Seismic proving test program for nuclear power plant in Japan

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ABSTRACT

The seismic reliability proving tests of nuclear power plant facilities are carried out by Nuclear Power Engineering Test Center (NUPEC), using the large-scale, high-performance vibration table of Tadotsu Engineering Laboratory, and sponsored by the Ministry of International Trade and Industry (MITI).

In 1982, the vibration table of Tadotsu Engineering Laboratory was completed, and the first test was started, since the proving tests of four nuclear power plant facilities (PWR containment vessel, BWR primary loop recirculation system, PWR reactor core internals and BWR core internals) were conducted. And currently next seismic proving tests are now underway on the test program for nuclear power plant in Japan.

1. INTRODUCTION

Since Japan is a country that has frequent earthquakes, soundness in earthquakes is rigorously required in the construction of nuclear power plants. Consequently, the soundness of the structure and the component must be ensured based on stricter anti-seismic requirements that in ordinary case, include anti-seismic design, quality control during manufacturing and construction, test and inspection before plant operation, etc.

On the other hand, the public attitude toward and reliability on nuclear power plant operation is not very stable at the present stage.

Accordingly, this seismic proving test intends to prove ability to maintain seismic reliability and soundness of the nuclear power plant with a sufficient margin in the occurrence of large earthquakes, using the large-scale vibration table with the test model of full scale, or close to the actual size of important components for the seismic safety of nuclear power plant.

2. GENERAL AIM

Seismic proving tests were planned to obtain the following proofs and confirmations:

(1) The major equipment of nuclear power plant is designed to provide sufficient safety margins of seismic strength. In this test,

confirmation of those provisions in made by applying vibration load corresponding to a large earthquake on the test component.

(2) To prove ability to continue doing required functions by applying vibration corresponding to a large earthquake to the test component, simulating the equipment and piping which are important for the safety of facility.

(3) The seismic designs of the complicated and large-scale nuclear power plants based on various kinds of vibration analysis methods using the large computer.

The seismic proving test confirms the appropriateness of the seismic analysis method comparing the results of vibration test and the calculation results of numerical analysis model.

3. SELECTION OF KEY STRUCTURE

Seismic proving tests are undertaken on simulated large models representing the key structures that ensure the safety of nuclear power plants using the large-scale, high-performance vibration table facility. These are: Reactor containment vessels, primary coolant system equipment, reactor core internals, reactor pressure vessels and other key nuclear components.

Fig. 1 illustrates layout of large components and equipment which are important for the safety in the nuclear reactor building of PWR and BWR.

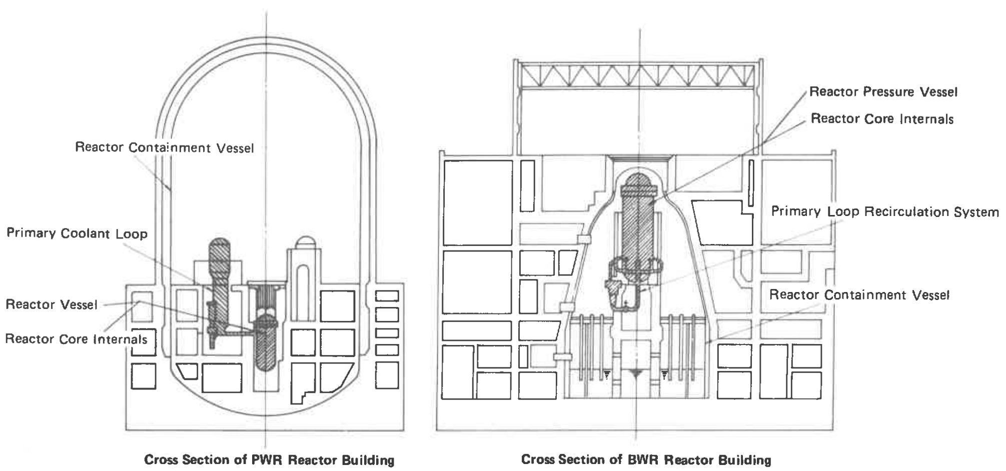


Fig. 1. Layout of large components and equipment which are important for the safety in the nuclear reactor building

4. SEISMIC CONDITION

In the seismic proving tests, large component and equipment designed for use in the high seismic zone in Japan are essentially subjected to the tests to prove seismic soundness and reliability against the basic design earthquake ground motion S_1 and S_2 (design standard seismic waves).

The basic design earthquake ground motions are classified into S_1 and S_2 depending upon their intensities:

For the earthquakes causing the above mentioned basic design earthquake ground motions S_1 (referred to as "the maximum design earthquakes"), reference is made to the earthquake among the recorded earthquakes that would have the greatest effect on the proposed site and surrounding region and which may occur again in the same fashion, or among those earthquakes that might be induced by highly active faults in the near future.

For earthquakes causing the above-mentioned basic design earthquake ground motions S_2 (referred to as "the extreme design earthquakes"), reference is made to the earthquake among those earthquakes exceeding the maximum design earthquake that would have the greatest effect on the proposed site based on engineering judgement following a seismological review of past earthquakes, the nature of any active faults and the seismotectonic structure underlying the site and the surrounding region.

5. TEST MODEL

For this purpose, the test models are designed and manufactured to be suitable for this proving test, and they are subjected to a vibration test using the large-scale, high-performance vibration table (maximum movable load: 1,000 ton, table size: 15m × 15m, exciting direction: horizontal and vertical simultaneously, maximum exciting force: horizontal 3,000 ton·f vertical 3,300 ton·f) of NUPEC in Tadotsu (1-1, Nishi-Minato-machi, Tadotsu-cho, Kagawa Pref. 764, Japan).

Seismic analysis and evaluations of structural strength and function of the test components are performed based on the test results.

The type and scale of the test model and the required functions of actual components are tabulated in Table 1.

6. TEST PROCEDURE

The following procedures are implemented during seismic proving tests:

Seismic response analysis is made by subjecting reactor building to the basic design earthquake ground motions S_1 and S_2.

Vibration (floor response wave) is generated at the actual location designated for the installation of equipment.

A wave identical to the above input wave for seismic proving tests is applied to excite the test model-mounted vibration table.

Tests may roughly be divided into three types:

① Sine wave vibration test
② Seismic response wave test
③ Functional test

In the sine wave vibration test, a sine wave is applied to excite the vibration table. The frequency characteristics (natural frequency, mode shape, damping ratio, etc.) of the equipment are then confirmed.

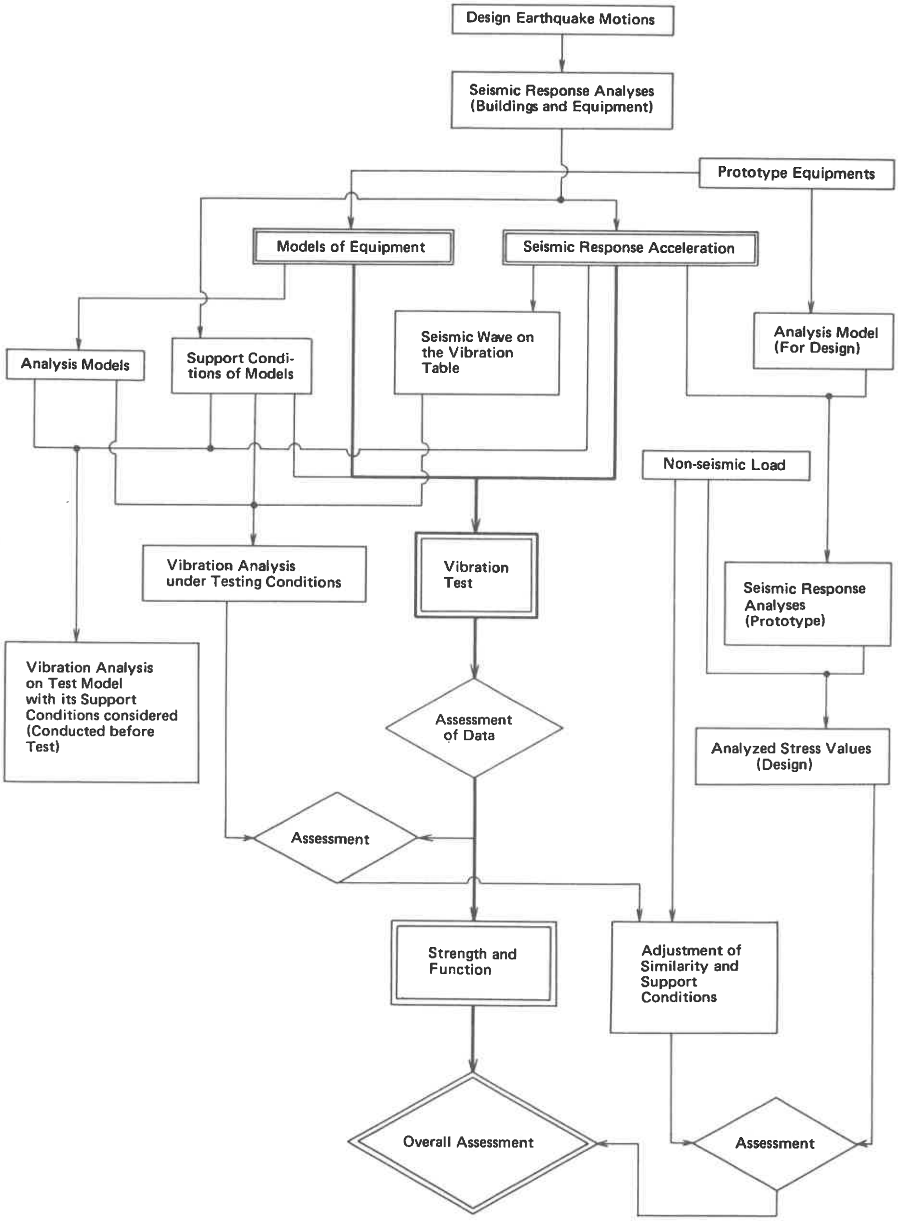


Fig. 2. Flow chart for overall assessment of the aseismic proving tests

Table 1 Type and scale of test model and function of Actual Component

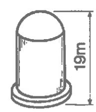
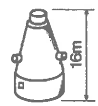
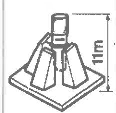
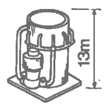
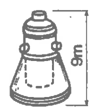
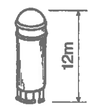
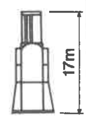
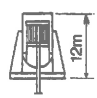
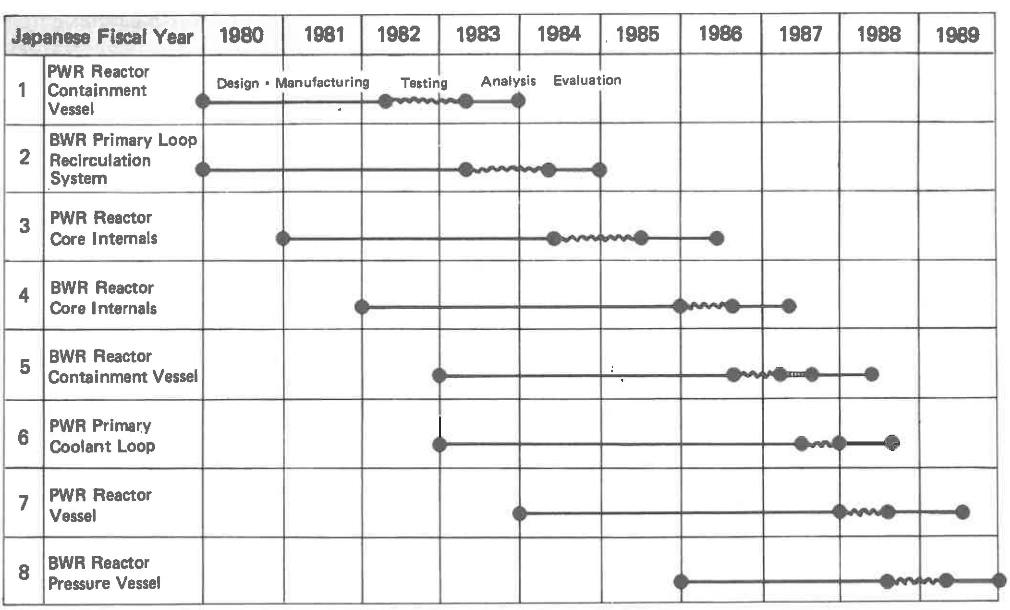
Test Model \ Item / Type	PWR Plant Weight [tons]	PWR Approx. Scale	PWR Weight [tons]	PWR Height [meters]	BWR Plant Weight [tons]	BWR Approx. Scale	BWR Weight [tons]	BWR Height [meters]	Items required at the time of earthquake
Reactor Containment Vessel	3 800	1/3.7	340		3 500	1/3.2	350		The functions are maintained even when additional load due to the loss of coolant accident is added to vessel against the basic design earthquake ground motion (S_1). The functions are maintained even against the basic design earthquake ground motion (S_2).
Primary Coolant Loop (PWR) Primary Loop Recirculation System (BWR)	1 000	1/2.5	550		800	1/1	665		The structure should be such that it is strong enough against the basic design earthquake ground motions (S_1,S_2) and that an earthquake does not cause a loss of coolant accident.
Reactor Pressure Vessel	800	1/1.5	700		800	1/2	290		The structure should be such that it is strong enough against the basic design earthquake ground motions (S_1,S_2) and that an earthquake does not cause a loss of the coolant accident.
Reactor Core Internals	500	1/1	555		500	1/1	750		It should be strong enough against the basic design earthquake ground motion (S_1). The control rod should be inserted without any difficulty and it should be possible to shutdown the operation of the reactor when the basic design earthquake ground motion (S_2) is present.

Table 2 Seismic Proving Tests Program



In the seismic response wave test, the above-mentioned input wave for seismic proving tests is applied to excite the vibration table. The response acceleration, displacement, strain (stress), etc. of equipment vibration are measured and it's strength is confirmed.

In the functional test, the following items are confirmed:

① Reactor containment vessel airtightness

② Control rod insertion function

③ Non-effect of water vibration (sloshing) in suppression chamber of BWR reactor containment vessel.

Finally, the seismic reliabilities of the actual nuclear equipments are evaluated, utilizing the results of analysis for the tests data of natural frequency, damping ratio, response values, etc.

Fig. 2 shows a flow chart of the overall assessment of the seismic proving tests.

7. TEST PROGRAM

Table 2 shows seismic proving test program at this present time.