\_\_\_\_ 12,000 rpm minimum at M.S. + 20 sec.
- c. \_\_\_\_\_ I less than 100 amps at M.S. + 5 sec.

3.7 \_\_\_\_\_ CTO/FO: Standby for motor start sequence on countdown.

Range time at start \_\_\_\_\_.

1. \_\_\_\_\_ 5-4-3-2-1-motor start.

2. \_\_\_\_\_ FO: Verify start sequence Good.

\_\_\_\_\_ CTO: Decrease  $P_V$  to 125 psi

and

Increase  $\Delta P_{RV}$  to 135 psid.

3.8

\_\_\_\_\_ CTO/TLM: Report or establish the following conditions:

\_\_\_\_\_  $T_{BUS}$  < 54°R

\_\_\_\_\_  $P_{BUS}$  225 psig

\_\_\_\_\_ FMFS 55 gpm

\_\_\_\_\_  $P_V$  125 psig

\_\_\_\_\_  $\Delta P_{RV}$  135 psig

\_\_\_\_\_  $P_R$  260 psig

\_\_\_\_\_  $N_T$  12,000 rpm

\_\_\_\_\_  $I$  \_\_\_\_\_ amps

1. \_\_\_\_\_ ICPO: Check Kaman and Spectral Dynamics System operation.

2. \_\_\_\_\_ T.D.: Acknowledge authorization to proceed.

3.9 \_\_\_\_\_ CTO/FO: Increase load and speed to run conditions.

1. \_\_\_\_\_ CTO: Adjust  $\Delta P_{RV}$  to \_\_\_\_\_ psid while maintaining preset on  $P_V$ .
2. \_\_\_\_\_ FO: Adjust  $N_T$  to \_\_\_\_\_ rpm. Range Time \_\_\_\_\_.
3. \_\_\_\_\_ TLM: Report run condition parameters.

_____ $T_{BUS}$	54°R
_____ $P_{BUS}$	225 ± 10 psig
_____ FMFS	55 to 60 gpm
_____ $P_V$	125 psig
_____ $\Delta P_{RV}$	_____ psig
_____ $P_R$	_____ psig
_____ $N_T$	_____ rpm
_____ I	_____ amps

\_\_\_\_\_ Range Time D.P. #2

4. \_\_\_\_\_ CTO/FO: Maintain above flow conditions until test termination.

3.10

TEST CONDITIONS/REMARKS

Range Time

Remark

<u>Range Time</u>	<u>Remark</u>
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

4.0

SHUTDOWN AND SECURE

4.1

\_\_\_\_\_ CTO/FO: Standby for motor stop on countdown.

Range time at stop \_\_\_\_\_.

1. \_\_\_\_\_ 5-4-3-2-1-motor stop.
2. \_\_\_\_\_ FO: Call out 0 rpm.
3. \_\_\_\_\_ CTO: \_\_\_\_\_ Bypass Flowmeter  
\_\_\_\_\_ Vent P<sub>R</sub>  
\_\_\_\_\_ CLOSE B-10  
\_\_\_\_\_ CLOSE B-02  
\_\_\_\_\_ Control  $\Delta P_{BUS}/P_V$  with BR-34
4. \_\_\_\_\_ CLOSE B-81.

E

5. \_\_\_\_\_ Push "Motor Stop" button to shut off M-G set.

4.2 \_\_\_\_\_ ICPO: Stop all recorders.

4.3 \_\_\_\_\_ CTO: Secure Dewar and  $\text{GH}_2$  load systems.

1. \_\_\_\_\_ Vent Dewar to 0 psig.

2. \_\_\_\_\_ Vent  $P_g$  PRD to .50 psig.

3. \_\_\_\_\_ OPEN or Verify OPEN:

\_\_\_\_\_ BR-34

\_\_\_\_\_ B-30

4. \_\_\_\_\_ Crank  $P_R$  hand loader to 100 psig to vent gas lock up.

5. \_\_\_\_\_ When  $P_R$  and  $P_V$  indicate 0 psi, vent  $P_R$  hand loader.

6. \_\_\_\_\_ De-energize BE-82.

4.4 \_\_\_\_\_ CTO: Secure  $\text{LH}_2$  supply line.

1. \_\_\_\_\_ Verify B-10 CLOSED.

2. \_\_\_\_\_ OPEN B-19.

3. \_\_\_\_\_ CLOSE B-11.

4.5 \_\_\_\_\_ CTO: Purge Bearing Tester LH<sub>2</sub> Systems.

1. \_\_\_\_\_ OPEN or verify OPEN the following valves:

B-30 \_\_\_\_\_ BR-32 \_\_\_\_\_

BR-34 \_\_\_\_\_ B-31 \_\_\_\_\_

B-33 \_\_\_\_\_

2. \_\_\_\_\_ Verify B-13/B-14 in "BP" mode.

3. \_\_\_\_\_ OPEN B-50.

NOTE: During the following dilution purges, B-13/B-14 will be cycled at low pressure to avoid FMFS overspeed.

4. \_\_\_\_\_ After 5 minutes, CLOSE B-30 until P<sub>BUS</sub> indicates 50 psi, then OPEN B-30 for 2 minutes.

5&6 \_\_\_\_\_ Repeat last operation of step 4 two more times for a total of three He dilution purges, then CLOSE B-50.

7. \_\_\_\_\_ OPEN or verify OPEN the following valves:

B-30 \_\_\_\_\_ B-31 \_\_\_\_\_ BR-34 \_\_\_\_\_

8. \_\_\_\_\_ CLOSE BR-32 and B-33.

9. \_\_\_\_\_ Verify B-13/B-14 in "BP" mode.

4.6 \_\_\_\_\_ TD/CTO: Return TCA Facility Control to AFM.

5.0 CONTINGENCY CHECKLISTS

5.1 There are no Contingency Checklists for this TOP.

5.2 Re-entry, where necessary, will be conducted in accordance with NRTO-A-0090:006.

5.3 Emergency evacuation, where necessary, will be conducted in accordance with NRTO-A-0090:001.

## NRTO-TOP-6

TABLE 1

TEST OPERATING LIMITS

PARAMETER	CHANNEL	DISPLAY TYPE/LOCATION	LIMIT TYPE	LIMIT VALUE	NOMINAL EXPECTED OPERATING CONDITION	ALARM TYPE/SETTING	CORRECTIVE ACTION
Run Tank Pressure	BP-003	L/N/R004-C Meter/R005-A2	High	400 psig	250 psig		Decrease Dewar pressure
Run Tank Level	BT-004	Beckman/R082 Meter/R005-A4	Low	5%	7.5% - 90%		Normal Shutdown
Test Bearing Upstream Press.	BP-102	L/N/R002-D Beckman R079 Meter/R006-A3	Low	190* psig for more than 10 sec.	225 psig		Decrease Bearing Tester Motor Speed to Zero
Test Bearing Upstream Temp.	BT-102	Beckman/R081 ERN/R001-C	High	54°R	46°R		As above
LH <sub>2</sub> Flow	BF-001	Beckman/R081 Meter/R006-A5 ERN/R001-D	Low	50 gpm	55 to 60 gpm		As above
Bearing Test Speed	BQ-001/002	Beckman/R081 Meter/R005B L&N/R003-D	High	31,000 rpm	6,000-30,000 rpm		As above
Bearing Test Speed	BQ-001/002	Beckman/R081 Meter/R005B L&N/R003-D	Low	3,000 rpm at greater than MS+5 sec or 12,000 rpm for greater than MS+20 sec	6,000-30,000rpm		Shut down MG Set
Electric Drive Motor Current	BI-001/002/ 003	Beckman/R081 L&N/R003-C	High	100 amps at greater than MS + 5 sec	45 to 70 amps		As Above
Electric Drive Motor Voltage	BH-001	Meter/R005-B	High	258 volts	230 volts		As above

\* - 180 psig instantaneous (pressure "spike")

## NRTO-TOP-

TABLE 1 - Cont'd

TEST OPERATING LIMITS

PARAMETER	CHANNEL	DISPLAY TYPE/LOCATION	LIMIT TYPE	LIMIT VALUE	NOMINAL EXPECTED OPERATING CONDITION	ALARM TYPE/SETTING	CORRECTIVE ACTION
Test Bearing Temp. Rise	BT-106 - BT-102	Beckman/R081 L&N/R003-C	High	10°R	5°R		Normal Shutdown
Slave Bearing Temp. Rise	BT-106 - BT-104	Beckman/R080 Beckman/R081	High	10°R	4°R		Normal Shutdown
Seal Differential Pressure	BP-109D ( $\Delta P_{EUS}/P_A$ )	Beckman/R079 L/N/R002-C Meter/R006-A2	Low	25 psid			Decrease Loader Vent Press.
Seal Differential Pressure	BP-109D ( $\Delta P_{BUS}/P_A$ )	Beckman/R079 L/N/R002-C Meter/R006-A2	High	150* psid			Normal Shutdown
Radial/Vent Differential Pressure	BP-110D	Beckman/R079 BRN/R003-D Meter/R006-A7	High	300 psid	35 - 270 psid		Decrease Loader Press.
Axial Loader Pressure	BP-105	Beckman/R079 Meter/R006-A10	High	300 psig	130 psig		Decrease Axial Loader Press
H <sub>2</sub> Concentration	N/A	Flashing Light/R-019	High	2%	0%	Visual/1% Audible/2%	Normal Shutdown
Helium Pressure	BP-050	Meter/R005-A6	Low	500 psig			Normal Shutdown
Hydrogen Pressure	BP-010	Beckman/R082 Meter/R005-A7	Low	500 psig			Normal Shutdown
Nitrogen Pressure	BP-060	Beckman/R082	Low	500 psig			Normal Shutdown
Control Room Press.	N/A		Low	Loss	(0.15" H <sub>2</sub> O)		Normal Shutdown

\* Not Applicable with Forward Seal in Place





AGCS-0800-11

SUBJECT

NERVA BEARING TESTER ASSEMBLY (65 MM)  
P/N 1138060-2 & 3 Ball Bearing

REPORT NO.  
TMP-103

PAGE 1 OF 13

B/U No.

DATE  
8 Dec. 1971

WORK ORDER

BY

D. H. Duke

CHK BY  
*[Signature]*

Q/A  
*[Signature]*

DATE

CHANGE LETTERS AND REVISION DATES VERIFIED

TESTER P/N \_\_\_\_\_ DASH NO. \_\_\_\_\_ LETTER CHG. \_\_\_\_\_

1.0 GENERAL

- \_\_\_\_\_ 1.1 Prior to assembly, all components to be cleaned per AGC-STD-9007 Level II.
- \_\_\_\_\_ 1.2 Visually inspect each component for physical damage. Document under "Remarks" any abnormal conditions (i.e., scratches, scoring, rubs, chipped, fretted, or otherwise abnormally worn areas).
- \_\_\_\_\_ 1.3 In the event of partial disassembly, "N/A" shall be written before operations eliminated by partial disassembly.
- \_\_\_\_\_ 1.4 Lube all threads at assembly using moly-disulfide 321. Always wipe of excess lubrication.
- \_\_\_\_\_ 1.5 Entire assembly procedure shall be under the direction of cognizant Project Engineer, and surveillance of Quality Engineer.
- \_\_\_\_\_ 1.6 Torque all bolts in alternating sequence per ASD 5226.
- \_\_\_\_\_ 1.7 Q.A. requirements per ANSC Memo N7000:2072 dtd 6-8-71.

REMARKS: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2.0 BALANCING OF SHAFT ASSY 1138201 - ( )

- 2.1 Apply thin layer of moly-disulfide 321 to all radial surfaces of shaft (P/N 1138057-4) (S/N \_\_\_\_\_). Wipe of excess lubrication.



REPORT NO. TMP-103	PAGE 2 OF 13
B/U No.	DATE 8 Dec. 1971
	WORK ORDER
BY D. H. Duke	CHK. BY Q/A <i>[Signature]</i>
	DATE

- 2.2 Place the following components in a 300-350<sup>0</sup>F oven (15-30 min.).  
Simultaneously chill shaft in LN<sub>2</sub>.
- Load sleeve - P/N 1136152-2 (S/N \_\_\_\_\_).
  - Bearing spacer - P/N 1138198-1 (S/N \_\_\_\_\_).
  - Dummy Spacer - P/N 1138202-1 (S/N \_\_\_\_\_).
  - Sleeve - P/N 1137999-1 (S/N \_\_\_\_\_).
  - Speed Deflection Pickup - P/N 1138217-1 (S/N \_\_\_\_\_).
  - Dummy 50 MM Roller Bearing Inner Race - P/N 290191 (S/N \_\_\_\_\_).
- 2.3 Assemble sleeve (d), speed deflection pickup (e), and dummy 50 mm roller bearing inner race (f) to shaft.
- 2.4 Invert shaft and assembly dummy spacer (c) and bearing spacer (b) to shaft.
- 2.5 Assemble keys (MS 20066-149) and load sleeve (a) to shaft. Allow shaft to remain in upright position (load sleeve "UP") in press within 10 ton load for 5 minutes to permit load sleeve to positively seize shaft.
- 2.6 Place shaft assembly in 300-350<sup>0</sup>F oven to allow shaft assembly to return to ambient temperature.
- 2.7 Place shaft assembly in press with 10 ton load for one minute to insure positive axial seating.
- 2.8 Lube threads and shoulder face of bolt (P/N 263727-1(S/N \_\_\_\_\_)) and install bolt and 263726-1 washer into shaft assembly. Torque bolt to 225-275 ft-lbs. Do not bend tabs.
- 2.9 Install locknut (P/N 297524-9)S/N \_\_\_\_\_ to shaft & torque 50-55 ft-lbs.



REPORT NO. TMP-103	PAGE 3 OF 13
B/U No.	DATE 8 Dec. 1971 WORK ORDER
Q/A <del>7/14</del>	DATE

SUBJECT NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138060-2 & 3 BALL BEARING	
BY D. H. Duke	CHK. BY

2.10 Support shaft assembly at bearing journals on V-blocks and determine load sleeve run-out. (Electronic Dial Indicator).

Run-out (armature spindle) = \_\_\_\_\_

Run-out (Load sleeve) = \_\_\_\_\_

NOTE: IF RUN-OUT IS .001 OR LESS, CONTINUE WITH STEP 2.17.

OTHERWISE, CONTINUE WITH STEP 2.11.

2.11 Remove bolt, load sleeve, and keys from shaft assembly (use Calrod coil to heat load sleeve prior to removal).

2.12 Re-assemble load sleeve and keys to shaft. (Load sleeve to be positioned 180° from previous location.)

2.13 Allow shaft assembly to return to ambient temperature.

2.14 Install bolt and washer 263726-1 into shaft assembly and torque to 225-275 ft-lbs. Do not bend tab.

2.15 Support shaft assembly at bearing journals on V-blocks and determine load sleeve run-out.

Run-out = \_\_\_\_\_

2.16 If run-out (2.15) is less than run-out (2.10), continue to 2.17.

If run-out (2.15) is greater than run-out (2.10), remove bolt, load sleeve, and keys from shaft assembly per 2.11 and re-assemble.

2.17 Place motor Armature (P/N 1139588-1) (S/N \_\_\_\_\_), and coupler (P/N 1135994-1 S/N \_\_\_\_\_) in a 300°-350° Oven for 15-30 min.

2.18 Assemble coupler (P/N 1135994-1), motor armature (P/N 1139588-1), inserts (P/N 256209), and check-nut (P/N AN316C-14R) (S/N \_\_\_\_\_) to shaft assembly.



REPORT NO. TMP-103	PAGE 4 OF 13
B/U No.	DATE 8 Dec. 1971
	WORK ORDER
Q/A	DATE

SUBJECT NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138060-2 & 3 BALL BEARING	
BY D. H. Duke	CHK. BY

- 2.19 Torque check nut to 75 to 80 ft-lbs.
- 2.20 Balance completed shaft assembly (P/N 1138201- ) (S/N )  
to requirements of G/N 8 ,  $\triangle 9$  , and  $\triangle 14$  , record final  
residual unbalance At Coupling \_\_\_\_\_ GRM. IN.  
At Load Sleeve \_\_\_\_\_ GRM. IN.
- 2.21 Match-mark load sleeve, bearing spacer, dummy spacer sleeve,  
speed deflection pickup, coupler, armature, and shaft to assure  
proper balance orientation on future buildups. (G/N 11<sub>2</sub>).  
NOTE: IF ASSEMBLED BALANCING METHOD WAS USED TO BALANCE  
SHAFT ASSEMBLY ITEM 2.23 WILL NOT APPLY. IF STEP BALANCING  
METHOD WAS USED TO BALANCE SHAFT ASSEMBLY ITEMS 2.2 THROUGH  
2.19 WILL NOT APPLY EXCEPT AS AN ASSEMBLY PARTS LIST.
- 2.22 Disassemble check-nut, armature, and coupler.  
NOTE: USE ARMATURE PULLER TO REMOVE ARMATURE.
- 2.23 Support shaft assembly at bearing journals on V-blocks and  
determine load sleeve run-out (Electronic Dial Indicator).  
Run-out (armature spindle) = \_\_\_\_\_  
Run-out (load sleeve) = \_\_\_\_\_  
NOTE: RUN-OUT SHALL BE .001 OR LESS.
- 2.24 Disassemble lock-nut and bearing inner race (50 mm) from shaft.  
NOTE: USE SPLIT SLEEVE (S.A. 004) TO PRESS OFF INNER RACE.
- 2.25 Invert shaft and disassemble bolt, load sleeve, bearing spacer,  
and dummy spacer.
- 2.26 Reclean all components per AGC-STD-9007, Level II.



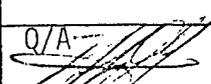
AGCS-0800-11

SUBJECT NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138060-2 & 3 BALL BEARING		REPORT NO. TMP-103	PAGE 4a OF 13
		B/U No.	DATE 8 Dec. 1971 WORK ORDER
BY D. H. Duke	CHK. BY	Q/A	DATE

3.0 MOUNTING FLANGE AND BEARING HOUSING ASSEMBLY

- \_\_\_\_\_ 3.1 Place mounting flange (P/N 1136142-1) (S/N \_\_\_\_\_) on buildup stand. (Use 4- 1/2 x 2 - 1/2 hi-strength torqued to 30-35 ft-lbs) Locate .218 diameter pin hole in upper right quadrant when viewed from bearing housing end.
- \_\_\_\_\_ 3.2 Heat mounting flange with heat gun.
- \_\_\_\_\_ 3.3 Apply Viton "A" to mounting flange seal gland and seal (P/N 22023 AL 5875). Install seal into mounting flange seal gland.
- \_\_\_\_\_ 3.4 Assembly bearing housing (P/N 1136148-1) (S/N \_\_\_\_\_) into mounting flange.



REPORT NO. TMP-103	PAGE 5 OF 13
B/U No.	DATE: 8 Dec. 1971
	WORK ORDER
Q/A 	DATE

SUBJECT NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138060-2 & 3 BALL BEARING	
BY D. H. Duke	CHK. BY

- 3.5 Lube threads of 8 bolts (P/N EWB-0420-6H12) and install into bearing housing. Torque bolts to 32-40 ft-lbs. Lockwire per G/N 
- 3.6 Allow assembly to return to ambient temperature.
- 3.7 Install outer spacer sleeve (P/N 1136155-1) S/N \_\_\_\_\_) into bearing housing.
- 3.8 Install speed probe (P/N 704682) (S/N \_\_\_\_\_) into bearing housing (finger tight only).
- 3.9 Heat mounting flange P/N 1136142-1 in 300<sup>o</sup>-350<sup>o</sup>F oven (1 hour) and install adapter ring (P/N 1138199-1) (S/N \_\_\_\_\_). Anti-rotation pin to be located at 167<sup>o</sup> 30' (5 o'clock).
- 3.10 Install 6 bolts (P/N AS4059-04-002H) and torque to 60-70 in-lbs.

#### 4.0 DUPLEX BEARING SUBASSEMBLY AND SHAFT ASSEMBLY

- 4.1 Place lower split ring holder on buildup mandrel.
- 4.2 Place downstream test ball bearing assembly (P/N \_\_\_\_\_) (S/N \_\_\_\_\_) on mandrel.
- 4.3 Assemble inner race spacer (P/N 1138197-1) (S/N \_\_\_\_\_) on mandrel.
- 4.4 Assemble outer race sleeve (P/N \_\_\_\_\_) (S/N \_\_\_\_\_) on mandrel over ball bearing assembly.
- 4.5 Install \_\_\_\_ (qty) springs (P/N 1137056) in outer race sleeve-amount, and location - per appropriate preload as stated on Test Request Supplement (\_\_\_\_\_).
- 4.6 Place upstream test ball bearing assembly (P/N \_\_\_\_\_) (S/N \_\_\_\_\_) in outer race sleeve over mandrel.
- 4.7 Place upper ring holder on mandrel.



REPORT NO. TMP-103	PAGE 6 OF 13
B/U No.	DATE 8 Dec. 1971
	WORK ORDER
BY D. H. Duke	CHK. BY Q/A <del>                    </del>
	DATE

- \_\_\_\_\_ 4.8 Install split ring holder bolts (6 each) finger tight.
- \_\_\_\_\_ 4.9 Place assembly in 300-350<sup>0</sup>F oven (30 min).
- \_\_\_\_\_ 4.10 Place in press and apply axial load of approximately 2.5 tons to insure proper axial seating.
- \_\_\_\_\_ 4.11 Tighten split ring holder bolts 15-20 ft-lbs.
- \_\_\_\_\_ 4.12 Remove axial load. Place subassembly buildup, spacer (P/N 1138198-1) (S/N \_\_\_\_\_) and load sleeve (P/N 1136152-2) (S/N \_\_\_\_\_) in 300-350<sup>0</sup> oven (25-35 min.). Simultaneously chill shaft assembly in LN<sub>2</sub>.
- \_\_\_\_\_ 4.13 Remove duplex bearing subassembly with split ring holder from mandrel. Install on shaft assembly. Remove upper and lower ring holders.
- \_\_\_\_\_ 4.14 Place spacer (P/N 1138198-1) S/N \_\_\_\_\_ on shaft assembly.
- \_\_\_\_\_ 4.15 Assemble keys (MS 20066-149) and load sleeve to shaft assembly. Allow shaft assembly to remain in upright position in press with 10 ton load for 5 minutes to permit positive axial seating.
- \_\_\_\_\_ 4.16 Allow shaft assembly to return to ambient temperature by placing in 300-350<sup>0</sup> oven.
- \_\_\_\_\_ 4.17 Insure positive axial seating by placing shaft assembly in press with 10 ton load for one minute.
- \_\_\_\_\_ 4.18 Lube threads and shoulder face of bolt (P/N 263727-1) (S/N \_\_\_\_\_) & install bolt and washer (P/N 263726-1) into shaft assembly. Torque bolt to 225-275 ft-lbs. Bend washer tabs into bolts and sleeve slot.



REPORT NO. TMP-103		PAGE 7 OF 13
B/U No.		DATE 8 Dec. 1971
		WORK ORDER
BY D. H. Duke	CHK. BY	Q/A <i>[Signature]</i> DATE

## 5.0 BEARING/CARTRIDGE INTERFACE CLEARANCE TEST

Perform following operations only if authorized by Test Request Supplement.

5.1 Attach actuating rods, 2 places (S.A. \_\_\_\_\_), to cartridge (outer face sleeve - (P/N 1138196-\_\_\_\_) or (P/N 1139308-\_\_\_\_)).

Rods to be diametrically opposed and secured in place with a 4-1/2" Hose Clamp.

Note: UNATTACHED ENDS OF RODS TO EXTEND PAST ARMATURE SPINDLE.

5.2 Immerse and completely chill shaft assembly (P/N 1138201-\_\_\_\_) in LN<sub>2</sub>. Shaft assembly to be in vertical position with load sleeve DOWN.

5.3 Actuate cartridge up and down and determine degree of axial freedom existing between 65 MM ball bearing outer races and bore of cartridge.

## 6.0 50MM BALL BEARING INSTALLATION

6.1 Place ball bearing (P/N 290125-19) (S/N \_\_\_\_\_) in a 275-325<sup>0</sup>F oven for 30 min. Simultaneously heat bearing housing with a heat gun.

6.2 Install shaft assembly into housing assembly.

6.3 Place ball bearing in bearing installation tool and install bearing over shaft and into bearing housing.

6.4 Assemble lock-nut (P/N 297524-9) (S/N \_\_\_\_\_) to shaft and torque momentarily to 95-105 ft-lbs while assembly is still warm. Relax torque.

6.5 Allow assembly to return to ambient temperature.

6.6 Re-torque lock-nut to 95-105 ft-lbs.



SUBJECT

NERVA BEARING TESTER ASSEMBLY (65 MM)  
P/N 1138060-2 & 3 BALL BEARING

REPORT NO.

TMP-103

PAGE 8 OF 13

B/U No.

DATE  
8 Dec. 1971

WORK ORDER

BY

D. H. Duke

CHK. BY

Q/A

DATE

- 6.7 Assemble labyrinth P/N 285264-1 to bearing housing. Lub-threads of bolts (P/N 1136163-1) and install into labyrinth flange. Torque bolts to 60-70 in-lbs.
- 6.8 Lockwire 12 Bolts P/N 1136136 per G/N  $\triangle 25$
- 6.9 Assemble anti-rotation Lock P/N 1139787-1 Lube Threads of 2 Bolts (P/N AS4059-04-002H) Install and torque to 60-70 in lbs.
- 6.10 Lockwire (8 Bolts P/N AS4059-04-002H) per G/N  $\triangle 26$  (includes 6 Bolts installed - Step 3.10).
- 7.0 SPEED PROBE ASSEMBLY
- 7.1 Remove speed probe. Apply Viton "A" to speed probe seal gland and conoseal gasket (P/N 54973-12) and place gasket on speed probe and install into bearing housing.
- 7.2 Lube threads of bushing adapter (P/N 265391-1) and torque to 70-80 ft-lbs.
- 8.0 SHAFT RUN-OUT MEASUREMENTS
- 8.1 With electronic dial indicator attached to bearing tester mounting flange, measure and record the following values:
- 8.1.1 Eccentricity of load sleeve (P/N 1136152-2) \_\_\_\_\_
- 8.1.2 Total radial movement of shaft \_\_\_\_\_
- 8.1.3 Total axial movement of shaft \_\_\_\_\_
- 8.2 Break-away torque (Torque > 10-12 in lbs requires Engineering evaluation.) \_\_\_\_\_



AEROJET-GENERAL CORPORATION  
SACRAMENTO CALIFORNIA

AGCS-0800-11

SUBJECT		REPORT NO.	PAGE 9 of 13
NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138060-2 & 3 BALL BEARING		B/U No.	DATE
			8 Dec. 1971
BY	CHK. BY	Q/A	DATE
D. H. Duke		<i>[Signature]</i>	

## 9.0 SHAFT HOUSING ADAPTER AND MOUNTING FLANGE ASSEMBLY

- 9.1 Chill seal assembly (P/N 700977-9) in LN<sub>2</sub> until temperature stabilizes. Simultaneously heat seal cavity in shaft housing adapter (P/N 1138063-1) (S/N \_\_\_\_\_) with a heat gun.
- 9.2 Install seal into shaft housing adapter. Snap ring on seal should face outward and be visible when properly installed.
- 9.3 Install spirolox retainer (P/N PR-381-S).
- 9.4 Apply Viton "A" to shaft housing adapter seal gland and to seal (P/N 22024-AL-8000). Install seal into seal gland.
- 9.5 Assemble shaft housing adapter to mounting flange. Use guide studs to facilitate assembly.
- NOTE: EXTREME CARE MUST BE TAKEN WHEN SLIPPING SEAL ASSEMBLY OVERLOAD SLEEVE TO PREVENT DAMAGE TO CARBON.
- 9.6 Lube threads of 8 Bolts; (4 EA P/N MS21291-27) (4 EA P/N MS21291-09) and install into shaft housing adapter. Torque bolts to 33-37 ft-lbs.

## 10.0 SHAFT HOUSING ASSEMBLY

- 10.1 Apply Viton "A" to shaft housing adapter seal gland and to seal (P/N 22023-AL-5875). Install seal into shaft housing adapter seal gland.
- 10.2 Assemble shaft housing (P/N 1136001-3) (S/N \_\_\_\_\_) to shaft housing adapter.
- 10.3 Lube threads of 10 Bolts; (8 EA P/N EWB-0420-6H8) (2 EA P/N EWB-0420-6H5) and install into shaft housing. Torque bolts to 40-45 ft-lbs.



REPORT NO. TMP-103	PAGE 10 OF 13
B/U No.	DATE 8 Dec. 1971
Q/A <del>7</del>	WORK ORDER
BY D. H. Duke	CHK. BY
	DATE

## SUBJECT

NERVA BEARING TESTER ASSEMBLY (65 MM)  
P/N 1138060-2 & 3 BALL BEARING

11.0 RADIAL LOADER INSTALLATION

- \_\_\_\_\_ 11.1 Remove end cap from radial load device (P/N 6000371) (S/N \_\_\_\_\_).  
Retract adjusting screw to fully unloaded position. Actuate piston assembly in bore to assure free movement.
- \_\_\_\_\_ 11.2 Apply Viton "A" to shaft housing seal gland, load device seal gland, and gasket (P/N 263806).
- \_\_\_\_\_ 11.3 Install gasket, shim (P/N 287749-1) and load device into shaft housing. Lube Threads of 7 bolts (P/N AS4059-06-001H) and install into loader flange. Torque bolts to 30-35 ft-lbs.
- \_\_\_\_\_ 11.4 Adjust loader set screw by turning six (6) full turns from fully backed-off position. Install gasket, end cap, and lube threads of 6 screws torque to 9-11 in-lbs.
- \_\_\_\_\_ 11.5 Lube Threads and shoulder of tube assembly adapter and (P/N 269368-19) S/N \_\_\_\_\_). Apply Viton "A" to load device inlet seal gland, tube assembly seal gland, and gasket (P/N 54973-12).
- \_\_\_\_\_ 11.6 Install tube assembly and gasket into load device and torque adapter nut to 40-50 ft-lbs.

12.0 TORQUE MEASUREMENTS

- \_\_\_\_\_ 12.1 Breakaway torque \_\_\_\_\_ in-lbs (Torque > 18 in-lbs)
- \_\_\_\_\_ 12.2 Running Torque \_\_\_\_\_ in-lbs requires Engineering Evaluation

13.0 MOTOR ASSEMBLY

- \_\_\_\_\_ 13.1 Place motor armature (P/N 7331-2 S/N \_\_\_\_\_) and coupler (P/N 1135994-1) (S/N \_\_\_\_\_) in a 300<sup>0</sup>-350<sup>9</sup> oven for 30 minutes.



AEROJET-GENERAL CORPORATION  
SACRAMENTO CALIFORNIA

AGCS-0800-11

SUBJECT NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138606-2 & 3 BALL BEARING		REPORT NO. TMP-103	PAGE 11 OF 13
		B/U No.	DATE 8 Dec. 1971
BY D. H. Duke	CHK. BY	Q/A <i>[Signature]</i>	WORK ORDER
			DATE

- \_\_\_\_\_ 13.2 Assemble coupler, motor armature, and check nut (P/N AN316C-14R) (S/N \_\_\_\_\_) to shaft assembly.
- NOTE: ASSURE THAT BALANCE MATCH-MARKS ARE ORIENTED CORRECTLY
- \_\_\_\_\_ 13.3 Torque check nut to 75-80 ft-lbs.
- \_\_\_\_\_ 13.4 Allow assembly to return to ambient temperature and re-torque check nut to 75-80 ft-lbs.
- \_\_\_\_\_ 13.5 Apply Viton "A" to bearing housing seal gland, motor housing seal gland and conoseal (P/N 57259-525S).
- Assemble conoseal and motor housing to bearing housing.
- NOTE: CARE SHOULD BE TAKEN TO KEEP MOTOR CENTERED AROUND SHAFT (WHILE SLIDING MOTOR HOUSING OVER SHAFT) TO AVOID BUMPING THE ARMATURE AGAINST THE MOTOR WINDINGS.
- \_\_\_\_\_ 13.6 Lube threads of 12 motor housing retaining studs (P/N KHNS428T-10) and install self-locking nuts (P/N FIC-428-1). Torque nuts to 70-75 in-lbs.
- 14.0 END COVER ASSEMBLY
- \_\_\_\_\_ 14.1 Apply Viton "A" to end cap seal gland (P/N 1136158-1) (S/N \_\_\_\_\_) and to seal (P/N 22023-AL-5000). Install seal and end cap to shaft housing.
- \_\_\_\_\_ 14.2 Lube threads of 12 Bolts (P/N EWB-0420-4H10) and install in end cap flange. Torque bolts to 85-95 in-lbs.
- 15.0 INSTALL INSTRUMENTATION
- \_\_\_\_\_ 15.1- Identify and mark with flow pen, all instrumentation ports in accordance with basic Test Request 1190-65-XXX-X.



SUBJECT		REPORT NO. TMP-103	PAGE 12 OF 13
NERVA BEARING TESTER ASSEMBLY (65 MM) P/N 1138606-2 & 3 BALL BEARING		B/U No.	DATE 8 Dec. 1971 WORK ORDER
BY D. H. Duke	CHK. BY	Q/A	DATE

## 15.2 Install 2 Accelerometers

\_\_\_\_\_ Motor Housing S/N \_\_\_\_\_

\_\_\_\_\_ End Cap S/N \_\_\_\_\_

## 15.3 Install 5 RTT's

\_\_\_\_\_ TV 134CT-250 S/N \_\_\_\_\_

\_\_\_\_\_ TBUS 134CT-250 S/N \_\_\_\_\_

\_\_\_\_\_ TBDS 134CT-350 S/N \_\_\_\_\_

\_\_\_\_\_ TMH 134CT-250 S/N \_\_\_\_\_

\_\_\_\_\_ TBH 134CT-200 S/N \_\_\_\_\_

## 15.4 Install 5 Proximity Probes (Touch, then retract approximately 1/8")

\_\_\_\_\_ DT<sub>1</sub> S/N \_\_\_\_\_

\_\_\_\_\_ DT<sub>2</sub> S/N \_\_\_\_\_

\_\_\_\_\_ DT<sub>3</sub> S/N \_\_\_\_\_

\_\_\_\_\_ DT<sub>4</sub> S/N \_\_\_\_\_

\_\_\_\_\_ DT<sub>5</sub> S/N \_\_\_\_\_

NOTE: FINAL SETTING WILL BE MADE AT TEST CELL.

16.0 REMOVE CAVITY VENT TUBE ASSEMBLY (P/N 269368-19) FROM SHAFT HOUSING (P/N 1136001-3) and REPLACE WITH "RADIAL PLAY" SPRING, SEAL AND PLUG (S.A. 025). N/A UNLESS AUTHORIZED BY TEST REQUEST SUPPLEMENT.

17.0 PROOF TEST PER G/N 14 @ 420 ± 15 psig with GN<sub>2</sub>  
Hold for one minute. Record pressure decay. (Required for 1st B/U only).

18.0 LEAK CHECK PER G/N 15 100 ± 10 psig GH<sub>e</sub> or GN<sub>2</sub> for 2 minutes minimum.  
Check with Leaktec. (Only "fuzz" leaks allowable)

19.0 PRESSURE PAD  
Establish Pressure Pad of 45-55 Psig (GN<sub>2</sub>) in Tester Assembly. Maintain 10 psig minimum at all time prior to installation, replenish as required.





REPORT NO. TMP-105	PAGE 1 OF 7
B/U No.	DATE 27 July 1971
Q/A <i>[Signature]</i>	WORK ORDER
	DATE

SUBJECT NERVA BEARING TESTER DISASSEMBLY (65mm) P/N 1138060-2 & 3	
BY D. H. Duke	CHK. BY J. B. Accinelli

Tester P/N \_\_\_\_\_ Dash No. \_\_\_\_\_ Letter Change \_\_\_\_\_

Change Letters and Revision Dates Verified.

1.0 GENERAL

- 1.1 Prior to disassembly, tester shall be at ambient temperature and dehydrated.
- 1.2 Visually inspect tester assembly for physical damage. Document under "Remarks" any abnormal conditions.
- 1.3 In the event of prior partial disassembly, "N/A" shall be written before operations eliminated by that partial disassembly.
- 1.4 Entire disassembly procedure shall be under the direction of cognizant Project Engineer, and surveillance of Quality Engineer.
- 1.5 Q. A. Requirements per ANSC Memo N7000:2072 dated 18 June 1971.

REMARKS: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



REPORT NO. TMP-105	PAGE 2 OF 7
B/U No.	DATE 27 July 1971
	WORK ORDER
BY D. H. Duke	CHK. BY J. B. Accinelli
Q/A <i>[Signature]</i>	DATE

2.0 SAFETY WIRE

\_\_\_\_\_ 2.1 Remove from End Cap Mounting Bolts

\_\_\_\_\_ 2.2 Remove from Shaft Housing Ass'y Mounting Bolts

\_\_\_\_\_ 2.3 Remove from Shaft Housing Adapter Mounting Bolts

\_\_\_\_\_ 2.4 Remove from Loader Ass'y Cap Mounting Bolts

\_\_\_\_\_ 2.5 Remove from Instrumentation

3.0 INSTRUMENTATION

3.1 Remove 2 Accelerometers

\_\_\_\_\_ Motor Housing S/N \_\_\_\_\_

\_\_\_\_\_ End Cap S/N \_\_\_\_\_

3.2 Remove 5 RTT's

\_\_\_\_\_ T<sub>v</sub> 134CT-250 S/N \_\_\_\_\_

\_\_\_\_\_ TBUS 134CT-250 S/N \_\_\_\_\_

\_\_\_\_\_ TBDS 134CT-350 S/N \_\_\_\_\_

\_\_\_\_\_ TMH 134CT-250 S/N \_\_\_\_\_

\_\_\_\_\_ TBH 134CT-200 S/N \_\_\_\_\_



REPORT NO. TMP-105	PAGE 3 OF 7
B/U No.	DATE 27 July 1971
	WORK ORDER
BY D. H. Duke	CHK. BY J. B. Accinelli
Q/A	DATE

## 3.3 Remove 4 Proximity Probs

\_\_\_\_\_ DT<sub>1</sub> S/N \_\_\_\_\_\_\_\_\_\_ DT<sub>2</sub> S/N \_\_\_\_\_\_\_\_\_\_ DT<sub>3</sub> S/N \_\_\_\_\_\_\_\_\_\_ DT<sub>4</sub> S/N \_\_\_\_\_

## 3.4 Remove Speed Sensors

\_\_\_\_\_ Speed Probe S/N \_\_\_\_\_

\_\_\_\_\_ DT<sub>5</sub> S/N \_\_\_\_\_

- 3.5 Remove Plug at B.D.C. of mounting flange (P/N 1136142-1).  
Collect debris and establish characteristics (color, floc, magnetic).

## 4.0 END CAP ASSEMBLY

- 4.1 Remove 12 End Cap Mounting Bolts (P/N EWB-0420-4H10) and End Cap (P/N 1136158-1) From Shaft Housing Ass'y.

Note: 22023-AL-5000 Static Face Seal will remain with End Cap.

## 5.0 MOTOR ASSEMBLY

- 5.1 Remove motor housing (P/N 1138223-1) and Seal (P/N 57259-525S) from flange housing assembly (P/N 1138872-2A).

Note: Care should be taken to keep motor centered around shaft (while sliding motor housing over shaft) to avoid bumping the armature against the motor windings.

## 6.0 RADIAL LOADER

- 6.1 Remove end cap (P/N 600371-11) from radial loader. Retract adjusting screw to fully unloaded position.



REPORT NO. TMP-105	PAGE 4 OF 7
B/U No.	DATE 27 July 1971
	WORK ORDER
Q/A <del>2/26/71</del>	DATE

SUBJECT NERVA BEARING TESTER DISASSEMBLY (65 mm) P/N 1138060-2 & 3	
BY D. H. Duke	CHK. BY J. B. Accinelli

7.0 SHAFT HOUSING

7.1 Remove 10 shaft housing assembly mounting bolts (8 ea. EWB-0420-6H8, 2 ea. EWB-0420-6H5) and shaft housing assembly (P/N 1136001-3) from Shaft Housing Adapter.

Note: 22023-AL-5875 Static Face Seal will remain with shaft housing adapter.

Use 3 ea Guide Studs (S.A. #10) to facilitate removal.

8.0 SHAFT HOUSING ADAPTER

8.1 Remove 8 shaft Housing Adapter Mounting Bolts (4 Ea MS 21291-27, 4 Ea MS 21291-09) and Shaft Housing Adapter (P/N 1138063-1), from Mounting Flange.

Note: 22024-AL-8000 Static Face Seal will remain with Shaft Housing Adapter.

700977-9 Seal Ass'y will remain with Shaft Housing Adapter.

Use 3 Ea Guide Studs (S.A. #10) to facilitate removal.

9.0 SHAFT TORQUE AND RUNOUT MEASUREMENTS (ENGINEERING DATA)

9.1 Break-away torque \_\_\_\_\_  
Running Torque \_\_\_\_\_

9.2 With electronic dial indicator attached to mounting flange, measure and record the following values:

9.2.1 Eccentricity of load sleeve\* \_\_\_\_\_

9.2.2 Total Radial Movement of Shaft \_\_\_\_\_

9.2.3 Total Axial Movement of Shaft \_\_\_\_\_

\* Taken at liquid seal position on load sleeve.



REPORT NO. TMP-105	PAGE 5 OF 7
B/U No.	DATE 27 July 1971 WORK ORDER
Q/A <i>[Signature]</i>	DATE

SUBJECT  
NERVA BEARING TESTER DISASSEMBLY (65mm)  
P/N 1138060-2 & 3

BY  
D. H. Duke

CHK. BY  
J. B. Accinelli

## 10.0 ARMATURE

- 10.1 Remove check-nut (P/N AN316C-14R), motor armature and coupler (P/N 1135994-1) from shaft assembly (P/N 1138058-1). Use armature pulling tool (S.A. #013).

## 11.0 SHAFT ASSEMBLY

- 11.1 Remove lockwire from labyrinth mounting bolts (P/N 1136163-1)
- 11.2 Remove 12 labyrinth mounting bolts (P/N 1136136-1) and labyrinth flange (P/N 285264-1) from bearing housing (P/N 1136148-1).
- 11.3 Remove locknut (P/N 297524-9) from shaft assembly (use S. A. #009).
- 11.4 Remove outer race sleeve anti-rotation lock.
- 11.5 Remove shaft assembly (P/N 1138201-\_\_\_) from housing assembly (P/N 1138872-1) (use S. A. #011).

## 12.0 OUTER SPACER SLEEVE

- 12.1 Remove outer spacer sleeve (P/N 1136155-1) from bearing housing (P/N 1136148-1).



REPORT NO. TMP-105	PAGE 6 OF 7
B/U No.	DATE 27 July 1971 WORK ORDER
Q/A <i>[Signature]</i>	DATE

SUBJECT NERVA BEARING TESTER DISASSEMBLY (65mm) P/N 1138060-2 & 3	
BY D. H. Duke	CHK. BY J. B. Accinelli

13.0 SHAFT DISASSEMBLY

13.1 Remove bolt (P/N 263727-1) and washer (P/N 263726-1) from shaft assembly (use S.A.# 007).

13.2 Remove load sleeve (P/N 1136152-1), spacer (P/N 1138198-3), and duplex bearing subassembly from shaft assembly (use S. A. #005B and S. A. #012).

14.0 DUPLEX BEARING SUBASSEMBLY

14.1 Document location of outer bearing race orientation marks, with respect to radial load vector. (T.D.C.).

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

14.2 Remove bearing assembly (P/N 1138952-7), inner race spacer (P/N 1138197-1), and springs (P/N 1137056) from outer race.

14.3 Document outer race fretting condition, location and evidence of rotation.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



REPORT NO. TMP-105	PAGE 7 OF 7
B/U No.	DATE 27 July 1971
	WORK ORDER
Q/A <i>[Signature]</i>	DATE

SUBJECT NERVA BEARING TESTER DISASSEMBLY (65mm) P/N 1138060-2 & 3	
BY D. H. Duke	CHK. BY J. B. Accinelli

14.4 Document condition of preload springs (P/N 1137056).

---

15.0 CLEAR ALL INSPECTION REPORTS

COMPLETED: \_\_\_\_\_  
Cognizant Project Engr. \_\_\_\_\_ Date \_\_\_\_\_

Quality Engr. \_\_\_\_\_ Date \_\_\_\_\_



REPORT NO. TMP-108	PAGE 1 OF 1
	DATE 9 August 1971
	WORK ORDER
BY D. A. Koch <i>D.A. Koch</i>	CHK. BY <i>J.B.A.</i>
QA <i>[Signature]</i>	DATE

SUBJECT  
CARTRIDGE/HOUSING INTERFACE CLEARANCE TEST  
65MM BALL BEARING TESTER - P/N 1138060

Build up 65MM Ball Bearing Tester, P/N 1138060-\_\_\_ per TMP-103, Rev. \_\_\_  
except as follows:

- \_\_\_ 1.0 In Step 6.1 of TMP-103, use 50MM Ball Bearing, P/N 290125-19 (Modified), S/N 878B in place of 50MM Ball Bearing (P/N 290125-19).
- \_\_\_ 2.0 After Step 6.6 and prior to Step 6.7 of TMP-103, install shims (P/N 278029) between bearing housing (P/N 1136148-1) and labyrinth flange (P/N 285264-1) to obtain a total shim thickness of .140 - .150.

<u>SHIM P/N</u>	<u>ACTUAL NO. OF SHIMS</u>
278029-5	_____
278029-3	_____

Actual Thickness of Shim Stack \_\_\_\_\_

- \_\_\_ 3.0 After Step 6.10 and prior to Step 7.0 of TMP-103, install push-pull continuity sensor (S.A. 020) into mounting flange (P/N 1136142-1). Use lower instrumentation port (MS 33649-4).

NOTE: TIP OF SENSOR MUST BE POSITIONED TO INSURE ELECTRICAL CONTINUITY BETWEEN OUTER RACE SLEEVE, P/N 1139308-\_\_\_ (OR P/N 1138196-\_\_\_) AND SENSOR WHEN SHAFT ASSEMBLY IS IN FULL AFT POSITION LESS .025 - .035. DETERMINE THIS VALUE BY PLACING A DIAL INDICATOR ON FORWARD EDGE OF OUTER RACE SLEEVE.

ACTUAL VALUE \_\_\_\_\_  
ROTATE AND/OR BEND TIP OF SENSOR TO MEET THIS REQUIREMENT.

_____ COGNIZANT PROJECT ENGINEER	_____ DATE
_____ QUALITY ENGINEER	_____ DATE



REPORT NO. TMP-110	PAGE 1 OF 5
B/U No.	DATE 12-8-71
	WORK ORDER
QA [Signature]	DATE

SUBJECT  
NERVA BEARING TESTER (65MM) P/N 1138060-2 & 3 INSTALLATION

BY  
D. H. Duke

CHK. BY

CHANGE LETTERS AND REVISION DATES VERIFIED

TESTER P/N \_\_\_\_\_ DASH NO. \_\_\_\_\_ LETTER CHG. \_\_\_\_\_

1.0 GENERAL

- 1.1 NERVA Ball Bearing Tester P/N 1138060-\_\_\_\_ was assembled at the NRDS E-MAD facility in accordance with N8300 Procedure TMP-103, Rev. \_\_\_\_\_.
- 1.2 This Procedure defines the operations necessary to install tester assembly P/N 1138060-\_\_\_\_ in the Test Fixture.
- 1.3 Internal cleanliness of the Tester Assembly must be maintained to the requirements of AGC-STD-9007, Level II. All Plugs, Caps, and Fittings installed to complete Leak Check shall remain in place at all reasonable times. GN<sub>2</sub> pad per TMP-103, Rev. B., Step 19.0 shall be maintained unless otherwise instructed by this procedure.
- 1.4 Any non-conformance to Procedure or Drawing Requirements shall be recorded on a Historical I.R.
- 1.5 Proper safe guards with respect to handling fixtures, tooling and protective covers shall be enforced to protect quality of the assembly.
- 1.6 Lubricate all bolt threads with M<sub>0</sub>S<sub>2</sub> (Molykote) prior to assembly. Lubricate all tube fittings, after first 2 threads are engaged, with DC 11 or acceptable equivalent.
- 1.7 Torque all B-nut to AGC Specification ASD 5040, Amendment #1.
- 1.8 Entire installation procedure shall be under the direction of Cognizant Project Engineer and the surveillance of the Quality Engineer.



SUBJECT NERVA BEARING TESTER (65MM) P/N 1138060-2 & 3 INSTALLATION		REPORT NO. TMP-110	PAGE 2 OF 5
		B/U No.	DATE 12-8-71
BY D. H. Duke		CHK. BY <i>QA [Signature]</i>	WORK ORDER
			DATE

2.0 TRANSPORTATION

- 2.1 Install lifting fixture on mounting flange (use 2 lubricated bolts (NAS1008-20A or acceptable equivalent) torqued to 20-25 ft lbs.
- 2.2 Remove Tester Assembly with mounting stand from Buildup Table.  
NOTE: USE PORTABLE HOIST: TESTER ASSEMBLY APPROXIMATE WEIGHT IS 350 LBS.
- 2.3 Place Tester Assembly in transport container and secure.
- 2.4 Move Tester Assembly to Test Cell.

3.0 INSTALLATION

- 3.1 Remove Tester Assembly from Transport Container using Lifting Fixture and suitable Hoist.
- 3.2 Place Tester Assembly in an installation attitude above Final Test Position in the Test Stand.  
Slowly lower Tester Assembly to Final Test Position and secure in Test Stand using 6 lubricated bolts. (NAS 1006-7A or acceptable equivalent) torqued to 20-25 ft lbs.
- 3.3 Remove GN<sub>2</sub> pressure pad and associated hardware from tester assembly.
- 3.4 Connect 1/2 inch LH<sub>2</sub> inlet lines (2 ea) to inlet bosses as identified (LSH) on Shaft Housing Adapter Flange. (Torque 35-40 ft lbs.).
- 3.5 Connect 1 inch LH<sub>2</sub> outlet line to outlet boss as identified (LDH) on Motor Housing. (Torque 110-120 ft lbs).



REPORT NO. TMP-110	PAGE 3 OF 5
	DATE 12-8-71
	WORK ORDER
BY D. H. Duke	CHK. BY <i>QA [Signature]</i>
	DATE

SUBJECT  
NERVA BEARING TESTER (65MM) P/N 1138060-2 & 3 INSTALLATION

- 3.6 Connect 3/4 inch GH<sub>2</sub> inlet line to inlet boss as identified (PR) on Radial Loader Assembly. (Torque 75-80 ft lbs).
- 3.7 Connect 3/4 inch GH<sub>2</sub> inlet line to inlet boss as identified (PA) on End Cap Housing. (Torque to 75-80 ft lbs).
- 3.8 Connect 3/4 inch GH<sub>2</sub> outlet line to outlet boss as identified (PV) on Shaft Housing Assembly. (Torque 75-80 ft lbs).

4.0 INSTRUMENTATION

- 4.1 Connect appropriate Electrical Connectors to RTT's as identified:
  - 4.1.1 TV (Shaft Housing Assy) (BT-108)
  - 4.1.2 TBUS (Shaft Housing Adapter) (BT-102)
  - 4.1.3 TBDS (Mounting Flange) (BT-106)
  - 4.1.4 TMH (Top Motor Housing) (BT-104)
  - 4.1.5 TBH (Bottom Motor Housing) (TB-103)
- 4.2 Connect appropriate 1/4 inch Pressure Transducer Impulse Lines to Pressure Bosses as identified: (Torque 135-150 in lbs).
  - 4.2.1 PBUS (Mounting Flange) (BP-102)
  - 4.2.2 PBDS (Shaft Housing Adapter) (BP-111)
  - 4.2.3 PBH (Motor Housing) (BP-104)
  - 4.2.4 PV (Shaft Housing Assy) (BP-107)
- 4.3 Connect appropriate electrical connectors to proximity probes as identified:
  - 4.3.1 DT<sub>1</sub> (Shaft Housing Assy 0°) (BD-001)
  - 4.3.2 DT<sub>2</sub> (Shaft Housing Assy 90°) (BD-002)
  - 4.3.3 DT<sub>3</sub> (Motor Housing Assy 0°) (BD-003)
  - 4.3.4 DT<sub>4</sub> (Motor Housing Assy 90°) (BD-004)
  - 4.3.5 DT<sub>5</sub> (Shaft Housing Assy Fwd 0°) (BQ-003)



SUBJECT

NERVA BEARING TESTER (65MM) P/N 1138060-2 &amp; 3 INSTALLATION

B/U No.

DATE  
12-8-71

WORK ORDER

BY

D. H. Duke

CHK. BY

QA [Signature]

DATE

- 4.4 Complete final setting of proximity probes. Establish communication with Instrumentation Engineer or authorized representative. Loosen Swagelok Retainer (use 11/16 inch and 13/16 inch open end wrenches), adjust probe position, per direction of Instrumentation Engineer to an air gap setting of .0145 inch  $\pm$  .0025 inch (40 millivolts equal .001 inch). Torque Swagelok Retainer to 50-75 in lbs. Record final millivolt value.

DT<sub>1</sub> \_\_\_\_\_ MV    DT<sub>3</sub> \_\_\_\_\_ MV    DT<sub>5</sub> \_\_\_\_\_ MVDT<sub>2</sub> \_\_\_\_\_ MV    DT<sub>4</sub> \_\_\_\_\_ MV

- 4.5 Connect appropriate electrical connectors to accelerometers as identified:

4.5.1 G<sub>1</sub> (Shaft Housing Assy) (BA-001)4.5.2 G<sub>2</sub> (Motor Housing ) (BA-002)

- 4.6 Connect electrical connector to speed probe pickup. (BQ-001 & -002).

- 4.7 Connect power wiring as identified to Tester Assembly Drive Motor.

## 5.0 LEAK CHECK

- 5.1 Establish, with the aid of Test Cell "A" personnel, a 100  $\pm$  10 psig GH<sub>e</sub> or GN<sub>2</sub> pressure in the tester assembly and associated adapter lines for a 2 minute minimum. Check with Leaktec all interface fittings. (Only "Fuzz" leaks allowable.)



AEROJET-GENERAL CORPORATION  
SACRAMENTO CALIFORNIA

REVISION B

AGCS-0800-11

SUBJECT

NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 INSTALLATION

REPORT NO. TMP-110	PAGE 5 OF 5
B/H No.	DATE 12-8-71
	WORK ORDER
BY D. H. Duke	CHK. BY <i>[Signature]</i>
	DATE

6.0 CLEAR ALL INSPECTION REPORTS.

7.0 RELEASE TEST ARTICLE FOR TESTING.

\_\_\_\_\_  
COGNIZANT PROJECT ENGINEER

\_\_\_\_\_  
DATE

\_\_\_\_\_  
QUALITY ENGINEER

\_\_\_\_\_  
DATE



AEROJET-GENERAL CORPORATION  
SACRAMENTO • CALIFORNIA

AGCS-0800-11

REPORT NO. TMP-111	PAGE 1 OF 5
E/LI # S/N #	DATE 12-8-71
	WORK ORDER
	DATE

SUBJECT  
NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 REMOVAL PROCEDURE

BY  
D. H. Duke

CHK. BY  
J. B. Accinelli

Q/A

CHANGE LETTERS AND REVISION DATES VERIFIED

TESTER P/N \_\_\_\_\_ DASH NO. \_\_\_\_\_ LETTER CHANGE \_\_\_\_\_

1.0 GENERAL

- 1.1 NERVA Bearing Tester P/N 1138060-\_\_\_\_\_ was installed for testing at NRDS TEST Cell "A" Facility in accordance with N8300 Procedure TMP-110, Revision \_\_\_\_\_.
- 1.2 This procedure defines the operations necessary to remove NERVA Bearing Tester Assembly from the test fixture.
- 1.3 Internal cleanliness of the tester assembly must be maintained. All plugs, caps, and fittings removed to facilitate installation and testing shall be reinstalled.
- 1.4 Any non-conformance to procedure or drawing requirements shall be recorded on a historical I.R.
- 1.5 Proper safeguards with respect to handling fixtures, tooling and protective covers shall be enforced to protect quality of the assembly.
- 1.6 Entire removal procedure shall be under the direction of the cognizant project engineer and the surveillance of the quality engineer.
- 1.7 Tester assembly shall be at zero pressure, ambient temperature and purged with GN<sub>2</sub> or GH<sub>e</sub> prior to start of removal from test fixture.
- 1.8 Visually inspect tester assembly for physical damage. Document any abnormal conditions.

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SUBJECT

NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 REMOVAL PROCEDURE

BY

D. H. Duke

CHK. BY

J. B. Accinelli

Q/A *[Signature]*

2.0 TESTER ASSEMBLY SHAFT TORQUE CHECK

2.1 Remove 3/4 inch GH<sub>2</sub> inlet line from inlet boss as identified (P.A.) on end cap housing.

2.2 Insert torque wrench adapter through P.A. inlet boss engaging internal hex in shaft bolt.

2.3 Break-away torque \_\_\_\_\_ in lbs  
Running Torque \_\_\_\_\_ in lbs

2.4 Remove torque wrench adapter from P.A. inlet boss and install pressure cap.

2.5 Remove and stow 3/4 inch GH<sub>2</sub> P.A. line. Maintain line cleanliness.

2.6 Install pressure cap on P.A. facility line.

3.0 INSTRUMENTATION

3.1 Disconnect power wiring to tester assembly drive motor.

3.2 Disconnect electrical connectors to accelerometers.

3.2.1 G<sub>1</sub> (Shaft Housing Assy) (BA-001)

3.2.2 G<sub>2</sub> (Motor Housing) (BA-002)

3.3 Disconnect electrical connector to speed probe pickup (BQ-001 and 002)



REPORT NO. TMP-111	PAGE 3 OF 5
DATE 12-8-71	
WORK ORDER	
DATE	

SUBJECT NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 REMOVAL PROCEDURE		
BY D. H. Duke	CHK. BY J. B. Accinelli	Q/A <del>_____</del>

3.4 Disconnect electrical connectors to proximity probes.

3.4.1 DT<sub>1</sub> (Shaft Housing Assy 0°) (BD-001)

3.4.2 DT<sub>2</sub> (Shaft Housing Assy 90°) (BD-002)

3.4.3 DT<sub>3</sub> (Motor Housing Assy 0°) (BD-003)

3.4.4 DT<sub>4</sub> (Motor Housing Assy 90°) (BD-004)

3.4.5 DT<sub>5</sub> (Shaft Housing Assy Fwd 0°) (BQ-003)

3.5 Disconnect electrical connectors to RTTs.

3.5.1 T<sub>V</sub> (Shaft Housing Assy) (BT-108)

3.5.2 TBUS (Shaft Housing Adapter) (BT-102)

3.5.3 TBDS (mounting flange) (BT-106)

3.5.4 TMH (Top Motor Housing) (BT-104)

3.5.5 TBH (Bottom Motor Housing) (TB-103)

3.6 Disconnect 1/4 inch pressure transducer impulse lines.

3.6.1 PBUS (Shaft Housing Adapter) (BP-102)

3.6.2 PBDS (Mounting Flange) (BP-111)

3.6.3 PBH (Motor Housing) (BP-104)

3.6.4 PV (Shaft Housing Assy) (BP-107)



REPORT NO. TMP-111	PAGE 4 OF 5
B/W # S/N #	DATE 12-8-71
Q/A	WORK ORDER
	DATE

SUBJECT NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 REMOVAL PROCEDURE	
BY D. H. Duke	CHK. BY J. B. Accinelli

4.0 REMOVAL OF ADAPTER LINES

- 4.1 Remove and stow 3/4 inch GH<sub>2</sub> outlet line identified (PV) on shaft housing assembly. Maintain line cleanliness.
- 4.2 Install pressure cap on PV facility line.
- 4.3 Remove and stow 3/4 inch GH<sub>2</sub> inlet line identified (PR) on radial loader assembly. Maintain line cleanliness.
- 4.4 Install pressure cap on PR facility line.
- 4.5 Remove and stow 1/2 inch LH<sub>2</sub> inlet lines (2 each) identified (LSH) on shaft housing adapter flange. Maintain line cleanliness.
- 4.6 Install pressure caps (2 each) on LSH facility lines.
- 4.7 Disconnect 1 inch LH<sub>2</sub> outlet line identified (LDH) on rear of motor housing
- 4.8 Install 1 inch plug in LDH facility line.

5.0 REMOVAL OF TESTER ASSEMBLY

- 5.1 Install lifting fixture on mounting flange (use 2 lubricated bolts NAS 1008-20A or acceptable equivalent) torqued to approx. 20-25 ft-lbs.
- 5.2 Connect hoist to lifting fixture (Tester assembly approximate weight is 350 lbs.)
- 5.3 Remove tester assembly mounting bolts from mounting stand (6 each).
- 5.4 Install all plugs, caps and fittings removed to facilitate installation and testing.



AGCS-0800-11

REPORT NO. TMP-111	PAGE 5 OF 5
DATE 12-8-71	
WORK ORDER	
BY D. H. Duke	CHK. BY J. B. Accinelli
DATE <i>[Signature]</i>	

SUBJECT  
NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 REMOVAL PROCEDURE

- \_\_\_\_\_ 5.5 Remove tester assembly and mounting stand from test stand.
- \_\_\_\_\_ 5.6 Place tester assembly and mounting stand in transport container and secure.
- \_\_\_\_\_ 5.7 Move tester assembly to E-MAD for disassembly per TMP-105.
- \_\_\_\_\_ 6.0 CLEAR ALL INSPECTION REPORTS.

\_\_\_\_\_  
Cognizant Project Engineer

\_\_\_\_\_  
Date

\_\_\_\_\_  
Quality Engineer

\_\_\_\_\_  
Date



REPORT NO. TMP-113	PAGE 1 OF 3
B/L #	DATE 9-7-71
S/N	WORK ORDER
DATE	

SUBJECT NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 ROTATIONAL DIRECTION CHECK	
BY D. H. Duke	CHK. BY J. B. Accinelli

Q/A *[Signature]*

1.0 GENERAL

- 1.1 This procedure defines the operations necessary to determine the direction of rotation of the NERVA Bearing Tester P/N 1138060-2 & 3 Shaft.
- 1.2 This procedure will be completed following facility experimental plan activity and prior to bearing tester removal from test stand.
- 1.3 Tester assembly shall be at zero pressure, ambient temperature, and purged with GN<sub>2</sub> or GH<sub>e</sub> prior to start of this procedure.
- 1.4 Internal cleanliness of tester assembly must be maintained during this operation.
- 1.5 Proper safeguards with respect to handling fixtures, tooling and protective covers shall be enforced to protect quality of the assembly.
- 1.6 Any non-conformance to procedure or drawing requirements shall be recorded on a historical inspection report.
- 1.7 Entire procedure shall be under the direction of the cognizant project engineer and the surveillance of the quality engineer.
- 1.8 Shaft rotation will be described as clockwise (CW) or counterclockwise (CCW) as viewed from loader housing end of tester assembly.





REPORT NO. TMP-113	PAGE 3 OF 3
DATE 9-7-71	
WORK ORDER	
DATE	

SUBJECT NERVA BEARING TESTER (65 MM) P/N 1138060-2 & 3 ROTATIONAL DIRECTION CHECK	
BY D. H. Duke	CHK. BY J. B. Accinelli Q/A <i>[Signature]</i>

3.0 SECURE

- \_\_\_\_\_ 3.1 Remove tape strip from end of load sleeve.
- \_\_\_\_\_ 3.2 Install end cap to shaft housing assembly using 12 mounting bolts and torque to approximately 70 in-lbs.
- \_\_\_\_\_ 3.3 Install 3/4 inch pressure cap on GH<sub>2</sub> inlet boss identified (P.A.) on end cap.

\_\_\_\_\_ 4.0 CLEAR ALL INSPECTION REPORTS

\_\_\_\_\_ Cognizant Project Engineer      \_\_\_\_\_ Date

\_\_\_\_\_ Quality Engineer      \_\_\_\_\_ Date



REPORT NO. TMP-115	PAGE 1 OF 13
B/U No.	DATE 15 October 1971
	WORK ORDER
	DATE

SUBJECT  
NERVA BEARING PRETEST PREPARATION FOR 1138146, 1139188,  
and 1139792

BY D. A. Koch *D. A. Koch* | CHK. BY *J. Blacorn* *J. Blacorn* | Q.A. *10/21/71*

1.0 GENERAL

- 1.1 Receive bearings (65mm ball bearing) and record P/N \_\_\_\_\_, S/N \_\_\_\_\_.
- 1.2 Visually inspect each bearing for physical damage. Document under "Remarks" any abnormal conditions.
- 1.3 Any non-conformance to procedure or drawing requirements shall be recorded on a Historical Inspection Report.
- 1.4 Q.A. Requirements per ANSC Memorandum N7000:2072 dated 18 June 1971.
- 1.5 Pretest preparation procedure shall be under the direction of cognizant Project Engineer and surveillance of Quality Engineer.

REMARKS: \_\_\_\_\_  
 \_\_\_\_\_  
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REPORT NO. TMP-115	PAGE 2 OF 13
B/U No.	DATE 15 October 1971
	WORK ORDER
BY D. A. Koch	CHK. BY Q.A.
	DATE

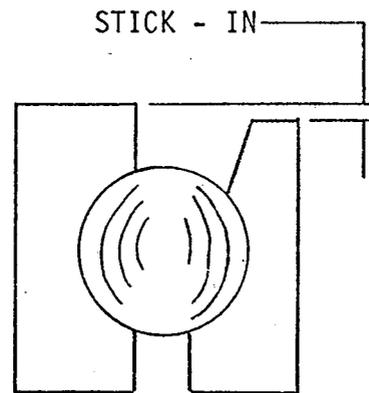
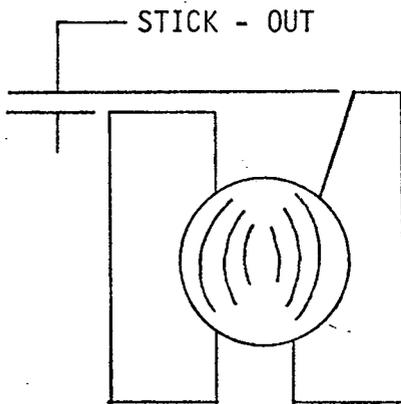
SUBJECT  
NERVA BEARING PRETEST PREPARATION

2.0 INNER RACE STICK IN (OUT) MEASUREMENT

- 2.1 Place bearing over 65mm inner race plug (S.A. 002) with axis in vertical position. (Inner race tapered surface facing UP).
- 2.2 Place bearing and plug from Step 1.0 on micro-flat table.
- 2.3 Install 65mm outer race support (S.A. 001) over bearing.
- 2.4 Measure and record elevation differential between inner and outer race axial faces at 4 locations (90° apart). Use electronic dial indicator inserted through .500 diameter port in outer race support (S.A. 001).

INNER RACE STICK IN (OUT) = Max. \_\_\_\_\_ in.

Min. \_\_\_\_\_ in.





REPORT NO. TMP-115	PAGE 3 OF 13
B/U No. Q.A.	DATE 15 October 1971
	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

### 3.0 CONTACT ANGLE MEASUREMENT

- \_\_\_ 3.1 Place bearing in 65mm outer race support (S.A. 001) with axis in vertical position. (Inner race tapered surface facing DOWN).
- \_\_\_ 3.2 Mark axial face of inner race, outer race, and retainer with fine black felt tip marker. All 3 marks must be in line and with zero degree mark on polar coordinate indicator.
- \_\_\_ 3.3 Insert 65mm inner race plug (S.A. 002) into inner race.
- \_\_\_ 3.4 Rotate inner race 32 complete turns. Note and record number of turns (complete  $\pm$  partial) performed by retainer.

$$N_e \text{ (RETAINER)} = \text{_____} \text{ TURNS } \pm \text{_____}^\circ$$

- \_\_\_ 3.5 Determine contact angle from Figure 1 and record.

$$\beta = \text{_____}^\circ$$

### 4.0 BEARING DISASSEMBLY

- \_\_\_ 4.1 Install .250 thick foam lining in inside-bottom of 65mm outer race support (S.A. 001).
- \_\_\_ 4.2 Place bearing in 65mm outer race support with axis in vertical position. (Inner race tapered surface facing UP).
- \_\_\_ 4.3 Chill 65mm inner race plug (S.A. 002) in LN<sub>2</sub> until temperature stabilizes.
- \_\_\_ 4.4 Carefully insert 65mm inner race plug into bearing inner race.
- \_\_\_ 4.5 Wait for inner race to chill and disengage from balls. Then, remove 65mm inner race plug (S.A. 002).
- \_\_\_ 4.6 Place entire bearing (do not remove from 65mm outer race support) in 200-250°F oven sufficient time required to permit dehydration.
- \_\_\_ 4.7 Remove from oven and allow bearing to return to ambient temperature.



REPORT NO. TMP-115	PAGE 4 OF 13
B/U No. Q.A.	DATE 15 October 1971
	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

5.0 BEARING CLEANING

5.1 Place metal parts of bearing in ultrasonic cleaning basket (brass or coated wire).

5.2 Use one of the following cleaning fluids:

- Chlorothene
- Trichloroethylene
- Freon
- Methylene Chloride

INDICATE WHICH FLUID IS USED.

5.3 Allow ultrasonic cleaning process to continue for  $10 \pm 1$  min.

5.4 Remove parts from fluid and air dry or use  $GN_2$  as required.  
ALTERNATE CLEANING PROCEDURE FOR METAL PARTS.

5.5 Place metal parts of bearing in cleaning basket (brass or coated wire) and submerge in cleaning fluid. Hand agitate and brush with bristle brush as necessary. NOTE: USE SUITABLE PROTECTIVE GLOVES.

5.6 Remove parts from fluid and air dry or use  $GN_2$  as required.

5.7 Clean retainer by wiping with cloth dampened with fluids used in Step 2.0 and blow dry with low velocity  $GN_2$  stream.

NOTE: IF PARTS ARE NOT ASSEMBLED WITHIN 8 HOURS AFTER CLEANING, THE METAL PARTS MUST BE REPROCESSED PER THIS PROCEDURE OR SUITABLY PACKAGED TO PREVENT CONTAMINATION.



REPORT NO. TMP-115	PAGE 5 OF 13
B/U No. Q.A.	DATE 15 October 1971
	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

6.0 WEIGHT EACH BALL AND RECORD

BALL WEIGHTS (5.4755 GRAMS, Typical)

1. _____ GRAMS	11. _____ GRAMS
2. _____ GRAMS	12. _____ GRAMS
3. _____ GRAMS	13. _____ GRAMS
4. _____ GRAMS	14. _____ GRAMS
5. _____ GRAMS	15. _____ GRAMS
6. _____ GRAMS	16. _____ GRAMS
7. _____ GRAMS	17. _____ GRAMS
8. _____ GRAMS	
9. _____ GRAMS	
10. _____ GRAMS	

7.0 PACKAGE EACH INDIVIDUAL BALL AND IDENTIFY NUMERICALLY (1 THRU 17).MAINTAIN TRACEABILITY TO P/N and S/N.8.0 INDIVIDUALLY WRAP OUTER RACE, RETAINER, AND INNER RACE IN KIM WIPES (T.M.) AND PLACE ALL PARTS IN SUITABLE CONTAINER (PLASTIC BAG). MAKE OUT TAG WITH THE P/N AND S/N AND INSERT INTO CONTAINER.

NOTE: HANDLE ALL PARTS WITH CARE, PACKAGE TO PREVENT SHIPPING DAMAGE AND RETAIN TRACEABILITY TO P/N AND S/N AT ALL TIMES.

9.0 SEND BEARING TO MEASUREMENT STANDARDS LABORATORY. RECORD REFERAL # \_\_\_\_\_ PERFORM DIMENSIONAL INSPECTION PER FOLLOWING REQUIREMENTS.







SUBJECT

NERVA BEARING PRETEST PREPARATION

B/U No.

Q.A.

DATE  
15 October 1971

WORK ORDER

BY  
D. A. Koch

CHK. BY

DATE

9.3 ITEM NAME BALL

CHARACTERISTICS REQUIRED

DIAMETER 0.4375/0.4373 IN.

	<u>MAX. DIA.</u>	<u>MIN. DIA.</u>	<u>MAX. DIA.</u>	<u>MIN. DIA.</u>
✓ 1.	_____ IN.	_____ IN.	11.	_____ IN.
2.	_____ IN.	_____ IN.	✓ 12.	_____ IN.
3.	_____ IN.	_____ IN.	13.	_____ IN.
4.	_____ IN.	_____ IN.	14.	_____ IN.
5.	_____ IN.	_____ IN.	15.	_____ IN.
6.	_____ IN.	_____ IN.	16.	_____ IN.
✓ 7.	_____ IN.	_____ IN.	17.	_____ IN.
8.	_____ IN.	_____ IN.		
9.	_____ IN.	_____ IN.		
10.	_____ IN.	_____ IN.		

MAXIMUM O.R. \_\_\_\_\_ IN.

SET, MAXIMUM DIAMETER \_\_\_\_\_ IN.

SET, MINIMUM DIAMETER \_\_\_\_\_ IN.

SET, MAX. DIA. VARIATION \_\_\_\_\_ IN.

MICROSCOPIC INSP. MAG \_\_\_\_\_

YES  NO

REMARKS: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





REPORT NO. TMP-115	PAGE 10 OF 13
B/U No.	DATE 15 October 1971
Q.A.	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

10.0 REIDENTIFY BEARING

\_\_\_\_\_ P/N \_\_\_\_\_ DASH NO. \_\_\_\_\_

Refer to applicable ball bearing assembly drawing for method and location of reidentification.

11.0 RECLEAN INNER AND OUTER RACES

\_\_\_\_\_ 11.1 Place metal parts of bearing in ultrasonic cleaning basket (brass or coated wire).

\_\_\_\_\_ 11.2 Use one of the following cleaning fluids:

Chloroethene  
Trichloroethylene  
Freon  
Methylene Chloride

INDICATE WHICH FLUID IS USED.

\_\_\_\_\_ 11.3 Allow ultrasonic cleaning process to continue for 10 ± 1 min.

\_\_\_\_\_ 11.4 Remove parts from fluid and air dry or use GN<sub>2</sub> as required.  
ALTERNATE CLEANING PROCEDURE FOR METAL PARTS.

\_\_\_\_\_ 11.5 Place metal parts of bearing in cleaning basket (brass or coated wire) and submerge in cleaning fluid. Hand agitate and brush with bristle brush as necessary.

NOTE: USE SUITABLE PROTECTIVE GLOVES

\_\_\_\_\_ 11.6 Remove parts from fluid and air dry or use GN<sub>2</sub> as required.



REPORT NO. TMP-115	PAGE 11 OF 13
B/U No. Q/A	DATE 15 October 1971
	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

12.0 BEARING LUBRICATION

\_\_\_ 12.1 Weigh Retainer. \_\_\_\_\_

\_\_\_ 12.2 Prior to the application of lubricant (dry film,  $M_0S_2$ ), verify cleanliness per approved procedure.

\_\_\_ 12.3 Retainer Lubrication

\_\_\_ 12.3.1 Prior to spraying the part, the operator shall establish the distance from nozzle to work by spraying a sheet of bond paper. Adjust distance from work to nozzle so that the resin arrives still wet on the surface without running or rippling. Distance shall not be so great that resin arrives partially dry. The distance limits, as established by spraying the paper, shall be used when spraying the part.

NOTE: PART IS NOT SPRAYED IN THIS STEP (STEPS 12.3.2 THRU 12.3.4 APPLICABLE ONLY IF AUTHORIZED BY COGNIZANT ENGINEER.)

\_\_\_ 12.3.2 Obtain liquid solution of lubricant ( $M_0S_2$ ) - by discharging spray can into suitable container (spray can top).

\_\_\_ 12.3.3 Using a cotton tip swab, thoroughly apply lubricant from Step 12.3.2 to all areas of the retainer (O.D., I.D., and pockets). Allow to air dry for 30 minutes.

\_\_\_ 12.3.4 Polish by hand with Kim Wipes (T.M.), applying light weight of hand pressure. Use clean cotton tip swab for polishing pockets.

\_\_\_ 12.3.5 Spray entire retainer (O.D., I.D., and pockets) per procedure in 12.3.1 and allow to air dry for 10 minutes.

\_\_\_ 12.3.6 Repeat polishing procedure per 12.3.4.

\_\_\_ 12.3.7 Spray retainer with second coat of lubricant and allow to air dry for 30 minutes.

\_\_\_ 12.3.8 Repeat polishing procedure per 12.3.4.

\_\_\_ 12.3.9 Identify pocket 1 and 2 in C. W. Direction on one edge using black marking pen and marks I (for 1) and II (for 2).



REPORT NO. TMP-115	PAGE 12 OF 13
B/U No. Q.A.	DATE 15 October 1971
	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

12.3.10 Weigh Retainer. \_\_\_\_\_ GRAMS  
[Net wt. MoS<sub>2</sub> applied \_\_\_\_\_ GRAMS

12.4 Raceway Lubrication

- 12.4.1 Lubrication shall NOT be applied to O.D. of outer race, I.D. of inner race or axial faces. This to be accomplished by masking affected areas and/or employing special barriers.
- 12.4.2 Prior to spraying the part, the operator shall establish the distance from nozzle to work per 12.3.1.
- 12.4.3 Place parts in 200-250°F oven for approximately 3 minutes or sufficient time to allow parts to become warm to the touch.
- 12.4.4 Remove from oven and spray raceways. Allow to air dry for 15-minutes.
- 12.4.5 Vigorously polish sprayed areas by hand with Kim Wipes (T.M.) until surface is shiny and excess lubricant is removed.
- 12.4.6 Remove all masking tape and insure that parts are free from any over spray.
- 12.4.7 Remove over spray from race faces by carefully rubbing affected faces on very lightly chlorothene moistened absorbent material.

ALTERNATE METHOD (Raceways)

12.4.8 Apply dry film lubricant per ANSC approved commercial process.

P.O. \_\_\_\_\_



REPORT NO. TMP-115	PAGE 13 OF 13
B/U No.	DATE 15 October 1971
Q.A.	WORK ORDER
BY D. A. Koch	CHK. BY
	DATE

13.0 BEARING ASSEMBLY PROCEDURE

- \_\_\_ 13.1 Place bearing outer race and retainer on top of support ring (85mm ball bearing inner race) (S.A. 003). Bearing identification (P/N, S/N, etc.) faces DOWN. Retainer pocket identification marks (1 & 11) face UP.
- \_\_\_ 13.2 Place bearing inner race inside support ring (centrally located) with identifying marks (P/N, S/N, etc.) face DOWN.
- \_\_\_ 13.3 Place balls in proper pocket location - numerically consecutive in C.W. order. Start with retainer pockets I and II.
- \_\_\_ 13.4 Grasp inner race on inside and gently lift up, thereby engaging the balls and allowing them to move up the taper toward the raceway.
- \_\_\_ 13.5 Place partially assembled bearing on top of bearing spacer (P/N 1138198). Identification marks still in DOWN position.
- \_\_\_ 13.6 Chill 65mm inner race plug (S.A. 002) in LN<sub>2</sub> until temperature stabilizes.
- \_\_\_ 13.7 Carefully insert 65mm inner race plug into bearing inner race.
- \_\_\_ 13.8 Slowly rotate outer race while simultaneously applying a small downward force, with finger, and continue until bearing snaps into place.
- \_\_\_ 13.9 Place bearing and spacer into 200-250°F oven for dehydration. DO NOT remove bearing from spacer until after temperatures return to ambient.
- \_\_\_ 13.10 Place fully assembled bearing in suitable container (plastic bag) & seal.

14.0 CLEAR ALL INSPECTION REPORTS

DATE

COGNIZANT PROJECT ENGINEER

65 MM BALL BEARING CONTACT ANGLE

$$\cos \beta = E/d \left( 1 - \frac{2 N_e}{N_i} \right)$$

E = Pitch Diameter = 3.248

d = Ball Diameter = .4375

N<sub>i</sub> = I.R. Turns = 32

N<sub>e</sub> = Cage Turns

CONTACT ANGLE - β - DEGREES

-2      0      +2      +4      +6      +8      +10      +12      +14

PARTIAL CAGE TURN\* - DEGREES

\*After 14 complete turns (+)  
Before 14 complete turns (-)

FIGURE 1

B





SUBJECT		B/U No.	DATE
NERVA BEARING TESTER (65MM) PRE-TEST SHAFT TORQUE CHECK (APPLICABLE TO P/N 1138060 & P/N 1138990)		S/N	10-26-71
			WORK ORDER
BY	CHK. BY	DATE	
D. A. Koch			

RUN NO.

	1	2	3	4	5	6	7	8	9
1.7 Re-establish pressure pad per Section 19.0 of TMP-103.									
1.8 Clear all inspection reports.									

\_\_\_\_\_  
Cognizant Project Engineer

\_\_\_\_\_  
Date

\_\_\_\_\_  
Quality Engineer

\_\_\_\_\_  
Date



REPORT NO. TMP-121	PAGE 1 OF 6
B/U NO.	DATE 11-28-71
	WORK ORDER
9/A 7/12/71	DATE

SUBJECT  
NERVA BEARING POST-TEST INVESTIGATION FOR 1138146, 1139188,  
and 1139792

BY  
D. A. Koch *D.A. Koch*

CHK. BY  
*J. Baccinella*

1.0 General

- 1.1 Receive bearing (65mm ball bearing) and record P/N \_\_\_\_\_, S/N \_\_\_\_\_.
- 1.2 Visually inspect each bearing for physical damage. Document under "Remarks" any abnormal conditions.
- 1.3 Any non-conformance to procedure or drawing requirements shall be recorded on a Historical Inspection Report.-
- 1.4 Q.A. requirements per ANSC Memorandum N7000:2072 dated 18 June 1971.
- 1.5 Post-Test investigation procedure shall be under the direction of cognizant project engineer and surveillance of Quality engineer.

REMARKS: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



REPORT NO. TMP-121	PAGE 2 OF 6
B/U NO.	DATE 11-28-71
	WORK ORDER
BY D. A. Koch	CHK. BY P/A
	DATE

2.0 Bearing Disassembly

- 2.1 Install .250 thick foam lining in inside-bottom of 65mm outer race support (S.A. 001).
- 2.2 Place bearing in 65mm outer race support with axis in vertical position. (Inner race tapered surface facing UP).
- 2.3 Chill 65mm inner race plug (S.A. 002) in LN<sub>2</sub> until temperature stabilizes.
- 2.4 Carefully insert 65mm inner race plug into bearing inner race.
- 2.5 Wait for inner race to chill and disengage from balls. Then, remove 65mm inner race plug (S.A. 002).
- 2.6 Place entire bearing (do not remove from 65mm outer race support) in 200-250°F oven sufficient time required to permit dehydration.
- 2.7 Remove from oven and allow bearing to return to ambient temperature.

NOTE: Steps 2.1 - 2.7 WILL BE N/A IF EXCESSIVE BEARING WEAR REQUIRED REMOVAL OF BALLS DURING STEP 14.2 OF TMP-105.

3.0 Preliminary visual and microscopic investigation by cognizant project engineer.

REMARKS: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



REPORT NO. TMP-121	PAGE 3 OF 6
B/U NO.	DATE 11-28-71
	WORK ORDER
BY D. A. Koch	CHK. BY P/A
	DATE

SUBJECT  
NERVA BEARING POST-TEST INVESTIGATION

4.0 Package each individual ball and identify numerically (1 thru 17).  
Maintain traceability to P/N and S/N

5.0 Individually wrap outer race, retainer, and inner race in Kim Wipes (T.M.) and place all parts in suitable container (plastic bag).  
Make out tag with the P/N and S/N and insert into container.

NOTE: HANDLE ALL PARTS WITH CARE, PACKAGE TO PREVENT SHIPPING DAMAGE AND RETAIN TRACEABILITY TO P/N AND S/N AT ALL TIMES.

6.0 Send bearing to Measurement Standards Laboratory. Record Referral No. \_\_\_\_\_ and I. R. No. \_\_\_\_\_. Perform Dimensional inspection per following requirements.

6.1 Weigh each ball and record. (Clean each ball prior to weighing with Kim Wipe (T.M.) moistened in Methylene chloride).  
Ball Weights (5.4755 Grams, typical)

- |                |                 |
|----------------|-----------------|
| 1. _____ grams | 10. _____ grams |
| 2. _____ grams | 11. _____ grams |
| 3. _____ grams | 12. _____ grams |
| 4. _____ grams | 13. _____ grams |
| 5. _____ grams | 14. _____ grams |
| 6. _____ grams | 15. _____ grams |
| 7. _____ grams | 16. _____ grams |
| 8. _____ grams | 17. _____ grams |
| 9. _____ grams |                 |

6.2 Weigh retainer \_\_\_\_\_ grams.



REPORT NO. TMP-121	PAGE 4 OF 6
B/U NO.	DATE 11-28-71
	WORK ORDER
Q/A	DATE

SUBJECT  
NERVA BEARING POST-TEST INVESTIGATION

BY  
D. A. Koch

CHK. BY

6.3 Item Name OUTER RACE

(Prior to dimensional inspection, clean affected surfaces with Kim Wipe (T.M.) moistened in methylene chloride).

CHARACTERISTICS	REQUIRED	0°	90°
Inside Diameter (Land)	<u>3.5110/3.5100 In.</u>	Top _____ In.	_____ In.
		Bot _____ In.	_____ In.
Outside Diameter	<u>3.9370/3.9368 In.</u>	_____ In.	_____ In.
Microscopic Insp.	MAG. _____	YES <input type="checkbox"/>	NO <input type="checkbox"/>

Remarks: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

6.4 Item Name INNER RACE

(Prior to dimensional inspection, clean affected surfaces with Kim Wipe (T.M.) moistened in methylene chloride).

CHARACTERISTICS	REQUIRED	0°	90°
Inside Diameter	<u>2.5589/2.5591 In.</u>	Top _____ In.	_____ In.
		Bot _____ In.	_____ In.
Microscopic Insp.	MAG. _____	YES <input type="checkbox"/>	NO <input type="checkbox"/>

Remarks: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



REPORT NO. TMP-121	PAGE 5 OF 6
B/U NO.	DATE 11-28-71
	WORK ORDER
P/A	DATE

SUBJECT  
NERVA BEARING POST-TEST INVESTIGATION

BY  
D. A. Koch

CHK. BY

6.5 Item Name RETAINER P/N \_\_\_\_\_ S/N \_\_\_\_\_

Material \_\_\_\_\_

<u>CHARACTERISTICS</u>	<u>REQUIRED</u>			
Outside Diameter	<u>3.502/3.497 In.</u>	0°	_____ In.	90° _____ In.
Land Diameter (O.D.)	_____	0°	_____ In.	90° _____ In.

O.D. Step = \_\_\_\_\_

Remarks: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

6.6 Item Name BALL

<u>CHARACTERISTICS</u>	<u>REQUIRED</u>
Diameter	<u>0.4375/0.4373 In.</u>

<u>MAX. DIA.</u>	<u>MIN DIA.</u>	<u>DIA. VARIATION</u>
1. _____ IN.	_____ In.	_____ In.
2. _____ IN.	_____ IN.	_____ IN.
3. _____ IN.	_____ IN.	_____ IN.
4. _____ IN.	_____ IN.	_____ IN.
5. _____ IN.	_____ IN.	_____ IN.
6. _____ IN.	_____ IN.	_____ IN.
7. _____ IN.	_____ IN.	_____ IN.
8. _____ IN.	_____ IN.	_____ IN.
9. _____ IN.	_____ IN.	_____ IN.
10. _____ IN.	_____ IN.	_____ IN.
11. _____ IN.	_____ IN.	_____ IN.
12. _____ IN.	_____ IN.	_____ IN.



REPORT NO. TMP-121	PAGE 6 OF 6
B/U No.	DATE 11-28-71
	WORK ORDER
Q/A	DATE

SUBJECT  
NERVA BEARING POST-TEST INVESTIGATION

BY  
D. A. Koch

CHK. BY

MAX DIA.	MIN DIA.	DIA. VARIATION
13. _____ IN.	_____ IN.	_____ IN.
14. _____ IN.	_____ IN.	_____ IN.
15. _____ IN.	_____ IN.	_____ IN.
16. _____ IN.	_____ IN.	_____ IN.
17. _____ IN.	_____ IN.	_____ IN.

MAXIMUM O.R. \_\_\_\_\_ IN.

SET, MAXIMUM DIAMETER \_\_\_\_\_ IN.

SET, MINIMUM DIAMETER \_\_\_\_\_ IN.

SET, MAX. DIA. VARIATION \_\_\_\_\_ IN.

MICROSCOPIC INSP. MAG. \_\_\_\_\_

YES  NO

Remarks: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## APPENDIX B

### Turbomachinery Procedures (TMP) for LH<sub>2</sub> Dual Duplex Bearing Tester 1138990-1

1. Assembly Procedure, TMP-102
2. Forward Cartridge/Housing Interface Clearance Test, TMP-119
3. Aft Cartridge/Housing Interface Clearance Test, TMP-120
4. Disassembly Procedure, TMP-107

/



REPORT NO. TMP-102	PAGE 1 <sup>a</sup> OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY *D.A. Koch*  
D. A. Koch

CHK. BY *J. Blacinn*

TESTER P/N \_\_\_\_\_ DASH NO. \_\_\_\_\_ LETTER CHANGE \_\_\_\_\_

1.0 GENERAL

- 1.1 Prior to assembly, all components to be cleaned per AGC-STD-9007, Level II (internal), Level I (external).
- 1.2 Visually inspect each component for physical damage. Document under "Remarks" any abnormal condition, i.e., scratches, scoring, rubs, chipped, fretted, or otherwise abnormally worn areas.
- 1.3 In the event of partial disassembly, "N/A" shall be written before operations eliminated by partial disassembly.
- 1.4 Lube all threads at assembly using Moly-disulfide 321. Always wipe off excess lubrication.
- 1.5 Torque all bolts in alternating sequence per ASD 5226.
- 1.6 Entire assembly procedure shall be under the direction of cognizant project engineer and surveillance of quality engineer.
- 1.7 Q.A. requirements per ANSC Memo N7000:2072 dated 6-8-71.

REMARKS: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_



REPORT NO. TMP-102	PAGE 2 OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

## 2.0 BALANCING OF ROTOR AND SHAFT ASSEMBLY (P/N 1138994-1)

- 2.1 Apply thin layer of moly-disulfide 321 to radial surfaces of shaft (P/N 1138988-1) (S/N \_\_\_\_\_) where balance bearings (2), ITI-12997 are located. Wipe off excess lubrication.
- 2.2 Place motor armature (P/N 113893-1) (S/N \_\_\_\_\_) and balance bearings (2), ITI-12997 in 275-300°F oven (25-30 min). Simultaneously chill shaft in LN<sub>2</sub>.
- 2.3 Assemble armature and 2 balance bearings to shaft per drawing 1138994. NOTE: USE .5" SPACERS (P/N 1139724-1) TO STAND OFF BEARINGS REQUIRED DISTANCE FROM SHAFT SHOULDERS.
- 2.4 Place shaft assembly in 275-300°F oven to permit dehydration and return to ambient temperature.
- 2.5 Place shaft assembly in press with 2 ton load for one minute to insure positive seating of armature. NOTE: USE SPLIT SLEEVE (P/N 1139726-1) TO SUPPORT SHAFT.
- 2.6 Balance completed shaft assembly per Drawing 1138994.
- 2.7 Match mark armature and shaft per G/N  and identify per G/N , Drawing 1138994.
- 2.8 Remove balance bearings from shaft assembly. NOTE: USE SPLIT SLEEVE (P/N 1139724-1) TO PRESS OF BEARINGS.
- 2.9 Reclean all components per 1.1.



REPORT NO. TMP-102	PAGE 3 OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

SUBJECT BUILD UP PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990	
BY D. A. Koch	CHK. BY

3.0 SHAFT ASSEMBLY (prior to assembly, apply Molykote 321 per Dwg 1138991)

3.1 Forward Duplex Bearing Subassembly (Refer to G/N 6, Dwg 1138991 for proper bearing alignment.)

3.1.1 Place forward lower split ring holder (P/N 1139725-1) on build up mandrel (P/N 1139725-5).

3.1.2 Place No. 2 ball bearing assembly (P/N \_\_\_\_\_), (S/N \_\_\_\_\_) on mandrel. NOTE: NO. 2 BEARING IS NEAREST TO ARMATURE.

3.1.3 Assemble inner race spacer (P/N 1138197-1), (S/N \_\_\_\_\_) on mandrel.

3.1.4 Assemble forward outer race sleeve (P/N 1138984-1) (S/N \_\_\_\_\_) over ball bearing assembly.

3.1.5 Install springs (P/N 1137056-1) in outer race sleeve. Amount and location per direction of cognizant engineer.

3.1.6 Place No. 1 ball bearing assembly (P/N \_\_\_\_\_), (S/N \_\_\_\_\_) in outer race sleeve and over mandrel.

3.1.7 Place forward upper ring holder (P/N 1139725-4) on mandrel.

3.1.8 Install ring holder bolts (6 each) finger tight.



REPORT NO. TMP-102	PAGE 4 OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

SUBJECT BUILD UP PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990	
BY D. A. Koch	CHK. BY

3.2 Aft Duplex Bearing Subassembly (Refer to G/N 6, Dwg 1138991 for proper bearing alignment.)

- 3.2.1 Place aft lower split ring holder (P/N 1139726-1) on build up mandrel (P/N 1139726-5).
- 3.2.2 Place No. 4 ball bearing assembly (P/N \_\_\_\_\_), (S/N \_\_\_\_\_) on mandrel. NOTE: NO. 4 BEARING IS NEAREST ARMATURE.
- 3.2.3 Assemble inner race spacer (P/N 1138197-1) (S/N \_\_\_\_\_) on mandrel.
- 3.2.4 Assemble aft outer race sleeve (P/N 1138985-1) (S/N \_\_\_\_\_) over ball bearing assembly.
- 3.2.5 Install springs (P/N 1137056-1) in outer race sleeve. Amount and location per direction of cognizant engineer.
- 3.2.6 Place No. 3 ball bearing assembly (P/N \_\_\_\_\_), (S/N \_\_\_\_\_) in outer race sleeve and over mandrel.
- 3.2.7 Place aft upper ring holder (P/N 1139726-4) on mandrel.
- 3.2.8 Install ring holder bolts (6 each) finger tight.
- 3.2.9 Place forward and aft duplex bearing subassemblies in 275-300°F oven (30 minutes). Simultaneously chill shaft assembly in LN<sub>2</sub>.



SUBJECT  BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990		REPORT NO. TMP-102	PAGE 5 OF 14
		B/U NO.	DATE 11-30-71 WORK ORDER
BY D. A. Koch	CHK. BY	Q/A	DATE

- 3.2.10 Remove forward duplex bearing subassembly from oven and place in press. Apply axial load of 2 tons to insure proper axial seating.
- 3.2.11 Tighten ring holder bolts 15-20 ft-lbs.
- 3.2.12 Remove axial load. Place subassembly in 275-300°F oven (20 minutes).
- 3.2.13 Remove aft duplex bearing subassembly from oven and place in press. Apply axial load of 2 tons to insure proper axial seating.
- 3.2.14 Tighten ring holder bolts 15-20 ft-lbs.
- 3.2.15 Remove axial load. Place subassembly in 275-300°F oven (20 minutes).
- 3.2.16 Remove forward duplex bearing subassembly from oven and press out mandrel (use mandrel press-out tube, P/N 1139727-1).
- 3.2.17 Remove aft duplex bearing subassembly from oven and press out mandrel (use mandrel press-out tube P/N 1139727-1).
- 3.2.18 Install forward duplex bearing subassembly on shaft subassembly.
- 3.2.19 Remove upper and lower ring holders and invert shaft.  
NOTE: SUPPORT SHAFT ON FORWARD UPPER RING HOLDER (P/N 1139725-4).
- 3.2.20 Install aft duplex bearing subassembly on shaft subassembly.



REPORT NO. TMP-102	PAGE 6 OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

- 3.2.21 Remove upper and lower ring holders and apply 10 ton load to bearing inner races for 5 minutes to insure positive axial seating. (Press with stack-up tube, P/N 1139728-1).
- 3.2.22 Place shaft assembly in 275-300°F oven to permit dehydration and return to ambient temperature.
- 3.2.23 Remove shaft assembly from oven and apply 10 ton load for 1 minute to insure positive axial seating. Support shaft on forward upper ring holder, P/N 1139725-4, and press with stack-up tube, P/N 1139728-1.
- 3.2.24 Place shaft assembly in torque support fixture, P/N 1139729-1.
- 3.2.25 Place forward locking sleeve (P/N 1138986-1) (S/N \_\_\_\_\_) and aft locking sleeve (P/N 1138987-1), (S/N \_\_\_\_\_) in 275-300°F oven for 5 minutes.
- 3.2.26 Place 3 forward locking tabs (P/N 1138992-1) in position and install forward locking sleeve.
- 3.2.27 Place 3 aft locking tabs (P/N 1138992-2) in position and install aft locking sleeve.
- 3.2.28 Allow assembly to return to ambient temperature.
- 3.2.29 Torque forward locking sleeve to 100-110 ft-lbs with spanner wrench, P/N 1139729-2. Bend one locking tab into matching slot.
- 3.2.30 Torque aft locking sleeve to 100-110 ft-lbs with spanner wrench, P/N 1139729-2. Bend one locking tab into matching slot.



REPORT NO. TMP-102	PAGE 7 OF 14
B/U NO.	DATE 11-30-71 WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

4.0 BEARING/CARTRIDGE INTERFACE CLEARANCE TEST

Perform following operations only if authorized by Test Request Supplement.

4.1 Attach actuating rods, 2 places, (S.A. \_\_\_\_\_) to aft cartridge (aft outer race sleeve, P/N 1138985-1). Rods to be diametrically opposed and secured in place with a 4-1/2" hose clamp.

4.2 Attach actuating rods, 2 places, (S.A. \_\_\_\_\_) to forward cartridge (Forward outer race sleeve, P/N 1138984-1). Rods to be diametrically opposed and secured in place with a 5" hose clamp.

NOTE: UNATTACHED ENDS OF RODS (4.1 & 4.2) TO EXTEND PAST LOADER END OF SHAFT.

4.3 Immerse and completely chill shaft assembly (P/N 1138991-1) in LN<sub>2</sub>. Shaft assembly to be in vertical position with loader (FWD) end UP.

4.4 Alternately actuate aft and forward cartridges up and down and determine degree of axial freedom existing between bearing outer races and bore of cartridges.

5.0 MOTOR HOUSING AND SUPPORT STAND ASSEMBLY

5.1 Place motor housing (P/N 1138983-1) (S/N \_\_\_\_\_) on support stand (P/N 1138996-1 (S/N \_\_\_\_\_)).

5.2 Install bolts (P/N NAS 1008-20H) and nuts (P/N MS9360-14). Torque to 520-550 in-lbs.

5.3 Safety wire per MS 33540, single wire method.



SUBJECT BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990		REPORT NO. TMP-102	PAGE 8 OF 14
		B/U NO.	DATE 11-30-71 WORK ORDER
BY D. A. Koch	CHK. BY	Q/A	DATE

## 6.0 SHAFT RIDING SEAL INSTALLATION

### 6.1 Seal Housing

6.1.1 Chill seal assembly (P/N 700977-9) in LN<sub>2</sub>.

NOTE: SUSPEND SEAL ABOVE LIQUID LEVEL.

6.1.2 Install seal into seal housing (P/N 1138998-1), (S/N \_\_\_\_\_). Snap ring on seal should face up and be visible when properly installed.

6.1.3 Install Spirolox retainer (P/N RR-381S) into seal housing.

6.1.4 Place seal housing assembly in 275-300°F oven for 30 minutes to permit dehydration.

### 6.2 Loader Housing

6.2.1 Chill seal assembly (P/N 700977-9) in LN<sub>2</sub>.

NOTE: SUSPEND SEAL ABOVE LIQUID LEVEL.

6.2.2 Install seal into loader housing (P/N 1138981-1) (S/N \_\_\_\_\_). Snap ring on seal should face up and be visible when properly installed.

6.2.3 Install Spirolox retainer (P/N RR-381S) into loader housing.

6.2.4 Place loader housing assembly in 275-300°F oven for 30 minutes to permit dehydration.

\* LABYRINTH RING (P/N 1138933-1) (S/N \_\_\_\_\_) MAY BE USED IN PLACE OF SEAL ASSEMBLY (P/N 700977-9) IF AUTHORIZED BY TEST REQUEST SUPPLEMENT.



REPORT NO. TMP-102	PAGE 9 OF 14
B/U NO.	DATE 11-30-71 WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER  
DRAWING 1138990

BY  
D. A. Koch

CHK. BY

7.0 SHAFT INSTALLATION

- 7.1 Install shaft assembly (P/N 1138991-1) into motor and housing assembly (P/N 1138983-1).
- 7.2 Assemble forward anti-rotation lock (P/N 1138982-1), 2 places and install retaining bolts (P/N EWB 0420-4H-2), 4 places.
- 7.3 Torque bolts to 60-70 in-lbs.
- 7.4 Safety wire per MS 33540, single wire method.
- 7.5 Assemble aft retainer rings (P/N 1138989-1), 2 places and install retaining bolts (P/N EWB 0420-4H-2) 6 places.
- 7.6 Torque bolts to 60-70 in-lbs.
- 7.7 Safety wire per MS 33540, single wire method.

8.0 SHAFT MOVEMENTS (RADIAL AND AXIAL)

- 8.1 With electronic dial indicator attached to motor and housing assembly, measure and record the following values:
  - 8.1.1 T.I.R. of forward locking sleeve at seal position. \_\_\_\_\_
  - 8.1.2 Total radial movement of shaft at forward seal position. \_\_\_\_\_
  - 8.1.3 T.I.R. of aft locking sleeve at seal position. \_\_\_\_\_
  - 8.1.4 Total radial movement of shaft at aft seal position. \_\_\_\_\_
  - 8.1.5 Total axial movement of shaft. \_\_\_\_\_
- 8.2 Shaft assembly breakaway torque. \_\_\_\_\_



REPORT NO. TMP-102	PAGE 10 OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER  
DRAWING 1138990

BY  
D. A. Koch

CHK. BY

9.0 LOADER HOUSING ASSEMBLY

9.1 Apply Viton "A" to motor housing seal gland. Install seal (P/N 22023AL6250) into seal gland and coat exposed face of seal with Viton "A".

9.2 Assemble loader housing (P/N 1138981-1) (S/N \_\_\_\_\_) to motor housing.

NOTE: USE GUIDE STUDS TO FACILITATE ASSEMBLY AND USE EXTREME CARE WHEN SLIPPING SEAL ASSEMBLY OVER LOCKING SLEEVE TO PREVENT DAMAGE TO CARBONS.

9.3 Install bolts (P/N EWB 0420-6H-2) 2 places and (P/N EWB 0420-6H-10) 10 places and torque to 200-220 in-lbs.

10.0 RADIAL LOADER INSTALLATION

10.1 Remove end cap from radial load assembly (P/N 1138979-1) (S/N \_\_\_\_\_). Retract adjusting screw to fully unloaded position. Actuate piston assembly in bore to assure free movement.

10.2 Apply Viton "A" to loader housing seal gland. Install seal (P/N 22022AL2687) into seal gland and coat exposed face of seal with Viton "A".

10.3 Assemble radial loader to loader housing. Install bolts (P/N EWB 0420-6H-4), 7 places.

10.4 Torque bolts to 200-220 in-lbs.

10.5 Adjust loader set screw by turning six (6) full turns  $\pm$  1/8 turn from fully unloaded position. Replace gasket, end cap, and screws. Torque screws to 9-11 in-lbs.



SUBJECT		REPORT NO.	PAGE 11 OF 14
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990		TMP-102	DATE 11-30-71
BY D. A. Koch	CHK. BY	B/U NO.	WORK ORDER
		Q/A	DATE

10.6 Apply Viton "A" to loader assembly inlet seal gland. Install gasket (P/N 54973-12S) into seal gland and coat exposed face of gasket with Viton "A".

10.7 Install tube assembly (P/N 269368-19) into loader assembly and torque adapter nut to 40-50 ft-lbs.

11.0 SEAL HOUSING INSTALLATION

11.1 Apply Viton "A" to motor and housing assembly seal gland. Install seal (P/N 22023AL6875) into seal gland and coat exposed face of seal with Viton "A".

11.2 Assemble seal housing (P/N 1138998-1) (S/N \_\_\_\_\_) to motor and housing assembly.

NOTE: USE GUIDE STUDS TO FACILITATE ASSEMBLY AND USE EXTREME CARE WHEN SLIPPING SEAL ASSEMBLY OVER LOCKING SLEEVE TO PREVENT DAMAGE TO CARBONS.

11.3 Install bolts (P/N EWB 0420-5H-8) 12 places and torque to 120-130 in-lbs.

12.0 SHAFT TORQUE MEASUREMENTS

12.1 Breakaway torque = \_\_\_\_\_ in-lbs.

12.2 Running Torque (1 RPS) = \_\_\_\_\_ in-lbs.



REPORT NO. TMP-102	PAGE 12 OF 14
B/U NO.	DATE 11-30-71
	WORK ORDER
Q/A	DATE

## SUBJECT

BUILD UP PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

### 13.0 AFT END COVER INSTALLATION

13.1 Apply Viton "A" to seal housing seal gland. Install seal (P/N 22022AL3812) into seal gland and coat exposed face of seal with Viton "A".

13.2 Assemble end cover (P/N 1138999-1) (S/N \_\_\_\_\_) to seal housing.

13.3 Install bolts (P/N EWB 0420-5H-8) 8 places and torque to 120-130 in-lbs.

### 14.0 FORWARD END COVER INSTALLATION

14.1 Apply Viton "A" to loader housing seal gland. Install seal (P/N 22023AL4125) into seal gland and coat exposed face of seal with Viton "A".

14.2 Assemble end cover (P/N 1138980-1) (S/N \_\_\_\_\_) to loader housing.

14.3 Install bolts (P/N EWB 0420-5H-8) 8 places and torque to 120-130 in-lbs.

15.0 Install Plug (Item 22) and seal (Item 45) or "RADIAL PLAY" spring, seal and plug (S.A. 021) as required by test request supplement.



REPORT NO. TMP-102	PAGE 13 OF 14
B/U NO.	DATE 11-30-71 WORK ORDER
Q/A	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

16.0 PROXIMITY PROBE INSTALLATION

16.1 Install transducers (P/N 1138997-1, 2 places and P/N 1138997-2, 7 places) to obtain a gap of .025 inch  $\pm$  .001 inch (at R.T.) between tip of probe and rotor. Gap adjustment is obtained by selecting spacers (P/N 1138995-1 thru -14) in sets of two as required.

16.2 Install "O" rings (P/N PRP 568-015) 9 places and torque to 520-550 in-lbs.

- \_\_\_\_\_ DT<sub>1</sub> (P/N 1138977-1) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>2</sub> (P/N 1138997-1) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>3</sub> (P/N 1138997-2) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>4</sub> (P/N 1138997-2) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>5</sub> (P/N 1138997-2) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>6</sub> (P/N 1138997-2) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>7</sub> (P/N 1138997-2) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>8</sub> (P/N 1138997-2) S/N \_\_\_\_\_
- \_\_\_\_\_ DT<sub>9</sub> (P/N 1138997-2) S/N \_\_\_\_\_

17.0 INSTALL RTT'S

- \_\_\_\_\_ T<sub>B</sub> (P/N 134 CT-300) S/N \_\_\_\_\_
- \_\_\_\_\_ T<sub>C</sub> (P/N 134 CT-300) S/N \_\_\_\_\_
- \_\_\_\_\_ T<sub>D</sub> (P/N 134 CT-300) S/N \_\_\_\_\_
- \_\_\_\_\_ T<sub>E</sub> (P/N 134 CT-300) S/N \_\_\_\_\_
- \_\_\_\_\_ T<sub>V</sub> (P/N 134 CT-186) S/N \_\_\_\_\_



REPORT NO. TMP-102	PAGE 14 OF 14
B/U NO.	DATE 11-30-71
Q/A	WORK ORDER
	DATE

SUBJECT  
BUILD UP PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER  
DRAWING 1138990

BY  
D. A. Koch

CHK. BY

18.0 INSTALL ACCELEROMETERS

- \_\_\_\_\_ G-1 (Fwd Flange - Vertical) S/N \_\_\_\_\_
- \_\_\_\_\_ G-2 (Fwd Flange - Lateral) S/N \_\_\_\_\_
- \_\_\_\_\_ G-3 (Aft Flange - Vertical) S/N \_\_\_\_\_
- \_\_\_\_\_ G-4 (Aft Flange - Lateral) S/N \_\_\_\_\_
- \_\_\_\_\_ G-5 (Aft Housing - Axial) S/N \_\_\_\_\_

\_\_\_\_\_ 19.0 Identify and mark with flow pen, all instrumentation ports in accordance with Basic Test Request 1190-65-XXX-X.

\_\_\_\_\_ 20.0 Proof test per G/N 8, Drawing 1138990.

\_\_\_\_\_ 21.0 Leak check per G/N 9, Drawing 1138990.

\_\_\_\_\_ 22.0 Establish pressure pad of 45-55 psig (GN<sub>2</sub>) in tester assembly. Maintain 10 psig minimum at all times prior to installation - replenish as required.

\_\_\_\_\_ 23.0 Safety wire per G/N 3, Drawing 1138990.

\_\_\_\_\_ 24.0 Coat motor terminals with Silastic RTV compound.

\_\_\_\_\_ 25.0 Clear all inspection reports.

\_\_\_\_\_ 26.0 Release assembly for testing.

\_\_\_\_\_  
COGNIZANT PROJECT ENGINEER

\_\_\_\_\_  
DATE

\_\_\_\_\_  
QUALITY ENGINEER

\_\_\_\_\_  
DATE



REPORT NO. TMP-119	PAGE 1 OF 2
B/U NO.	DATE 11-22-71
	WORK ORDER
Q/A	DATE

## SUBJECT

FORWARD CARTRIDGE/HOUSING INTERFACE CLEARANCE TEST -  
65 MM BALL BEARING TESTER - P/N 1138990

BY

D. A. Koch

CHK. BY

BUILD UP 65 MM BALL BEARING TESTER, P/N 1138990-\_\_\_ per TMP-102, Rev. \_\_\_  
EXCEPT AS FOLLOWS:

- \_\_\_ 1.0 In Step 3.1.3 of TMP-102, replace inner race spacer (P/N 1138197-1) with undersize spacer (P/N T.A. 119-1).
- \_\_\_ 2.0 In Step 3.1.5 of TMP-102, delete pre-load springs (P/N 1137056-1) and write "OMIT" in check off column.
- \_\_\_ 3.0 In Step 3.2.3 of TMP-102, replace inner race spacer (P/N 1138197-1) with oversize spacer (P/N T.A. 119-2).
- \_\_\_ 4.0 In Step 7.2 of TMP-102, delete forward anti-rotation lock (P/N 1138982-1), 2 places and retaining bolts (P/N EWB 0420-4H-2), 4 places. Write "OMIT" in check off column.  
NOTE: STEPS 7.3 & 7.4 WILL BE N/A.
- \_\_\_ 5.0 In Step 7.5 of TMP-102 replace aft retainer rings (P/N 1138989-1) 2 places with oversize retainer rings (P/N T.A. 119-3), 2 places.
- \_\_\_ 6.0 After Step 8.2 and prior to Step 9.0 of TMP-102, install push-pull continuity sensor (S.A. 020) into motor and housing assembly (P/N 1138983-1). Use instrumentation port located at 11 o'clock in plane "B-B" (Ref. ANSC Facility Requirements Document F004-CP090290-F1).



SUBJECT FORWARD CARTRIDGE/HOUSING INTERFACE CLEARANCE TEST - 65 MM BALL BEARING TESTER - P/N 1138990		REPORT NO. TMP-119	PAGE 2 OF 2
		BU NO.	DATE 11-22-71
BY D. A. Koch	CHK. BY	Q/A	WORK ORDER
			DATE

NOTE: TIP OF SENSOR MUST BE POSITIONED TO INSURE ELECTRICAL CONTINUITY BETWEEN FORWARD OUTER RACE SLEEVE, P/N \_\_\_\_\_ AND SENSOR WHEN SHAFT ASSEMBLY IS IN FULL FORWARD POSITION LESS .025 - .035. DETERMINE THIS VALUE BY PLACING A DIAL INDICATOR ON FORWARD EDGE OF OUTER RACE SLEEVE.

ACTUAL VALUE \_\_\_\_\_

ROTATE AND/OR BEND TIP OF SENSOR TO MEET THIS REQUIREMENT.

\_\_\_\_\_  
COGNIZANT PROJECT ENGINEER      DATE

\_\_\_\_\_  
QUALITY ENGINEER      DATE



REPORT NO. TMP-120	PAGE 1 OF 2
B/U NO.	DATE 11-22-71
Q/A	WORK ORDER
	DATE

## SUBJECT

AFT CARTRIDGE/HOUSING INTERFACE CLEARANCE TEST -  
65 MM BALL BEARING TESTER - P/N 1138990

BY  
D. A. Koch

CHK BY

*Bleccinelli*

BUILD UP 65 MM BALL BEARING TESTER, P/N 1138990-\_\_\_ PER TMP-102, REV: \_\_\_  
EXCEPT AS FOLLOWS:

- \_\_\_ 1.0 In Step 3.2.3 of TMP-102, replace inner race spacer (P/N 1138197-1), with undersize spacer (P/N T.A. 119-1).
- \_\_\_ 2.0 In Step 3.2.5 of TMP-102, delete preload springs (P/N 1137056-1) and write "OMIT" in check off column.
- \_\_\_ 3.0 In Step 7.2 of TMP-102, delete forward anti-rotation lock (P/N 1138982-1) 2 places and retaining bolts (P/N EWB 0420-4H-2), 4 places. Write "OMIT" in check off column.
- NOTE: Steps 7.3 & 7.4 will be N/A.
- \_\_\_ 4.0 In Step 7.5 of TMP-102, replace aft retainer rings (P/N 1138989-1), 2 places with undersize retainer rings (P/N T.A. 119-4), 2 places.
- \_\_\_ 5.0 After Step 8.2 and prior to Step 9.0 of TMP-102, install push-pull continuity sensor (S.A. 020) into motor and housing assembly (P/N 1138983-1). Use instrumentation port located at 11 o'clock in plane "E-E" (Ref. ANSC Facility Requirements Document F004-CP090290-F1).



REPORT NO. TMP-120	PAGE 2 OF 2
BU NO.	DATE 11-22-71
	WORK ORDER
Q/A	DATE

SUBJECT AFT CARTRIDGE/HOUSING INTERFACE CLEARANCE TEST - 65 MM BALL BEARING TESTER - P/N 1138990	
BY D. A. Koch	CHK. BY

NOTE: TIP OF SENSOR MUST BE POSITIONED TO INSURE ELECTRICAL CONTINUITY BETWEEN AFT OUTER RACE SLEEVE, P/N \_\_\_\_\_, AND SENSOR WHEN SHAFT ASSEMBLY IS IN FULL AFT POSITION LESS .025 - .035. DETERMINE THIS VALUE BY PLACING A DIAL INDICATOR ON FORWARD EDGE OF OUTER RACE SLEEVE.

ACTUAL VALUE \_\_\_\_\_

ROTATE AND/OR BEND TIP OF SENSOR TO MEET THIS REQUIREMENT.

\_\_\_\_\_  
COGNIZANT PROJECT ENGINEER      DATE \_\_\_\_\_

\_\_\_\_\_  
QUALITY ENGINEER      DATE \_\_\_\_\_



REPORT NO. TMP-107	PAGE 1 OF 7
B/U NO.	DATE 11-19-71
Q/A	WORK ORDER
	DATE

SUBJECT  
DISASSEMBLY PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY *D. A. Koch*  
D. A. Koch

CHK BY *J. Blinnell*

TESTER P/N \_\_\_\_\_ DASH NO. \_\_\_\_\_ LETTER CHANGE \_\_\_\_\_

1.0 GENERAL

- 1.1 Prior to disassembly, tester shall be dehydrated and at ambient temperature.
- 1.2 During disassembly, visually inspect tester for physical damage. Document under "Remarks" any abnormal conditions.
- 1.3 In the event of partial disassembly, "N/A" shall be written before operations eliminated by partial disassembly.
- 1.4 Entire disassembly procedure shall be under the direction of cognizant Project Engineer and surveillance of quality engineer.
- 1.5 Q.A. requirements per ANSC memo N7000:2072 dated 18 June 1971.

REMARKS: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

2.0 REMOVE SAFETY WIRE AT FOLLOWING LOCATIONS:

- 2.1 Radial loader (P/N 1138979-1) to loader housing assembly (P/N 1138980-1).
- 2.2 Loader housing assembly (P/N 1138980-1) to motor and housing assembly (P/N 1138983-1).



REPORT NO. TMP-107	PAGE 2 OF 7
B/U NO.	DATE 11-19-71
	WORK ORDER
9/A	DATE

SUBJECT DISASSEMBLY PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990	
BY D. A. Koch	CHK. BY

2.3 Seal housing (P/N 1138998-1) to motor and housing assembly (P/N 1138983-1).

2.4 End cap (P/N 1138979-11) to radial loader (P/N 1138979-1).

2.5 All temperature sensors and proximity transducers.

3.0 INSTRUMENTATION

3.1 Remove accelerometers

- G-1 (Fwd Flange -Vertical) - S/N \_\_\_\_\_
- G-2 (Fwd Flange - Lateral) - S/N \_\_\_\_\_
- G-3 (Aft Flange - Vertical) - S/N \_\_\_\_\_
- G-4 (Aft Flange - Lateral) - S/N \_\_\_\_\_
- G-5 (Aft Housing - Axial) - S/N \_\_\_\_\_

3.2 Remove RTT's

- T<sub>B</sub> (P/N 134CT300) - S/N \_\_\_\_\_
- T<sub>C</sub> (P/N 134CT300) - S/N \_\_\_\_\_
- T<sub>D</sub> (P/N 134CT300) - S/N \_\_\_\_\_
- T<sub>E</sub> (P/N 134CT300) - S/N \_\_\_\_\_
- T<sub>V</sub> (P/N 134CT186) - S/N \_\_\_\_\_

3.3 Remove proximity probes

- DT<sub>1</sub> (P/N 1138997-1) - S/N \_\_\_\_\_
- DT<sub>2</sub> (P/N 1138997-1) - S/N \_\_\_\_\_
- DT<sub>3</sub> (P/N 1138997-2) - S/N \_\_\_\_\_
- DT<sub>4</sub> (P/N 1138997-2) - S/N \_\_\_\_\_
- DT<sub>5</sub> (P/N 1138997-2) - S/N \_\_\_\_\_
- DT<sub>6</sub> (P/N 1138997-2) - S/N \_\_\_\_\_
- DT<sub>7</sub> (P/N 1138997-2) - S/N \_\_\_\_\_
- DT<sub>8</sub> (P/N 1138997-2) - S/N \_\_\_\_\_
- DT<sub>9</sub> (P/N 1138997-2) - S/N \_\_\_\_\_



REPORT NO. TMP-107	PAGE 3 OF 7
B/U NO.	DATE 11-19-71
	WORK ORDER
Q/A	DATE

SUBJECT DISASSEMBLY PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990	
BY D. A. Koch	CHK. BY

4.0 SHAFT TORQUE MEASUREMENTS - Insert torque adapter tool thru 1 inch union in forward end cover.

\_\_\_\_\_ 4.1 Breakaway Torque = \_\_\_\_\_ in-lbs.

\_\_\_\_\_ 4.2 Running Torque (1 RPS) = \_\_\_\_\_ in-lbs.

5.0 RADIAL LOADER

\_\_\_\_\_ 5.1 Remove end cap from radial loader (P/N 1138979-1) (S/N \_\_\_\_\_) and retract adjusting screw to fully unloaded position.

\_\_\_\_\_ 5.2 Remove bolts (P/N EWB 0420-6H-4), 7 places and radial loader from loader housing assembly (P/N 1138981-1).

NOTE: STATIC FACE SEAL (P/N 22022AL2687) WILL REMAIN IN LOADER HOUSING SEAL GLAND.

6.0 LOADER HOUSING

\_\_\_\_\_ 6.1 Remove bolts (P/N EWB 0420-6H-10), 10 places and (P/N EWB 0420-6H-2), 2 places.

\_\_\_\_\_ 6.2 Remove loader housing (P/N 1138981-1) (S/N \_\_\_\_\_) from motor & housing assembly (P/N 1138983-1). Use guide studs to facilitate removal.

NOTE: STATIC FACE SEAL (P/N 22023AL6250) WILL REMAIN IN MOTOR & HOUSING ASSEMBLY SEAL GLAND.



REPORT NO. TMP-107	PAGE 4 OF 7
B/U NO.	DATE 11-19-71 WORK ORDER
Q/A	DATE

SUBJECT DISASSEMBLY PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990	
BY D. A. Koch	CHK. BY

7.0 SEAL HOUSING

7.1 Remove bolts (P/N EWB 0420-5H-8) 12 places.

7.2 Remove seal housing (P/N 1138998-1) S/N \_\_\_\_\_ from motor and housing assembly (P/N 1138983-1). Use guide studs to facilitate removal.

NOTE: STATIC FACE SEAL (P/N 22023AL6875) WILL REMAIN IN MOTOR & HOUSING SEAL GLAND.

8.0 SHAFT TORQUE AND RUNOUT MEASUREMENTS

8.1 Breakaway torque = \_\_\_\_\_ in-lbs.

8.2 With electronic dial indicator attached to motor and housing assembly, measure and record the following values:

8.2.1 T.I.R. of forward locking sleeve at seal position. \_\_\_\_\_

8.2.2 Total radial movement of shaft at forward seal position. \_\_\_\_\_

8.2.3 T.I.R. of aft locking sleeve at seal position. \_\_\_\_\_

8.2.4 Total radial movement of shaft at aft seal position. \_\_\_\_\_

8.2.5 Total axial movement of shaft. \_\_\_\_\_



REPORT NO. TMP-107	PAGE 5 OF 7
B/U NO.	DATE 11-19-71
	WORK ORDER
Q/A	DATE

SUBJECT  
DISASSEMBLY PROCEDURE FOR 65MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

## 9.0 SHAFT DISASSEMBLY

- 9.1 Remove safety wire from forward anti-rotation locks (P/N 1138982-1) and from aft retainer rings (P/N 1138989-1).
- 9.2 Remove bolts (P/N EWB 0420-4H-2) 6 places and aft retainer rings 2 places.
- 9.3 Remove bolts (P/N EWB 0420-4H-2) 4 places and forward anti-rotation locks 2 places.
- 9.4 Remove shaft assembly (P/N 1138991-1) from motor and housing assembly.
- 9.5 Place shaft assembly in torque support fixture (P/N 1139729-1).
- 9.6 Unbend forward locking tab (P/N 1138992-1) and aft locking tab (P/N 1138992-2).
- 9.7 Heat forward locking sleeve (P/N 1138986-1) (S/N \_\_\_\_\_) with heat gun. Protect bearings with heat shield (P/N 1139730-1).
- 9.8 Remove forward locking sleeve.
- 9.9 Heat aft locking sleeve (P/N 1138987-1) (S/N \_\_\_\_\_) with heat gun. Protect bearings with heat shield (P/N 1139730-1).
- 9.10 Remove aft locking sleeve.



REPORT NO. TMP-107	PAGE 6 OF 7
B/U NO.	DATE 11-19-71
	WORK ORDER
Q/A	DATE

SUBJECT DISASSEMBLY PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER PER DRAWING 1138990	
BY D. A. Koch	CHK. BY

9.11 Note and document location of all inner and outer race high spots with respect to shaft index marks.

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9.12 Chill shaft assembly in LN<sub>2</sub>.

9.13 Support shaft assembly on forward lower ring holder (P/N 1139725-1) and press off forward bearing assembly.

9.14 Support shaft assembly on aft lower ring holder (P/N 1139726-1) and press off aft bearing assembly.

9.15 Place forward bearing assembly, aft bearing assembly, and shaft assembly in 275°-300°F oven to permit dehydration and return to ambient temperature.

9.16 Complete disassembly by removing bearings (P/N \_\_\_\_\_) S/N's \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, inner race spacers (P/N 1138197-1), and springs (P/N 1137056-1) from outer race sleeves (P/N 1138984-1 and P/N 1138985-1).

NOTE: EXERCISE CAUTION AT THIS STEP TO PREVENT SEPARATION OF BEARING INNER AND OUTER RACES.

10.0 SHAFT RIDING SEAL REMOVAL

10.1 Remove safety wire from forward end cover (P/N 1138980-1) (S/N \_\_\_\_\_).



REPORT NO. TMP-107	PAGE 7 OF 7
B/U NO.	DATE 11-19-71
	WORK ORDER
Q/A	DATE

SUBJECT  
DISASSEMBLY PROCEDURE FOR 65 MM DUPLEX BALL BEARING TESTER  
PER DRAWING 1138990

BY  
D. A. Koch

CHK. BY

- 10.2 Remove bolts (P/N EWB 0420-5H-8) 8 places and end cover.  
NOTE: STATIC FACE SEAL (P/N 22023AL4125) WILL REMAIN IN LOADER HOUSING SEAL GLAND.
- 10.3 Remove Spirolox retainer (P/N RR-391S) from loader housing assembly.
- 10.4 Remove seal assembly (P/N 700977-9) with press-out bar (P/N 1139731-1).
- 10.5 Remove safety wire from aft end cover (P/N 1138999-1) (S/N \_\_\_\_\_).
- 10.6 Remove bolts (P/N EWB 0420-5H-8) 8 places and end cover.  
NOTE: STATIC FACE SEAL (P/N 22022AL3812) WILL REMAIN IN SEAL HOUSING SEAL GLAND.
- 10.7 Remove Spirolox retainer (P/N RR-381S) from seal housing.
- 10.8 Remove seal assembly (P/N 700977-9) with press-out bar (P/N 1139731-1).
- 11.0 CLEAR ALL INSPECTION REPORTS

COMPLETED:

\_\_\_\_\_  
COGNIZANT PROJECT ENGINEER      DATE

\_\_\_\_\_  
QUALITY ENGINEER      DATE