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Seismic qualification tests of a nuclear power installation isolation valve

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ABSTRACT: The design codes for nuclear power plants and their components require that nuclear safety-related mechanical and electrical equipment must be qualified to withstand the effects of earthquakes.

Three methods are used to demonstrate the seismic qualification of equipment: analysis, testing or a combination of the two. In the seismic qualification two conditions must be satisfied:

a) the equipment must not malfunction (operability);

b) there must be no structural damage that could render the equipment inoperable (structural integrity).

These conditions can be satisfied by analysis only if structural integrity alone assure the design safety function. Therefore, analysis is restricted to limited applications. However, testing simulates the stressing events and checks both conditions.

For power operated isolation valves of nuclear power plants usually associated with systems that are essential to emergency reactor shutdown and reactor core cooling it must be demonstrated that they can perform their safety function during and after an earthquake. In this case, seismic qualification by tests is recommended. In this paper it is presented the description and the results of seismic qualification tests of a nuclear power installation isolation valve.

1 INTRODUCTION

The power operated isolation valves for nuclear power plants are usually associated with systems that are essential to emergency reactor shutdown and reactor core cooling. Their design involves the structural design for strength and operability. Design codes such as the ASME III (1992) provides rules to ensure the pressure retaining integrity of nuclear service valves. It does not, however, address the valve operability under seismic conditions. Therefore, supplementary requirements are specified by the licensing commissions to provide an assurance of valve operability (e.g., the United States Nuclear Regulatory Commission indicates USNRC (1988) as a guidance for seismic qualification of electrical and mechanical equipment for nuclear power plants).

A more detailed information regarding seismic qualification is given in IEEE (1987). Although this standard is directly applicable to electric equipment it has been used in mechanical equipment qualification because there is no standard applicable to this type of components. For power operated isolation valves, the IEEE (1985) is applicable, too.

In response to a need for a nuclear power installation, one prototype of a power operated isolation valve was tested under seismic conditions. It is important to mention that the pressure boundary of the valve was designed according to ASME III (1992) requirements.

Seismic qualification of equipment requires that they must be subjected to simulated operating basis earthquake (OBE) and safe shutdown earthquake (SSE), and that other significant environmental factors must be superimposed.

This paper presents some details of the seismic qualification tests of a nuclear power installation power operated isolation valve prototype, including test description, test procedures, test results and acceptance criteria.

2 TEST VALVE DESCRIPTION

The seismic qualification tests were included in a test program covering the following steps: first assembly check, first pressure test, flow measurement, second assembly check, first helium test, vibration and seismic tests, cold functional test, hot functional test, auxiliary medium test, second helium test, second pressure test and final check.

The test specimen was a prototype of a gate valve equipped with pre-tested solenoid valves and position indicator (see Figure 1).

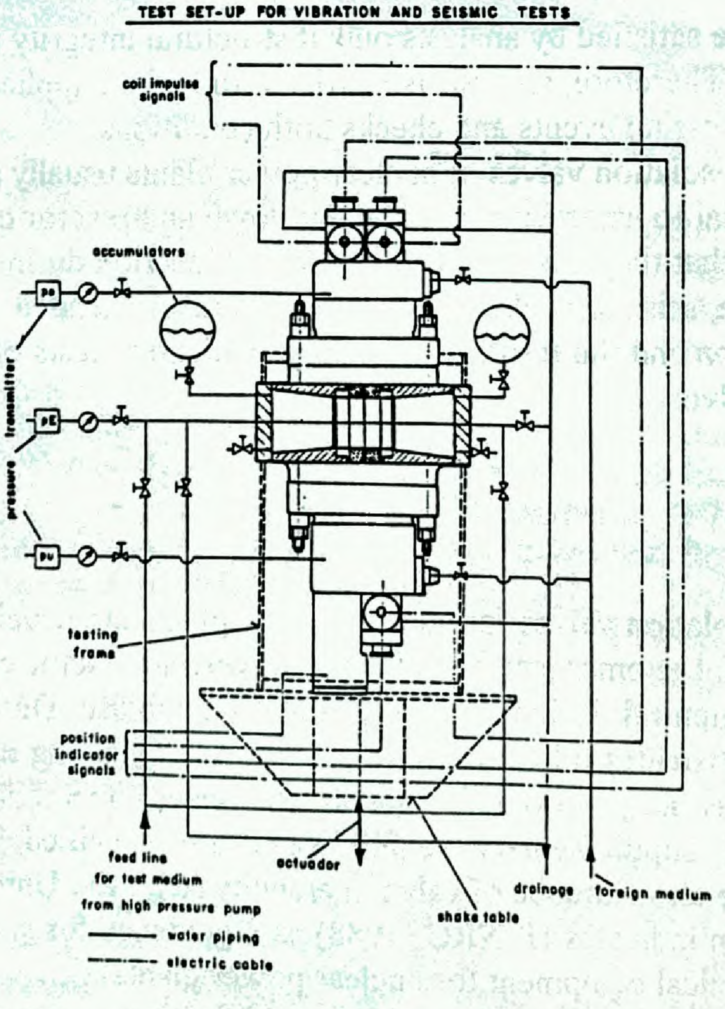

Figure 1 : Test set-up diagram

The prototype was tested in an uni-directional shake table, whose driving system is servo-hydraulic, with the following characteristics:

Horizontal direction:

table dimension: 1,1 m x 1,1 m
maximum dynamic force: 100 kN
maximum displacement: ± 100 mm
maximum velocity: 1,4 m/s
maximum acceleration: 5 g (g is the acceleration of gravity)
frequency range: 0-50 Hz

Vertical direction:

table dimension: 1 m x 1 m
maximum dynamic force: 100 kN
maximum displacement: ± 100 mm
maximum velocity: 1,4 m/s
maximum acceleration: 20 g (g is the acceleration of gravity)
frequency range: 0-200 Hz

In the test set-up, the prototype was mounted on the shake table by means of a stiff testing frame. The only force transmitting connection between the valve assembly and testing frame was two pipe ends (welding necks) of the valve casing. To perform its function during the tests, the valve was equipped with the necessary installations as shown in Figure 1.

Accelerometers were the main sensors for the tests. They were installed in different locations to monitor the response accelerations at the equipment (top of coil housing of the solenoid valves and inlet and outlet pipe end of the valve casing) and to control the test input (at the testing frame and at the shake table). For OBE and SSE tests, the measured accelerations were recorded against the input frequency of the tests. In addition, for SSE tests the position indicator signals were recorded.

3 TEST PROCEDURES

As the shake table was uni-directional, the following sequence was performed in the tests: vertical direction (OBE test and SSE test), horizontal direction 1 (OBE test and SSE test) and horizontal direction 2 (OBE test and SSE test). The test directions are referred to the prototype directions.

The OBE tests consist in two sinusoidal sweeps from 2 to 35 to 2 Hz at an acceleration level of 1,6 g (this value is 2/3 of the SSE level) in a sweep rate of 1 octave/s. One sweep was performed with the valve open and the other with the valve closed. Since in the exploratory vibration tests, performed before the seismic tests, no resonances occurred in the frequency range up to 35 Hz, only the response acceleration of one solenoid valve was monitored in addition to the test input acceleration.

The SSE tests were performed imposing 12 cycles sine beats of 15 seconds in duration at each frequency given in Table 1. During the tests 6 close-open-close cycles were performed. The response and input accelerations plus the piston positions were monitored during the SSE tests.

Table 1: SSE tests, frequencies and accelerations levels

Frequency (Hz)	Acceleration (g)
2,0	1,45 (*)
2,5	2,3 (*)
3,1	2,4
4,0	2,4
5,0	2,4
6,3	2,4
8,0	2,4
10,0	2,4
12,5	2,4
16,0	2,4
20,0	2,4
25,0	2,4
32,0	2,4

(*) limitation by stroke of shake table

4 TEST RESULTS

The test accelerations were stored as response spectra as shown in Figure 2. The test response spectra were greater than required response spectra in all frequencies of all tests.

During the SSE tests, the opening times of the valve ranged from 12,8 to 13,1 s and the closing times from 2,1 to 2,2 s. The specified values were 16 and 2 s to the opening times and closing times, respectively. The margin of ± 10 % in closing times was considered acceptable.

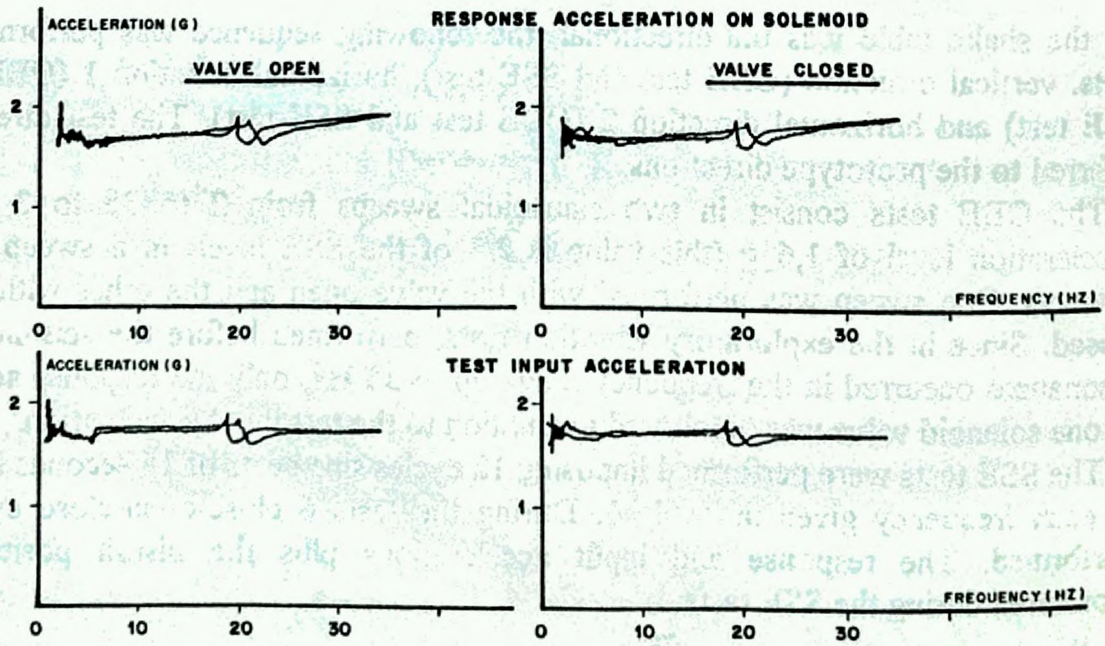

Figure 2: OBE test, required versus test response spectra

5 FUNCTIONAL TEST AND VISUAL INSPECTION

During and after the tests no structural failure, loss of pressure boundary integrity, loss of required functional characteristics, and leakage were detected.

After the seismic tests, the correct function of the prototype was checked by an open-close cycle. The measured operating times were 13 s for the opening and 2,2 s for the closing, respectively.

No mechanical damage or other irregularities were detected by inspection.

6 CONCLUSION

One prototype of a power operated isolation valve for a nuclear power installation was successfully qualified by seismic testing. The seismic test conditions enveloped the specified required response spectra. During and after the seismic tests no structural failure, loss of pressure boundary integrity, loss of required functional characteristics, and leakage were detected.

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