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APPENDIX F

Seismic Qualification Envelope

Report B0037

2.0.5.1

SEISMIC QUALIFICATION ENVELOPE

LIMITORQUE VALVE ACTUATORS

REPORT B0037

TESTS PER IEEE 344-75

PREPARED BY LIMITORQUE CORPORATION

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SMB-AC Units				
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	Aero Nav Report 6-6246-1	SMC-04	3/18/76	Appendix 3
SB-AC Units				
	Aero Nav Report 5774	SB-0-25	7/23/75	Appendix 4
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SMB-DC Units				
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SEISMIC QUALIFICATION ENVELOPE

1.0 INTRODUCTION

A group of Limitorque Valve Actuators, chosen to envelope the entire generic family of available actuators type SMB/SB/SBD sizes 000 to 5 and SMC-04 (refer Fig. 1) were subjected to a seismic qualification per IEEE 344-1975. Included were SMB,SB (which are mod SMB units), as well as SMC actuators. SMB and SMC valve actuators mounted on secondary reducers (type HBC) also were chosen to envelope the worst possible unit assembly combinations and were also subjected to seismic qualifications per IEEE 344-1975.

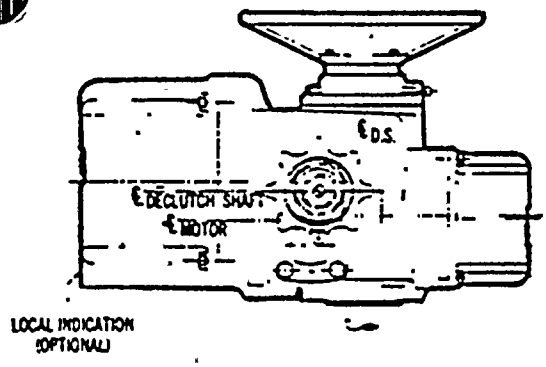
2.0 DISCUSSION

The "Seismic Qualification Envelope" establishes a generic test plan to envelope all standard Limitorque actuators as support for Limitorque's environmental qualifications. This report discusses shake table limitations and presents Limitorque's test philosophy to provide a better understanding of the test methods employed. Figure 1 is included showing representative actuators from the generic family.

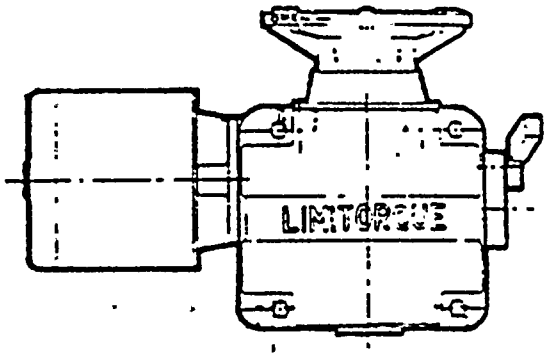
2.0.1 Generic Family

The entire line of Valve Actuators, including the electric motors types SMB/SB/SBD/SMC/HBC, is a generic family, all constructed of similar materials and designed to same concepts, tolerance and stress levels with physical size varying as a function of rating.

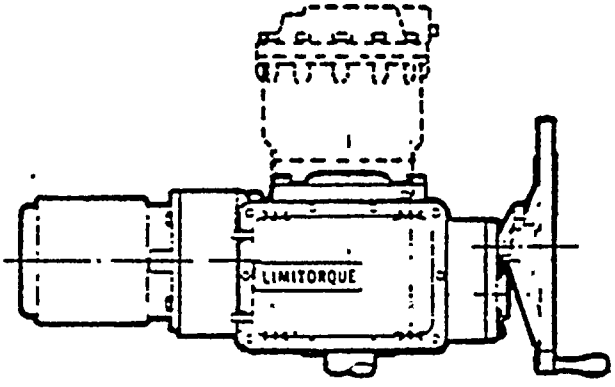
LIMITORQUE ACTUATOR GENERIC FAMILY



SMC-04

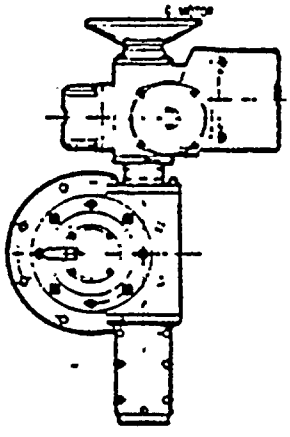


SMB-000 & SMB-00

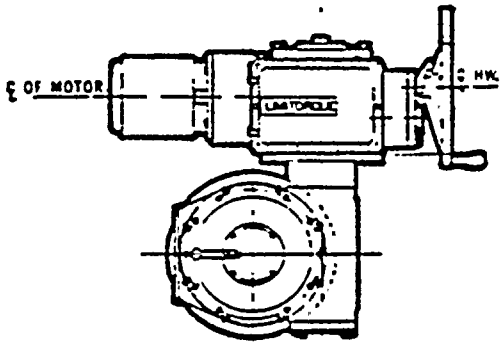


SMB-0 THRU 5

NOTE: VIEW WITH BROKEN LINES SHOW ADDITION OF SPRING PACK TO MAKE SB OR SBD ACTUATOR.



SMC-04/HBC



SMB/HBC

FIGURE 1

2.0.1 (Continued)

The same principle applies to the electric motors used with our actuators. Valve actuator weight is a mathematical function of torque and further the largest motor permissible on a specific actuator is nominally a fixed percentage of the overall actuator weight, further supporting the generic family concept (refer to Figures 3 and 4).

2.0.2 Seismic Qualification Envelope

This document "Seismic Qualification Envelope" - Report B0037, has been created to support our generic envelope used in our various environmental qualifications. Based on the generic family concept, the following applies to seismic qualification:

A. Since all Limitorque A.C. and D.C. equipment respond and are generically equivalent with regard to seismic excitation under 6g and under 35 hz, the A.C. and D.C. seismic test data would be mutually supportive of each other.

B. Seismic tests on SMB/HBC assemblies can be used to qualify the SMB actuator to the seismic level obtained from accelerometers on the SMB mounting flange as well as qualify the adaption between the SMB and HBC units to the seismic test levels.

2.0.3 Loading Simulation

During each of the seismic test dwells, the actuators are operated from a limit switch position to a torque seated position, back to the limit switch position to assure the actuator is performing

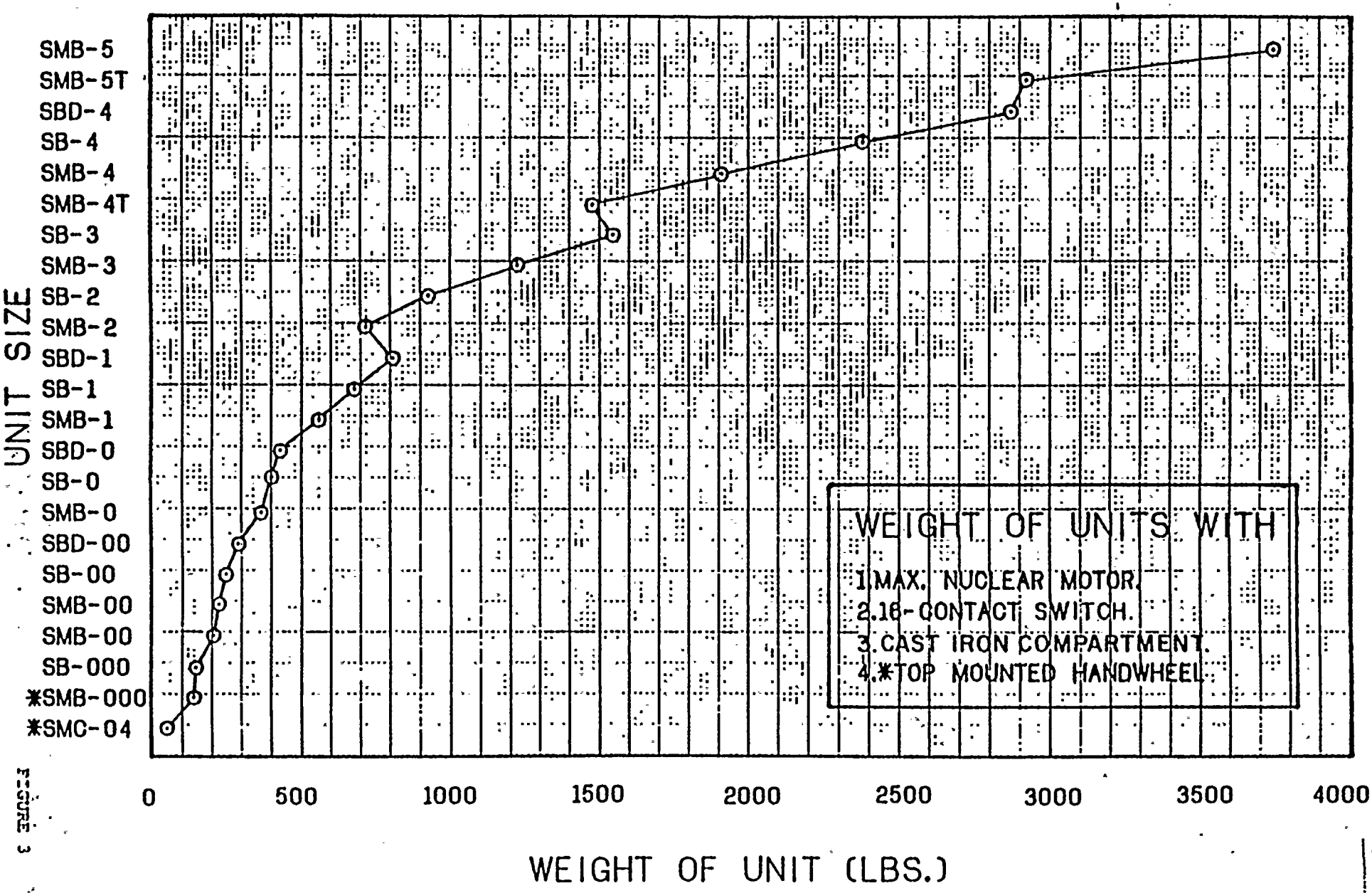

UNIT SIZE
SMB-5
SMB-5T
SBD-4
SB-4
SMB-4
SMB-4T
SB-3
SMB-3
SB-2
SMB-2
SBD-1
SB-1
SMB-1
SBD-0
SB-0
SMB-0
SBD-00
SB-00
SMB-00
SMB-00
SB-000
*SMB-000
*SMC-04
WEIGHT OF UNITS WITH
1.MAX. NUCLEAR MOTOR.
2.16-CONTACT SWITCH.
3.CAST IRON COMPARTMENT.
4.*TOP MOUNTED HANDWHEEL.
0
500
1000
1500
2000
2500
3000
3500
4000
WEIGHT OF UNIT (LBS.)

FIGURE 3

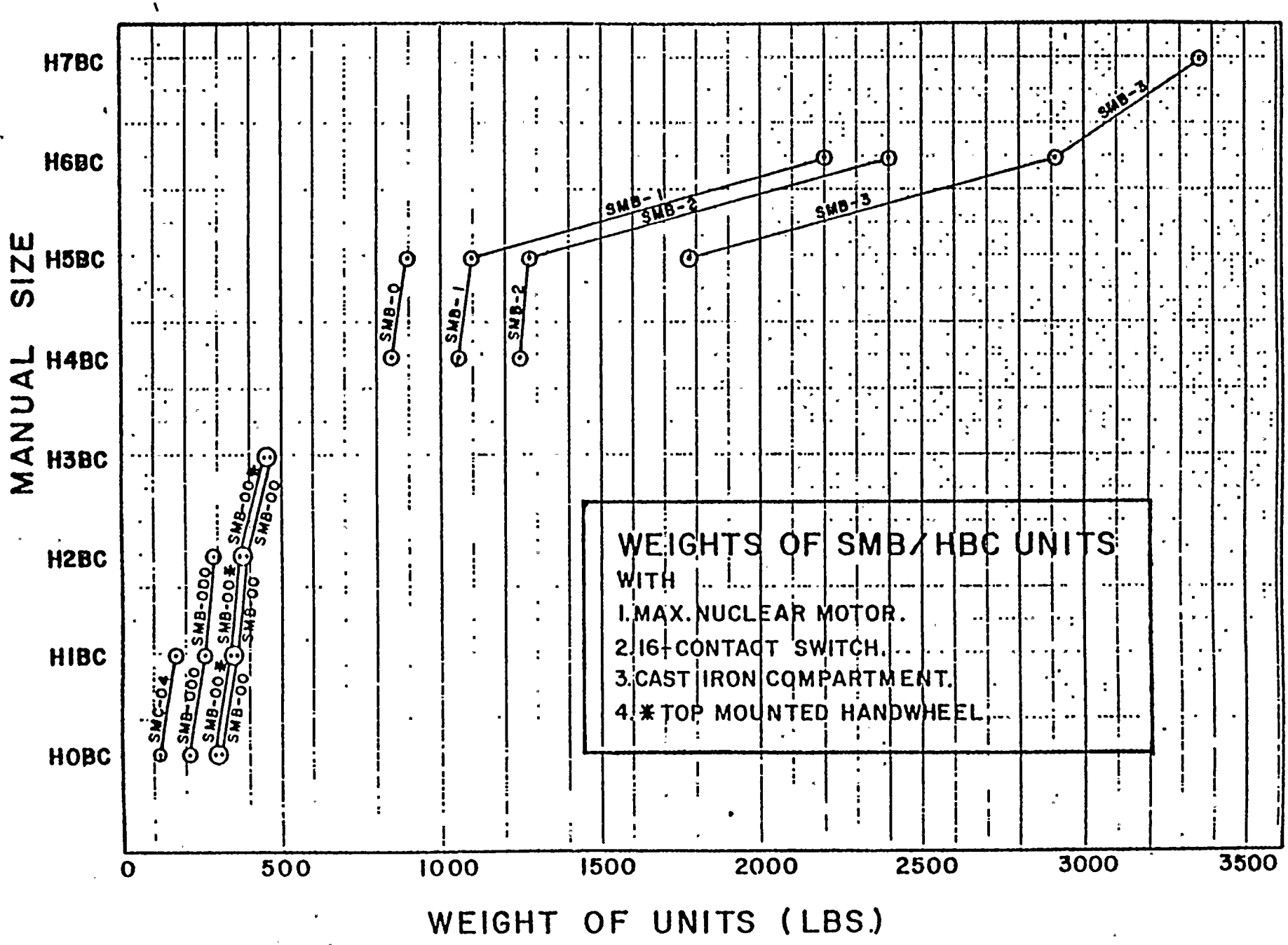

MANUAL SIZE
H7BC
H6BC
H5BC
H4BC
H3BC
H2BC
H1BC
H0BC
0
500
1000
1500
2000
2500
3000
3500
WEIGHT OF UNITS (LBS.)
SMB-1
SMB-2
SMB-3
SMB-0
SMB-00*
SMB-00
SMB-000
SMB-0000
WEIGHTS OF SMB/HBC UNITS
WITH
1. MAX. NUCLEAR MOTOR.
2. 16-CONTACT SWITCH.
3. CAST IRON COMPARTMENT.
4. * TOP MOUNTED HANDWHEEL.

FIGURE 4

2.0.3 Continued

properly during the seismic excitation. The torque switch is calibrated prior to the seismic test to the units rating for both thrust and torque. The stroke time of the actuator during seismic testing is normally less than established for Environmental Qualifications due to restrictions established by seismic fixturing. However, the actual stroke time during a seismic test is unimportant since the intent is to subject the unit to seismic vibration with operation merely proving the Valve Actuator capable of operating and providing the required torque and thrust.

2.0.4 Weight Distribution

Primarily, seismic consideration directs itself to a weight distribution problem and resolves into the necessity of checking the adequacy of various connecting flanges. This document is a group of seismic tests conducted on units that are considered to contain either the typical or worst weight distribution that would provide the most severe loading on connecting flanges during seismic excitations, thereby providing a generic envelope for seismic qualification.

2.0.5 Discussion - Test Method

Most actuators are installed on valves mounted in pipe runs. It is the general contention in the industry that during an actual seismic event that, due to the pipe run, the valve and actuator would be

2.0.5 Continued

subject to excitation in one mode dominated by one frequency. This supports the sine dwell method of testing.

Furthermore, the sine dwell seismic test is, from our experience, the most severe test that can be performed on Limitorque actuators and thereby a more important reason for conducting this type of test.

2.0.6 Discussion - Resonance

Seismic tests conducted on a hydraulic shake table supported our engineering opinion that no resonances would be found below 5 hz and that no resonances or cross-coupling exist in the frequency range of 1 to 33 hz. Verification of this can be found in the tests conducted after Novmeber 1977 (included in the Appendix of this document). Accelerometer charts, that are light sensitive and not capable of being reproduced, are available for audit.

Currently, no seismic resonance checks have been made on all internal components. However, engineering evaluation of the internal components used in the construction of Limitorque Actuators shows that the elements used are rigid members with closely spaced supports with resonant frequencies much in excess of 33 hz.

2.0.7 Discussion - Cross Coupling

The great number of seismic tests we have conducted have shown no resonant frequencies below 33 hz and clearly provides verification that no cross coupling exists. Since the actuators respond independently

2.0.7 Continued

in each of the three orthogonal axis (no cross coupling), our seismic testing, even that performed prior to 1975, was in fact conducted per IEEE 344-1975 (refer to paragraph 6.6.6 of IEEE 344-1975).

In the seismic testing we have performed, we used several test facilities with these facilities having both mechanical and hydraulic shake tables. Some of the test data from the mechanical table illustrates slight indication of cross-coupling, however, shows no signs of resonance. During our progress of seismic testing, we evaluated the mechanical table and found that the slight signs of cross-coupling were in the table itself and not in the Limitorque Actuator.

2.0.8 Actuator Test Criteria

2.0.8.1 Description - Seismic Fixturing

Limitorque Actuators are required to produce their rated thrust and torque during seismic dwell tests to simulate an actual seismic event and provide assurance all of the actuator components are operating properly.

For linear actuators, such as SMB/SB/SBD/SMC, this is accomplished by use of an acme screw in the Actuator with anti-rotation device and shoulder to bear against the test stem in the seismic test fixture to cause torque switch tripping of the Actuator in the "close" position. This stimulates the seating of a gate or globe valve.

2.0.8.1 (Refer to Fig. 2)

When rotary actuators such as SMB/HBC or SMC/HBC are prepared for a seismic test, the fixture bolted to the secondary reducer (HBC) contains a stop with a key on the HBC output bearing against this stop in the "close" position. The torque switch on the SMB/SMC is calibrated to provide the rated output torque of the HBC. (Refer Fig. 2)

2.0.8.2 Switch Calibration

Prior to the start of the seismic test, the Actuator's torque switch is calibrated to the units output torque rating. Proper choice of the acme thread assures obtaining or slightly exceeding the units rated thrust for linear actuators.

2.0.8.3 Stroke Time

To provide reasonable fixturing (low silhouette) to insure dynamic stability of the seismic testing machine, the stroke of the valve actuator is substantially reduced (for seismic test only) maintaining the torque seat feature and reducing stroke time. The actual stroke time during seismic testing/aging is unimportant since the intent is to age the unit by seismic vibration with operation merely proving the Valve Actuator capable of operating, providing the required torque and thrust, which has been demonstrated.

SEISMIC FIXTURING

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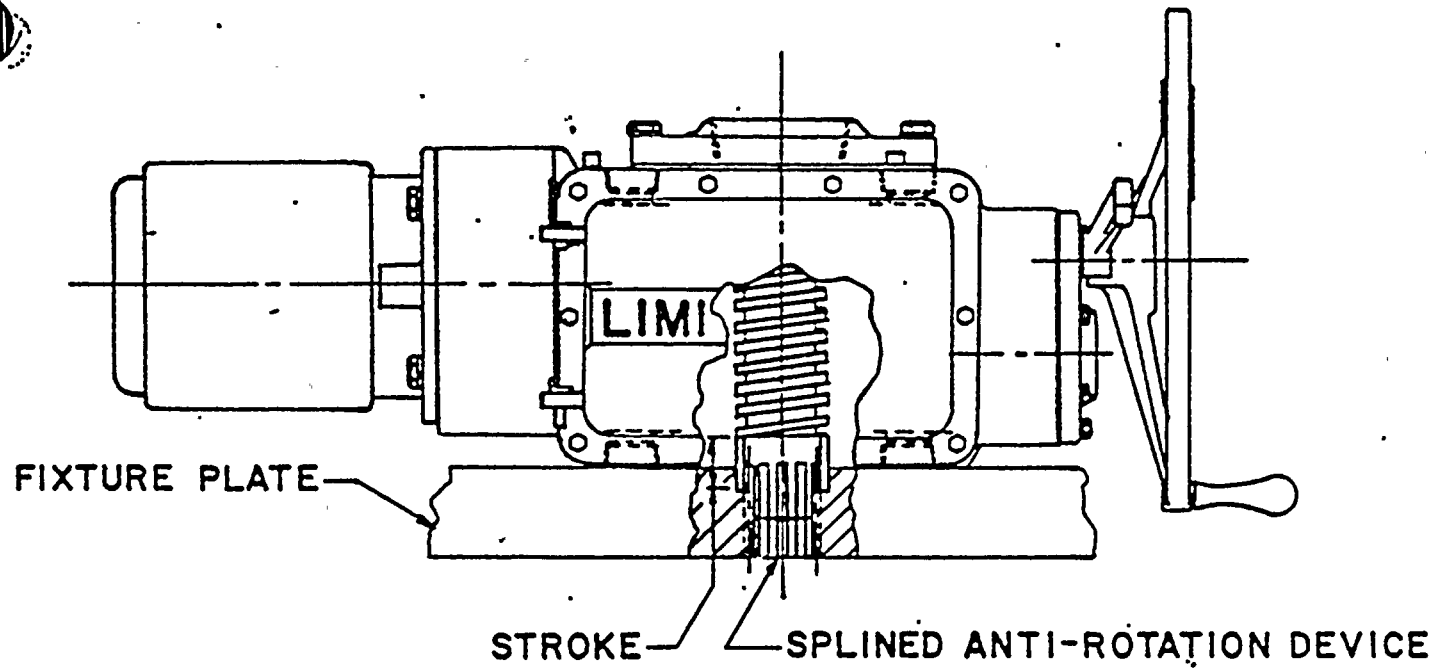
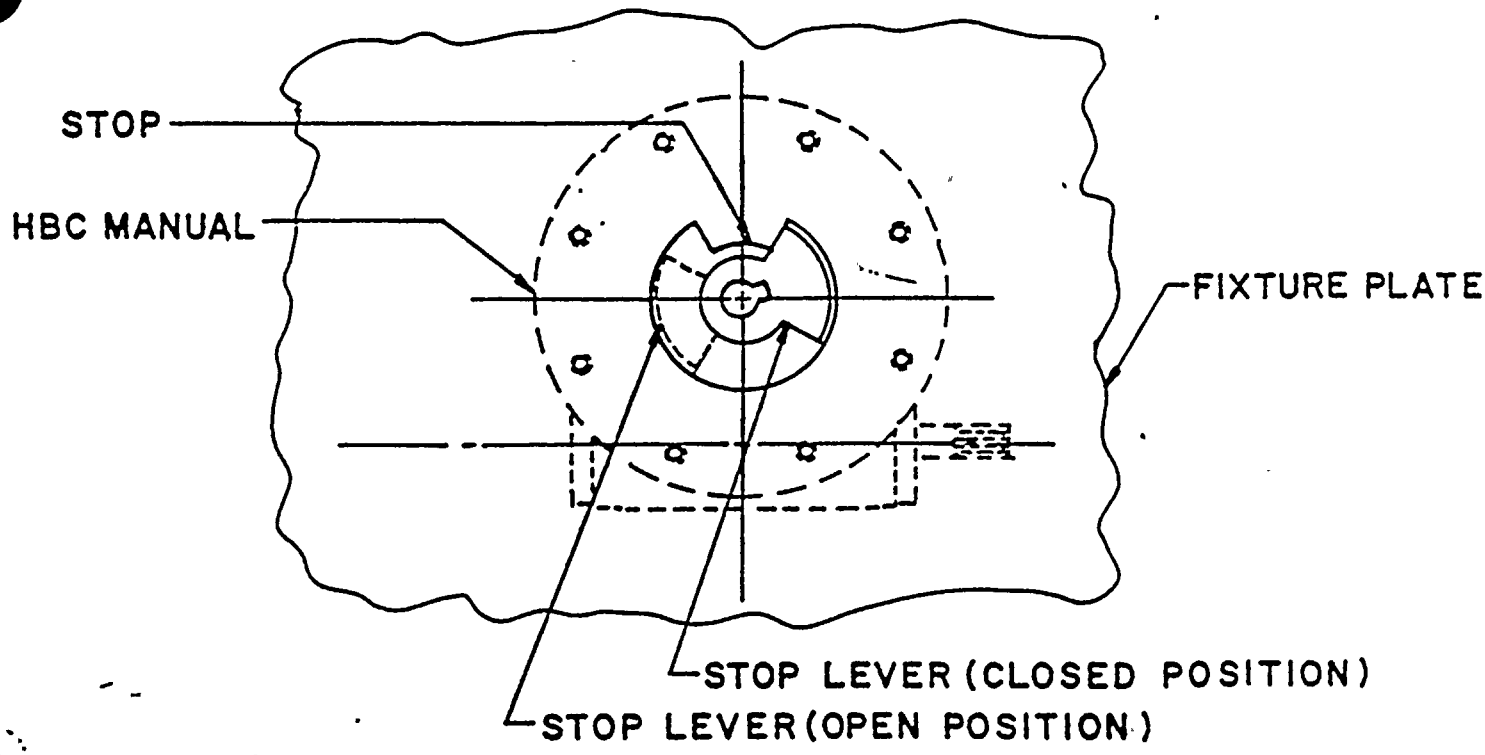


LINEAR ACTUATORS- SMB/SB/SBD/SMC



ROTARY ACTUATORS- SMB/HBC & SMC-04/HBC

FIGURE-2

2.0.9 Acceptance Criteria

The acceptance criteria for seismic testing is the lack of visible signs of overstress in the unit being tested. This means lack of any visible difference in equipment or performance detrimental to proper operation compared to the unit prior to the seismic test, which would encompass cracks, bent shafting, or other permanent deformation that could be noted by eye.

2.0.10 Switch Chatter Analysis

Relating to the switches in the Limitorque Valve Actuator, engineering evaluation of the limit switch construction shows the limit switches would not chatter at low frequencies within the qualified acceleration levels. The primary cause of malfunction of the limit switch would be caused by the fingers physically being lifted from the rotors (contact chatter) by inertia during seismic excitation. The contact fingers are light, weighing approximately .011 pounds each and are preloaded by a spring that provides approximately .32 pounds load. Accounting for the location of the cg of the finger in relation to the center of the spring, it would require an acceleration loading of 22 g's before the fingers could possibly leave the limit switch rotor, regardless of frequency. The torque switch would also require accelerations in this range before the contacts would break contact.

2.0.11 Motor Insulation Class

Limitorque Valve Actuators are supplied with class B insulation motors for normal outside containment service and with class RH insulation motors for inside containment service. Seismically, the weight difference in the two insulation systems are negligible with the result that seismic tests conducted on units with either insulation system in the motor would also qualify the Actuator with the other insulation system. The motor leads, although differing in diameter and appearance, also would not be effected, since they pass through an internal conduit in the motor mounting flange and then connected in the limit switch compartment. The length of unsupported motor leads is small (inches) thereby minimizing undue loads on either the wire or end connection points during seismic excitation.

2.0.12 Seismic Qualification Definition

The seismic tests we have conducted qualify our units seismically to g levels indicated when the seismic excitation is imparted to the mounting flange of our unit.

3.0 IDENTIFICATION OF TESTED VALVE ACTUATORS

The Valve Actuators as tested are identified in each individual seismic report. The reports are as listed in the Table of Contents and are included in the Appendix.

4.0 TYPE TEST PROCEDURE

The test procedure used is as marked on the cover page of each test report. Prior to conducting the seismic test, the unit is mounted on a test stand and the torque switch calibrated to develop the rated unit torque and thrust for SMC, SMB and SB units and the rated unit torque for SMB/HBC assemblies.

4.1 Standard Seismic Test Procedure

4.1.1 Mount the Limitorque Valve Actuator or Limitorque Valve Actuator/secondary reducer combination actuator assembly with fixture capable of simulating seating torque and/or thrust (as appropriate to unit tested) to the shaker table with the axis of the output drive sleeve mounted vertically.

4.1.2 Connect the limit switches and torque switch into the control circuit for operation per wiring diagram 19-499-0022-4. Connect limit switch contacts 11 and 15 (which is set to be normally closed during mid stroke) and the open torque switch to electronic chatter circuits per MIL-STD-202D or equivalent with 2 millisecond break time detection (prior to 1978, a sensitive relay with 7 to 8 milisecond dropout time, as shown on wiring diagram 19-499-0022-4, was used to detect contact chatter).

4.1.3 At minimum, install (3) accelerometers on the motor (for SMB and SB units) and on the motor and SMB mounting flange (for SMB/HBC assemblies) to measure accelerations in each of the three axis (one vertical and two horizontal). Install (3) matching accelerometers on the shaker table.

4.1.4 Scan in each of the three axis at a minimum of .2g from 1 to 33 Hz at a sweep rate not exceeding 2 octaves per minute (prior to 1976, due to the "shaker table" used, the resonance scan was made at a minimum acceleration of .1g (not exceeding 1g) from 5 to 33 Hz, dwelling at each integer frequency for 6 seconds).

Record the accelerometer readings in each of the three axis, both on the Limitorque Valve Actuator and shaker table - - - V (vertical), H1 (horizontal parallel to motor axis) and H2 (horizontal perpendicular to motor axis) for determination of cross coupling.

Note resonant frequency in axis being scanned. (Resonance is defined as a minimum acceleration multiplication factor of 2 and/or a 90^{o} phase shift of response accelerometers.)

4.1.5 Prepare to conduct dwell tests in each of the three axis on the basis of 6g in each of the axis (on basis of 3g if seismic bracket is not included on SMB/HBC assemblies and 6g if seismic bracket is included).

Conduct dwell test in vertical axis V at resonant frequency determined in Step 4.1.4 or dwell at 33 Hz if resonant frequencies not evident. Determine required test dwell g level as follows:

4.1.5.1 At dwell frequency, note cross coupling on V axis. (This would be the difference between the accelerometer readings on the Limitorque Valve Actuator and the shaker table to eliminate effects of table "cross coupling")

4.1.5.2 If any cross coupling noted, calculate acceleration adder to V axis as follows:

$$\text{V Adder} = \frac{\text{(test g level) x (cross couple g level)}}{\text{(g level of scan)}}$$

H1 axis & H2 axis

4.1.5.3 Add the calculated values of the V adder of both H1 and H2 axis determined in 4.1.5.2 to 6g (3g in case of SMB/HBC assembly without seismic support) establishing the acceleration level for the seismic dwell test.

4.1.5.4 Conduct (5) dwell tests each of 30 second duration at one half g level determined in 4.1.5.3. Operate unit through full open and close cycle during each dwell. Note results.

4.1.5.5 Conduct (1) dwell test of 30 second duration at full g level determined in 4.1.5.3. Operate unit through full open and close cycle during the dwell and note results.

4.1.6 Conduct dwell test in horizontal axis H1 at resonant frequency determined in Step 4.1.4 (dwell at 33 Hz if resonant frequency not evident).

4.1.6.1 Determine dwell g level as indicated in 4.1.5.1, 4.1.5.2 and 4.1.5.3 except interchange V axis and H1 axis.

4.1.6.2 Conduct dwell tests as indicated in 4.1.5.4 and 4.1.5.5.

4.1.7 Conduct dwell test in horizontal axis H2 at resonant frequency determined in Step 4.1.4 (dwell at 33 Hz if resonant frequencies not evident).

4.1.7.1 Determine dwell g level as indicated in 4.1.5.1, 4.1.5.2 and 4.1.5.3 except interchange V axis and H2 axis.

4.1.7.2 Conduct dwell tests as indicated in 4.1.5.4 and 4.1.5.5.

4.1.8 After completion of above tests, operate unit through full open and close cycle and note results.

4.1.9 Before removing from shaker table, visually inspect for any signs of overstress comparing to the unit before the test. This would encompass such areas as cracks, bent shafting or other permanent deformation. Note observations.

4.2 Fragility Test Procedure

4.2.1 Mount the Limitorque Valve Actuator or the SMB/HBC assembly on fixture capable of simulating seating torque and/or thrust (as appropriate to unit tested) to the shaker table with the axis of the output mounted vertically.

4.2.2 Connect the limit switches and torque switch into the control circuit for operation per wiring diagram 19-499-0022-4. Connect limit switch contacts 11 and 15 (which is set to be normally closed during mid stroke) and the open torque switch to electronic chatter circuits per MIL-STD-202D or equivalent with 2 millisecond break time detection (prior to 1978, a sensitive relay with 7 to 8 millisecond dropout time, as shown on wiring diagram 19-499-0022-4, was used to detect contact chatter).

4.2.3 At minimum, install (3) accelerometers on the motor (for SMB and SB units) and on the motor and SMB mounting flange (for SMB/HBC assemblies) to measure accelerations in each of the three axis (one vertical and two horizontal). Install (3) matching accelerometers on the shaker table.

4.2.4 Scan in each of the 3 axis at a minimum of .2g from 1 to 33 Hz at a sweep rate not exceeding 2 octaves per minute (prior to 1976, due to the shaker table used, the resonance scan was made at a minimum acceleration of .1g varying to 1g at a frequency span of 5 to 33 Hz, dwelling at each integer frequency for 6 seconds).

Record the accelerometer readings in each of the three axis, both on the Limitorque Valve Actuator and shaker table - - - V (vertical), H1 (horizontal parallel to motor axis) and H2 (horizontal perpendicular to motor axis) for indication of cross coupling, if any.

Note resonant frequency in axis being scanned. (Resonance is defined as a minimum acceleration multiplier factor of 2 and/or a 90^{o} phase shift of response accelerometers).

4.2.5 When testing an SMB/HBC assembly (motor actuator mounted on a secondary reducer), start dwells at a 3g level and when SMB (motor actuator) at a 6g level. Note: If the SMB/HBC assembly includes a seismic bracket start dwells at a 6g acceleration level. Continue testing in this axis at each integer g level until unit failure occurs or until the capacity of the shaker table is reached.

4.2.6 Conduct dwell tests at resonant frequency determined in step 3.2.4 or at 33 Hz if resonant frequencies not evident in each of the three axis with each dwell being of 30 second duration. During each dwell, run unit through full close and open stroke and note results. Also record the accelerometer readings on each axis.

4.2.7 Before removing from shaker table, visually inspect for any signs of overstress comparing to the unit before the test. This would encompass such areas as cracks, bent shafting or other permanent deformation. Note observations.

4.2.8 Should any damage have been incurred, repair if possible and subject the actuator to dwells in the second axis per step 4.2.6 and inspect per 4.2.7. Repeat the dwells and inspection in the third axis.

4.2.9 Should the unit have failed during the fragility testing, provide detailed report of failure plus record any observations made during the test at time of failure. In event of failure before fragility test completed in all three axis, replace failed component and complete the test.

5.0 CONCLUSION

5.0.1 Linear Actuators

The units tested consisted of units with the most adverse weight distribution, enveloping the entire generic family of Actuators, SMB/SB/SBD/SMC-04/SMB-HBC/SMC-HBC assemblies. The Limitorque Valve Actuators performed all functions at seismic dwells and tripped at the preset torque switch setting (the resulting load approximating the unit rating) with no indication of malfunction. Further, the chatter circuit connected to limit switch contacts did not de-energize even during dwells up to 8g acceleration. Therefore, the generic line of Limitorque Valve Actuators, type SMB/SB/SBD/SMC-04 is considered qualified per IEEE 344-1975 up to levels of 6g acceleration in any of the three axis.

5.0.2 Rotary Actuators

The SMB Limitorque Valve Actuators mounted on HBC secondary reducers were chosen and performed during the seismic test in the same manner stipulated in paragraph 5.0.1 above. The SMC type actuator, being lighter than the SMB, would be enveloped by above tests. The SMB/HBC or SMC/HBC assemblies, without spur gear attachments, are considered qualified per IEEE 344-1975 up to levels of 3g acceleration without seismic bracket and up to 6g acceleration with the seismic bracket in any of the three orthogonal axis.