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Shock Testing of Gate Valve

R S Khire[1], Sanjay Bhise[2], Dipak V Bhirud[3]

[1]*Research & Development Establishment (Engineers), DRDO, Pune, ravi_khire@hotmail.com*
[2]*Research & Development Establishment (Engineers), DRDO, Pune, sanjayhb1@yahoo.com*
[3]*Research & Development Establishment (Engineers), DRDO, Pune, dipak_bhirud22@rediffmail.com*

Abstract-Gate valve is used to start/stop the flow of steam from one system to another system. It is designed to operate at 30 bar pressure. Time needed to fully close the valve from fully open position is 16s. In the current study, qualification testing of the gate valve is discussed. Shock testing is carried out along three mutually perpendicular directions one after another. Desired shock pulse is generated after number of trials by varying rubber thickness and drop height. The criterion of acceptance is that valve should be able to close in prescribed time after test along each direction and there should not be any fluid leakage and structural damage in the valve.
Keywords-Shock Testing, Rubber Thickness, Drop Height.

I. INTRODUCTION

Main function of the gate valve is to start/stop the flow of steam from one system to another system. The valve is to be tested for specified shock loads. The valve is kept filled with water during testing. As per requirement, valve is to be tested in three mutually perpendicular directions for two different shock loads, each load single time. This testing is carried out to check mechanical strength as well as sealing capability of valve under specified shock loads. The performance of the valve is also checked pre and posts every shock test to validate the design.
The objective of this research paper is to investigate the Shock Testing methodology, data acquisition activities and the associated criticalities with the help of a case study. Section 2 enumerates the Shock Testing Machine in brief and the calibration tests conducted on the machine for its characterization. Section 3 briefly describes the test procedure and section 4 & 5 describes the data acquisition activities. Results are discussed at Section 6, data analysis is enumerated in section 7 and conclusions and future work is discussed at section 8.

II. SHOCK TESTING MACHINE (STM)

The shock testing machine used here is a horizontal twin sided pendulum type setup. It is intended to carry out testing of various objects for their resistance to shock. The machine is designated to test objects for their resistance to single powerful shock pulse of half sinusoidal nature. Schematic diagram of Shock Testing Machine is shown in Figure. 1.
The STM is operated by lifting the test table with test object to a predetermined height and allowing it to fall freely under gravity and colliding with a heavy buffer mass and hence generating the shock. The time period of the pulse is controlled by introducing rubber pulse shapers at the impact point.

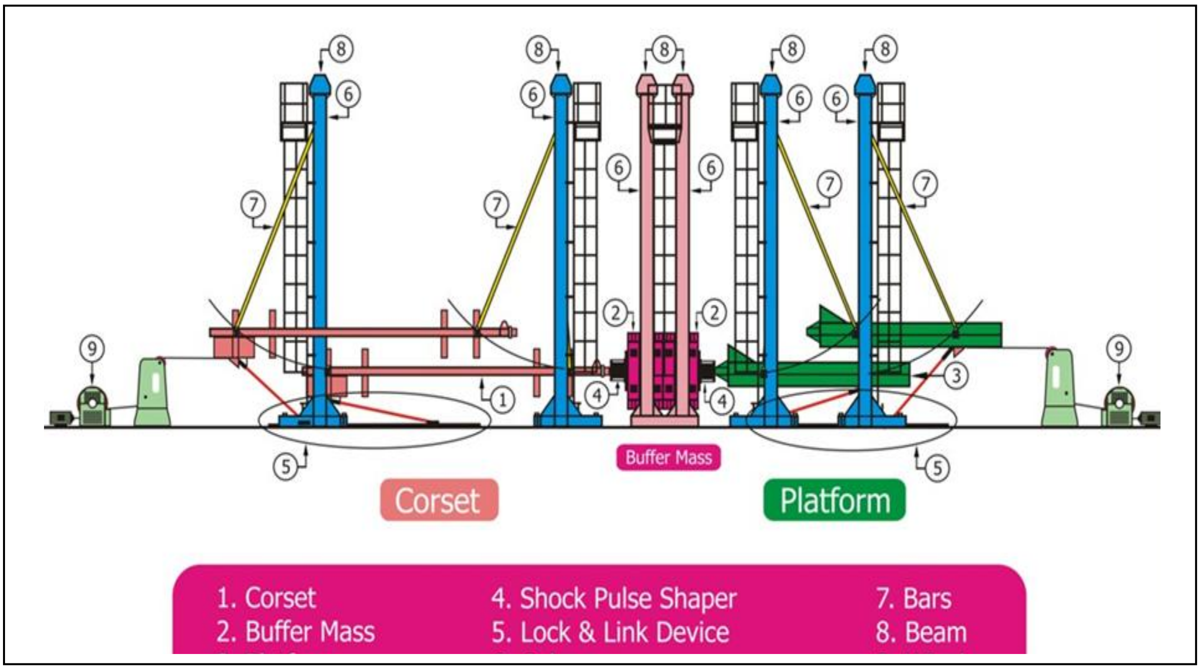

Figure 1.Shock Testing Machine

When platform assembly impacts with the buffer mass, shock pulse is generated and applied to the object mount on platform. There are 2 variables that govern the shock pulse parameters,

a. Drop height (H) is the height from which the platform along with the payload is released

b. Pulse shaper thickness (S) is the thickness of rubber pads mounted at the impact point to absorb the energy of the impact.

Although, the shock simulation can never exactly duplicate shock conditions that occur in the field, the machine can generate shock pulses very close to the actual shock loads on the basis of their Shock Response Spectra (SRS).

III. SHOCK TEST PROCEDURE

Shock testing procedure is evolved from experience gained over a period of time. Initially, dummy object as shown in Figure 2 of equivalent mass and geometrical properties is subjected to specified shock loads in order to establish machine parameters (Drop Height and Pulse shaper thickness). Also, the characteristic nomograms of the machine for various combinations of masses, drop heights & rubber thicknesses were referred. After that, the actual object is subjected to the specified loads in gradual manner to validate the test methodology.The detailed shock test procedureis depicted in Figure 3shown below.

Fig 2: Shock Testing Procedure

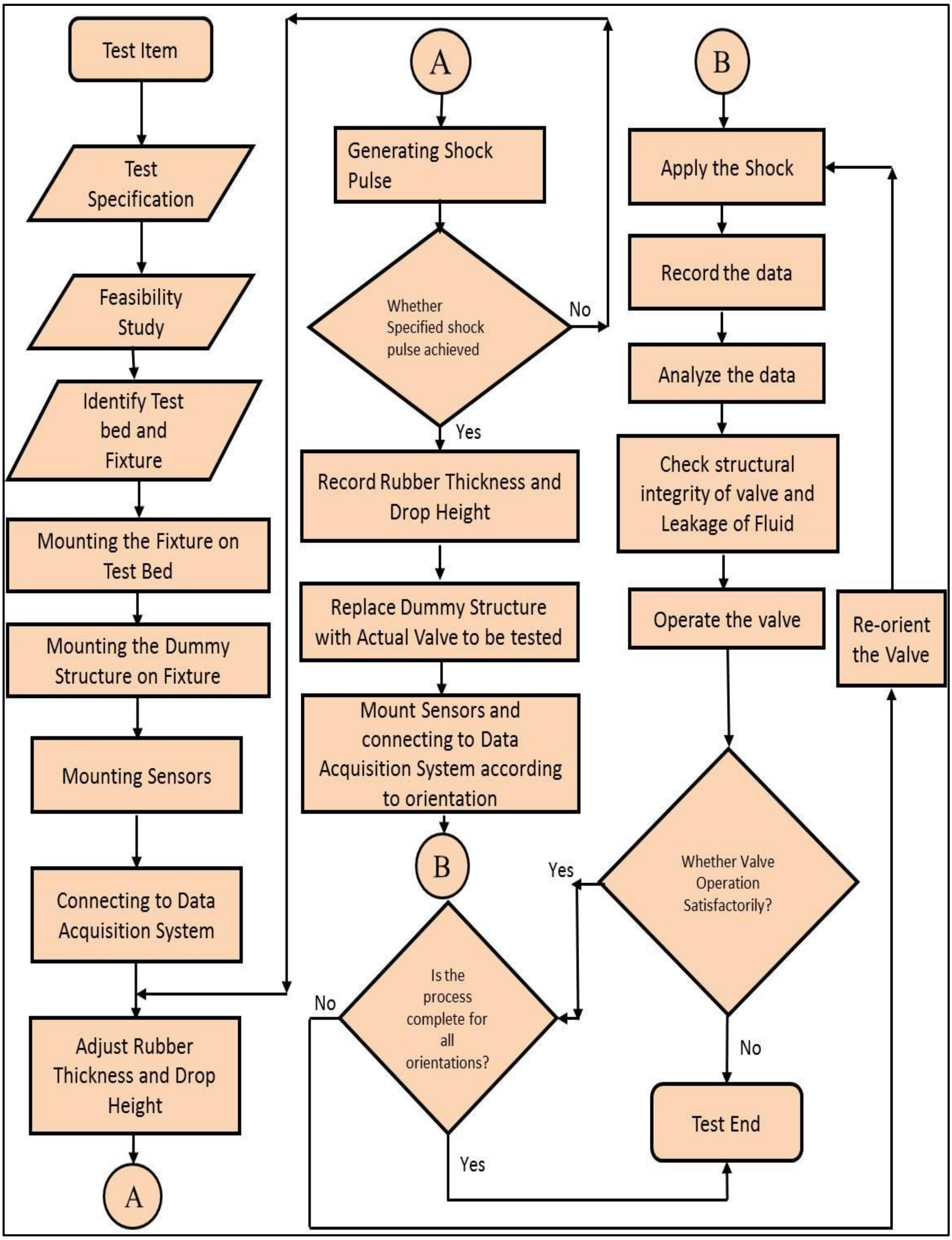

Fig 3: Shock Testing Procedure[1], [2], [3], [5]

IV. DESIGN OF DATA ACQUISITION SCHEME

Design of data acquisition scheme includes Feasibility study, Selection and Location of sensors, Cable routing and determination of sampling frequency etc.

1.1. Feasibility study

The characteristics of the specified half sinusoidal shock pulse are depicted in the Table 1 below. The specified shock pulse characteristics are within the range. So the required shock parameters are achievable.

Tabel 1.Characteristics of Shock Pulse

Sl. No.	Amplitude, g	Time period, ms	Number of shock tests
1	A1	T1	01 in X, Y & Z direction
2	A2	T2	01 in X, Y & Z direction

Based on the mass, shape and size of the test article, the platform side of the test machine is decided to conduct the shock tests.

1.2. Selection of Sensors

Axial accelerometersas shown in Figure 4, were used in order to measure 'g' values at various locations. These accelerometers were preferred as they are smaller in size and can cover wider frequency range. Also, they have advantage of being light in weight so that they do not to change characteristic of actual system. These accelerometers are adhesive mounted.

Fig 4. Axial Accelerometer

1.3. Location of Sensors

Total 7 accelerometers[4] were used during testing. Accelerometers A1 and A7 were mounted on test bed at back side and front side respectively to measure 'g' value on test bed. A2 was mounted on fixture bottom plate. A2 is the location where desired 'g' is to be obtained.A3 was mounted on Valve body. A4, A5 and A6 were mounted on bonnet, support plate for actuator and actuator top respectively. Mounting of all accelerometers are as shown in Figure5. Mounting surfaces were properly grinded, polished, buffed and cleaned before mountingthe accelerometers.

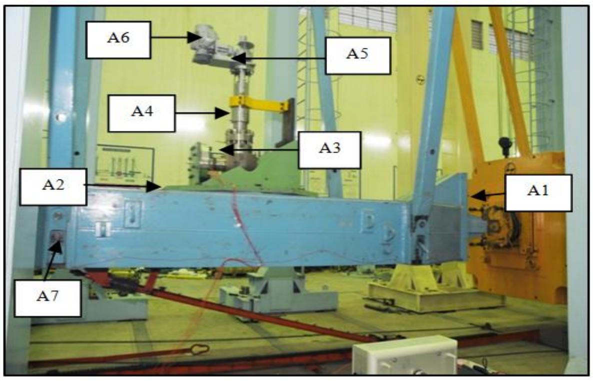

Fig 5. Accelerometer Locations

1.4. Cable Routing

Length of cables and routing was done in such a way that during the entire testing, cables do not interfere with other systems.

1.5. Determination of Sampling Frequency

For shock testing, sampling frequency is taken at least 10 times to that of test frequency. This is done for better reproduction of the original signal.

V. TESTING AND DATA ACQUISITION

Testing Data acquisition activity was carried out for all six cases mentioned in Table 1. After machine setting and readiness of data acquisition system, the gate valve was mounted on the platform. Exact values of torque on the fasteners were maintained using torque wrench, so as to negotiate the loads arising during shock. Shock testing in all three directions was conducted by orienting the gate valve on the test platform as shown Figure 6 and Figure 7.

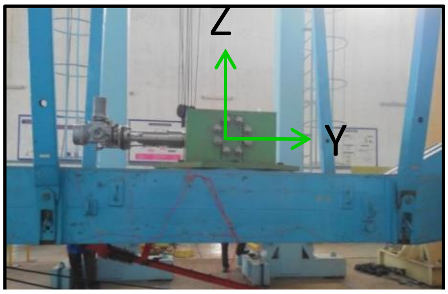

Figure 6.Testing along Y-Direction

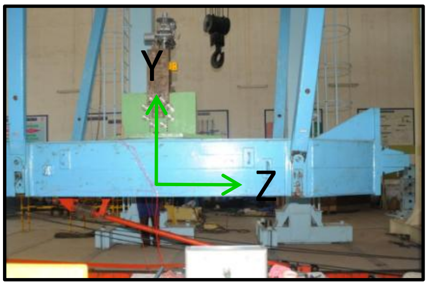

Figure 7. Testing along Z-Direction

Acceleration data during shock was acquired by using all the seven sensors. The acquired data was processed and analyzed using data acquisition system.

VI. RESULTS

Shock testing was carried out for three mutually perpendicular axis, X, Y and Z. Results for each test is shown in figures (Figure 8 to Figure 13) shown below.

a. X-axis

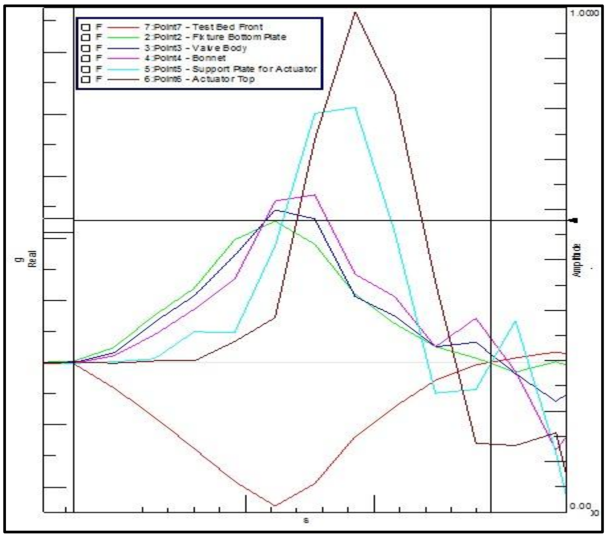

Fig 8: Test-1 along X-axis

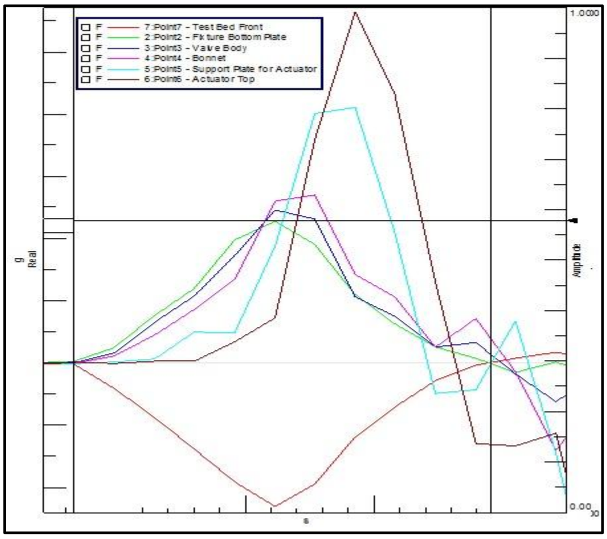

Fig 9: Test-2 along X-axis

3.2 Y-axis

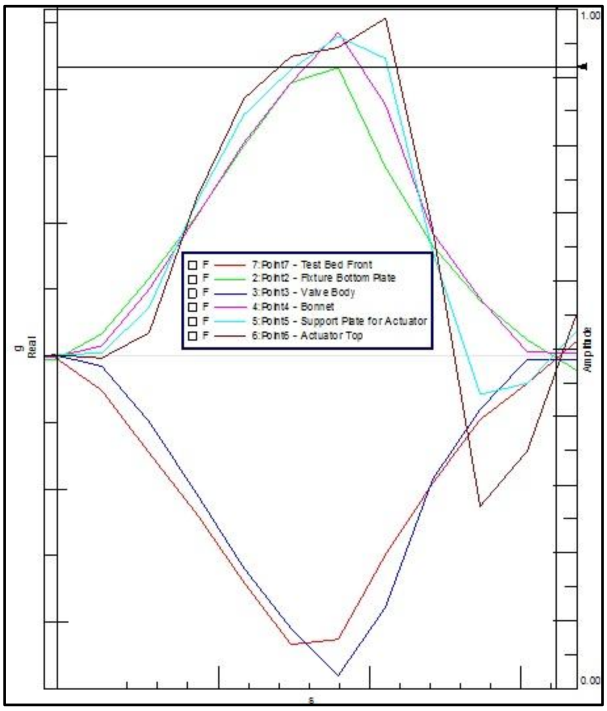

Fig 10: Test-1 along Y-axis

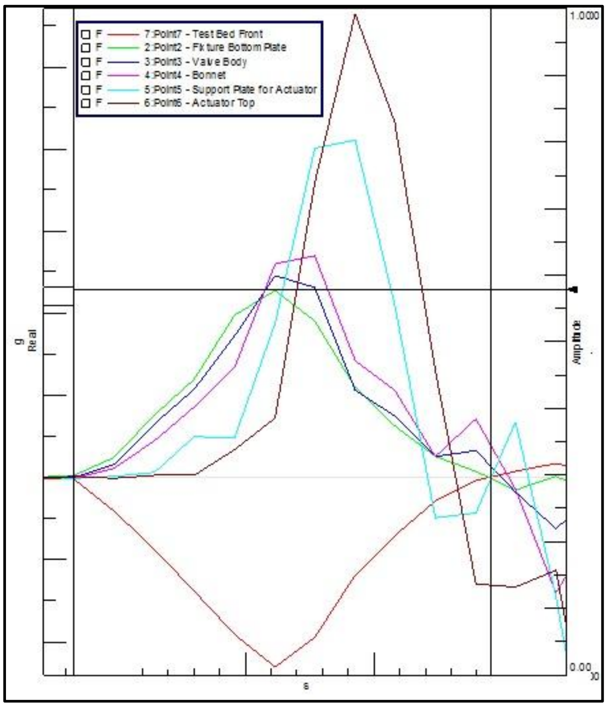

Fig11:Test-2 along Y-axis

b. Z-axis

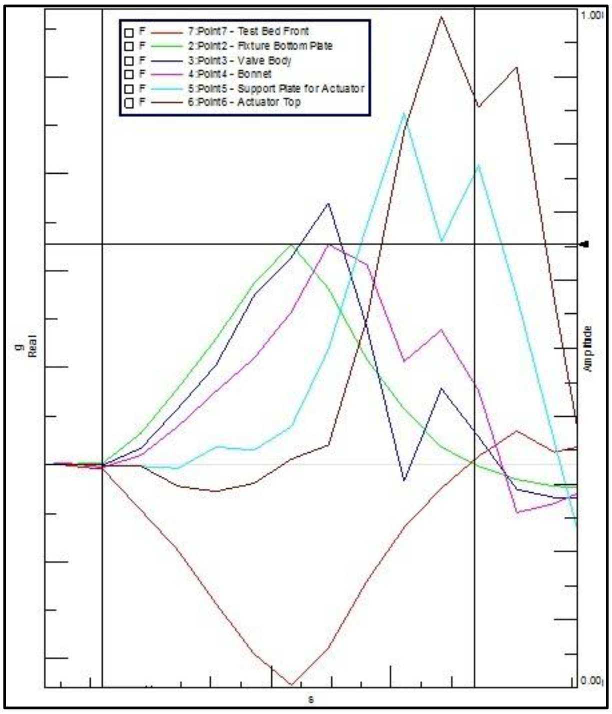

Fig 12:Test-1 along Z-axis

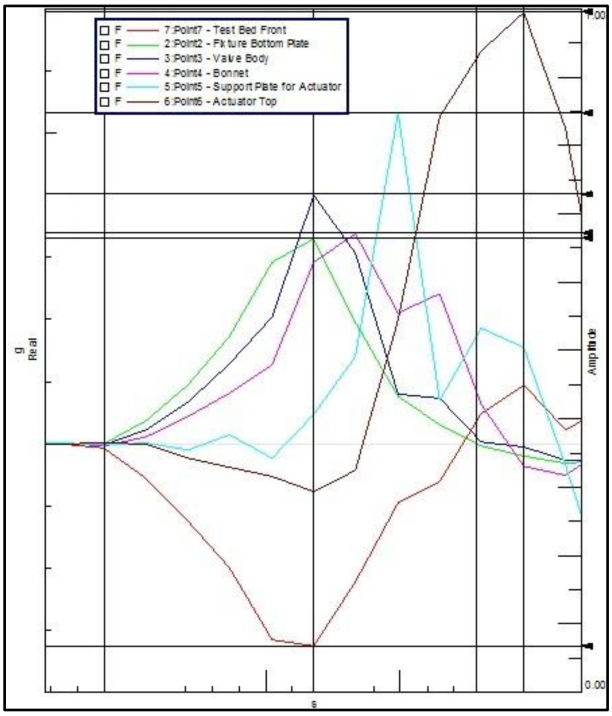

Fig13:Test-2 along Z-axis

VII. DATA ANALYSIS

The 'g' values at fixture bottom plate, Time period, rubber thickness and drop height are mentioned in Table2. Values of rubber thickness and drop height have been achieved from the series of trials on dummy structure.

Tabel 2.Shock Test Data

Sl. No.	Orientation	Acceleration 'g'	Time Period (ms)	Rubber Thickness (mm)	Drop Height (mm)
1	X	1.09*A1	0.926*T1	RT1	DH1
2	X	0.923*A2	0.786*T2	RT2	DH2
3	Y	1.033*A1	0.94*T1	RT1	DH1
4	Y	1.020*A2	0.871*T2	RT2	DH2
5	Z	1.082*A1	0.882*T1	RT1	DH1
6	Z	0.95*A2	0.788*T2	RT2	DH2

After each test, valve motor is operated to check its functionality. It was observed that the valve was working as desired after each test. Also, no change in operation timing was observed. Also leakage of water was checked to assess effectiveness of seals. There was no leakage observed after each test. Structure of Valve assembly was found intact after each test. Hence, it was concluded that Valve assembly cleared qualification requirements and is safe for further usage.

Specified shock parameters were successfully achieved at fixture bottom plate by using dummy structure method. 'g' amplitude increases when moving from fixture bottom plate to actuator top. Reason behind this is behavior of valve as cantilever beam. As distance from mounting base increases, 'g' value experienced increases. Also phase difference was observed when moving from base to top of the valve. This is because of wave propagation, as few milliseconds are required to travel the wave from base to top of the valve. Validation of experimental results with analytical data remains the future work.

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