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ATOMICS INTERNATIONAL A Division of North American Aviation, Inc.		NAA-SR- TDR NO. 10161	APPROVALS <i>M. E. Queener 8/28/64</i>
TECHNICAL DATA RECORD		PAGE 1 OF 54	<i>W. C. Sturtevant 8-28</i>
AUTHOR H. L. Powell <i>H. L. Powell</i>	DEPT. & GROUP NO. 723 - 343	DATE 6-30-64	<i>W. C. Sturtevant 9-4-64</i>
TITLE Final Qualification Test Report, SNAP 10A Reflector Bearings - Part Number 10FSM1-11039		GO NO. 7623	S/A NO. 2751 TWR
PROGRAM SNAP 10A	SUBACCOUNT TITLE Reflector Bearing Qualification	SECURITY CLASSIFICATION	
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W. J. Kurzeka			
G. P. Licciardi		STATEMENT OF PROBLEM	
C. R. Meeks		Subject three sets reflector bearings to qualification tests in accordance with qualification test specification NA 0408-008.	
R. M. Ohlenkamp		APPROVALS:	
H. L. Powell		<i>[Signature]</i>	
G. F. Queener		Department Director	
R. J. Smith		<i>[Signature]</i>	
O. P. Steele III		Reactor Project Engineer	
W. C. Sturtevant		<i>[Signature]</i>	
J. Susnir		Chief Project Engineer	
J. P. Thorel		<i>[Signature]</i>	
I. Villalva		Qualification Project Engineer	
D. K. Weisensee			
R. F. Wilson			
ABSTRACT:		The purpose of the qualification tests is to demonstrate that the SNAP 10A reflector bearings will withstand the environments to which they will be exposed in flight and still operate properly.	
		The bearings were subjected to the following tests:	
		Thermal Cycle	
		Shock, Vibration and Acceleration	
		Endurance	
		Compact Systems Data Reports were prepared and released.	
		The reflector bearings were tested to Specification NA 0408-008 and have met its requirements with the following approved deviations:	
		A. Alignment torque measurements were not included in the specification until after the first shock, vibration and acceleration test was completed.	
		B. The alignment torque measurement was slightly in excess of the	

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ABSTRACT (CONTINUED):

maximum specified limit on one bearing after the second shock, vibration and acceleration test series and following removal of the bearings from the test fixture after the endurance test.

C. There were two temperature deviations during endurance tests when power interruptions caused temperature to decrease below specification limits. The endurance test duration was increased to cover this out of spec. time.

D. Excessive rotational torque measurement was recorded as follows:
(1) One bearing set after endurance test when temperature was decreased to room ambient and pressure continued at 2.2×10^{-7} . (2) On a second bearing set following endurance test when the pressure was increased to atmospheric.

NOTE: All pressures referred to in this report are in units of torr, unless otherwise stated.

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I. INTRODUCTION

The object of component qualification testing is to demonstrate that flight design components are suitable for their intended use. The function of the reflector bearings is to provide free moving pivotal support for the reactor reflector drums during launch, ascent, startup, and control during orbit. The coarse control drums will be actuated only once (during startup) while the fine control drums will be moved periodically during startup and orbit to control power.

A. The bearings will be subjected to different environments from factory to orbit as follows:

1. Ambient conditions during fabrication and assembly.
2. Temperature cycling and vacuum during system acceptance ground test.
3. Controlled atmosphere and inertia loading during system shipment to launch port.
4. Shock, vibration and acceleration during launch and pre-orbital flight.
5. Temperature variations at vacuum in orbit before startup according to sun and shade affects and length of time before startup.
6. High temperature at vacuum during orbit.

B. Qualification tests listed in the test specification consist of the following in accordance with Qualification Specification NA 0408-008:

1. Inspection to assure fabrication and preparation to flight component requirements.
2. Performance record test.
3. Thermal cycle test at vacuum to simulate system acceptance ground testing.
4. Performance record test.
5. Shock, vibration and acceleration test to simulate inertia loads during launch and pre-orbital flight.
6. Performance record test.
7. Endurance test at vacuum and temperature to simulate reactor control operation after extended exposure to high reactor operating temperature.
8. Performance record test.

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II. TESTS AND DISCUSSION

All tests conducted on the bearings are described in detail in this report. According to the test specification, the maximum permissible torque during testing is as follows: rotation 40 in. ozs., alignment 12 in. lbs. A test history log is given in Table VI. Equipment used is described in Appendix II.D.

The following Data Reports Form 707-B were released on the bearings: 767, 768, 769, 2114, 2115, and 2116. The original test data were recorded in Laboratory Notebook No. B153701. All other original data, including temperature recorder charts, will be stored in the Mechanical Component Qualification Test Lab for two years from completion of the last test.

A. THERMAL CYCLE TEST DESCRIPTION

1. Bearing Preparation

Molykote X-15, a dry film lubricant, was applied to the bearing races (AI Drawing No. 1961-11035), the shaft thrust shoulder, the portion of the shaft on which the bearing rotates, and the bearing face of the spacer (AI Drawing No. 1961-11036). The bearing components were weighed (Table I, Column A), then assembled per AI Drawing No. 1961-11039. All weights were taken by the Mass Standards Unit, Department 744-42, and are recorded in Table I. The dry film lubricant was applied in accordance with Specification No. NAO112-002 and inspected in accordance with Specification No. NAO612-001 on Engineering Order No. 42196. (Planning Ticket No. 10FSM1-11039-1-2).

2. Thermal Cycle Tests

The bearings were assembled in the bearing thermal cycle and endurance qualification test fixture as shown in Photograph 7623-55155 and in accordance with AI Drawing No. 7573-D127315. The fixture was installed on an ultra high vacuum chamber and rotational torque measurements taken with a maximum 13 in. ozs. indicated (Table II Column A). Photograph 7623-1834 illustrates the test fixture installed and the control panel. Thermal cycle testing was started on November 1, 1963, and was concluded on November 6, 1963. Ten thermal cycles were made following the temperature curve shown in Figure 4. Rotational torque measurements were taken at frequent intervals during each thermal cycle with a maximum 34 in. ozs. indicated (Table III) and before removal from the fixture with a maximum 16.5 in. ozs. indicated (Table II Column B). The bearing assemblies were removed from the assembly, inspected, photographed and weighed.

3. Test Results

No apparent damage was caused by the thermal cycle tests. No significant changes were noted by rotational torque measurements. Maximum weight loss of 153 milligrams was noted and loose particles of lubricant were observed on each bearing. Light burnishing of the shaft coatings may be observed in Photograph 7623-55167.

B. SHOCK, VIBRATION AND ACCELERATION TEST

1. Test Description

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The shock, vibration and acceleration tests were conducted by the Environmental Test Unit at Santa Susana. One set of bearings and the control drum weight simulator were installed in a rigid aluminum fixture (Photograph 7623-55261) which was first mounted on the shaker table for shock and vibration and then on the centrifuge for acceleration tests. The bearings were not disturbed in the fixture until the series of shock, vibration and acceleration tests were completed. Upon test completion, the bearings were removed from the fixture and stored in a plastic bag with desiccant. The next set of bearings was then installed and the above process repeated. When the second shock, vibration and acceleration tests were conducted at the request of project management (See Appendix II.A.), the only variation to the above procedure was the measurement of the alignment torque before removing the bearings from the fixture. Upon completion of the tests, a resonance search of the test fixture was conducted and resonant frequencies established at 290 cps and 2000 cps.

The bearings were stored in plastic bags with a desiccant when they were not being tested. During the first shock and vibration tests, the relative humidity ranged from 45 to 53% as measured by a sling psychrometer. During the second series of tests the temperature and relative humidity were continuously recorded on a temperature-humidity recorder. The maximum relative humidity during this test was 20%.

a. Vibration

A sinusoidal constant octave sweep over a 25 minute period was applied to the lateral, normal and longitudinal axis as follows:

5 to 20 cps @ 1/4" double amplitude
20 to 400 cps @ 5g
400 to 3000 cps @ 7.5g

b. Shock

Two shocks in each direction were applied to the lateral, normal and longitudinal axis. Each shock was a half sine wave of 20g amplitude for six millisecond duration.

c. Acceleration

The bearings were subjected to a sustained acceleration of 9.4g for 10 minutes along the lateral, normal and longitudinal axis.

d. Test Result

Two accelerometers were used--one to monitor input to the shaker table and one to monitor bearing response which was recorded on a X-Y plotter. These records are appended to the Laboratory Notebook No. B153701, and the results are tabulated in Table VII.

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2. Acceleration Test No. 1

During the first series of tests the maximum bearing response was 30g at 1200 cps with 7.5g input while the average response was less than 15g (Figure 2). When the bearings were removed from the fixture the upper bearings were free to move during the alignment test. However, two lower bearings were tight to finger movement and the third was medium tight to finger movement. Traces of dislodged lubricant were noted on both the upper and lower bearings. The bearings were disassembled for examination in the presence of project management. Considerable transfer of lubricant between the race and the ball was apparent, as can be seen in Photograph 7623-55189.

The bearings were weighed (Table I, Column C), reassembled and weighed again (Table I, Column D). The bearings were mounted in the shock and vibration test fixture, and the alignment torques measured with a maximum indicated 5.25 in. lbs. (Table IV.A.). The bearings were then installed in the thermal cycle test fixture and rotation torques measured with a maximum 29 in. ozs. indicated (Table II Column C). The rotational torques had increased by a factor of two but were still within limits. No alignment torque had been required for this series of tests according to the test specification; therefore, no pretest measurements are available for comparison. Particles of lubricant were dislodged with each movement. At this time a maximum of 12 in. lbs. was established as the rotation torque limit.

3. Acceleration Test No. 2

The second shock, vibration and acceleration tests caused an additional increase to 32 in. ozs. in rotational torque (Table II Column D) and a substantial increase to 12.8 in. lbs. in the alignment torque (Table IV.B.). It will also be noted that these torque readings remained high with successive measurements, whereas they had progressively diminished after the first tests. Only the Number 1 lower bearing exceeded the 12 in. lb. maximum, indicating 12.8 in. lbs.

The bearing response during this test was much higher than during the first test. Responses in excess of 100g's were recorded at frequencies above 100 cps. A check made at 165 cps with a 5g input revealed a 130g response (Figure 3). The responses recorded during the first test compare favorably with those reported in Reference 4. At this time no report is available covering the FSM-1 responses. However, verbal information from W. Daughterman, D/726, indicates the FSM-1 responses are similar to the DRM-1. The high responses during the second test is attributed to the increased clearances caused by loss of lubricant during and following the first tests. The shock vibration and acceleration test reports are included in Appendix II.B.

The bearings were again weighed (Table I, Column E), dismantled and examined. A maximum weight loss of 48 milligrams net was recorded, but visually there was no additional damage.

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C. ENDURANCE TEST DESCRIPTION

1. Test Preparation

This section describes the last series of tests run on the bearings. Personnel of the Mechanical Component Qualification Unit, Reactor Development Department, 723-343, conducted the tests during the period from January to May, 1964. The bearings were reweighed (Table I, Column F), then reassembled, with the drum mass simulators, in the thermal cycle test fixture and installed in the chamber. The pressure was reduced to 7×10^{-7} , and the temperature regulated at 700°F . In order to control the bearing temperature, individual variacs were adjusted until each bearing thermocouple indicated 700°F , and this setting was maintained throughout the test. The magnetic feedthrough units were modified from the direct-coupled type used during thermal cycle testing, to an indirect finger-pickup type (Figure 1) in order to read out the tare torque measurements of the magnetic feedthrough, as well as make possible the daily movement of the feedthrough units without disturbing the bearings. The indicator assembly shown in Figure 1 was used to verify non-movement of the bearings during the endurance test.

2. Endurance Test

The endurance test was started at 0800, January 8, 1964, with all bearing temperatures holding at 700°F and an indicated pressure of 4×10^{-7} . The pressure steadily improved to 2.2×10^{-7} on February 7 and remained at this pressure for the balance of the test. The minimum temperature recorded during the test was 690°F except for the two deviations listed in Appendix II.A. and References 1 and 2. The maximum temperature recorded except for those listed in the deviations (Appendix II.A.) was 715°F . These extremes were caused by gross variations in the laboratory ambient temperature, which varied from 58°F to 78°F .

The bearings were not moved throughout the test which was completed on April 8, 1964, at 0800. The total elapsed time of the endurance test was 2184 hours. The net elapsed time within specification was 2174.5 hours. At the end of the endurance test, rotational torque readings were measured, and all units were within specification with a maximum 17 in. ozs. indicated. The temperature was then lowered within two hours to room ambient at which time the rotational torque was again measured. Bearing set #1 (S/N 23 and 11) indicated a high torque of 48 in. ozs., exceeding the specification. (Appendix II.A.). The pressure was then increased to atmospheric by back-filling slowly with dry nitrogen and torque measured directly on the shaft with the magnetic feedthroughs removed. Bearing Set #2 (S/N 17 and 14) indicated a high torque reading of 108 in. ozs., as well as Bearing Set #1 at 106 in. ozs., indicating an increase over the torque measured when the temperature was reduced. At this time it was decided that alignment torque measurement would not be made on Bearing Set #2 (Appendix II.A.) but would be performed on Sets 1 and 3 as required by the specification (Table IV.C.). When the drum mass simulator fasteners were loosened for removal, the resistance to rotation immediately decreased indicating a misalignment that was not compensated for by the bearings. The bearings were dismantled, examined

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and photographed (Photo 7623-55393).

3. Test Results

No damage was visibly apparent to the upper bearings. The lower bearings showed considerable transfer of lubricant from the coated to the uncoated surfaces with indications of flaking (Photo 7623-55393). All bearing rotational torques remained well within specification while at 700°F. It is not known what caused the high torque following reduction of temperature and increase in pressure.

4. Test Discussion

The endurance test has proven the ability of the drum drive bearings to operate satisfactorily following extended exposure to 700°F temperatures and high vacuum. Since there is not provision for restarting the reactor in space once it has been shut down, the excessive torque following temperature decrease does not preclude the use of the bearings. This also applies to the excessive torque following pressure increase since the reactor will not see atmospheric pressure after being placed in orbit.

Several welds were made on the test fixture during checkout to seal leaks, and stress relieving of these welds during high temperature endurance testing may have caused warping in the fixture. This may account for the excessive torque readings following temperature decrease. Dry nitrogen was used for backfilling the test chamber to atmospheric pressure, and at this time no reason can be given for the increase in torque following this operation.

III. CONCLUSIONS

The bearings were tested to Specification NAO408-008 and have met all requirements with the acceptable deviations listed below and are considered as qualified for flight use. The accepted deviations are authorized in IL, R. I. Jetter to H. L. Powell, "SNAP 10A Bearing Test Deviations" dated 5-25-64. A copy of this IL is included as Appendix II.A.

A. Alignment torque measurements were not required until the end of the first shock, vibration and acceleration test. At this time, it was requested the alignment measurement be included in the specification, and a maximum torque of 12 in. lbs. was established by project management.

B. The alignment torque measurement on bearing set 1, lower (S/N 23) was 12.8 in. lbs., slightly exceeding the maximum.

C. The specification required that the endurance test temperature be maintained at 700°F. There were two deviations from this temperature. One occurred when a momentary plant power outage caused all temperature controllers to shut off the heaters allowing the temperature to drop to 470°F. The maximum cooling ramp was 12.5°F per minute for 10 minutes. The maximum heating ramp after the heaters were reset was 12.3°F per minute for 12

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minutes with a total recovery time of 1 hour 37 minutes. The total elapsed time the bearings were out of specification was two hours two minutes except for Bearing No. 3, which had, from causes unknown, cut off earlier and was out of specification for 5 hours 12 minutes.

The second temperature deviation occurred when a planned temporary plant power outage did not adhere to the schedule causing all temperature controllers to shut off. The bearings were out of specification for four hours with the following maximum cooling and heating ramps.

<u>Cooling Ramp</u>	<u>Time Period</u>	<u>Heating Ramp</u>	<u>Time Period</u>
10°F/min.	11 min.	37°F/min.	9 min.
7.5°F/min.	12 min.	24°F/min.	4 min.
4°F/min.	23 min.	16°F/min.	5 min.
17°F/min. (1)	8 min.	18°F/min. (2)	5 min.

- (1) cooling after overshoot on reheat.
(2) recovery after overshoot and undershoot.

D. (1) At the end of the endurance test the specification required the temperature be reduced to room ambient temperature. Following this step the rotational torque on Bearing Set 1 exceeded the 40 in. oz. maximum by 8 in. ozs. Since the drive motor has a torque safety factor in excess of 80 in. ozs. at high temperature and an additional safety factor as the temperature decreases, the bearing is considered acceptable.

(2) The specification required the pressure be increased to atmospheric pressure following endurance testing. Following this step the rotational torque on Bearing Sets 1 and 2 indicated 106 and 108 in ozs., respectively. Since the reactor will not be subjected to conditions of operation after re-entry, this step is considered to have no application to flight qualification.

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REFERENCES

1. IL - H. L. Powell to R. A. Johnson, "SNAP 10A Reflector Bearing Endurance Qualification Testing" (March 18, 1964).
2. IL - H. L. Powell to R. A. Johnson, "Effect of Power Shutdown on SNAP 10A Bearing Endurance Test" (March 23, 1964).
3. IL - R. A. Johnson to H. L. Powell, "SNAP 10A Bearing Qualification" (March 30, 1964).
4. TDR - NAA-SR-8120 "Vibration, Shock and Qualification Test - DRM-1 Spec. NA 0401-002".

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APPENDIX I

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Photographs and Figures

Photo	7623-55155	Bearings assembled in test fixture.
	7623-1834	Control panel and test fixture on chamber.
	7623-55167	Representative of lubricated appearance of lower bearings after thermal cycle tests.
	7623-55261	Shock, vibration and acceleration fixture.
	7623-55189	Representative of lower bearings after first shock, vibration and acceleration.
	7623-55393	Representative of lower bearings after endurance test to show lubricant transfer.
Figure 1		Bearing test fixture schematic.
Figure 2		Representative plot of bearing response to first shock, vibration and acceleration.
Figure 3		Representative plot of bearing response to second shock, vibration and acceleration.
Figure 4		Thermal cycle temperature program.

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PHOTOGRAPHIC DEPT. CANOGA PARK, CALIF.

7623-55155

7623-55155

Bearings Assembled in Test Fixture

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PHOTOGRAPHIC DEPT. CANOGA PARK, CALIF.

7623-1834

7623-1834 Control Panels and Test Fixture

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7623-55167 Bearing Assembly after Thermal Cycle Test

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7623-55261 Shock, Vibration and Acceleration Fixture

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7623-55189 Lower Bearing #3 after Shock, Vibration and Acceleration

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BEARING

SHAFT

SPACER

SNAP TO A LOWER BEARING ASSY. NO. 2

7623-55393 Lower Bearing #2 after Endurance Test

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NUMBER	REVISION LETTER	PAGE 13
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FIG. 1 BEARING TEST FIXTURE ASSEMBLY

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FIG 2

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Fig 3

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FIG. 3

PREPARED BY: H. J. POWELL	ATOMICS INTERNATIONAL A DIVISION OF NORTH AMERICAN AVIATION, INC.		Date: 6--30--64 PAGE NO. 22 OF 54
CHECKED BY:			REPORT NO.
DATE: Dec. 12, 1963	Bearing thermal cycle qualification Test		MODEL NO.

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DEGREES F.

FIGURE IV

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APPENDIX II

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- A. Letters of Deviation
- B. Shock, Vibration and Acceleration Test Reports
- C. Applicable Documents and Drawings
- D. Test Equipment List
- E. Test Description

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INTERNAL LETTER

ATOMICS INTERNATIONAL

A Division of North American Aviation, Inc.

DATE May 25, 1964

TO H. L. Powell
ADDRESS 723-34
AI/Canoga-4

FROM R. I. Jetter
ADDRESS 727-71
AI/Canoga-5

PHONE 305

SUBJECT SNAP 10A Bearing Test Deviations

- REFS: 1) IL - H. L. Powell to R. I. Jetter, 5/13/64, "SNAP 10A Bearing Test Deviations"
- 2) IL - R. A. Johnson to H. L. Powell, 3/30/64, "SNAP 10A Bearing Qualification"
- 3) IL - H. L. Powell to R. A. Johnson, 12/27/63, "Analysis of SNAP 10A Bearings After Thermal Cycle and Shock, Vibration and Acceleration"
- 4) IL - C. B. Palmer to R. I. Jetter, 2/17/64, "Allowable Self-Aligning Ball Torque for SNAP 10A Control Drum Bearings".

In Reference (1) a letter was requested covering the following deviations during SNAP 10A bearing qualification testing:

- A. Alignment torque measurement not included in Spec. NAO408-008 until end of first shock, vibration and acceleration (S.V.A.).
- B. Excessive alignment torque measurement on Bearing S/N 22 (Set #3 lower).
- C. Two temperature deviations due to power interruption during endurance testing.
- D. (1) Excess rotational torque measurement on Set #1 (S/N 23 and 11) at end of endurance test when cooled to room ambient temperature.
- (2) Excess rotational torque measurement on Set #2 (S/N 17 and 14) at end of endurance test when pressure was increased to atmospheric pressure.
- E. Eliminate alignment torque measurement on Bearing Set #2 after endurance testing.

The following discussion will cover items A, B, D, and E. Item C was covered in Reference (2).

The torque measurements originally included in Spec. NAO408-008 were intended to measure the control drum rotational drag as seen by the coarse and fine control drum drive systems. Specifications were not established on the various interacting torques which make up the net system, rotational drag torque. As reported in Reference (3), after S.V.A. qualification tests, the ball was

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tight to finger movement in its socket in two of the lower bearing assemblies. Dry film lubricant was transferred from the socket to the ball in all three lower bearings. Although the S.V.A. tests approximately doubled the rotational torque, the maximum value was less than 2 in-lb. Since the bearings met system specifications, it was decided to recycle the bearings through S.V.A., this time measuring the alignment torque.

Concurrently, the reaction between ball alignment torque and rotational torque was analyzed. It was estimated that a 12.5 in-lb alignment torque would cause a maximum rotational drag torque of 2.5 in-lb based on a maximum shaft-journal coefficient of friction of $\mu = 0.4$. The upper limit of ball alignment torque was then specified as 12 in-lb. In Reference (4), a maximum coefficient of friction of $\mu = 0.51$ was obtained from an analysis of developmental bearing test data. This resulted in a somewhat lower allowable ball alignment torque.

After the second S.V.A. qualification tests, the rotational torques of the bearing sets were two in-lb or less. However, the second S.V.A. qualification tests approximately doubled the alignment torques. The maximum alignment torque reading was 12.8 in-lb as compared to the specified upper limit of 12 in-lb. Since the bearings sets again met the drive system specifications and since the maximum allowable alignment torque was somewhat arbitrary, it was decided to proceed with the endurance tests.

At the end of the 90-day endurance test, the rotational torque in bearing set #1 had reached the upper limit of 2.5 in-lb at temperature and vacuum. Since the bearings in flight systems and FS-1 will be operated at temperature and vacuum after 90 days, this completes the flight simulation phase of the qualification program. The excess rotational torques measured on set #1 after cooling and on set #2 after cooling and exposure to atmospheric pressure do not represent flight or FS-1 conditions.

In addition, as pointed out in Reference (4), the actuator torque available at operating temperature at the fine control drum shaft is 20 to 25 in-lb. This is a factor of 8 to 10 greater than the maximum rotational torque measured at temperature at the end of the endurance test and about 10 in-lb greater than the maximum rotational torque measured after cooling and at atmospheric pressure.

The coarse control drum bearings are actuated by the snap-in spring at the start of operation or endurance. They are not moved after startup. The minimum torque available at the coarse drum shaft in the full-in position is 4.5 in-lb. This is a factor of 2.3 greater than the maximum rotational drag measure after thermal cycles and S.V.A. and a factor of 1.8 greater than the maximum rotational torque measured at temperature at the end of the endurance test.

The alignment torque measurements made on the bearings after the endurance test were considered to be engineering tests and not part of the qualification procedure. The misalignment torque was not measured in bearing set #2 so that the surface condition of set #1 could be compared to set #2 to see if the rubbing action during the alignment torque measurements significantly disturbed the lubricant. No significant differences were observed.

The deviations in the SNAP 10A bearing qualification testing can be summarized as follows:

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CONFIDENTIALSNAP 10A Bearing Test DeviationsMay 25, 1964
Page Three

- A. The original omission of alignment torque measurements in Spec. NA408-008 is acceptable because this specification is intended to measure the torques as seen by the control drum drive systems and not the individual components which interact to make up that torque.
- B. The 12.8 in lb alignment torque measurement on Bearing Set #3 is acceptable since the bearing set met the rotational torque specifications. The alignment torque measurement is included in the specification for engineering information and is not in itself a criteria of failure for bearings which meet the other requirements of the specification.
- C. See Reference (2) for temperature deviations.
- D. The excess rotational torques measured on Bearing Set #1 and #2 are acceptable since these measurements were made at the end of the endurance test after cooling and at atmospheric pressure and do not represent flight or FS-1 conditions. In addition, the stepper motors have more than enough torque to rotate the bearings even at the excessive drag torques measured.
- E. The elimination of the alignment torque measurement on Bearing Set #2 after endurance testing is acceptable. In this case the engineering information obtained on the effect of rubbing on the surface properties of the lubricant was more significant than the additional alignment torque measurement.

R. I. Jetter
Supervisor
Engineering Mechanics Unit

RIJ:sm

cc: D. J. Cockeram
J. V. Facha
R. J. Gimera
R. A. Johnson
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C. R. Meeks
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G. F. Queener
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D. K. Weisensee
R. F. Wilson

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PREPARED BY: <i>229</i>	ATOMICS INTERNATIONAL A DIVISION OF NORTH AMERICAN AVIATION, INC.	No. NAA-SR-10161
CHECKED BY:		PAGE NO. 27 OF 54
DATE: 5-25-64		Date 6-30-64
		REPORT NO.
		MODEL NO.

CALCULATION OF ALLOWABLE ALIGNMENT TORQUE

T_R = ROTATIONAL DRAG ON CONTROL DRUM SHAFT

T_a = ALIGNMENT TORQUE ON BALL

F = REACTIONS ON SHAFT

μ = COEFFICIENT OF FRICTION BETWEEN
SHAFT & BALL

$$T_a = LF$$

$$T_R = \mu d F$$

$$T_R = \frac{T_a \mu d}{L} \quad \text{OR} \quad T_a = \frac{L T_R}{\mu d}$$

FOR $\mu = .4$, $T_R = 2.5 \text{ in. LB.}$, $L = .628"$, $d = .3125"$

$$T_a = \frac{.628}{.3125} \left(\frac{2.5}{.4} \right) = 12.5 \text{ in. LB.}$$

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INTERNAL LETTER

NORTH AMERICAN AVIATION, INC.

DATE March 30, 1964

TO H. L. Powell
ADDRESS 723-34
AI/Canoga-4

FROM R. A. Johnson
ADDRESS 727-70
AI/Canoga-5

PHONE 643

SUBJECT SNAP 10A Bearing Qualification

- REFERENCE (a) IL, H. L. Powell to R. A. Johnson, "Effect of Power Shutdown on SNAP 10A Bearing Endurance Test," March 23, 1964
(b) IL, H. L. Powell to R. A. Johnson, "SNAP 10A Reflector Bearing Endurance Qualification Testing," March 18, 1964

References (a) and (b) describe the malfunction of the bearing qualification test heaters due to electrical power shutdowns. Continue this test until a period of 90-days of operation within specification has been achieved. In the test report, the maximum continuous time should be given as well as the total time within specification.

R. A. Johnson
Project Engineer
SNAP 10A Reactor

RAJ:fl

cc: D. Cockeram
J. Facha
R. Gimera
R. Jetter
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TO: H. L. Powell

DEPT. 723-34 HQ 4

DATE: 11-25-63

ENVIRONMENTAL EVALUATION COMPONENT TEST REPORT # 324

Component Identification Three SNAP 10A Bearing Tests, Serial #'s 23 & 11, 17 & 14, 22 & 33.

Responsible Engineer and/or Unit supplying component H. L. Powell date rec'd 11-13-63

Applicable environmental specifications IL, H. L. Powell to R. M. Oliva, "SNAP 10A Bearing Tests," 11-14-63

Tests requested Shock, Vibration, Acceleration Qualification

TEST PLAN OF ACTION

Test assigned to D'Amico & Pearlman ext. 6463, date 11-13-63, scheduled test start 11-13-63

Test equipment to be utilized Ling 7500# shaker slip table system, shock instrumentation & centrifuge

Instrumentation required Accelerometer for monitoring table input,

X-Y plotter, Dyna-Monitor

Measurements required Bearing response

Specimen support fixture A test specimen designed to simulate a typical SLOA control drum bearing installation was assembled by the Mechanical Qualification Unit. A dummy mass was used in lieu of an actual control drum. Exact bearing design, materials, clearances and assembly methods were not made known to us

Test inputs: VIBRATION (constant octave sweep rate requiring 45 minutes)

Lateral and Normal axes {
5 to 20 cps @ $\frac{1}{4}$ " DA
20 to 400 cps @ $\frac{5}{8}$ g
400 to 3000 cps @ 7.5 g
to cps @ g

Longitudinal {
5 to 20 cps @ $\frac{1}{4}$ " DA
20 to 400 cps @ $\frac{5}{8}$ g
400 to 3000 cps @ 7.5 g
to cps @ g

Vibration (Other) _____

SHOCK

Lateral and Normal axes {
 $\frac{20}{2}$ g, $\frac{1}{2}$ sine, $\frac{6}{2}$ millisecc pulse;
shocks in each direction of each axis

Longitudinal {
 $\frac{20}{2}$ g, $\frac{1}{2}$ sine, $\frac{6}{2}$ millisecc pulse;
shocks in each direction

ACCELERATION

Lateral and Normal axes {
 $\frac{9.4}{10}$ g, for a total of $\frac{10}{10}$ minutes

Longitudinal {
 $\frac{9.4}{10}$ g, aft direction, for a total of $\frac{10}{10}$ minutes.
g, forward direction, for a total of minutes.

TEST RESULTS

Test conducted by D'Amico & Pearlman, ext. 6463, date 11-13-63, IN page No. B166248

Results No bearing damage was evident and no restriction to drum movement could be noted on any of the three bearing assemblies after each test as specified above.

Considerable rattle could be heard from all the assemblies throughout the tests. A thorough examination for damage will be made by the Project when the bearing assemblies are disassembled for inspection. X-Y plots of bearing response vs input were sent to the Qualification Unit for evaluation.

Specimen disposal Returned to the Mechanical Qualification Unit for further evaluation.

Report prepared by M. J. D'Amico, date 11-19-63; Approved R. M. D., date 12-2-63

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TO: H. L. Powell

DEPT. 723-34 HQ 4

DATE 12-18-63

ENVIRONMENTAL EVALUATION COMPONENT TEST REPORT # 338

Component Identification SNAP 10A Bearing Fixture

Responsible Engineer and/or Unit supplying component H. L. Powell date rec'd 12-2-63

Applicable environmental specifications IL, H. L. Powell to R. M. Oliva, "SNAP 10A Bearing Fixture" 11-25-63

Tests requested Vibration Qualification

TEST PLAN OF ACTION

Test assigned to M. J. D'Amico, ext. 6463, date 12-10-63, scheduled test start 12-10-63

Test equipment to be utilized Ling 7500# Shaker-Slip table system

Instrumentation required Accelerometer for monitoring table input, Dynamometer, X-Y Plotter & Accelerometer for monitoring fixture response.

Measurements required Bearing fixture response vs table input

Specimen support fixture A test specimen designed to simulate a typical control drum was assembled in a special fixture by the Mechanical Qualification Unit.

Test inputs: VIBRATION (constant octave sweep rate requiring 25 minutes)

Lateral and Normal axes	{	5 to 20 cps @ 1/4" DA	Longitudinal	{	5 to 20 cps @ 1/4" DA
		20 to 400 cps @ 5 g			20 to 400 cps @ 5 g
		400 to 3000 cps @ 7.5 g			400 to 3000 cps @ 7.5 g
		to cps @ g			to cps @ g

Vibration (Other)

SHOCK

Lateral and Normal axes { g, 1/2 sine, millisecc pulse;
shocks in each direction of each axis

Longitudinal { g, 1/2 sine, millisecc pulse;
shocks in each direction

ACCELERATION

Lateral and Normal axes { g, for a total
of minutes

Longitudinal { g, aft direction, for a total of minutes.
g, forward direction, for a total of minutes.

TEST RESULTS

Test conducted by M. J. D'Amico & D. Pearlman, ext. 6463, date 12-10-63, IN page No. B166250

Results No visual damage was evident. The X-Y plots of fixture response vs table input are being evaluated by the Mechanical Qualification Unit.

Specimen disposal Returned to the Mechanical Qualification Unit for further evaluation

Report prepared by M. J. D'Amico, date 12-17-63, Approved R. M. O., date 12-18-63

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TO H. L. Powell DEPT. 723-34 HQ 4 DATE 12-18-63
ENVIRONMENTAL EVALUATION COMPONENT TEST REPORT # 337

Component Identification SNAP 10A Bearing Assemblies (Re-Run)* S/N 23 & 11, 17 & 14, 22 & 33

Responsible Engineer and/or Unit supplying component: H. L. Powell date rec'd 12-2-63
Applicable environmental specifications IL, H. L. Powell to R. M. Oliva, "SNAP 10A Bearing Tests",
11 25-63

Qualification Vibration
Tests requested Shock and Acceleration

TEST PLAN OF ACTION

Test assigned to M. J. D'Amico ext. 6463, date 12-2-63, scheduled test start 12-2-63
Test equipment to be utilized Lang 7500# Shaker-Slip table assembly, Shock Instrumentation &
Instrumentation required Accelerometer for monitoring table input, Dynamometer, X-Y
Plotter, and Accelerometer for monitoring Bearing response
Measurements required Bearing response vs input
Specimen support fixture A test specimen designed to simulate a typical SNAP 10A control drum
bearing installation was assembled by the Mechanical Qualification Unit. A dummy
mass was used in lieu of an actual control drum. Exact bearing design, materials
& clearances were not made known to us.
Test inputs: VIBRATION (constant octave sweep rate requiring 25 minutes)

	5 to 20 cps @ $\frac{1}{4}$ " DA		5 to 20 cps @ $\frac{1}{4}$ " DA
Lateral and	20 to 400 cps @ 5 g	Longitudinal	20 to 400 cps @ 5 g
Normal axes	400 to 3000 cps @ 7.5 g		400 to 3000 cps @ 7.5 g
	to cps @ g		to cps @ g

Vibration (Other)

SHOCK

Lateral and Normal axes { 20 g, $\frac{1}{2}$ sine, 6 millisecc pulse;
2 shocks in each direction of each axis
Longitudinal { 20 g, $\frac{1}{2}$ sine, 6 millisecc pulse;
2 shocks in each direction

ACCELERATION

Lateral and Normal axes { 9.4g, for a total
of 10 minutes
Longitudinal { 9.4g, aft direction, for a total of minutes.
9.4g, forward direction, for a total of 10 minutes.

TEST RESULTS

Test conducted by M. J. D'Amico & D. Pearlman ext. 6463, date 12-2-63, IN page No. B166249
Results *These bearings, which had been previously tested on 11/13/63, were reworked for
this test. No bearing damage was evident & no restriction to drum movement could
be noted on either bearing assembly after testing, even though considerable rattle
was heard from both assemblies throughout the tests. A thorough examination for
internal damage will be made by Project when the bearing assemblies are returned for
their evaluation. The X-Y plots of bearing fixture response are being evaluated.
Specimen disposal Returned to the Mechanical Qualification Unit for further evaluation

Report prepared by M. J. D'Amico, date 12-17-63; Approved QMD, date 12-18-63

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APPENDIX II.C.

C. APPLICABLE DOCUMENTS

C.1 AI Specifications and Drawings

NA 0112-002	Process Specification for Coating with Dry Film Lubricants.
NA 0612-001	Dry Film Lubricant Inspection for Ball and Shaft Assembly.
NA 0408-008	Qualification Test Specification for SNAP 10A.

C.2 Drawings

1961-11034	Ball Assembly-Drum Support.
1961-11035	Socket Assembly-Drum Support.
1961-11036	Shaft Top and Bottom Drum Support.
10FSM1-11039	Ball and Shaft Assembly Drum Support.
T-766503	Modification: Shake Test Fixture.
7573-D127315	Fixture Assembly-Bearing Thermal Cycle and Endurance Qualification Test.
7573-D127316	Details-Bearing Thermal Cycle and Qualification Test Fixture.
7573-D127317	Structure-Bearing Thermal Cycle and Qualification Test Fixture.
7573-D127318	Thermocouple Assembly-Bearing Thermal Cycle and Endurance Qualification Test.

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APPENDIX II.C. (CONTINUED)

C.2 Drawings (continued)

7623-275104

Base Assembly Shake Test Fixture.

7623-275105

Modification - Bearing Thermal Cycle
and Endurance Test Fixture.

7622-262120

Bearing Torque Measuring Fixture.

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APPENDIX II.D., TEST EQUIPMENT

- D. Test Equipment List - Testing was accomplished by use of the following test equipment items or equivalents with calibrated accuracies, as follows:

<u>Equipment</u>	<u>Accuracy</u>
Twelve point strip chart recorder, Minneapolis Honeywell, Model 12PH560-12, Range 0-1500F.	+ - 1.0 percent
Single point indicator recorder controller, Wheelco Chronotral, Model 72000-S253, Range 0-1200F.	+ - 1.0 percent
Vacuum gage, Varian nude ion, Varian Assoc., Model UHV-14.	+ - 1 decade
Power supply, Ultek Model 60-154.	+ - 1.0 percent
Torque meters, Snap-On, Model TQS-004-FU range, 0-8 in-oz, and Model TQS-012-FU range, 0-24 in-oz, Model TQ 6-FU range, 0-75 in-lbs, Torque Controls, Inc., Model No. TG 48R-L, TG 216R-L and TG 108R-L.	+ - 1%
Weighing scale, Right-A-Weight Co., Model SC-300.	+ - 0.001 gram
Michrometers, Starrett Co., zero to 1 inch and 1 inch to 2 inch.	
Ammeter, Triplett Model 321T.	+ - 3.0 percent
Voltmeter, Simpson Model 269.	+ - 3.0 percent
Weight simulator (refer to drawing 7573-D127316).	
Twenty inch diameter by sixteen inch length vacuum chamber, Ultek Co., Model 70-180.	
Powerstat, Valley Electronics Supply Inc., Model 2520B.	
Two 1200 1/sec ion pumps, Ultek Co., Model 20-551.	
Roughing system and connections, consisting of four sorption pumps and liquid nitrogen flasks.	

ALL INSTRUMENTS WERE CALIBRATED ON OCTOBER 21, 1963.

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APPENDIX II.E., TEST DESCRIPTION

E. Following is a step by step description of each test.

E.1.a Inspection

Bearing assemblies and components shall be inspected for conformance to drawings 1961-11034, 1961-11035, 1961-11036 and 1961-11039. After coating, the test units shall be weighed in accordance with E.1.b, step 2.

E.1.b Inspection Sequence

- (1) Measure all component dimensions including ID, OD, thickness, length and width.
- (2) Weigh entire assembly and each component.
- (3) Inspect oxide coating of bearings for conformance to drawing 10FSM1-11039. Perform a visual inspection for coating color, porosity, uniformity and continuity.

E.2.a Performance Record Test

The test unit shall run performance record tests before starting any test and during the tests to determine if the bearing assemblies are functioning properly. The tests shall require the following test equipment and shall be performed in the sequence indicated:

E.2.b Test Sequence

Prior to coating, in accordance with Specification NA 0112-002, the test units shall be subjected to the following test procedure:

- (1) Mount test units in shock and vibration fixture. Do not attach weight simulator. Refer to Drawing 7623-275105.
- (2) Clamp fixture in vertical attitude.
- (3) Attach bearing torque measuring fixture and torque meter to shaft. Refer to Drawing 7622-262120 and Figure 7.
- (4) Measure alignment breakaway torque in a clockwise direction (facing fixture). Do not exceed 25 degrees.
- (5) Measure alignment breakaway torque counterclockwise through an equal angle of rotation. Stop shaft in vertical position.
- (6) Perform Steps 4 and 5 at three different angles, each rotated 60 degrees clockwise from previous measurement. Maximum torque shall be 12 inch-pounds.

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- (7) Mount test units in bearing test fixture assembly (Figure 1).
- (8) Attach weight simulator. Refer to Drawing 7573-D127316.
- (9) Attach torque meter to bearing shaft.
- (10) Measure breakaway torque. Maximum acceptable torque shall be 2.5 inch-pounds. If the breakaway torque reaches 2.5 inch-pounds, the task engineer shall be notified. No further testing shall be performed without the consent of the task engineer.
- (11) Measure rotation, or running torque. Maximum acceptable torque shall be 2.5 inch-pounds. If the running torque reaches 2.5 inch-pounds, the task engineer shall be notified. No further testing shall be performed without the consent of the task engineer.
- (12) Install rotary motion magnetic feedthrough to the test fixture.
- (13) Attach torque meter to magnetic feedthrough.
- (14) Repeat Steps 10 and 11.
- (15) Submit the test units for treatment in accordance with NA 0112-002 and inspect to the criterion of NA 0612-001.
- (16) Repeat Steps 1 through 11.

E.3 Thermal Cycle

E.3.a Preparation

Refer to Drawings 7573-D127315, 7573-D9127316, 7573-D127317, 7573-D127318 and 7623-275105.

- (1) Assemble and pin bearings.
- (2) Install bearings in titanium bearing housings.
- (3) Install bearing housings in test fixture. Refer to Figure 1.
- (4) Connect thermocouples in accordance with Drawing 7573-D127318 and 7573-D127315.
- (5) Attach reflector simulator to lower shaft by "V" block attachment. Refer to Figure 1 and Drawing 7573-D127315.
- (6) Attach and tighten upper "V" block attachment on upper shaft.

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- (7) Install flange on vacuum system with new copper gasket.
- (8) Install the rotary motion magnetic feedthrough to the test fixture (Figure 1).
- (9) Attach thermocouple leads to controlling instrumentation.
- (10) Follow roughing procedure posted near vacuum system.
- (11) Connect programmer, chiller and instrumentation in accordance with Figures 2, 3 and 4.
- (12) Lead thermocouples to outside of bakeout oven. Refer to Figure 5.

E.3.b Test Sequence

- (1) Start up vacuum system and instrumentation in accordance with manufacturer's procedure posted on vacuum equipment.
- (2) Establish a pressure less than 10^{-6} torr in test chamber.
- (3) Confirm that 30F to 700F cam is installed in controller.
- (4) Start controller.
- (5) Check individual temperatures and adjust powerstats to maintain bearing temperatures.
- (6) Perform thermal cycle in accordance with Figure 6. Ramp shall be less than 10F per minute.
- (7) Adjust brine flow during cooling portion of cycle to maintain control of bearing temperature.

Note

Reflector rotation shall be accomplished on the increasing ramp of each thermal cycle. As the increasing ramp is controlled by a four-hour cam controller, each ramp will be identical.

- (8) Measure time required to increase temperature from 30 degrees to 700 degrees and divide time into ten equal segments.
- (9) Rotate reflectors 2.5 degrees during each segment for a total of 25 - 2 degrees for each thermal cycle.
- (10) Rotate reflectors clockwise for the first five thermal cycles, and counterclockwise for the remaining five, for a total of ten thermal cycles.

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(11) Remove magnetic feedthrough.

(12) Repeat E.2.b, Steps 9 through 11.

E.3.c Performance Record Test

E.4 Shock, Vibration and Acceleration Tests

Note

Shock, vibration and acceleration tests shall be performed by Department 722-22 in the sequence indicated. Department 722-22 shall issue a report to the task engineer detailing the test equipment used, the frequencies and amplitudes, and test results.

E.4.a Preparation

(1) Subject test fixture (Drawings T-766503 and 7623-275104) to low level search from 5 to 3000 cps. Record all resonant frequencies.

(2) Mount bearings in test fixture.

(3) Mount accelerometers near each bearing.

E.4.b Shock Test

Subject bearings to two shocks in each direction along three mutually perpendicular axes for a total of 12 shocks. Each shock shall be 20g amplitude and shall be half sine wave of six millisecond duration.

E.4.c Vibration Test

Apply a sinusoidal sweep along each of three mutually perpendicular axes at the following vibration amplitudes. The test along each axis shall consist of a single sinusoidal sweep starting at the lower frequency limit and proceeding at a constant octave sweep rate to the upper limit in 25 minutes.

Frequency

Amplitude

5 to 20 cps
20 to 400 cps
400 to 3000 cps

1/4 inch peak to peak
5g
7.5g

E.4.d Acceleration Test

Subject bearings to a sustained acceleration of 9.4g for a duration of 10 minutes in each direction along three mutually perpendicular axes.

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E.4.e Performance Record Test

- (1) Repeat E.2.b., Steps 2, 10 and 11.
- (2) Remove weight simulator.
- (3) Repeat E.2.b., Steps 1 through 6.
- (4) If bearings are not within acceptable torque levels, they shall be rejected, dismantled and photographed.

E.5 Endurance

E.5.a Preparation

Repeat E.2.a.

E.5.b Test Sequence

- (1) Repeat E.2.b, Steps 10 and 11.
- (2) Start up vacuum system and instrumentation in accordance with manufacturer's procedure posted on vacuum equipment.
- (3) Reduce pressure to less than 10^{-6} torr.
- (4) Repeat E.2.b., Steps 10 and 11.
- (5) Raise bearing temperature to $700F \pm 10F$.
- (6) Repeat E.2.b, Steps 10 and 11.
- (7) Continued test at 700F and at a pressure less than 10^{-6} torr for 2160 hours. Do not move test unit.
- (8) Repeat E.2.b, Steps 10 and 11.
- (9) Reduce temperature to room ambient in less than two hours. If necessary, use chiller. The rate shall not exceed 10F per minute. The pressure shall be less than 10^{-6} torr.
- (10) Repeat E.2.b, Steps 10 and 11.
- (11) Remove magnetic feedthrough.
- (12) Repeat E.2.b, Steps 9 through 11.

E.5.c Performance Record Test.

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APPENDIX III

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Table V	Bearing Dimensions
Table VI	Component Test History Log
Table VII	Shock, Vibration and Acceleration Maximum Response

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TEST DESCRIPTION

COLUMN

- A - Before Thermal Cycle Tests (Completely Disassembled)
- B - After Thermal Cycle Tests (Ball and Socket Assembled)
- C - After First S.V.A. (Completely Disassembled)
- D - After First S.V.A. (Ball and Socket Reassembled)
- E - After Second S.V.A. (Ball and Socket Assembled)
- F - After Second S.V.A. (Completely Disassembled)
- G - After Endurance Test (Completely Disassembled)

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TABLE I-A
Bearing Set I Weights in Grams

		A	B	C		D				
S/Brg. Set	11 (Top)	Before Thermal Cycle	After Thermal Cycle	Change (A + B)	After Shock & Vib.	Change (B + C)	Net Change (A + C)	Reassembled After 1st Shock & Vib.	Net Changes (C + D)	Total Loss A + D
S/4										
1 1/2 Race		17.9942			17.9933		- .0009			
1/2 Race		17.9346			17.9348		+ .0002			
		35.9288			35.9281		- .0007			
Ball		18.6903			18.6915		+ .0012			
Pins		.2275			.2275					
Brg Assy		54.8466	54.8480	+ .0014	54.8471	- .0009	+ .0005	54.8464	- .0007	- .0002
Shaft					14.6567			14.6565		
Key					.5822			.5821		
		15.2468	15.2456	- .0012	15.2389	- .0067	- .0079	15.2386	- .0093	- .0082
Total		70.0934	70.0936	+ .0002	70.0860	- .0076	- .0074	70.0850	- .0010	- .0084
S/23										
N (Bottom)										
1 1/2 Race		37.9790			37.9750		- .0040			
1/2 Race		25.4524			25.4464		- .0060			
		63.4314			63.4214		- .0100			
Ball		60.7269			60.7289		+ .0020			
Pins		.3286			.3286					
Brg Assy		124.4869	124.4838	- .0031	124.4789	- .0049	- .0080	124.4753	- .0036	- .0116
Shaft					20.6982			20.6981		
Key					.5693			.5693		
		21.2697	21.2683	- .0014	21.2675	- .0008	- .0022	21.2674	- .0001	- .0023
Spacer		2.8804	2.8798	- .0006	2.8790	- .0008	- .0014	2.8790	- .0000	- .0014
Total		148.6370	148.6319	- .0051	148.6254	- .0065	- .0116	148.6217	- .0037	- .0153
Test Date	11/1	11/6			11/13-11/15			11/15/63		
Weigh Date		11/8/63			11/20/63			11/25/63		

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TABLE I-B

Bearing Set II Weight in Grams

Brg. Set	14 (Top)	Before Thermal Cycle	After Thermal Cycle	Change (A - B)	After Shock Vib.	Change B - C	Net Loss (A - C) Gain (C - A)	Re- Assembled After Shock & Vib.	Net Loss (C - D) Gain (D - C)	Total Loss (A - D)
S/ N 1/2 Race	17.9534				17.9504		- .0030			
1/2 Race	17.9542				17.9571		+ .0029			
	35.9076				35.9075		- .0001			
Ball	18.7003				18.7036		+ .0033			
Pins	.2266				.2266					
Brg. Assy	54.8345	54.8392	+ .0047	54.8377	- .0015	+ .0032	54.8373	- .0004	+ .0028	
Shaft					14.5774			14.5770		
Key					.5763			.5763		
	15.1606	15.1593	- .0013	15.1537	- .0056	- .0069	15.1533	- .0004	- .0073	
Total	69.9951	69.9985	+ .0034	69.9914	- .0071	- .0037	69.9906	- .0008	- .0045	
S/ N 17 (Bottom)										
2 1/2 Race	37.9341				37.9263		- .0078	- .0113		
1/2 Race	25.4628				25.4548		- .0080			
	63.3969				63.3811		- .0158			
Ball	59.7662				59.7688		+ .0026			
Pins	.3099				.3099					
Brg. Assy	123.4730	123.4628	- .0102	123.4598	- .0030	- .0132	123.4580	- .0018	- .0150	
Shaft					20.6749			20.6736		
Key					.5623			.5623		
	21.2408	21.2400	- .0008	21.2372	- .0028	- .0036	21.2359	- .0013	- .0049	
Spacer	2.7961	2.7958	- .0003	2.7955	- .0003	- .0006	2.7953	- .0002	- .0008	
Total	147.5099	147.4986	- .0113	147.4925	- .0061	- .0174	147.4892	- .0033	- .0207	
Test Date	11/4 - 11/6				11/13-11/15			11/15/63		
Weigh Date		11/8/63			11/20/63			11/25/63		

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TABLE I-C

Bearing Set III Weight in Grams

Srg. Set	33 (Top)	Before Thermal Cycle	After Thermal Cycle	Change (A - B)	After Shock & Vib.	Change (B - C)	Net Loss (A - C) Gain (C - A)	Re- Assembled After Shock & Vib.	Net Loss (C - D) Gain (D - C)	Total Loss (A - D)
3 N										
3 1/2 Race		17.9704			17.9679		- .0025			
1/2 Race		17.9491			17.9475		- .0016			
		35.9195			35.9154		- .0041			
Ball		18.7049			18.7075		+ .0026			
Pins		.2307			.2307					
Brg. Assy		54.8551	54.8550	- .0001	54.8536	- .0014	- .0015	54.8545	+ .0009	- .0006
Shaft					14.6408			14.6415		
Key					.5535			.5536		
		15.2018	15.2002	- .0016	15.1943	- .0059	- .0075	15.1951	+ .0008	- .0067
Total		70.0569	70.0552	- .0017	70.0479	- .0073	- .0090	70.0496	+ .0017	- .0073
22 (Bottom)										
3 1/2 Race		37.4427			37.4337		- .0090			
1/2 Race		25.4327			25.4253		- .0074			
		62.8754			62.8590		- .0164			
Ball		60.0720			60.0738		+ .0018			
Pins		.3301			.3301					
Brg. Assy		123.2775	123.2633	- .0142	123.2629	- .0004	- .0146	123.2614	- .0015	- .0161
Shaft					20.6288			20.6275		
Key					.5840			.5840		
		21.2158	21.2150	- .0008	21.2128	- .0022	- .0030	21.2115	- .0013	- .0043
Spacer		2.7760	2.7757	- .0003	2.7752	- .0005	- .0008	2.7750	- .0002	- .0010
Total		147.2693	147.2540	- .0153	147.2509	- .0031	- .0184	147.2479	- .0030	- .0214
Test Date		11/1	- 11/6		11/13	- 11/15		11/15/63		
Weigh Date			11/8/63		11/20/63			11/25/63		
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* New pins required during reassembly. .0031 gms heavier. Weights from										
column D are corrected using original pin weights.										

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TABLE I-C

Bearing Set III Weight in Grams Continued

Brg. Set	E	Change D + E	F	Change E + F	G	Change F + G	Total Change A + G		
3 Upper									
1/2 Race			17.9666		17.9663	- .0003	- .0041		
1/2 Race			17.9465		17.9462	- .003	- .0029		
			35.9131		35.9125	- .0006	- .0070		
Ball			18.7052		18.7054	+ .0002	+ .0005		
Pins			.2307		.2307		-0-		
Brg. Assy	54.8506	- .0039	54.8490	- .0016	54.8486	- .004	- .0065		
Shaft	14.6406		14.6402						
Key	.5536		.5536						
	15.1942	- .0009	151.938	- .0004	15.1932	- .0006	- .0086		
Total	70.0448	- .0048	70.0428	- .0020	70.0418	- .0010	- .0151		
3 Lower									
1/2 Race			37.4332		37.4307	- .0025	- .0120		
1/2 Race			25.4220		25.4190	- .0030	- .0137		
			62.8552		62.8497	- .0055	- .0257		
Ball			60.0736		60.0730	- .0006	+ .0010		
Pins			.3301		.3301	-0-			
Brg. Assy	123.2619		123.2589	- .0030	123.2528	.0061	- .0247		
Shaft	20.6258		20.6246						
Key	.5841		.5840						
	21.2099	- .0016	21.2086	- .0013	21.2064	- .0022	- .0094		
Spacer	2.7749	- .0001	2.7749		2.7743	- .0006	- .0017		
Total	147.2498	- .0012	147.2424	- .0074	147.2335	- .0089	- .0358		
Test Date	12/4/63		12/4/63		4/8/64				
Weigh Date	12/9/63		12/26/63		4/17/64				

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TABLE II

Bearing Rotation Torque Measurements

Brg. Set	Brg. S/N	Rotation Direction	(Columns identified on bottom of next page)						
			A	B	C	D	E	F	G
1	11	CW	Breakaway	9.5	21.0	32.0			
	23			11.5	20.0	27.0			
				16.5	23.0	19.0			
			Average	13	12.5	21.5	26.0	13.0	45.0
			Running	8	10	15	18	9.0	48.0
		CCW	Breakaway	13.0	24.0	29.0			
				12.5	25.0	22.0			
				16.0	26.0	26.0			
			Average	12	14.0	25.0	26.0	17.0	43.0
2	14	CW	Breakaway		8.0	18.0	29.0		
	17		"		7.5	16.0	21.0		
			"		12.0	20.0	27.0		
			Average	12.0	9.0	18.0	26.0	12.0	12.0
			Running	8.0	8.0	13.0	15.0	7.0	24.0
		CCW	Breakaway		8.0	22.0	31.0		
			"		7.5	20.0	28.0		
			"		8.0	16.0	32.0		
			Average	11.0	8.0	19.0	30.0	15.0	34.0
3	33	CW	Breakaway		11.5	25.0	27.0		
	22		"		9.5	18.0	21.0		
			"		10.5	20.0	23.0		
			Average	12.0	10.5	21.0	24.0	8.0	11.0
			Running	8.0	7.0	16.0	16.0	4.0	6.0

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Thermal Cycle Torque Measurements (in. ozs.)

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TABLE IV
Bearing Alignment Torque Measurements

IVA - Before Second Shock, Vibration, Acceleration Test

Bearing Set	Serial No.	(In. Lbs.)							
		Starting Measurement		Rotated 60°		Rotated 120°			
		CW	CCW	CW	CCW	CW	CCW		
1	11	0	0	0	0	0	0		
	23	5.25	2.4	1.3	.3	.45	.85		
2	14	0	0	0	0	0	0		
	17	1.5	1.25	.75	.90	1.2	1.1		
3	33	0	0	0	0	0	0		
	22	3.5	2.0	.8	.6	.8	.8		

IVB - After Second Shock, Vibration and Acceleration

				(In. Lbs.)					
1	11	0	0	0	0	0	0		
	23	12.8	11.2	8.1	7.5	11.2	11.9		
2	14	0	0	0	0	0	0		
	17	10.0	9.4	8.8	8.1	8.8	11.0		
3	33	0	0	0	0	0	0		
	22	8.1	7.5	9.4	10.2	11.9	10.6		

IVC - After Endurance Test

		Initial Rotated							
		Reading	135°						
1	11	0	0						
	23	216	198						
2	14	No measurements taken							
	17								
3	33	0	0						
	22	11.1	9.5						

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TABLE V

Measurements (in inches) of Lubricant-Coated Surfaces

Test Cond. *	Bearing Set No. & Loc.	Serial Number	A	B	C	D	E	F	G
1	No. 1 Top	S/N	.0741	.3130	.5024	.81176	.3146	.8117	
2			.0739	.31241	.50241	.81176	.31465	.81175	"
			-.0002	.0006	-	-	-	-	
1	No. 1 Bottom	S/N	.2793	.31369	.70715	1.18545	.3148	1.18545	.06370
2			.2792	.31347	.7073	1.18563	.31475	1.18560	.06380
			-.0001	-.0002	-.00015	+ .00018	-	+ .00015	+ .0001
1	No. 2 Top	S/N	.0719	.3129	.5022	.81178	.3146	.8118	
2			.0719	.3125	.5022	.8118	.3145	.8118	
			-	-.0004	-	-	.0001	-	
1	No. 2 Bottom		.2797	.31370	.70740	1.18570	.31475	1.18570	.06230
2			.2796	.31355	.7075	1.18570	.31470	1.18570	.06230
			-.0001	-.00015	+ .0001	-	-	-	-
1	No. 3 Top		.0700	.3125	.50235	.81179	.3147	.8118	
2			.0700	.3124	.52075	.8118	.31475	.81185	
			-	-.0001	+ .0004	-	-	-	
1	No. 3 Bottom		.2781	.31326	.70702	1.18570	.3147	1.18570	.06235
2			.2779	.31320	.70702	1.1857	.3147	1.18570	.06250
			-.0001	-.00006	-	-	-	-	-.00015
*									
1	After Second Shock, Vibration, and Acceleration Test								
2	After Endurance Test								

The schematic shows a shaft-housing assembly. Dimension A is the distance from the left end of the housing bore to the inner race of the ball bearing. Dimension B is the thickness of the housing flange at the left end. Dimension C is the diameter of the outer race of the ball bearing. Dimension D is the angle of the taper fit between the shaft and the inner race. Dimension E is the axial clearance or gap between the inner races of two bearings. Dimension F is the total width of the housing bore.

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