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November 24, 1964

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QUALIFICATION SPECIFICATIONS FOR CONTROL DRUM
PNEUMATIC ACTUATORS FOR XE-1 APPLICATION

Astronuclear Laboratory
Westinghouse Electric Corporation

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TITLE: QUALIFICATION SPECIFICATIONS FOR CONTROL DRUM
PNEUMATIC ACTUATORS FOR XE-1 APPLICATION

DATE: November 24, 1964

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INFORMATION CATEGORY

Excluded from Automatic Downgrading
and Declassification

Confidential Restricted Data

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Authorized Classifier Date

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A. VIBRATION QUALIFICATION TESTS FOR CONTROL DRUM PNEUMATIC ACTUATORS

1.0 PURPOSE

The purpose of this test is to determine the acceptability of the pneumatic drum actuator for use in the NERVA X-Engine Test XE-1. This investigation will be limited to qualification in a vibration environment, which consists of a sinusoidal forcing function varying in frequency at a logarithmic rate.

2.0 GUIDING SPECIFICATIONS

The following specifications shall serve as guidelines in completing the requirements of this specification:

MIL-STD-810--"Environmental Test Methods for Aerospace and Ground Equipment" (Equipment Class 4, and Equipment Class 6, Mounting Method "a")

AGC Report Number RN-DR-0020--"Preliminary Specification, NERVA X-Engine, NERVA Program, Contract SNP-1"

WANL-Specification-E-675378--"Development Specification, Control Actuators for the NERVA Reactor"

3.0 PROCEDURE

3.1 Pre-Test Performance Record

Prior to the initiation of the vibration tests, the actuator shall be mounted on an ambient test stand and a complete set of performance data shall be recorded. This data will be used as a

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reference throughout the subsequent test and will be referred to as "the base line data". The base line data shall include the following items:

- 3.1.1 Linearity Check
- 3.1.2 Static Resolution
- 3.1.3 Scram Turnaround
- 3.1.4 Transient Response
- 3.1.5 Frequency Response
- 3.1.6 Dynamic Resolution

The definition and test conditions for these tests shall be as outlined in the appropriate paragraphs of WANL Specification E-675378, except as modified herein.

3.2 Installation in the Test Facility

After establishing the base line data, the actuator shall be mounted on the vibration table. With the actuator completely installed, the base line data shall be repeated in order to insure that no malfunction has occurred due to handling or installation on this load fixture.

3.3 Vibration Tests

3.3.1 Test Plan

The tests described in the table below shall be conducted to determine the performance of the actuator when subjected to these vibratory environments. A separate

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document outlining the procedure to be followed in performing these tests will be issued at a later date.

3.3.2 Planes of Vibration

The actuator shall be vibrated according to the test schedule of Table 1 in each of the following planes:

Vertical: Applied vibration force in a plane parallel to the actuator output shaft.

Horizontal
Number 1: Applied vibration force in a plane parallel to the direction of piston travel.

Horizontal
Number 2: Applied vibration force in a plane normal to the direction of piston travel.

3.3.3 Test Sequence

The tests listed in Table 1 shall be conducted in the following sequence:

Vertical: 1,2,3,5,6

Horizontal
Number 1: 1,2,4,5,7

Horizontal
Number 2: 1,2,4,5,7

In addition, a complete set of performance data shall be taken to compare with the base line data after each of these tests: 3,4,6,7 whenever they occur in the test sequence.

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TABLE 1

PHASE	ACTUATOR CONDITION	VIBRATION PLANE	RESONANCE DWELL			PERFORMANCE TESTS				
			TEST NUMBER	DWELL TIME AT RESONANCE	APPLIED FORCE (g) VECTOR	TEST NUMBER	SWEEP FREQ. CPS	NUMBER OF SWEEPS	TIME/ SWEEP	APPLIED FORCE g
Low Level Vib. Search	Non- Opera- tional	All 3	--	--	--	1	5-2000- -5	2	3 min.	1.0
Ship- ment and Storage	Non- Opera- tional	All 3	5	30 Minutes	4.0	2	10-30 -10	3	2 min.	4.0
Ground Firing	Operating	Vertical	6	10 Minutes	See Curve 1	3	5-2000 -5	1	30 min.	See Curve 1
Ground Firing	Operating	Horizontal	7	10 Minutes	See Curve 2	4	5-500 -5	2	15 min.	See Curve 2

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3.3.4 Actuator Conditions

3.3.4.1 Non-operating

In those tests where the actuator is non-operating, the following conditions shall prevail:

3.3.4.1.1 The drive and coolant gas supplies to the actuator shall be turned off.

3.3.4.1.2 The actuator shall be locked at the 15° shaft position.

3.3.4.1.3 The electrical supplies to the torque motor shall be turned off.

3.3.4.2 Operating

In those tests where the actuator is operating, the following conditions shall prevail:

3.3.4.2.1 Drive gas pressure at 200 ± 5 psig.

3.3.4.2.2 Coolant gas pressure at 650 ± 15 psig.

3.3.4.2.3 Return gas pressure at 35 ± 3 psig.

3.3.4.2.4 Drive and coolant gas temperature at ambient conditions.

3.3.4.2.5 External friction load varied between 0 and 32 inch pounds.

3.3.4.2.6 Simulated inertia load at .24 inch pound second².

3.3.4.2.7 Actuator velocity limit set at 250 degrees to 350 degrees per second.

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3.3.4.2.8 The actuator set at a nominal drum position of 90°, with various command signals super-imposed on the nominal position.

3.3.5 Data Requirements

The following data shall be recorded during the tests:

- 3.3.5.1 Vibration control accelerometer.
- 3.3.5.2 Two accelerometers mounted on the actuator housing.
- 3.3.5.3 One accelerometer recording cross-motion.
- 3.3.5.4 Drive gas pressure.
- 3.3.5.5 Coolant gas pressure.
- 3.3.5.6 Return gas pressure.
- 3.3.5.7 Two cylinder pressures.
- 3.3.5.8 Actuator shaft position.
- 3.3.5.9 Actuator command.
- 3.3.5.10 Torquemotor current.
- 3.3.5.11 Position error.

4.0 PERFORMANCE REQUIREMENTS FOR QUALIFICATIONS

To successfully demonstrate the qualification of the actuator in the XE-1 vibration environment the following performance parameters should be satisfied during and after the vibration tests described in Table 1. Isolated cases that vary beyond the allowable limits shall be evaluated individually in light of the control system requirements.

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If it is determined that these items will not adversely affect the control system operation, they will be made a part of the qualification conditions.

4.1 Scram Operation

Maximum allowable turnaround time -- .05 seconds.

4.2 Transient Response

Rise Time	-	$T \pm 10$ per cent of base line data*.
Settling Time	-	0.150 seconds maximum.
Overshoot	-	6.0% maximum

4.3 Frequency Response to 4" Peak to Peak Sine Wave

4.3.1 Maximum amplitude ratio below 10 cps shall not exceed +3db.

4.3.2 Maximum amplitude ratio above 10 cps not to exceed a value defined by a line starting at 3db and 10 cps and decreasing at a rate of 20db per decade.

4.3.3 Phase lag below 2 cps not to exceed 35°.

4.3.4 Phase lag at 6 cps not to exceed 90°.

4.3.5 Phase lag at 12 cps not to exceed 180°.

4.4 Dynamic Resolution During a 3" Per Second Ramp Command

Maximum error from true position shall be $\pm 0.5^\circ$.

4.5 Static Resolution

Static position resolution at the output shaft shall not exceed 0.4°.

*Rise time must not change by more than ± 10 per cent of the value recorded in the base line data of paragraph 2.0.

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5.0 POST VIBRATION INSPECTION

Upon completion of all of the scheduled tests the actuator shall be completely disassembled and inspected for physical damage or changes. A careful record shall be maintained of each step in the disassembly process. Pictures shall be taken wherever it is deemed necessary.

6.0 REPORT PREPARED

6.1 Preliminary Report

Within one week after the completion of the disassembly process described in step 5, a preliminary report of the test results is required. This should include a summary of the test findings, based on a cursory inspection of the records available at that time. A complete documentation of the data need not be included at this time, however, any data available should be included.

6.2 Final Report

The final report should be a comprehensive analysis of the test results. It should include, but not be limited to, the following sections:

- 6.2.1 Introduction
- 6.2.2 Description of Test Setup
- 6.2.3 Description of Test Procedure
- 6.2.4 Presentation and Discussion of Test Data
- 6.2.5 Conclusions and Recommendations.

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CURVE NO. 1 ANTICIPATED VIBRATION ENVIRONMENT, NERVA XE-1;
GROUND FIRING TEST, LONGITUDINAL PLANE.

Note: D.A. = Double Amplitude

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CURVE NO. 2 ANTICIPATED VIBRATION ENVIRONMENT NERVA XE-1;
GROUND FIRING TEST; LATERAL PLANE

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B. LIFE QUALIFICATION TESTS FOR CONTROL DRUM PNEUMATIC ACTUATORS

1.0 SCOPE

This memorandum defines the life test requirements for the XE-1 Engine Control Drum Actuators. The test conditions as specified herein represent the design life requirements as specified in WANL-Specification E-675378 but modified to what is currently known of the XE-1 Engine test environment.

2.0 OBJECTIVE OF TEST

The objective of the life test defined herein is to qualify the control drum actuators for the XE-1 Engine Test by demonstrating satisfactory performance over an extended operating duration.

The life test shall consist of a 150 hour room temperature test followed by a one hour combined low temperature and vibration test.

3.0 ENVIRONMENTAL CONDITIONS

3.1 Room Temperature Test

The room temperature test shall consist of 150 hours of operation in accordance with the duty cycle specified in paragraph 4.1. Helium shall be used as the drive gas and nitrogen as the coolant. The only purpose of the coolant in these tests is to provide the same gas loading as would be seen under XE-1 engine test conditions. The test shall be conducted continuously in so far as possible with any necessary shutdowns held to a minimum.

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3.2 Combined Low Temperature and Vibration Test

The combined low temperature and vibration test shall consist of one hour of operation in accordance with the duty cycle defined in paragraph 4.2 while subjected to the vibratory conditions defined by Curve 1. Vibration shall be in the vertical plane, i.e., along the axis of the output shaft. The drive gas, coolant gas and the actuator housing temperature shall be maintained at -65°F . Sufficient time shall be allowed prior to running the one hour test to allow the housing temperature to stabilize.

4.0 DUTY CYCLE

The actuator shall be subjected to the following duty cycle during the test. During the room temperature test the cycling sequence shall be such that the actuator will be cycled through each of the six steps at least once per hour.

4.1 Room Temperature Test

4.1.1 Sinusoidally at 6 cps and 4° p-p amplitude	12.5 hours
4.1.2 Sinusoidally at 0.5 cps and 40° p-p amplitude	20.0 hours
4.1.3 Ramp at 3° per second over full stroke	45.0 hours
4.1.4 Scram, lock and reset	22.5 hours
4.1.5 Step at 0.1 cps between 81° - 99°	25.0 hours
4.1.6 Dwell at static position of 90°	<u>25.0 hours</u>

TOTAL 150.0 hours

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4.2 Combined Low Temperature and Vibration Test	15.0 minutes
4.2.1 Ramp at 3° per second over full stroke	15.0 minutes
4.2.2 Step at 0.1 cps between 81° - 99°	15.0 minutes
4.2.3 Dwell at static position of 90°	15.0 minutes
4.2.4 Sinusoidally at 6 cps and 4° p-p amplitude	<u>15.0 minutes</u>
TOTAL	<u>60.0 minutes</u>

5.0 TEST PARAMETERS

The various test parameters shall be controlled as specified in the following table.

5.1 Pressures

<u>Parameter</u>	<u>Room Temperature Test</u>	<u>Combined Environment Test</u>
(a) drive gas	210-220 psia.	210-220 psia.
(b) coolant	650-700 psia.	650-700 psia.
(c) exhaust	33-37 psia.	33-37 psia.

5.2 Temperatures

(a) drive gas	530-540°R	385-405°R
(b) coolant	530-540°R	385-405°R
(c) actuator housing	530-540°R	385-405°R

5.3 Load

(a) inertia	0.24 inch pound second ²	0.24 inch pound second ²
(b) friction	0.32 inch pound	0.00

6.0 DATA

Prior to the start of the test, a complete set of data, as defined in paragraph 7.0, shall be taken and shall be referred to as the base line data. A complete set of data shall also be taken at the completion of the 150 hour room temperature test and upon completion of the one hour combined low temperature and vibration test.

During the room temperature test a frequency response test shall be made every 25 hours.

The following data shall be recorded continuously (except gas flow) throughout the test except during the dwell period defined in paragraph 4.1.6.

6.1 Temperatures

6.1.1 Drive gas

6.1.2 Coolant gas

6.1.3 Structural temperature (to be taken only during cold test of paragraph 3.2)

6.2 Pressures

6.2.1 Drive gas

6.2.2 Coolant gas

6.2.3 Exhaust

6.2.4 Piston chamber, P_1

6.2.5 Piston chamber, P_2

6.3 Electrical Measurements

6.3.1 Manual Command

6.3.2 Dynamic Command

6.3.3 Actuator position

6.3.4 Torquemotor current

6.3.5 Error

6.4 Gas Flow

The drive gas and coolant flow shall be read during the dwell period of paragraph 4.1.6 approximately every 8 hours.

6.5 Test Time

A running time meter shall be used to record the actual operating time. The time meter shall be operated on and off by means of a pressure actuated switch in the drive gas supply line.

7.0 PERFORMANCE REQUIREMENTS FOR QUALIFICATION

The actuator shall be considered to have passed the life qualification test provided the following performance requirements are met. Isolated cases that vary beyond the allowable limits shall be evaluated individually in light of the control system requirements. If it is determined that these particular items will not significantly affect control system operation, they will be made a part of the qualification conditions.

7.1 Scram Operation

Maximum allowable turnaround time--0.05 seconds.

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7.2 Transient Response

7.2.1 Rise time - ± 10 per cent of base line data

7.2.2 Settling Time - 0.150 second maximum

7.2.3 Overshoot - 6.0° maximum

7.3 Frequency Response to 4° Peak to Peak Sine Wave

7.3.1 Maximum amplitude ratio below 10 cps shall not exceed +3 db.

7.3.2 Maximum amplitude ratio above 10 cps shall not exceed a value defined by a line starting at +3 db and 10 cps and decreasing at a rate of 20 db/decade.

7.3.3 Phase lag below 2 cps shall not exceed 35° .

7.3.4 Phase lag at 6 cps shall not exceed 90° .

7.3.5 Phase lag at 12 cps shall not exceed 180° .

7.4 Dynamic Resolution During a 3° Per Second Ramp Command

Maximum error from true position shall be $\pm 0.5^\circ$.

7.5 Static Resolution

Static position resolution at the output shaft shall not exceed 0.4° .

8.0 INSPECTION

Upon completion of the test the actuator shall be completely disassembled and a visual inspection made of all parts. A dimensional inspection shall be made and photographs taken of any parts exhibiting significant wear.

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9.0 REPORTS

Within one week after completion of the tests a memorandum shall be issued presenting the data available at that time and also preliminary conclusions concerning performance of the actuator throughout the test.

A comprehensive report including all performance and inspection data shall be issued at a later date.

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CURVE NO. 1 ANTICIPATED VIBRATION ENVIRONMENT, NERVA XE-1;
 GROUND FIRING TEST, LONGITUDINAL PLANE.

Note: D.A. = Double Amplitude

C. RADIATION QUALIFICATION SPECIFICATIONS FOR CONTROL DRUM PNEUMATIC ACTUATORS FOR XE-1 APPLICATION

1.0 SCOPE

The installation requirements imposed by XE-1 place the Control Drum Pneumatic Actuators above the external shield in the vicinity of Station 130.0. At this location estimates have been made of the radiation level expected in the fully shielded condition. The dose rates are defined by Aerojet Letter 7425:009 dated July 28, 1964. The integrated dose and environmental conditions are based on information contained in the NERVA X-Engine Specification RN-DR-0020 dated September, 1964.

2.0 OBJECTIVE

The purpose of this specification is to define the necessary conditions for qualification of the Control Drum Pneumatic Actuator in The XE-1 radiation environment.

3.0 ENVIRONMENTAL CONDITIONS

Since the functional operation of the pneumatic actuator is dependant upon the material properties of the components, it is necessary that the materials be qualified under the most severe conditions expected. The combined environments of radiation and low temperature represent the most severe environmental condition because the low temperature tends to accelerate or intensify the material degradations due to radiation.

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3.1 Radiation Field

The radiation field in and near the pneumatic actuator in the XE-1 shielded condition can be characterized by the following values:

<u>Item</u>	<u>Dose Rate</u>
Gamma	2.8×10^5 RADS/HR.
Fast Neutron (E 1 MEV)	4×10^{10} N/CM ² /sec.
Thermal Neutron (E .48EV)	Not Reported

Neglecting the heating effect due to neutrons, the heating value due to γ -rays is calculated at 0.35 watts/lb.

3.2 Temperature Field

Accurate information is not presently available with regard to the temperature distribution within the actuator mechanism. It is sufficient to consider the lowest value expected, and the temperature is based on the actuator coolant flow obtained from the reactor plenum volume. The estimated value for the actuator mechanism on XE-1 is 250°R.

4.0 QUALIFICATION REQUIREMENTS

4.1 Unconditional Qualification

In this sense the entire actuator mechanism must be tested under the conditions of Section 3.0 with the following results.

- 4.1.1 The actuator mechanism must retain its mechanical and electrical integrity.
- 4.1.2 The actuator mechanism must perform satisfactorily when operated in the sub-system. Satisfactory performance exists

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when the requirements of WANL Specification E-675378, Section 5, are met.

4.2 Conditional Qualification (XE-1 Application)

In this context the actuator mechanism components (as opposed to the actuator mechanism) must be tested under conditions of Section 3.0 with equivalent input/output characteristics, including loading, yielding the following results:

4.2.1 The components must retain their mechanical and electrical integrity.

4.2.2 The components must perform satisfactorily when operated under the sub-system conditions encountered in the closed loop, i.e. a dynamically similar and equivalent test.

4.3 Exceptions

Minor departures from the required performance may occur in either case (4.1 or 4.2). These will be analyzed with regard to the control system requirements, and if no adverse effects result, they will become a part of the final XE-1 qualification conditions.

4.4 Equivalence

Either 4.1 or 4.2 is sufficient to show qualification for XE-1.

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5.0 REPORT

A summary report will be issued indicating the actuator qualification for the XE-1 radiation environment. The report must include:

- (a) Abstract
- (b) Description of Test(s)
- (c) Results
- (d) Conclusions and Recommendations

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D. MECHANICAL SHOCK QUALIFICATION SPECIFICATION FOR CONTROL DRUM PNEUMATIC ACTUATORS FOR XE-1 APPLICATION

1.0 PURPOSE

The purpose of this test is to qualify the pneumatic durm actuators for use in the NERVA X-Engine Test XE-1. This investigation will be limited to observing the actuator closed loop performance while it is subjected to mechanical shock loads, which are considered typical of the XE-1 environment.

2.0 Guiding Specifications

The following specifications will serve as guidelines in completing the requirements of this specification:

MIL-STD-810 - "Environmental Test Methods for Aerospace and Ground Equipment" (Test Method No. 516, Procedure 1)

AGC Report No. RN-DR-0020 (Revised) - "Preliminary Specification, NERVA Program, Contract SNP-1" September, 1964.

WANL Specification E-675378 - "Development Specification, "Control Actuators for the NERVA Reactor", Section 5.

3.0 PROCEDURE

3.1 Pre-Shock Test Performance Record

Prior to the initiation of the shock tests, the actuator shall be mounted on the test stand and a complete set of performance data

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shall be recorded. This data will be used as a reference throughout the subsequent test and will be referred to as "the base line data". The base line data shall include the following items:

- 3.1.1 Linearity Check
- 3.1.2 Static Resolution
- 3.1.3 Scram Turnaround
- 3.1.4 Transient Response
- 3.1.5 Frequency Response
- 3.1.6 Dynamic Resolution

The definition and test conditions for these tests shall be as outlined in the appropriate paragraphs of WANL Specification E-675378, except as modified herein.

3.2 Shock Test

3.2.1 Test Plan

The following tests shall be conducted to determine the actuator performance when subjected to shock loads. A separate document outlining the procedure to be followed in performing these tests will be issued prior to the test.

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WANL-TME-1040TABLE 1

Plane	Actuator Condition	Load g's	Dwell Time	Shocks in each direction	Shocks in each plane
Vertical	Operating	± 2.0 g	0.01 sec.	3	6
Horizontal No. 1	Operating	± 1.0 g	0.01 sec.	3	6
Horizontal No. 2	Operating	± 1.0 g	0.01 sec.	3	6

3.2.2 Direction of Applied Loads

The shock loads shall be applied as described in the table above in the following planes:

Vertical: Applied force parallel to the actuator output shaft.

Horizontal No. 1: Applied force parallel to the direction of the piston travel.

Horizontal No. 2: Applied force normal to the direction of the piston travel.

3.2.3 Actuator Conditions

During all of the tests described in Table 1, the conditions to be imposed on the actuator shall be as follows:

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- 3.2.3.1 Drive gas pressure at 200 $\pm$ psig
- 3.2.3.2 Coolant gas pressure at 650 $\pm$ 15 psig
- 3.2.3.3 Exhaust gas pressure at 35 $\pm$ 3 psig
- 3.2.3.4 Drive and coolant gas temperatures at ambient conditions
- 3.2.3.5 Simulated inertia load at 0.24 in-lb-sec²
- 3.2.3.6 Actuator velocity limit set at 300 $\pm$ 50 degrees per second
- 3.2.3.7 The actuator set at a nominal drum position of 90° and a 3°/second triangular wave of 100° peak to peak amplitude applied.

3.2.4 Data Requirements

The following data shall be recorded during the tests:

- 3.2.4.1 Applied shock pulse
- 3.2.4.2 Shock pulse as recorded at two places on the actuator housing
- 3.2.4.3 Drive gas pressure
- 3.2.4.4 Coolant gas pressure
- 3.2.4.5 Return gas pressure
- 3.2.4.6 Actuator shaft position
- 3.2.4.7 Actuator command
- 3.2.4.8 Torquemotor current
- 3.2.4.9 Position error

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3.3 Post Shock Test Performance Record

Upon completion of the tests described in Section 3.2, a complete set of performance data shall be recorded to compare with the base line data recorded in Section 3.1. This data shall include the same requirements as specified in Section 3.1.

4.0 PERFORMANCE REQUIREMENTS FOR QUALIFICATION

To successfully demonstrate qualification of the actuator in the XE-1 environment, the following performance parameters should be satisfied after the shock tests described in Table 1. In addition, the physical structure of the actuator should remain intact. There should be no damage to the individual components such that they would be unable to perform their intended functions. Isolated cases that vary beyond the allowable limits shall be evaluated individually in light of the control system requirements. If it is determined that these items will not adversely affect the control system operation, they will be made a part of the qualification conditions.

4.1 Scram Operation

Maximum allowable turnaround time .05 seconds.

4.2 Transient Response

Rise Time	± 10 per cent of base line data*
Settling Time	0.150 seconds maximum
Overshoot	6.0 maximum

*Rise time must not change by more than ± 10 per cent of the value recorded in the base line data of paragraph 3.1.

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4.3 Frequency Response to 4° Peak to Peak Sine Wave

4.3.1 Maximum amplitude ratio below 10 cps shall not exceed ± 3.0

4.3.2 Maximum amplitude ratio above 10 cps not to exceed a value defined by a line starting at ± 3 db per decade

4.3.3 Phase lag below 2 cps not to exceed 35°

4.3.4 Phase lag at 12 cps not to exceed 180°

4.4 Dynamic Resolution During a 3°/sec. Ramp Command

Maximum error from true position shall be $\pm 0.5^\circ$

5.0 POST SHOCK TEST INSPECTION

Upon completion of all of the scheduled tests, the actuator shall be completely disassembled and visually inspected for physical damage or changes. A careful record shall be maintained of each step in the disassembly process. In the event that any part(s) has evidence of material failure or excessive wear, a dimensional check with suitable photographs of the failure will be made.

6.0 TEST REPORTS

6.1 Preliminary Report

Within two weeks after the completion of the disassembly process described in Step 5.0, a preliminary report of the test results is required. This should include a summary of the test findings, based on a cursory inspection of the records available at that time. A complete documentation of the data need not be included at this time, however, any data available should be included.

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6.2 Final Report

A complete analysis of the test results is required in the final report. This report should include, but not be limited to, the following sections:

6.2.1 Introduction

6.2.2 Description of Test Setup

6.2.3 Description of Test Procedure

6.2.4 Presentation and Discussion of the Test Data

6.2.5 Conclusions and Recommendations

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E. SEAL LEAKAGE RATE QUALIFICATION SPECIFICATION FOR CONTROL DRUM PNEUMATIC ACUTATORS FOR XE-1 APPLICATION

1.0 SCOPE

For purposes of reducing hydrogen concentration in the vicinity of the XE-1 Engine, a leak rate has been specified for all external seals. The Control Drum Actuator has several seals directly exposed to the engine operating environment, and therefore, must provide low leakage under those conditions.

2.0 OBJECTIVE

It is the objective of this document to demonstrate by tests that the actuator external seals are qualified for XE-1 Engine operation.

3.0 GUIDING SPECIFICATIONS

The sources used as the guiding specifications for qualification of actuator seals are:

AGC Report RN-DR-0020, "Preliminary Specification, NERVA X-Engine, NERVA Program Contract SNP-1" September, 1964.

Development Specification E-675378 Control Actuators for the NERVA Reactor - Westinghouse, Rev. 2, July 16, 1963, Section 5.

4.0 PARTS TO BE TESTED

The parts required to be tested are those actuator seals used for external sealing. In the XE-1 Engine operation, the purge cavity between the double external seals will not be utilized, thus making the largest diameter seal at each interface the only external seal.

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5.0 TEST PARAMETERS

The following specified parameters must be controlled, measured, and/or recorded during test operation. The test gases shall be H₂ and He.

5.1 Hydrogen Gas Pressures and Temperature

<u>Seal</u>	<u>Pressure (psid)</u>	<u>Temp. (°R)</u>
Actuator Mounting Flange Interface	650±15	250±25
Potentiometer Cover Interface	650±15	250±25
Piston Chamber Cover Interface (each end)	200±5	250±25
Rack-Back Up Bearing Cover Interface	60±3	250±25
Bellows Lock-Servo Cover Interface	35±3	250±25
Bellows of Bellows Lock	35±3	250±25
Servo-Cover - Actuator Interface	35±3	250±25

5.2 Helium Gas Pressures

For each external seal listed in paragraph 5.1 above, a helium gas condition shall be obtained simulating purge conditions.

Pressure 50±3 psid

Temperature 530±10°R

5.3 Test Cycle

During normal engine operation the actuator seals will have four duty cycles which will be duplicated as follows:

5.3.1 Helium gas purge at 50 psig and 620°R followed by:

5.3.2 Hydrogen gas pressurization as per paragraph 5.1, at 250±25°R for 300 second maximum followed by:

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5.3.3 Helium gas purge again at 50 psig and 520°R.

5.3.4 Pressure rates will not exceed psi/sec.

5.3.5 Temperature rates will not exceed deg/min.

5.4 Test Specimens

Each seal to be tested shall be assembled in a test fixture which will consist of a seal and two matching seal surfaces. The seal and one portion of the matching seal surface will be actuator vendor supplied parts. The second matching seal surface, the portion containing the seal grooves, will be supplied by the test group and will match the vendor's specification as to material, groove size, dimensions, and surface finishes. In all cases, the two matching surfaces will be fastened by the same method and means as in the actuator construction.

5.5 Data Requirements

The following data should be acquired during each seal test:

5.5.1 Gas pressure upstream of seal

5.5.2 Leak-Volume downstream of seal including manometer

5.5.3 Pressure of gas per unit time downstream of seal

5.5.4 Temperature of gas upstream

5.5.5 Leak rate of seal in standard cc/second for each cycle.

6.0 ACTUATOR SEAL QUALIFICATION REQUIREMENTS

Each external actuator seal shall demonstrate by tests as described previously in this document, that it is singly capable of maintaining a

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leak rate under normal operating pressure loads of H₂ and He gases. This leak rate shall be no greater than 10⁻² std. cc/sec per inch of seal diameter.

7.0 REPORTS

Two weeks after completion of all actuator seal tests a memorandum will be issued reporting the data available as well as any preliminary conclusion concerning the seal performance during testing.

A complete detailed report will be issued containing all test and inspection data at a later date.

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F. LOW TEMPERATURE QUALIFICATION SPECIFICATIONS FOR CONTROL DRUM PNEUMATIC ACTUATORS
FOR XE-1 APPLICATION1.0 SCOPE

The XE-Engine control drum pneumatic actuators, herein called actuators, must be capable of operating satisfactorily when using low temperature gas as supplied by the XE-Engine. Specific operating requirements and conditions required to qualify actuators for XE-1 Engine use are defined and specified by this document.

2.0 OBJECTIVE

It is the primary objective of this document to demonstrate by tests that the actuators are qualified for XE-1 during low temperature operation. This qualification will be considered for both mechanical integrity of the actuator and components as well as functional operation of the actuator sub-system.

3.0 REFERENCE SPECIFICATIONS

The following sources shall serve as specification guide lines in interpretation of the actuator requirements for low temperature qualification:

AGC Report RN-DR-0020

"Preliminary Specification, NERVA X-Engine
NERVA Program Contract SNP-1" (Sept. 1964)
Section 5

WANL Specification E-675378

"Development Specification, Control
Actuators for the NERVA Reactor", Section 5

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4.0 TEST PARAMETERS

Test parameters, as specified herein, must be controlled and recorded during all phases of test qualifications. The only exception being the inertia load value which should be constant, but need not be measured.

4.1 Actuator Drive Gas Parameters

Fluid	He or H ₂
Pressure	200±5 psig
Temperature	250±25°R

4.2 Actuator Coolant Gas Parameters

Fluid	N ₂ or H ₂
Pressure	650±15 psig
Temperature	250±25°R

4.3 Actuator Return Gas Parameters

Fluid	Mixture of coolant and drive
Pressure	35±3 psig
Temperature	Resultant of mixture

4.4 Friction Load

Friction Value 0 to 32 inch pounds

4.5 Actuator Temperature

Metal Temperature	250-350°R
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4.6 Inertia Load

Inertia Value	0.24 inch-pound-seconds ²
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4.7 Test Duration

Number of Cycles	4
Length of Cycles	300 seconds minimum with steady state actuator temperatures

4.8 Actuator Subsystem Gain Controls

Gain control values shall remain constant for the entire test.

Actual settings will be adjusted prior to testing.

5.0 TEST PLAN

5.1 Test Description

It will be required to provide all of the test parameters as specified above for each test cycle. A test cycle will be to attain the gas temperatures of $250 \pm 25^\circ\text{R}$ for a minimum of 300 seconds. The actuator should be allowed to "warm up" to room temperature after each cycle prior to beginning another cycle. During each cycle the actuator must be operated in such a manner as to demonstrate the actuator qualification requirements as outlined in Section 6.0 of this document. A detailed test plan shall be written prior to testing.

5.2 Data Required

The following data shall be measured and recorded.

5.2.1 Pressures

- (a) Drive gas
- (b) Coolant gas

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(c) Return gas

(d) Cylinder gas (P_1 and P_2)

5.2.2 Temperatures

(a) Drive gas

(b) Coolant gas

(c) Return gas

5.2.3 Actuator Data

(a) Shaft position

(b) Position command

(c) Position error

(d) Torquemotor current

6.0 QUALIFICATION REQUIREMENTS

Prior to low temperature operation an ambient "base line" operation shall be accomplished and the values of the following "Qualification Performance Requirements" shall be measured and recorded. These values shall be referred to as "Base Line Data" for evaluation of actuator performance at low temperature.

6.1 Scram Operation

Maximum allowable turnaround time - 0.05 seconds

6.2 Transient Response

Rise Time - ± 10 per cent of value obtained in Base Line Data

6.3 Frequency Response to 4° Peak-Peak Sine Wave

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6.3.1 Maximum amplitude ratio above 10 cps shall not exceed ± 3 db.

6.3.2 Maximum amplitude ratio above 10 cps shall not exceed a value defined by a line starting at ± 3 db and decreasing at a rate of 20 db/decade.

6.3.3 Phase lag below 2 cps shall not exceed 35° .

6.3.4 Phase lag at 6 cps shall not exceed 90° .

6.3.5 Phase lag at 12 cps shall not exceed 180° .

6.4 Dynamic Resolution During a 3° per second Ramp Command

Error from true position - $\pm 0.5^\circ$ (Maximum)

6.5 Static Resolution

Resolution (output shaft reference) 0.4° (Maximum)

7.0 POST MORTEM INSPECTION

Upon completion of low temperature testing the actuator shall be disassembled and a visual inspection performed on all parts. In the event that any part(s) has evidence of material failure or excessive wear a dimensional check with suitable photographs of the failure will be made.

8.0 REPORTS

Two weeks after completion of the low temperature test a memorandum shall be issued presenting the data available at that time as well as the preliminary conclusions concerning performance of the actuator throughout the test.

A complete report, including all performance and post-mortem data, shall be issued at a later date.

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G. HYDROGEN OPERATION QUALIFICATION SPECIFICATIONS FOR CONTROL DRUM PNEUMATIC ACTUATORS
FOR XE-1 APPLICATION

1.0 SCOPE

This specification defines the test to be conducted on the pneumatic control drum actuator on hydrogen gas to qualify the actuator for use on the XE-1 engine test. Defined herein are the test conditions to be imposed upon the actuator and the performance requirements to be met. This specification forms a part of the overall XE-1 actuator qualification requirements.

2.0 OBJECTIVE

Primary objective of this test is to qualify the actuator for use on the XE-1 engine test by demonstrating satisfactory performance utilizing hydrogen gas. Since all actuator testing to date has been on helium and nitrogen gas and, furthermore, since the actuator must operate on hydrogen on the XE-1 test, this test is necessary to assure satisfactory performance during that test.

A secondary objective is to verify certain mechanical and pneumatic design features such as nozzle and orifice sizing and materials compatibility when operating on hydrogen.

3.0 TEST CONDITIONS

3.1 Environmental

The ambient temperatures shall be normal room temperature and the ambient pressure shall be atmospheric.

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3.2 Operating

3.2.1 Drive gas

The drive gas shall be hydrogen at normal storage temperature and shall be regulated to 215 ± 5 psia pressure.

3.2.2 Coolant Gas

The coolant gas shall be hydrogen at normal storage temperature and shall be regulated to a pressure of 675 ± 25 psia.

3.2.3 Exhaust Gas

The exhaust gas shall be regulated to a pressure of 35 ± 2 psia.

3.2.4 Actuator Load

The actuator shall drive an inertia load of 0.24 in. lb. sec.² In addition, a load fixture capable of providing a friction load of 0 to 32 in. lb. shall be used.

4.0 PERFORMANCE TESTS

Prior to conducting the performance tests on hydrogen, the actuators shall be performance tested on helium to obtain data which shall be referred to as "Base Line Data". The test conditions shall be as specified in paragraph 3. Amplifier gain settings shall be set for optimum performance on helium gas. Upon completion of the helium tests, the amplifier gains shall be re-set for hydrogen operation. The following performance tests

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shall be conducted on both helium and hydrogen.

4.1 Frequency response

4.2 Transient

4.3 Scram characteristics

4.4 Dynamic resolution

4.5 Static resolution

5.0 DATA

The following parameters shall be measured during the performance testing. All data shall be continuously monitored, with the exception of gas flow.

5.1 Temperature

5.1.1 Drive gas

5.1.2 Coolant gas

5.2 Pressures

5.2.1 Drive gas

5.2.2 Coolant gas

5.2.3 Exhaust

5.2.4 Cylinder pressure - P_1

5.2.5 Cylinder pressure - P_2

5.3 Electrical measurements

5.3.1 Manual command

5.3.2 Dynamic command

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- 5.3.3 Actuator position
- 5.3.4 Torquemotor current
- 5.3.5 Error

6.0 PERFORMANCE REQUIREMENTS FOR QUALIFICATION

The actuator shall be considered to be satisfactory for use on the XE-1 engine test provided the following performance requirements are met on hydrogen gas. Isolated cases that vary beyond the allowable limits shall be evaluated individually considering the overall control system requirement. If it is determined that these particular items will not significantly affect control system operation, the following pertinent requirement shall be waived.

6.1 Frequency Response to 4° Peak to Peak Sine Wave

- 6.1.1 Maximum amplitude ratio below 10 cps shall not exceed ± 3 db.
- 6.1.2 Maximum amplitude ratio above 10 cps shall not exceed a value defined by a line starting at ± 3 db and 10 cps and decreasing at a rate of 20 db/decade.
- 6.1.3 Phase lag below 2 cps shall not exceed 35°.
- 6.1.4 Phase lag at 6 cps shall not exceed 90°.
- 6.1.5 Phase lag at 12 cps shall not exceed 180°.

6.2 Transient Response to an 18° step input.

- 6.2.1 Rise Time - shall not exceed the "Base Line Data" of paragraph 4.2.

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6.2.2 Settling Time - 0.150 seconds maximum

6.2.3 Overshoot - 6° maximum

6.3 Scram Operation

Maximum allowable turnaround time - 0.05 sec.

6.4 Dynamic Resolution during a 3°/sec. ramp command

Maximum error from tru position shall be $\pm 0.5^\circ$

6.5 Static Resolution

Static position resolution at the output shaft shall not exceed 0.4°.

7.0 REPORTS

Within two weeks after completion of the test, a memorandum shall be issued summarizing the test and presenting a preliminary review of the data and any conclusions derived therefrom.

A comprehensive report shall be issued at a later date and shall include a description of the test, final analysis and presentation of the test data, and conclusions.

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