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**VIBRATION TEST OF AN
ELECTRO-PNEUMATIC ACTUATOR
GENERAL ELECTRIC MODEL 7T-AG14-A01**
(Title Unclassified)

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VIBRATION TEST OF AN ELECTRO-PNEUMATIC ACTUATOR
GENERAL ELECTRIC MODEL 7T-AG14-A01

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I. ABSTRACT

TITLE: Vibration Test of an Electro-Pneumatic Actuator - General Electric Model 7T-AG14-A01

ABSTRACT: A General Electric actuator was vibrated so that the effects of limited vibration on the actuator performance could be studied.

SUMMARY: The actuator performance and the physical structure of the actuator are not adversely affected by a vibration force of 5 g's within the frequency range of 20 cps to 2000 cps.

The actuator has significant resonant frequencies of 270 cps, 740 cps, 1600 cps and 1900 cps in the horizontal plane and 1000 cps in the vertical plane. Small changes in the output waveshape were evident at the resonant frequency of 1000 cps. This change was small and did not affect the characteristic performance of the actuator.

II. INTRODUCTION

The purpose of this test was to study the effects of limited vibrations on the performance of the General Electric AG 14 actuator.

A future development program of the actuator includes a more exhaustive investigation of vibration effects. At that time, the design of the actuator will be qualified by testing a unit in accordance with the proper Government Specifications.

The levels of excitation and the methods of testing were so chosen that some valuable data would be obtained before the unit might be damaged due to excessive vibration. These levels are shown in Figure 10 and are a combination of the vibration environments described in a letter from SNPO and the capabilities of the vibration equipment available.

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III. DESCRIPTION

The item tested was the General Electric actuator, Model No. 7T-AG 14-A01, shown in Figure 1. This actuator was specified by WANL specification WANL-CD-147 and ordered on Purchase Order No. 59-YA-07184 dated February, 1962. The General Electric Drawing No. 1076510-761 describes the actuator.

The actuator was delivered to WANL in August 1962 and its performance has been evaluated using both ambient and "cold" helium drive gas and nitrogen coolant gas. Approximately 100 hours of running time had been logged on it during those tests. Prior to this vibration test, the unit was completely disassembled, inspected, repaired and reassembled by General Electric personnel under the constant surveillance and approval of members of the actuator control group at Westinghouse.

FIGURE 1 - Model 7T-AG14-A01 Actuator

IV. DESCRIPTION OF TEST SETUP

The vibration tests were conducted in the Actuator Control Development Laboratory located at Large, Pennsylvania. The equipment includes a MB Electronic Model C-10E Vibration Exciter powered by a MB Electronic Model T251Y Amplifier and controlled by a Bruel and Kjaer Model 1014 Beat Frequency Oscillator as shown in Figure 2.

FIGURE 2 - Vibration Table and Associated Controls

The vibration tests were monitored with three Endevco Models 2213C and 2226 accelerometers fed into Endevco Model 2702B Dyna Monitor gauge readouts. (Figure 3). Records were produced by a Minneapolis Honeywell Model 1508 Visicorder.

Three special vibration fixtures were used to mount the actuator on the vibration table and they are shown in Figure 4. The actuator was held in the vertical position (non-operating) by fixture A, the horizontal position (non-operating) by fixture B, and the vertical position (operating) by fixture C.

FIGURE 3 - Vibration Monitoring Equipment

FIGURE 4 - Vibration Test Mounting Fixtures

The Ambient Gas Test stand shown in Figure 5 was used to determine the performance of the actuator before and after the vibration test. The actuator was placed on the stand, and drive and coolant gas were provided along with the necessary electrical power.

FIGURE 5 - Ambient Gas Test Stand

V. PROCEDURE

The vibration testing was divided into two major categories:

- a. Non-Operating Vibration Tests
- b. Operating Vibration Tests
- a.. Non-Operating Vibration Tests

These tests were conducted to determine major resonant frequencies and to insure that the actuator would remain intact at low "g" level vibrations during which period the actuator would not be pressurized. Performance data was taken on the actuator both before and after the vibration tests.

After establishing the performance characteristics on the warm gas test stand, the actuator was placed on test fixture "A" and mounted on the vibration table in the vertical position (Figure 6).

FIGURE 6 - Actuator Mounted in Vertical Plane for Non-Operating Vibration Test

An accelerometer placed below the marman clamp was used to control the motion of the test item. The excitation was advanced to 1 g and the frequency was increased from 20 to 2000 cps at a logarithmic rate in 104 seconds. Five seconds was allowed to stop the sweep and start the sweep in the reverse direction. The frequency was decreased from 2000 to 20 cps at the logarithmic rate in 104 seconds and then the 1g excitation was removed. The output from the three accelerometers was observed on gauges and recorded on the visicorder. The No. 1 accelerometer recorded the motion of the base, (control accelerometer) No. 2 recorded the crosstalk (vibration normal to the direction of excitation) and No. 3 recorded the motion of the top of the unit.

The actuator was then placed on test fixture B and mounted on the vibration table in the horizontal position with the line of force in the direction of the cylinder as shown in Figure 7.

FIGURE 7 - Actuator Mounted in Horizontal Plane for Non-Operating Vibration Test. (force parallel to piston axis)

The accelerometer placed on the pedestal between the fixture and the actuator was used to control the motion of the test item. The 1 g excitation was applied and the frequency spectrum was scanned at the logarithmic rate described in the preceding paragraph. The output from the three accelerometers was observed on the gauges and recorded on the visicorder. The No. 1 accelerometer recorded the motion of the base, No. 2 recorded the crosstalk, and No. 3 the motion at the end of the piston cylinder.

The actuator was then rotated 90° on test fixture B so that the line of force was perpendicular to the cylinder as shown in Figure 8. The procedure described in the above paragraph was repeated.

Next the actuator was returned to the ambient gas test stand and performance data was taken to compare with that taken prior to the vibration tests.

FIGURE 8 - Actuator Mounted in Horizontal Plane for Non-Operating Vibration Test. (force normal to piston axis)

FIGURE 9 - Actuator Mounted in Vertical Plane for "Operating" Vibration Test.

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Following the post vibration testing connected with Phase "a" the actuator was remounted on the vibration table using test fixture C. The actuator was connected to the gas supply and control and recording system as shown in Figure 9. With the actuator mounted in the vertical plane, spot checks were made to record typical output waveshapes prior to the vibration test. Phase "b" of the test plan was then completed.

b. Operating Vibration Tests

An accelerometer mounted on the base of the pedestal was used to control the power to the vibration exciter. An accelerometer mounted on the main portion of the actuator recorded the crosstalk and the velocity pickup built into the vibration table recorded the motion of the table.

The actuator was positioned at 90° shaft position and a $\pm 2^\circ$ sine wave at 2 cps was applied to the command circuit of the actuator. The actuator and load were vibrated in accordance with curve 2 on Figure 10. The excitation was held at 1.33 g from 20 to 90 cps at which point the logarithmic sweep was stopped, the excitation readjusted to 5 g, and the sweep continued up to 2000 cps. The sweep was stopped and reversed downward to 90 cps. The excitation was reduced to 1.33 g and the sweep resumed down to 20 cps.

The $\pm 2^\circ$ sine wave input to the actuator was replaced with a $3^\circ/\text{sec}$ ramp. The actuator was vibrated a second time according to curve 2 on Figure 10.

Having completed this test, the $3^\circ/\text{sec}$ ramp was replaced with a 18° step input. Again the actuator was vibrated in accordance with curve 2 on Figure 10.

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Curve No. 1 - Vibration environments in NERVA engine.

Curve No. 2 - Vibration curve followed in phase "b" of testing.

FIGURE 10

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V I. TEST RESULTS AND OBSERVATIONS

Table I is a comparison of the actuator performance before and after the non-operating vibration tests. These results show that there was no change in the performance attributable to the vibration test. Figures 14 through 19 show typical waveshapes before and after the vibration test.

The non-operating vibration tests showed that the actuator had significant resonant frequencies at 270 cps, 740 cps, 1600 cps, and 1900 cps in the horizontal plane and 1000 cps in the vertical plane. Peak g levels of 6.5 g's at 270 cps in the horizontal plane and 7.5 g's at 1000 cps in the vertical plane were attained with an input level of 1 g.

Figures 11, 12, and 13 are plots of amplitude ratio (output "g" level divided by input "g" level) versus frequency. These plots pertain to the non-operating tests.

Figures 20 through 28 are photographs of the visicorder traces taken during the vibration tests in which the actuator was pressurized (phase "b" of the testing). They show actuator performance with no vibration and during vibration at a resonant frequency. Each photograph shows traces of the accelerometer outputs in addition to various parameters associated with the actuator performance.

During phase "b" of the testing a change in waveshape was observed within the frequency band of 800 cps to 1300 cps. Figures 22 and 25 show a slight change in the shape of the sine and triangular waves. The change may be due to a resonant condition between the load fixture and the actuator, as evidenced by the resonant surges in the control accelerometer (see Figures 22 and 25).

A marked change in the shape of the step response is apparent when Figure 16 or 19 is compared with Figures 26 through 28. This change occurred

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prior to the start of the vibration testing described in phase "b". The 5 g vibration forces applied during the subsequent testing did not seem to alter this waveshape. Changes in the servo valve poppet settings could conceivably cause this change, but due to a lack of time this theory could not be pursued. Further investigation into this problem will be carried out at a future date.

VII. CONCLUSIONS

On the basis of the test results shown it can be concluded that vibration at the levels indicated does not adversely affect the performance or the physical structure of the actuator. At the resonant frequency of 1000 cps, the output waveshape is changed slightly, however, the degree of change is small, so that the characteristic performance is not affected.

The results of the test are encouraging even though the test conditions were not particularly severe. As mentioned previously, a more complete vibration program is planned for the actuator. At that time the areas not covered here will be examined.

Table I - Actuator Performance Comparison

<u>Test</u>	<u>Pre-Vibration Tests</u>		<u>Post Vibration Tests</u>	
18° Step Response	Toward 0°	Toward 180°	Toward 0°	Toward 180°
Rise Time to 62.5%	.050 sec.	.048 sec.	.048 sec.	.052 sec.
Settling time to $\pm 1^\circ$	.067 sec.	.067 sec.	.067 sec.	.069 sec.
Overshoot	0.64°	.70°	0.26°	0.33°
Dynamic Resolution	0.99°		1.45°	
Static Resolution	.162° P-P		.144° P-P	
Maximum Velocity	Toward 0°	Toward 180°	Toward 0°	Toward 180°
	398°/sec.	351°/sec.	422°/sec.	456°/sec.
Frequency Response				
Phase lag at 8 cps.	92°		85°	
Phase lag at 20 cps.	220°		214°	
Scram Turnaround Time	.035 sec.		.037 sec.

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Excitation: 1G in the Vertical Plane, Parallel to Axis of Output Shaft.

FIGURE 11

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Excitation: 1G in the Horizontal Plane, Parallel to Piston Axis.

FIGURE 12

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Excitation: 1G in the Horizontal Plane, Normal to Piston Axis.

FIGURE 13

PRE-VIBRATION TEST (PHASE α)

DRIVE GAS: Helium at 200 psig and 530°R

COOLANT GAS: Nitrogen at 638 psig and 530°R

RETURN GAS: 33 psig

QUIESENT POSITION: 90°

FRICTION: 33 1/2 in-lbs.

Figure 14 - Command Signal - 3°/sec. Ramp.
Chart Speed - 0.4 in/sec.

Figure 15 - Command Signal: $+2^\circ$ Sine at 8.0 cps..
Chart Speed - 10.0 in/sec.

Figure 16 - Command Signal: 18° Step.
Chart Speed - 4.0 in/sec.

POST VIBRATION TEST (PHASE a)

DRIVE GAS: Helium at 200 psig and 530°R

COOLANT GAS: Nitrogen at 650 psig and 530°R

RETURN GAS: 35 psig

QUIESENT POSITION: 90°

FRICTION: 33 1/2 in-lbs.

Figure 17 - Command Signal - 3°/sec. Ramp.
Chart Speed - 0.1 in/sec.

Figure 18 - Command Signal - $+2^\circ$ Sine at 8 cps.
 Chart Speed - 4.0 in/sec.

Figure 19 - Command Signal - 18° Step.
 Chart Speed - 4.0 in/sec.

VIBRATION TEST (PHASE b)

DRIVE GAS: Helium at 200 psig and 530°R

COOLANT GAS: Nitrogen at 650 psig and 530°R

RETURN GAS: 35 psig

QUIESENT POSITION: 90°

FRICTION: None

Figure 20 - Command Signal - $\pm 2^\circ$ Sine at 2.0 cps.
Vibration Excitation - None.
Chart Speed - 1.0 in/sec.

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Figure 21 - Command Signal $\pm 2^\circ$ Sine at 2.0 cps.
Vibration Excitation - 5G's at 270 cps.
Chart Speed - 1.0 in/sec.

Figure 22 - Command Signal - $\pm 2^\circ$ Sine at 2.0 cps.
Vibration Excitation - 5G's at 1000 cps.
Chart Speed - 1.0 in/sec.

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Figure 23 - Command Signal - $3^{\circ}/\text{sec.}$ Ramp.
Vibration Excitation - None.
Chart Speed - 0.4 in/sec.

Figure 24 - Command Signal - $3^{\circ}/\text{sec.}$ Ramp.
Vibration Excitation: 5G's at 270 cps.
Chart Speed - 0.4 in/sec.

Figure 25 - Command Signal $3^\circ/\text{sec.}$ Ramp.
Vibration Excitation: 5G's at 1000 cps.
Chart Speed - 0.4 in/sec.

Figure 26 - Command Signal: 18° Step.
Vibration Excitation: None.
Chart Speed - 1.0 in/sec.

Figure 27 - Command Signal: 18° Step.
Vibration Excitation: 5G's at 270 cps.
Chart Speed - 1.0 in/sec.

Figure 28 - Command Signal - 18° Step.
Vibration Excitation: 5G's at 1000 cps.
Chart Speed - 1.0 in/sec.