

Seismic Isolation Test Program

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A B S T R A C T

A test and research program was developed, and started in 1987 under the contract with Ministry of International Trade and Industry to verify the reliability and effectiveness of seismic isolation for FBR. It was intended to select appropriate seismic isolation concepts, to determine their effectiveness and feasibility, and to develop a rough draft of design technical guideline by 1989.

It is further intended to establish seismic isolation concepts, to verify their reliability and to prepare a design technical guideline by 1993 in order to reflect the results in the design of the demonstration reactor.

1. Introduction

Seismic isolation is expected to be effective in raising the reliability during earthquakes, reducing the cost, enlarging siting, and promoting the design standardization of FBR.

Although seismic isolation has been applied to several office buildings and residences in Japan, more research and demonstration are considered to be needed to verify the reliability and the effectiveness of seismic isolation for such important structures as FBR. A test and research program was developed, and started in 1987 sponsored by Ministry of International Trade and Industry so that the results could be reflected in the demonstration reactor. It was intended to select appropriate seismic isolation concepts, to determine their effectiveness and feasibility, and to develop a rough draft of design technical guideline within three years. It was further intended to establish seismic isolation concepts, to verify their reliability, and to prepare a design technical guideline(draft)within seven years. On the basis of a survey of past researches, designs, and seismic safety reviews of nuclear power stations, a research program were decided to consist of the following items. (Fig.1)

- 1) To prepare a FBR seismic isolation design technical guideline (draft) on the basis of a survey of domestic and overseas standards and codes and the results of the present research.
- 2) To select appropriate seismic isolation systems and seismic isolation elements on the basis of a survey of past cases and seismic response analyses.
- 3) To develop structural concepts and to investigate technical issues through analyses, model experiments, etc.
- 4) To demonstrate the reliability of FBR seismic isolation systems during strong earthquake by large-scale shaking table.
- 5) To demonstrate the reliability of the seismic isolation elements by conducting breaking tests with large-scale seismic isolation element models.

FIG. 1 SEISMIC ISOLATION STUDY PROGRAM

	1987~1989	1990~1993
Seismic Isolation Element Demonstration Test	<ul style="list-style-type: none"> Fabrication of Test Rig Isolation Element Test 	<ul style="list-style-type: none"> Isolation Element Test
Development of Seismic Isolation Structure	<ul style="list-style-type: none"> Study on Various Systems Evaluation of Concept and Determination of Development Target Preliminary Model Test Preliminary Draft of Design Method 	<ul style="list-style-type: none"> Draft Proposal of Design Guideline for Seismic Isolation System Design and Fabrication of Large Scale Seismically Isolated Structure Model Large Scale Seismically Isolated Model Test at Tadotsu
Study on Earthquake Load and Response		<ul style="list-style-type: none"> Construction of Seismically Isolated Nuclear Island Building Model
PSA Methodology Development and Application on the Isolation System		<ul style="list-style-type: none"> Examination of Design-Basis Earthquake
		<ul style="list-style-type: none"> Proposal of Design Method
		<ul style="list-style-type: none"> Observation of Characteristics Seismically Isolated Nuclear Island Building Model
		<ul style="list-style-type: none"> Proposal of Design-Basis Earthquake
		<ul style="list-style-type: none"> Evaluation using Reliability Method

- 6) To evaluate relatively long period components of earthquake motion by collecting and analyzing seismic observation records and by applying analytical methods, and to propose a method for setting an appropriate design earthquake motion.
 - 7) To construct simulated seismically-isolated FBR buildings, and verify the reliability of the seismic isolation system under real working conditions by observing the response of the system during actual earthquakes.
 - 8) To develop seismic PSA techniques for seismic isolation system.
- In this paper, details of the program are described.

2. Proposal of Design Guideline for Seismic Isolation System

It is intended to propose a technical guideline which will be required in designing seismic isolation for FBR.

First, a comprehensive survey of aseismic design standards, guidelines and actual designs of nuclear power stations and seismically-isolated buildings in and out of Japan were conducted.

On the basis of the findings of the survey, terms to be covered by the guideline were picked up, the basic philosophy and framework of the guideline were formulated, and remaining technical tasks were clarified.

The tasks remained are to be investigated in this program, and by reflecting the results of the program, the design guide line will be proposed.

The principal contents of the technical guideline (draft) are as follows.

Section I Safety design policy for seismic isolation systems

① Safety design policy for seismic isolation systems

Section II Seismic isolation design policy for seismic isolation systems

- ① Basic policy
- ② Classification of importance
- ③ Methods for evaluating seismic isolation design
 - Methods for calculating seismic forces
 - Methods for evaluating design earthquake motion
 - Methods for evaluating seismic isolation system
- ④ Combination of loads and tolerances

Section III Engineering data

- (1) Evaluation of earthquake motion
- (2) Seismic isolation design methods
- (3) Seismic isolation elements design methods
- (4) Building design methods
- (5) Component design methods
- (6) Construction methods

3. Seismic Isolation Element Demonstration Test

It is intended to conduct tests on large-scale seismic isolation elements for FBR so as to demonstrate the safety against seismic load, and the durability of these elements in service life of the plant.

The tests on the elements are conducted according to the following procedure:

- 1) A survey of past tests on seismic isolation elements is made to select necessary test items and to develop a test program
- 2) A specification of a laminated elastomer for base isolation of FBR building is examined.
A full-scale (500t class) and reduced scale (200t and 50t class) models are fabricated, (Fig. 2)
- 3) A static biaxial load tester, which is capable of breaking large scale (200t class) isolation elements, is fabricated. (Fig. 3)
- 4) Scale law is confirmed by conducting tests on full-sale and reduced scale models using the load tester and by testing cut-out samples from the elastomers of different scales.

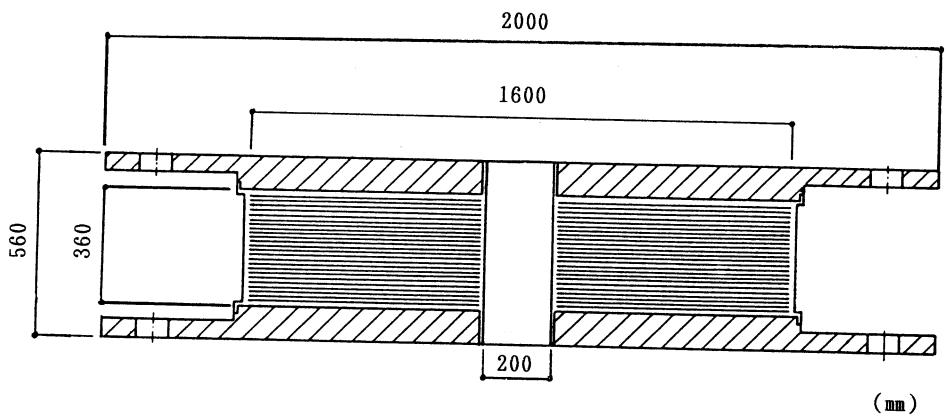


FIG. 2 A FULL-SCALE SEISMIC ISOLATION ELEMENT

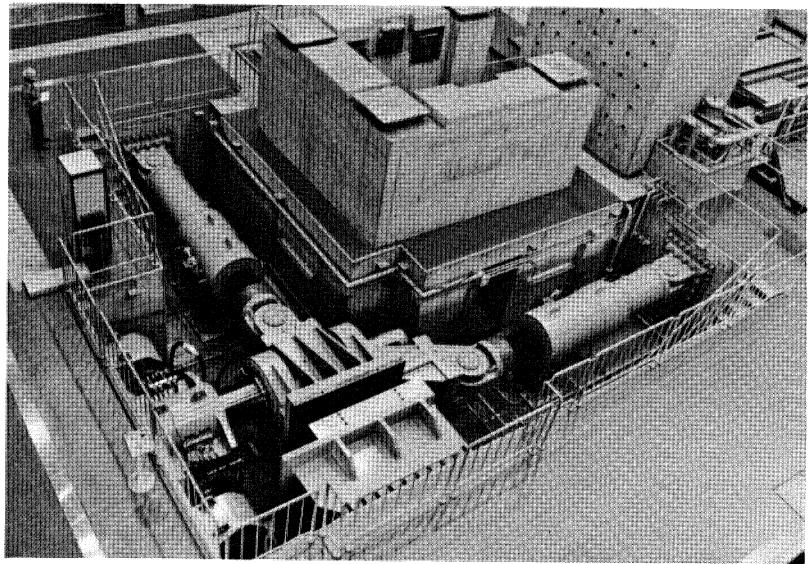


FIG. 3 BIAXIAL LOAD TESTER

- 5) The breaking loads and displacements are determined from the test results of reduced-scale models using the biaxial load tester, while load-displacement relationships for design loads are determined using full-scale models.

4. Development of Seismically Isolated structure

It is intended to select appropriate seismic isolation concepts for FBR, to develop an isolation structure, and to verify the reliability of the structure.

It is conducted according to the following procedure.

- 1) Several promising seismic isolation concepts and corresponding isolation devices are picked up based on existing knowledge.
- 2) Each plant concept is subjected to seismic response analysis using a tentative design spectrum for seismically isolated FBR, the applicability, cost reduction effects and future research and development items are evaluated on the basis of the results of their findings, and an isolation concept is selected.
- 3) The design of an isolation system for FBR is developed in some detail, (Fig. 4) and tasks for further investigation are identified.
- 4) Analytical studies and model tests are conducted for the identified tasks, and the design of the isolation system is revised.
- 5) The reliability of the isolation system are verified by large scale model tests using the shaking table of Nuclear Power Engineering Test Center at Tadotsu, Japan. (Table 1)

5. Study on Earthquake Load and Response.

In order to design seismic isolation systems for FBR, it is necessary to make rational design earthquake ground motion which includes relatively long-period components. It is also important to confirm the performance of isolation systems and to verify the response analysis method by observing the response of actual seismically isolated structures.

It is intended to propose a method to determine design earthquake ground motion for seismically isolated FBR, and to construct and observe the response of the about 1/3 scale seismically isolated nuclear island building model.

For investigation of design earthquake ground motion, seismic observation records of large earthquakes (Magnitude >6) are analyzed and comparison are made with the results of evaluation methods such as the semi-experimental formula for Love wave, semi-experimental formula for body wave, and a method for synthesizing strong ground motion using observed seismograms of small events.

6. PSA methodology development and application on the isolation system

It is intended to investigate the reliability of seismically isolated FBR structures during earthquakes from the view point of probabilistic safety assessment.

Following methods are employed in the study.

- 1) Estimation of probabilistic factor of safety which consists of capacity factor, response factor, and deterministic safety factor.
- 2) Simulation and evaluation of safety margin measures based on second moment reliability for estimating the reliability index of both isolated and non-isolated FBR structure.
- 3) Development of a Monte Carlo simulation technique for more accurate assessment and for investigation of the effect of randomness of isolation devices on the response of seismically-isolated FBR.

7. Conclusion

A test and research program is developed, and started under the contract with MITI in 1987.

This program is expected to verify the reliability and effectiveness of seismic isolation for FBR.

TABLE 1 SPECIFICATION OF SHAKING TABLE

Equipment	Major Specifications
Vibration Table	15m X 15m X 3.5m (H) Weight 420 ton
Horizontal Actuators	Exciting Force 450 ton f Stroke \pm 200mm
Vertical Actuators	Exciting Force 300 ton f Stroke \pm 100mm Built-in Balance Cylinder
Fixed Guide	Compression Force 360 ton f
Movable Guide	Compression Force 360 ton f Stroke 100mm

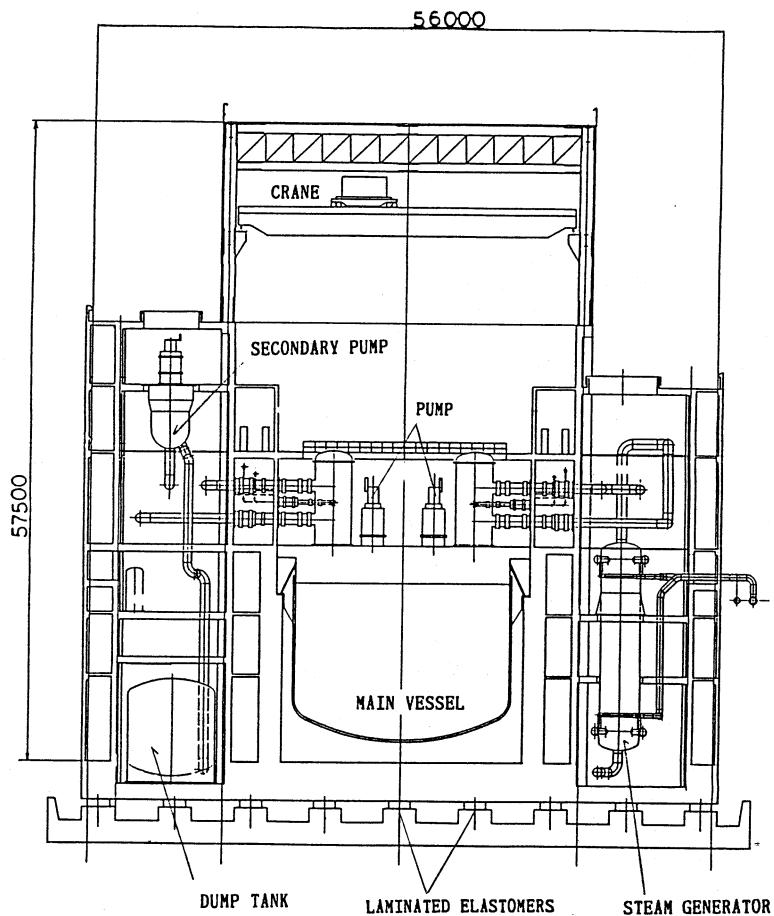


FIG. 4 SEISMICALLY ISOLATED FBR PLANT