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Volume II

ENGINEERING SAFETY REVIEW SERVICES
SEISMIC SAFETY EXPERT MISSION

"PRELIMINARY FINDINGS AND LESSONS LEARNED FROM THE 16 JULY 2007 EARTHQUAKE AT KASHIWAZAKI-KARIWA NPP"

"The Niigataken Chuetsu-Oki earthquake"

Kashiwazaki-Kariwa NPP and Tokyo, Japan
6 – 10 August 2007

ENGINEERING SAFETY REVIEW SERVICES (ESRS)

DIVISION OF NUCLEAR INSTALLATION SAFETY

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY

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REPORT TO
THE GOVERNMENT OF JAPAN

Kashiwazaki-Kariwa NPP and Tokyo, Japan

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Mission date:	6 – 10 August 2007
Location:	Kashiwazaki-Kariwa NPP and Tokyo, Japan
Facility:	Kashiwazaki-Kariwa NPP, Units 1 – 7
Organized by:	International Atomic Energy Agency

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INTRODUCTION TO VOLUME II

Upon request from the Government of Japan an IAEA expert mission was conducted at the Kashiwazaki-Kariwa NPP following a strong earthquake that affected the plant on 16 July 2007.

Thus, the mission complemented the ongoing safety evaluations of the incident as they are currently being performed by Japan's Nuclear and Industrial Safety Agency, Japan's Nuclear Safety Commission and the plant operator, the Tokyo Electric Power Company.

The scope of the mission was limited to three subject areas:

Area 1: *Seismic design basis – design basis ground motions*

Preliminary investigations of the actual earthquake and its ground motions and comparison with the design basis ground motions for the plant seismic design.

Area 2: *Plant behaviour – structures, systems and components*

Observation of the damage that occurred as a consequence of the earthquake of 16 July 2007 to the seven units at Kashiwazaki-Kariwa nuclear power plant site on the basis of the information gathered and made available by TEPCO and by performing limited but representative plant walkdowns.

Area 3: *Operational safety management*

Preliminary investigations of the operational safety management response and releases of radioactive material during and after the earthquake, on the basis of the examination of documents and of discussions with TEPCO.

The mission report is composed of two volumes, Volume I and Volume II.

This Volume II contains all supporting documentation and information collected during the mission and provided by the counterpart to the IAEA Expert Team.

It is arranged in a way that it will be relatively easy for the reader to find the necessary information. There is a significant amount of information contained in Volume II that has come from different sources and that has been gathered for different purposes. The information has been compiled under headings that indicate its origin and purpose as well as their relationship to the observations and topics discussed in Volume I.

First, a few photographs are presented that give the impression of the way the mission was conducted and showing the atmosphere of the mission, such as the meetings and encounters with the media. The preparatory meeting held at the hotel in Nagaoke, upon arrival on Sunday, is portrayed in the first photograph. The arrival at Kashiwazaki-Kariwa NPP on Monday and the encounter with the media and the technical meetings at the plant are shown in the next three photographs. The interest of the media to this event is also shown in the next two photographs taken at the exit of the meetings in the plant and in Tokyo. In the last photograph the IAEA expert team is shown at the hotel after delivery of the draft mission report to Japanese authorities.

Subsequently, Volume II is organized in the following way:

1. Part I: BACKGROUND

First of all, there is a significant amount of information provided by NISA, JNES and TEPCO as general background. This information mainly relates to Japanese regulations and general data about the Kashiwazaki-Kariwa NPP and does not pertain specifically to the 16 July 2007 event. All this information is presented under the title of “Background” and it is not necessarily referenced to any particular discussion area of the mission.

2. Part II: INFORMATION SPECIFIC TO THE THREE AREAS COVERED BY THE MISSION AS SUPPLIED BY THE JAPANESE COUNTERPART

Secondly, there is information supplied by the Japanese counterpart as information specifically relevant to the purpose of the mission, that is, the 16 July 2007 Niigataken Chuetsu-oki earthquake and in general the plant response to this event. This information includes the presentations made by counterpart specialists at the beginning of the mission and also their response to the queries raised by the IAEA team members during the course of the mission. These presentations and the responses are presented under the three discussion areas A1, A2 and A3. If a presentation or response pertains to more than one area this is also indicated.

3. **Part III: INFORMATION SPECIFIC TO THE THREE AREAS COVERED BY THE MISSION AS COMPILED BY THE IAEA EXPERTS TEAM.**

Finally, there is the third category of information which was compiled by the IAEA team members during the mission. These are photographs that have been taken either by team members themselves (with the explicit permission of the Japanese counterpart organizations NISA and TEPCO) or by TEPCO engineers following the request of the IAEA expert team. Some have been taken to illustrate a technical point during walkdowns and these are linked again to the three areas of discussion A1, A2 and A3.

Preparatory meeting with NISA and JNES TEPCO, Nagaoka, Sunday, 5 August.

First day arrival at the K-K NPP meting facilities, Monday, 6 August.

Technical Meetings at K-K NPP; the IAEA Team, NISA, JNES, TEPCO and interpreters.

Final day at K-K NPP, Thursday, 9 August: The media waits for the exit meeting closure

IAEA Team Leader, Mr. Ph. Jamet, is questioned by the media in Tokyo, after the meeting with NISA, Friday, 10 August.

The IAEA Team relaxes after the delivery of the Draft Report to NISA on Friday, 10 August

PART I – BACKGROUND

I.1. Nuclear Safety Commission (NSC) – "*Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities"* (September 19, 2006) (provisional English translation) – Provided by NISA as the high level regulatory guidance on seismic safety.

I.2. NISA presentation on the methodology for seismic design of NPPs

I.3. Site geology - Geological structure of the site area (in Japanese)

I.4. Foundation, Base Stratum and Seismic Input Levels for Units 1 -7

I.1. Nuclear Safety Commission (NSC) – "*Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities*" (September 19, 2006) (Provisional English Translation).

Note from the IAEA Expert Team:

Please, note that the 19 September 2006 revision of this regulatory guide, as included hereby, was not in place at the time of the design of the KK NPP units. Previous versions were used for such purpose.

Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities

Decision of the Atomic Energy Commission
September, 1978.
Revised by the Nuclear Safety Commission
July 20, 1981.
Revised by the Nuclear Safety Commission
September 19, 2006.

September 19, 2006.

Nuclear Safety Commission

(URL:http://www.nsc.go.jp/english/taishin.pdf)

CONTENTS

Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities

September 19, 2006
Nuclear Safety Commission

1 INTRODUCTION

This guide is provided to show the basis of the judgment for adequacy of the seismic design policy in the standpoints to ensure seismic safety at the Safety Review related to the application for the establishment license (includes the application of alteration of an establishment license) of the individual light water power reactor.

The former 'Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (decided by the Nuclear Safety Commission "NSC" on 20 July 1981 and revised on 29 March 2001, hereinafter referred to as "Former Guide") ' was the guide which was revised based on the state of arts of evaluating methods of static seismic force etc. by the NSC in July 1981, which had been provided in September 1978 by the Atomic Energy Commission. And it was partially revised in March 2001.

This time, overall revision of Former Guide has been conducted by reflecting accumulated new seismological and earthquake engineering knowledge and remarkable improvement and development of seismic design technology of nuclear power reactor facilities.

Incidentally, this guide shall be revised to reflect the coming new knowledge and experiences suitably according to accumulation of new findings.

2 SCOPE OF APPLICATION

This guide shall be applied to the nuclear power reactor facilities (hereinafter referred to as "Facilities").

Nevertheless, basic concept of this guide could be referred to other type nuclear reactor facilities as well as other nuclear related facilities.

Incidentally, if some part of application contents could not comply with this guide, it would not be excluded if it reflected technological improvements or developments and seismic safety could be ensured farther than satisfying this guide.

3 BASIC POLICY

A part of Facilities designated as important ones from the seismic design points shall be designed to bear seismic force exerted from earthquake ground motion and to maintain their safety function, which could be postulated appropriately to occur but very scarcely in the operational period of Facilities from the seismological and earthquake engineering standpoints such as geological features, geological structure, seismicity, etc. in the vicinity of the proposed site.

Moreover, any Facilities shall be designed to bear the design seismic force sufficiently which is assumed appropriately for every classification in the seismic design from the standpoint of radiological effects to the environment which could be caused by earthquake.

Besides, buildings and structures shall be settled on the grounds which have sufficient supporting capacity.

(Commentary)

I. Regarding Basic Policy

(1) Regarding determination of earthquake ground motion in the seismic design

In the seismic design, it shall be based on the principle that ‘ the ground motion which could be postulated appropriately to occur but very scarcely in the operational period of Facilities and are feared affecting severely to Facilities’ shall be determined adequately, and that, on the premise of this ground motion, the seismic design shall be conducted not to give any risk of serious radiological exposure to the public in the vicinity of Facilities from the external disturbance initiated by an earthquake.

This policy is equal to the ‘ basic policy’ in Former Guide which is required to the seismic design with the provision of ‘ nuclear power reactor facilities shall maintain seismic integrity against any postulated seismic force assumed so sufficiently that no earthquake would induce significant accidents’.

(2) Regarding existence of “Residual Risk”

From the seismological standpoint, the possibility of occurrence of stronger earthquake ground motion which exceeds one determined on the above-mentioned (1) can not be denied. This means, in determination of seismic design earthquake ground motion, the existence of “Residual Risk”(defined as such a risk that, by extension of the effect of the ground motion which exceeds the determined design ground motion of Facilities, impairing events would occur to Facilities and the event in which massive radioactive materials diffuse from Facilities would break out, or the result of these events would cause radiological exposure hazards to the public in the vicinity of Facilities).

Therefore, at the design of Facilities, appropriate attention should be paid to possibility of occurrence of the exceeding ground motion to the determined one and, recognizing the existence of this “Residual Risk”, every effort should be made to minimize it as low as practically possible not only in the stage of design basis but also in the following stages.

4 CLASSIFICATION OF IMPORTANCE IN SEISMIC DESIGN

Importance in seismic design of Facilities shall be classified into the followings from the standpoints of the possible impact of radiation to the environment caused by earthquake corresponding to the categories of Facilities.

(1) CLASSIFICATION ON FUNCTION

S Class:

Facilities containing radioactive materials by themselves or related directly to Facilities containing radioactive materials, whose loss of function might lead to the diffusion of radioactive materials to the environment, Facilities required to prevent the occurrence of those events and Facilities required to mitigate the consequences resulting from the diffusion of radioactive materials in the occurrences of those accidents, and also whose influences are very significant.

B Class:

Facilities of the same functional categories as above S Class, however whose influences are relatively small.

C Class:

Facilities except for S or B Class, and ones required to ensure equal safety as general industrial facilities.

(2) FACILITIES OF CLASSES

Facilities of Classes are shown as follows by the above classification of the importance in the seismic design.

1) S Class Facilities

i. Equipment/piping system composing of the ‘reactor coolant pressure boundary’ (the definition is the same that is described in other Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power Reactor Facilities)

ii. Spent fuel storage pool

iii. Facilities to add the negative reactivity rapidly to shutdown the reactor and Facilities to preserve the shutdown mode of the reactor,

iv. Facilities to remove the decay heat from the reactor core after reactor shutdown

v. Facilities to remove the decay heat from the reactor core after the failure accident of reactor coolant pressure boundary

vi. Facilities to prevent the propagation of radioactive materials directly as the pressure barrier at the failure accident of reactor coolant pressure boundary

vii. Facilities, except for those in the category vi) above, to mitigate the diffusion of radioactive materials to the environment at the accident which involves the release of radioactive materials.

2) B Class Facilities

i. Facilities connected directly to reactor coolant pressure boundary and containing radioactive materials by themselves or have possibility to contain radioactive materials,

ii. Facilities containing radioactive materials. Except for those whose effect of radiological exposure to the public due to their break is smaller enough to compare with annual exposure limit at the outside of the peripheral observation area, because of its small inventory of containing radioactive materials or of the difference of the type of storage system

iii. Facilities related to the radioactive materials except radioactive wastes and have possibility to give excessive radiological exposure to the public and the operational personnel from their break

iv. Facilities to cool the spent fuels

v. Facilities except for those of S Class, to mitigate diffusion of radioactive materials to the environment at an accident which involves the release of radioactive materials.

3) C Class Facilities

Those Facilities not belong to above S or B Class.

5 DETERMINATION OF DESIGN BASIS EARTHQUAKE GROUND MOTION

The ground motion to be established as the basis of the seismic design of the Facilities shall be determined adequately as the ground motion to be postulated to occur but very scarcely in the operational period of Facilities from the seismological and earthquake engineering point of view relating to geology, geological structure, seismicity, etc. in the vicinity of the proposed site, and to be feared making a serious impact to Facilities. (Hereinafter this ground motion is referred to as ”Design Basis Earthquake Ground Motion Ss” or “DBGM Ss”.)

DBGM Ss shall be determined on the following principles:

(1) DBGM Ss shall be determined as following two types of earthquake ground motions in horizontal direction and vertical direction on the free surface of the base stratum at the proposed site, relating to (2)”Site specific earthquakes ground motion whose source to be identified with the proposed site” and (3) ”Earthquake ground motion whose source not to be identified” mentioned below.

(2) Site specific earthquakes ground motion whose source to be identified with the proposed site shall be determined on the following principles:

1) Taking account of the characteristics of active faults and the situation of

earthquake occurrences in the past and at present in the vicinity of the proposed site, and classifying the earthquakes by the pattern of earthquake occurrence etc. plural number of earthquakes which are feared making severe impact to the proposed site shall be selected (hereinafter referred to as “Investigation Earthquakes”).

2) Following items shall be taken into account concerning the ‘characteristics of the active faults around the proposed site’ in above-mentioned 1).

i) The active faults considered in the seismic design shall be identified as the one of which activities since the late Pleistocene epoch can not be denied. Incidentally, judgment of the faults can depended upon whether the displacement and deformation by the faults exist or not in the stratum or on the geomorphic surface formed during the last interglacial period.

ii) The active faults shall be investigated sufficiently by integrating geomorphological, geological and geophysical methods, etc. to make clear the location, shape, activity of the active faults, etc. according to the distance from the proposed site.

3) For any Investigation Earthquakes selected in above-mentioned 1), following evaluations of earthquake ground motion both ⅰ) with response spectra and ⅱ) by the method with fault models shall be conducted, and DBGM Ss shall be determined from respective Investigation Earthquakes. Incidentally, in evaluating the earthquake ground motion various characteristics (include the regional peculiarity) according to the pattern of earthquake occurrences, seismic wave propagation channel, etc. shall be taken into account sufficiently.

i) Evaluation of earthquake ground motion with response spectra
For respective Investigation Earthquakes, response spectra shall be appraised by applying appropriate methods and the design response spectra shall be evaluated on these spectra, and earthquake ground motions shall be evaluated in considering the earthquake ground motion characteristics such as duration time, time depending change of amplitude-enveloping curve suitably.

ii) Evaluation of earthquake ground motion by the method with fault model
For respective Investigation Earthquakes, earthquake ground motions shall be evaluated by settling the seismic source characteristics parameters with appropriate methods.

4) Uncertainty (dispersion) concerned with the evaluation process of the DBGM Ss in above-mentioned 3) shall be considered by applying the appropriate methods.

(3). Earthquake ground motion whose source not to be identified shall be determined on the following principle.
Design Earthquake Ground Motions shall be determined by collecting the observation records near the source which are obtained from past earthquakes inside the inland earth’s crust, of which the source can not be related directly to any active faults, settling the response spectra based on those records by taking account of the ground material

characteristics of the proposed site, and adding consideration of the earthquake ground motion characteristics such as the duration time, time dependent change of amplitude-enveloping curve, etc. suitably to these results.

(Commentary)

II. Regarding to determination of DBGM Ss.

(1) Regarding to characteristics of DBGM Ss.

In Former Guide, regarding design basis earthquake ground motion two categories of "Earthquake Ground Motion S1" and "Earthquake Ground Motion S2" were required to be determined, however in this revision both these motions were integrated, and enhancement of selection of Investigation Earthquakes, evaluation of ground motion etc. were strived for DBGM Ss.

This DBGM Ss is the premise ground motion of the seismic design to ensure seismic safety of Facilities and, in determining it, its adequacy should be checked sufficiently according to the latest knowledge in the specific examination.

(2) The interpretation of the terminology regarding determination of DBGM Ss are as follow:

1) "Free surface of the base stratum" is defined as the free surface settled hypothetically without any surface layer or structure and as the surface of base stratum postulated to be nearly flat with considerable expanse and without eminent unevenness to plan out design basis earthquake ground Motion.

   "Base stratum" mentioned here is defined as a solid foundation of which sear wave velocity Vs exceeds 700m/s, and which has not been weathered significantly.

2) "Active faults" are defined as faults which moved repeatedly in recent geological age and have also possibility to move in the future.

(3) Regarding the principle of determination DBGM Ss

1) In selecting Investigation Earthquakes, the characteristics of active faults and the situation of earthquake occurrence in the past and at present should be investigated carefully, and furthermore existing research results concerned with distribution of middle, small and fine size of earthquakes in the vicinity of the proposed site, stress field, pattern of earthquake occurrence (including shape, movement and mutual interaction of the plate) shall be examined comprehensively.

2) Investigation Earthquakes shall be selected depending on the classification considering the pattern of earthquake occurrence etc. as follows:

   i) Inside Inland Earth's Crust Earthquake

   'Inside inland earth's crust earthquake' is defined as the earthquake which occurs in the upper crust earthquake generation layer and includes one which occurs in the rather offshore coast.

   ii) Inter-plates Earthquake

'Inter-plates earthquake' is defined as one which occurs in the interfacial plane of two mutually contacting plates.

iii) Inside Oceanic Plate Earthquake

'Inside oceanic plate earthquake' is defined as one which occurs inside a subducting (subducted) oceanic plate, and is classified into two types,

'Inside subducting oceanic plate earthquake' which occurs near the axis of sea trench or in it's rather offshore area, and 'Inside subducted oceanic plate earthquake (Inside slab earthquake) 'which occurs in the land side area from the vicinity of the axis of sea trench.

3) The evaluation method using fault model should be regarded as important in the case of earthquake whose source is near the proposed site and process of its failure could be supposed to make large impact to evaluation of the ground motion.

4) In consideration of 'uncertainty (dispersion) concerned with the determination process of DBGM Ss', appropriate method should be applied considering the cause of uncertainty (dispersion) and it's extent which are supposed to make large impact directly to plan out DBGM Ss.

5) The principle of determination of 'Earthquake ground motion whose source not to be identified' is implied that, if the detailed investigation would be conducted sufficiently considering the situation etc. in the vicinity of the proposed site, it could not be asserted to evaluate all earthquakes inside inland earth's crust in advance which could have still the possibility to occur near the proposed site, therefore this earthquake should be considered commonly in all applications in spite of the results of the detailed investigation around the proposed site.

   The validity of DBGM Ss determined by materializing this principle should be confirmed specifically in checking on the latest information at the time of each application. Incidentally, on that occasion, probabilistic evaluation could be referred as the needs arise regarding the ground motion near the source generated from the source fault which does not indicate any clear trace on the ground surface.

6) Regarding 'Site specific earthquakes ground motion whose source to be identified with the proposed site' and 'Earthquake ground motion whose source not to be identified', the exceedance probability of respective earthquakes should be referred in each safety examination from the standpoint that it is desirable to grasp that the response spectra of each seismic ground motion planed out correspond to what extent of the exceedance probability.

7) In the case that the necessary investigation and evaluation are implemented in selection of Investigation Earthquakes and determination of DBGM Ss, existing materials etc. should be referred in considering the accuracy of them sufficiently. If different result would be obtained compared with the existing evaluation results, its

reason should be shown clear.

8) Regarding the ground which supports the structures of Facilities and Facilities themselves, if the peculiar frequency characteristics could be found in the seismic response, it should be reflected to determination of DBGM Ss as the needs arise.

(4) Regarding evaluation of the faults which assumed as the source of earthquake

1) As investigation of the active faults is the basis of the evaluation concerning the faults which is assumed as the source of earthquake, appropriate investigation should be implemented combining adequately the survey of existing materials, tectonic geomorphologic examination, the earth's surface geological feature examination, geophysical examination, etc. according to the distance from the proposed site. Especially in the area near the proposed site, precise and detailed investigation should be applied. Incidentally extent of the area near the proposed site should be decided suitably considering the relation etc. with DBGM Ss determined as 'Earthquake ground motion whose source not to be identified'.

2) Regarding active folds, active flexures, etc. these should also be the object of investigation in above-mentioned 1) as well as the active faults and should be considered in the evaluation of the faults assumed to be the source in accordance with their dispositions.

3) The dispositions of the faults should be evaluated appropriately grasping the under ground structure etc. depending on the regional situation. Incidentally, the special consideration should be required if the earthquake should be assumed from the dispositions of faults in the area where the faults are indistinct.

4) In the case, the scale of earthquake shall be postulated from the length of the fault etc. by applying the empirical formula, the scale should be evaluated adequately considering the special features etc. of the empirical formula.

5) Uncertainty shall be considered appropriately in assumption of the characteristics of the source, in the case that sufficient information could not be obtained to settle the source characteristics parameter including the shape evaluation of the fault to be assumed as the source even by implementing investigation of the active faults.

6 PRINCIPLE OF SEISMIC DESIGN

(1) PRIMAL POLICY

Facilities shall be designed to fulfill the following primal policies of the seismic design for respective categories of Class.

1) Respective Facilities of S Class shall maintain their safety functions under the seismic force caused by DBGM Ss. And also shall bear the larger seismic force loading of those caused by “Elastically Dynamic Design Earthquake Ground Motion Sd” or the static seismic force shown below.
(Hereinafter Elastically Dynamic Design Earthquake Ground Motion Sd is referred to as “EDGM Sd”.)

2) Respective Facilities of B Class shall bear the static seismic force shown below. And, as for the Facilities those are feared of resonating with earthquake, the influence shall be evaluated.

3) Respective Facilities of C Class shall bear the static seismic force shown below.

4) In respective items shown above, the integrity of upper Class Facilities shall not be impaired by the damage of the lower Class Facilities.

(2) COMPUTATION METHOD FOR SEISMIC FORCE

The seismic force for seismic design of Facilities shall be obtained by using the methods shown below.

1) Seismic forces caused by DBGM Ss
Seismic force caused by DBGM Ss shall be computed by applying DBGM Ss in combining horizontal seismic force with the vertical seismic force appropriately.

2) Seismic forces caused by EDGM Sd
EDGM Sd shall be established based on DBGM Ss with the technological judgments. And the seismic forces caused by EDGM Sd shall be also evaluated in combining horizontal seismic forces with the vertical seismic force appropriately.

3) Static seismic force
Evaluation of the Static seismic force shall be based on the following:

i) Buildings and structures
Horizontal seismic force shall be evaluated by multiplying the seismic story shear coefficient Ci by the coefficient corresponding to the importance classification of the facilities as shown below, and multiplying the weight at the above height of the story concerned.

S Class	3.0
B Class	1.5
C Class	1.0

Here, Ci of the seismic story shear coefficient shall be obtained in putting the standard shear coefficient Co to be 0.2, considering the vibration characteristics of the buildings and structures, categories of the ground, etc.
As for the facilities of S Class, both horizontal and vertical seismic forces shall be combined simultaneously in the most adverse fashion. The vertical seismic force shall be evaluated with the vertical seismic intensity which is obtained by putting the seismic intensity 0.3 as a standard, and by considering the vibration characteristics of buildings and structures, categories of the ground, etc.
However the vertical seismic coefficient shall be constant in the height direction.

ii) Components and piping system
The seismic force of respective Classes shall be evaluated with the seismic intensities which are obtained by multiplying the seismic story shear coefficient Ci in above-mentioned i) by the coefficient corresponding to the importance classification of the Facilities as the horizontal seismic intensity, and by increasing the horizontal seismic intensity concerned and the vertical seismic intensity in above-mentioned i) by 20% respectively.
Incidentally, horizontal seismic force shall be combined with the vertical seismic force simultaneously in the most adverse fashion. However, vertical seismic forces shall be assumed to be constant in the height direction.

(Commentary)

III. Regarding the Design Principle

(1) Regarding the necessity of establishment of EDGM Sd

In Former Guide, the design basis earthquake ground motion should have been determined classified as two categories of Earthquake Ground Motion S1 and Earthquake Ground Motion S2 corresponding to the seismic importance classification of the buildings, structures, components and piping system, however in this revision, the determination of DBGM Ss shall only be required. In the seismic design concept to ensure seismic safety of Facilities, it is the basic principle that the safety functions of the seismically important Facilities shall be maintained under the seismic forces by this DBGM Ss.

In addition to confirm maintenance of seismic safety functions of the Facilities under this DBGM Ss with higher precision, establishment of EDGM Sd, which is closely related with DBGM Ss from technical standpoint, is also required to be prescribed.

(2) Regarding establishment of EDGM Sd

The concept of ‘to bear the seismic force’ which prescribed in the Article 6. in this Guide means that Facilities as a whole are designed in the elastic range on the whole to a certain seismic force.

In this case, design in the elastic range means to retain the stress of respective parts of the Facilities under the allowable limits by implementing stress analysis supposing the facilities as the elastic body.

Incidentally, the allowable limits shown here, does not require strict elastic limits and requires the situation that the Facilities as a whole should retain in elastic range on the whole even though the case in which the Facilities partially exceeds the elastic range could be accepted.

Although respective S Class Facilities are required ‘to bear the seismic force’ by EDEGM Sd, this EDGM Sd is established based on the technological judgment.

The elastic limits condition is the condition that the impact which the Earthquake Ground Motion makes to the Facilities and the situation of the Facilities can be evaluated clearly, and that it makes a grasp of maintenance of seismic safety functions as a whole of the Facilities under the seismic force by DBGM Ss more reliable by confirming that the Facilities as a whole retains in elastic limits condition on the whole under the seismic force by EDEGM Sd.

Namely EDEGM Sd assumes a part of the roles which the Design Earthquake Ground Motion S1 of Former Guide used to be attained in the seismic design.

EDGM Sd should be established by multiplying DBGM Ss by coefficients obtained on the technological judgment in considering the ratio of input seismic loads for the safety functional limits and the elastic limits for the respective Facilities and their composing elements. Here, in evaluating the coefficient, the exceedance probability which is referred in the determination of DBGM Ss would be consulted.

The concrete established value and reason of establishment of EDGM Sd should be made clear sufficiently in respective specific application.

Incidentally, the ratio of EDGM Sd and DBGM Ss (Sd/Ss) should be expected larger than a certain extent in considering the characteristics required to EDGM Sd, and should be obtained not to be less than 0.5 as an aimed value.

In addition, EDGM Sd would be established specifically to respective elements which compose the Facilities depending on the difference of their characteristics to be considered in seismic design.

Incidentally, regarding to B Class Facilities, 'as for Facilities that are feared resonating with seismic force loading, the influence shall be evaluated', the earthquake ground motion applied to this evaluation would be established with multiplying EDGM Sd by 0.5.

(3) Regarding the evaluation of the seismic force by DBGM Ss and EDGM Sd

In case that the seismic force by DBGM Ss and EDGM Sd are evaluated based the seismic response analysis, the appropriate analytical methods should be selected and suitable analytical consideration should be settled based on the sufficient investigation in considering to the applicable range of response analysis methods, applicable limits, etc.

Incidentally, in the case 'free surface of the base stratum' is very deep compared with the ground level on which Facilities would be settled, amplification characteristics of the ground motion on the ground level above free surface of the base stratum should be investigated sufficiently and be reflected to the evaluation of the seismic response as the needs arise.

(4) Regarding Static seismic force

Evaluation of the static seismic force should be depended upon 1) and 2) shown below.

In addition, regarding to the buildings and structures, the adequate safety margin of retained horizontal strength of buildings and structures concerned should be checked to maintain the retained horizontal strength required relating to the importance of Facilities, and the evaluation of retained horizontal strength required should be complied to the 3) shown below.

1) Horizontal seismic force

i) The datum plane for evaluation of horizontal seismic force should be the ground surface in principle. However, if it is needed to consider the characteristics such as the constitution of the building and the structures and the relation to the surrounding ground around Facilities, the datum plane should be provided appropriately and be reflected to the evaluation.

ii) Horizontal seismic force applied to aboveground part from the datum plane should be obtained to be the total of the seismic forces acted on the part concerned in accordance with the height of the building and the structure and be calculated with the following formula,

$$Qi = n \cdot Ci \cdot Wi$$

where,

Qi: Horizontal seismic force acting on the part in question,

n: Coefficient in accordance with importance classification of facilities (Earthquake-proof S Class 3.0, Earthquake-proof B Class 1.5, Earthquake-proof C Class 1.0).

Ci: Seismic story shear coefficient, it depends on the following formula,

$$Ci = Z \cdot Rt \cdot Ai \cdot Co$$

where,

Z: Zoning factor (to be 1.0, the regional difference is not considered),

Rt: A value representing vibration characteristics of building to be obtained by the appropriate calculation methods specified in standards and criteria which are assumed to be adequate for safety. Here, ‘the appropriate calculation methods in standards and criteria which are assumed to be adequate for safety’ corresponds to the Building Standard Law etc.
However, if the value which expresses the vibration characteristics and is evaluated considering the structural characteristics of buildings and structures, and the response characteristics and situation of the ground in the seismic condition would be confirmed to fall short of the value calculated by the methods in the Building Standard Law etc. it could be reduced to the evaluated value by this method (but equal to or not less than 0.7).

Ai: A value representing a vertical distribution of seismic story shear coefficient according to the vibration characteristics of building, to be calculated by the appropriate methods specified in standards, criteria and the other appropriate methods as is like Rt.

Co: Standard shear coefficient (to be 0.2),

Wi: Total of fixed loads and live loads supported by the part in question.

iii) Horizontal seismic force which acts on the parts of the buildings and structures under the datum plane should be evaluated by following formula,

$$Pk = n \cdot k \cdot Wk$$

where,

Pk: Horizontal seismic force acting on the part in question.

n: Coefficient in accordance with importance Classification of Facilities (Earthquake-proof S Class 3.0, Earthquake-proof B Class 1.5, Earthquake-proof C Class 1.0)

k : Horizontal seismic coefficient by the following formula,

$$k \geqq 0.1 \cdot \left[1 - \frac{H}{40} \right] \cdot Z$$

where,

H: Depth of each under part from the datum plane;

20 (m) at depths of >20 m,

Z: Zoning factor (to be 1.0, the regional difference is not considered),

Wk: Summation of dead loads and live loads of the part concerned.

Incidentally, in the case if the value would be calculated in evaluating the vibration characteristics suitably by considering the structural characteristics of buildings and structures, and the response characteristics and situation of the ground in the seismic condition, it would be the value calculated by this method.

2) Vertical seismic force

The vertical seismic force in the evaluation of the static force to Earthquake-proof S Class Facilities should be evaluated with the vertical seismic intensity by the following formula,

$$Cv = Rv \cdot 0.3$$

where,

Cv: Vertical seismic intensity,

Rv : A value representing the vertical vibration characteristics of the building , to be 1.0. However, based on special investigation or study, if it would be confirmed to fall short of 1.0, it would be reduced to be the value based on the results of investigation or study (but equal to or not less than 0.7).

3) Retained horizontal strength required

Retained horizontal strength required should be evaluated specified in the method in standards and criteria which are accepted to be adequate for safety.

Here, the standards and criteria which are accepted to be adequate for safety corresponds to the Building Standard Law etc.

Incidentally, in evaluation of retained horizontal strength required, the coefficient regarding the importance classification of the facilities which is multiplied by the seismic story shear coefficient should be settled to be 1.0 in all the case of Earthquake-proof S, B, C Class and standard shear force coefficient Co which is used in this case should be provided to 1.0.

7 LOAD COMBINATION AND ALLOWABLE LIMITS

The basic concept about combination of loads and allowable limits which shall be considered in assessing adequacy of design principle regarding seismic safety is as follows:

(1) Buildings and Structures

1) Earthquake-proof S Class Buildings and Structures

i) Combination with DBGM Ss and allowable limit

Regarding the combination of normal loads and operating loads with the seismic forces caused by DBGM Ss, the buildings and structures concerned shall have sufficient margin of deformation acceptability (deformation at ultimate strength)as a whole, and adequate safety margin compared to the ultimate strength of buildings and structures.

ii) Combination with EDGM Sd and allowable limit

Regarding resulted stress in combining the normal loads and operating loads imposed with the seismic loads caused by EDGM Sd or Static seismic force, allowable unit stress specified in standards and criteria assumed to be adequate for safety shall be established as the allowable limits.

2) Earthquake-proof B, C Class Buildings and Structures

Regarding resulted stress in combining the normal loads and operating loads imposed with Static seismic forces, allowable unit stress in above-mentioned 1) ii) shall be established as the allowable limits.

(2) Components and Piping System

1) Earthquake-proof S Class Components and Piping System

i) Combination with DBGM Ss and allowable limits

The functions of Facilities shall not be affected by the occurrence of excessive deformations, crack and failure, even if the most part of structures would reach yield condition and the plastic deformation would occur, with respective resultant stress due to combined respective loads which occur in the normal operating condition, unusual transient condition in operation and accident condition with the seismic loads caused by DBGM Ss.

As for the active components etc., acceleration limit etc. for retaining of function shall be established as the allowable limit, which is confirmed by the verification test etc. regarding the response acceleration caused by the DBGM Ss.

ii) Combination of EDGM Sd with allowable limits

The yield stress or the stress with equivalent safety to this shall be established as allowable limits to respective resultant loads due to combined loads at normal operating condition, unusual transient condition in operation and accident condition imposed with the seismic loads caused by EDGM Sd or Static seismic force.

2) Earthquake-proof B, C Class Components and Piping System

The yield stress or the stress with equivalent safety to this shall be established as allowable limits to respective resultant loads due to combined loads in normal operating condition and unusual transient condition in operation imposed with the seismic loads caused by Static seismic force.

(Commentary)

IV. Regarding Load Combination and Allowable Limit

The interpretation of the combination of loads and allowable limits should be based on the followings.

(1) Regarding ‘respective loads which occur in unusual transient operation and accident’, if the load acted on by the events which are feared being caused by the earthquake and the loads, even if which are not feared being caused by the earthquake but being caused by the events which continue in long term if they would occur once, should be considered to be combined with the seismic load. However, even if the load is ‘a load which occurs in accident’, considering the relation between occurrence probability of this accidental event and the duration time, and the exceedance probability of the earthquake, the load caused by this event needs not be considered to be combined with the seismic loads if the probability that the both of them occur simultaneously is extremely small.

(2) Regarding the allowable limits for combination of buildings and structures with EDGM Sd etc. though it was required to be established as the ‘allowable unit stress specified in standards and criteria assumed to be adequate for safety’, this standards and criteria correspond concretely to the Building Standard Law etc.

(3) ‘Ultimate strength’ in the terms regarding combination of the buildings and structures with DBGM Ss means the bounding maximum bearing load in reaching the condition, which is considered as the ultimate condition of the structures, where deformation and strain of the structure would increase remarkably by adding the load to the structure gradually.

(4) Regarding the allowable limit of components and piping system, though the basic principle requires to maintain the resulted stress under the ‘ yield stress or equivalent safety situation’, this situation corresponds concretely to the situation specified in the ‘Technical Standards on Structures etc. of Nuclear Power Generation Facilities etc.’ which is prescribed in the Electricity Utilities Industry Law.

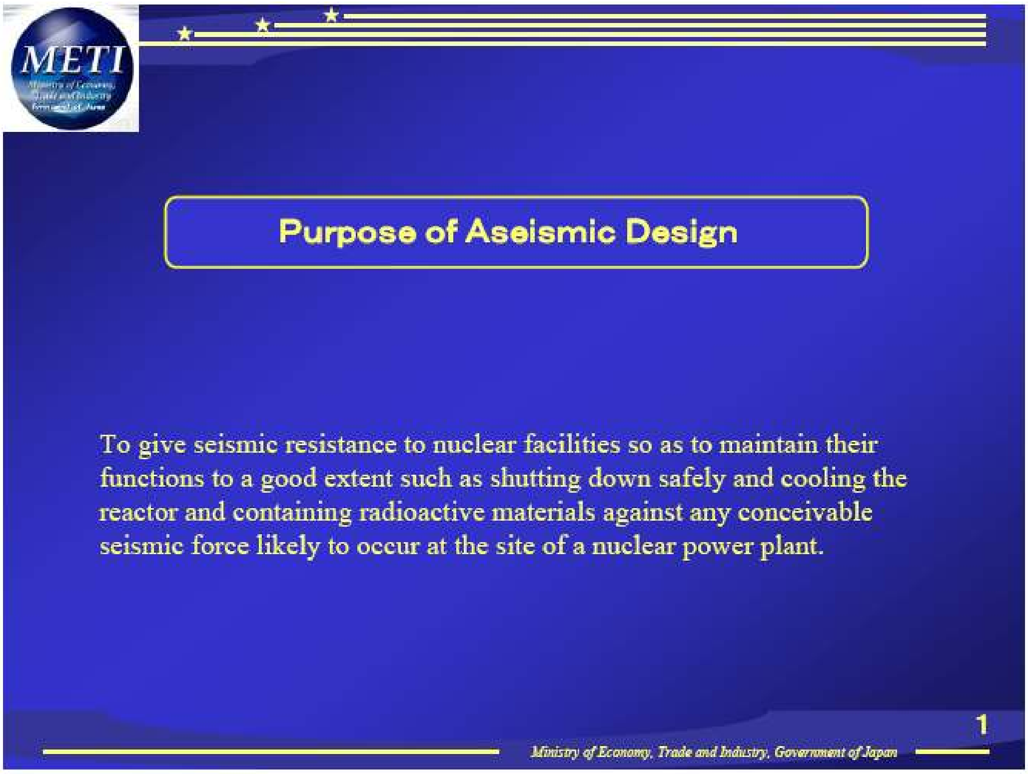
8 CONSIDERATION OF THE ACCOMPANYING EVENTS OF EARTHQUAKE

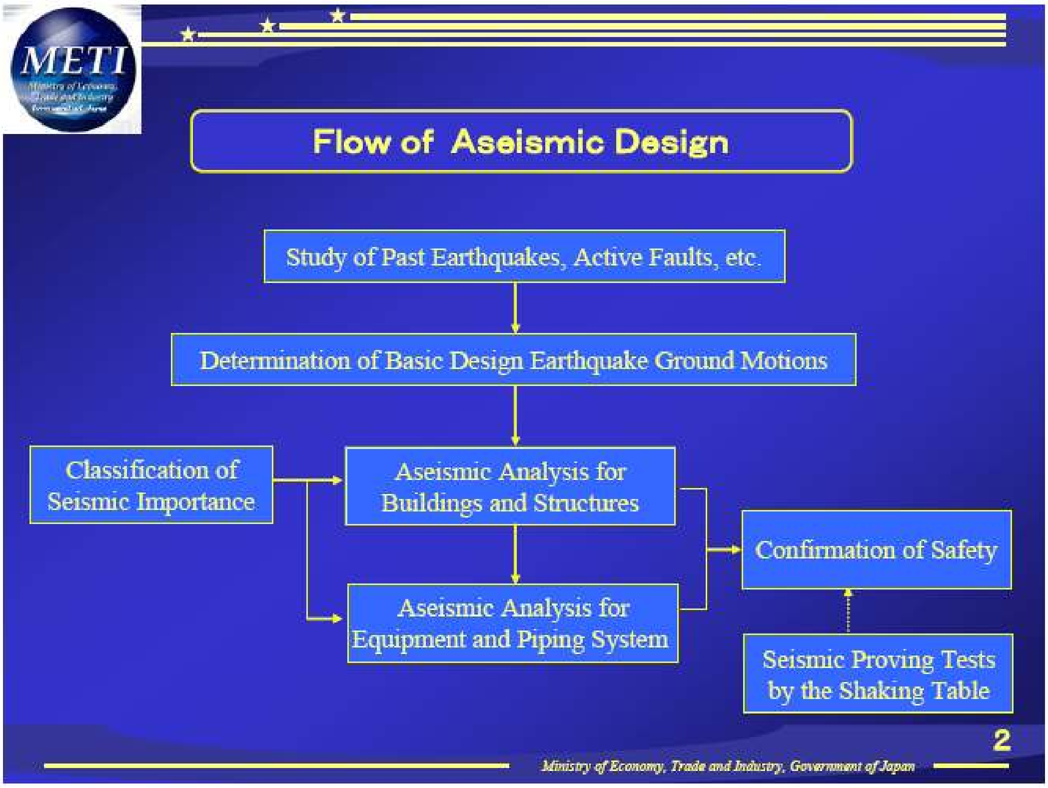
Facilities shall be designed regarding the accompanying events of earthquake with sufficient consideration to the following terms:

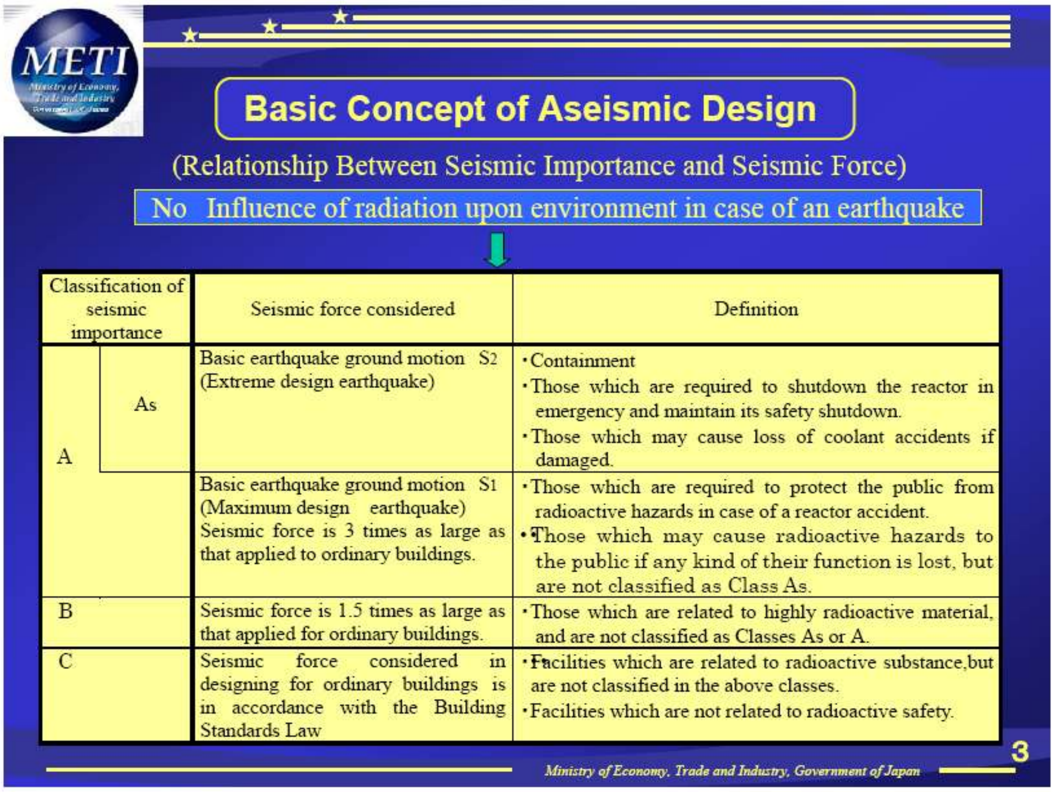
(1) Safety functions of Facilities shall not be significantly affected by the collapses of the inclined planes around Facilities which could be postulated in the seismic events.

(2) Safety functions of Facilities shall not be significantly affected by the tsunami which could be postulated appropriately to attack but very scarcely in the operational period of Facilities.

I.2. NISA presentation on the methodology for seismic design of NPPs







Classification of seismic importance		Seismic force considered	Definition
A	As	Basic earthquake ground motion S2 (Extreme design earthquake)	·Containment ·Those which are required to shutdown the reactor in emergency and maintain its safety shutdown. ·Those which may cause loss of coolant accidents if damaged.
A		Basic earthquake ground motion S1 (Maximum design earthquake) Seismic force is 3 times as large as that applied to ordinary buildings.	·Those which are required to protect the public from radioactive hazards in case of a reactor accident. ·Those which may cause radioactive hazards to the public if any kind of their function is lost, but are not classified as Class As.
B		Seismic force is 1.5 times as large as that applied for ordinary buildings.	·Those which are related to highly radioactive material, and are not classified as Classes As or A.
C		Seismic force considered in designing for ordinary buildings is in accordance with the Building Standards Law	·Facilities which are related to radioactive substance,but are not classified in the above classes. ·Facilities which are not related to radioactive safety.

Safety Measures Taken at Nuclear Power Plants

[Design]

1. Selection of firm bedrock
2. Determination of earthquakes based on a thorough examination
3. Confirmation of safety through dynamic analysis for vibrations caused by an earthquake

[In Operation]

4. Automatic shutdown system for reactors in case of an earthquake,
   in addition, safety of components and facilities has been confirmed by seismic proving tests.

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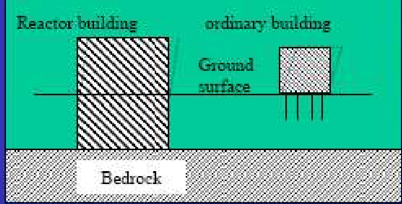
1. Selection of Firm Bedrock

- Nuclear reactor buildings are constructed directly on the bedrock.
- Those buildings are more rigid which are resistant to deformation compared with ordinary buildings.
- Important equipment, pipings, etc, are fixed to those rigid buildings.

Vibration of buildings and equipment is designed to be minimum.

Reactor building is more rigid compared with ordinary buildings.



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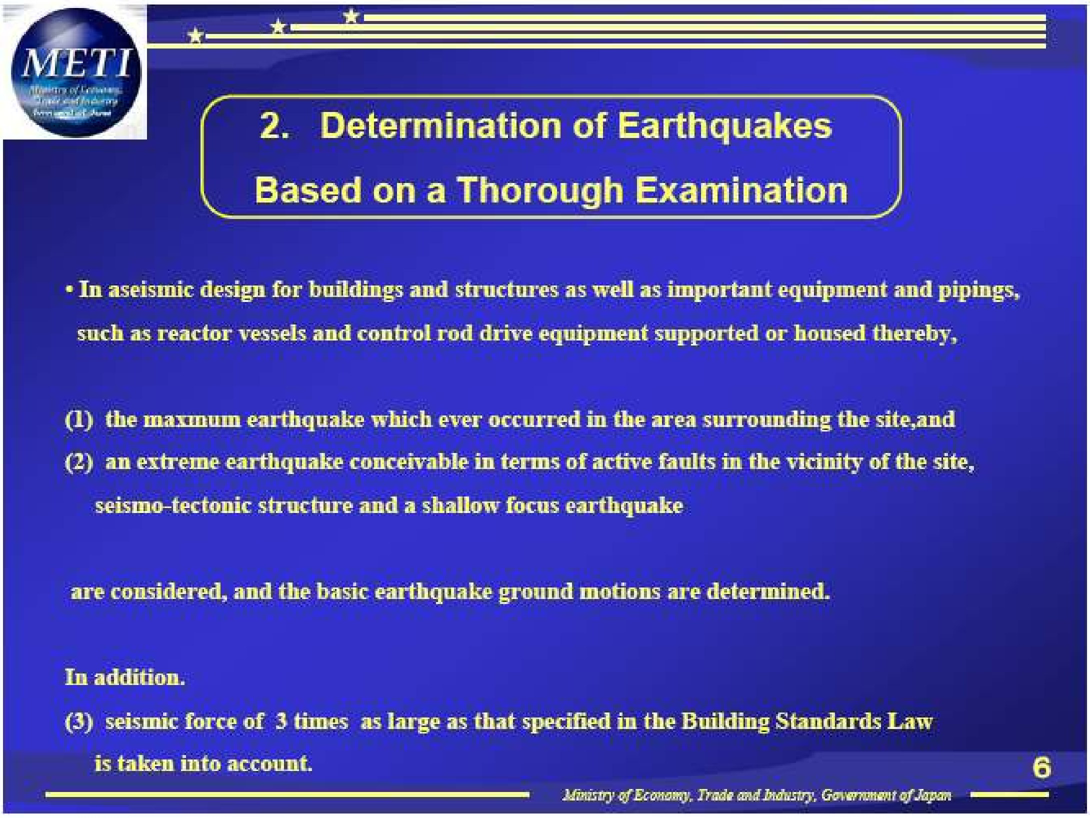
2. Determination of Earthquakes
Based on a Thorough Examination
• In aseismic design for buildings and structures as well as important equipment and pipings, such as reactor vessels and control rod drive equipment supported or housed thereby,
(1) the maxmum earthquake which ever occurred in the area surrounding the site,and
(2) an extreme earthquake conceivable in terms of active faults in the vicinity of the site, seismo-tectonic structure and a shallow focus earthquake
are considered, and the basic earthquake ground motions are determined.
In addition.
(3) seismic force of 3 times as large as that specified in the Building Standards Law is taken into account.
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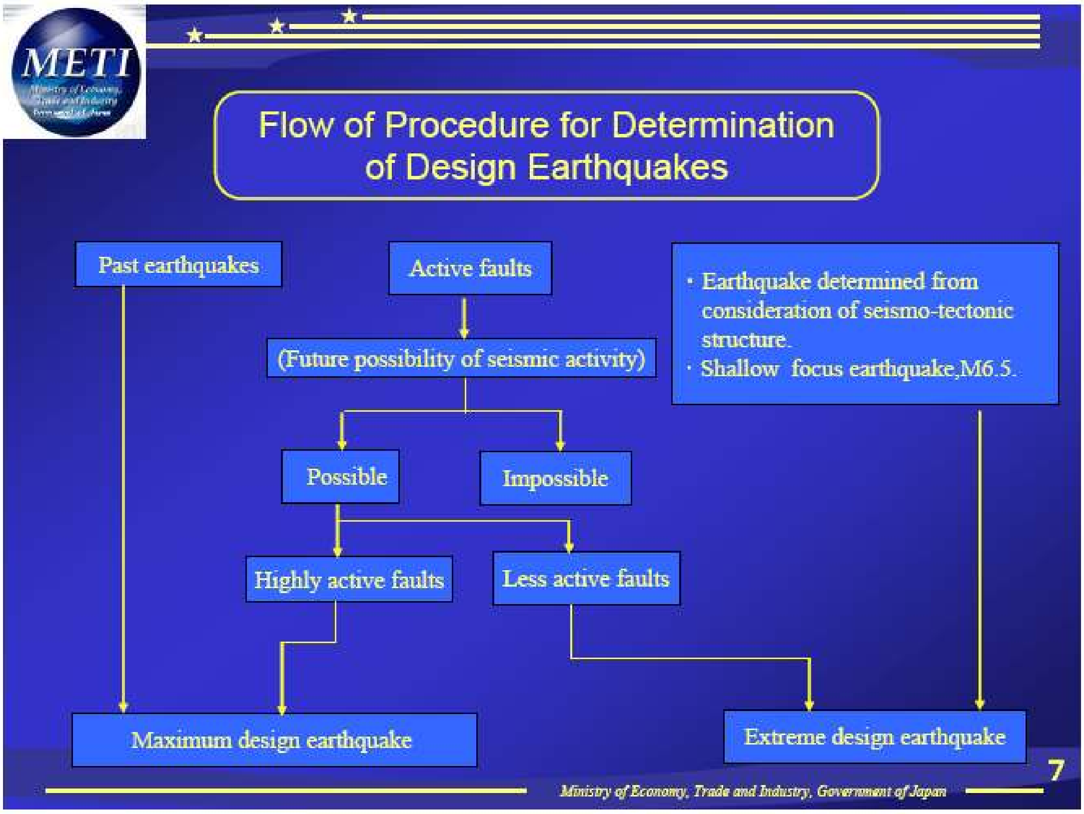
Flow of Procedure for Determination of Design Earthquakes
Past earthquakes
Active faults
(Future possibility of seismic activity)
· Earthquake determined from consideration of seismo-tectonic structure.
· Shallow focus earthquake,M6.5.
Possible
Impossible
Highly active faults
Less active faults
Maximum design earthquake
Extreme design earthquake
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METI

3. Confirmation of Safety Through Dynamic Analysis for Vibrations Caused by an Earthquake

○ The safety of nuclear power plants has been confirmed through calculations using a large computer for complicated vibrations generated by earthquakes with respect to buildings, equipment and pipings, etc.

○These facilities are essential to the safety of a nuclear power plant and are designed to maintain enough strength margin.

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METI

4. Automatic Shutdown System for Reactors in Case of an Earthquake

○ The nuclear power plant has earthquake detectors equipped in each unit. When it detects vibration of about **V** in the Japanese Intensity scale※,the reactor can be automatically shut down.

※ Less than 0.9 time of maximum response acceleration at each installed floor level subjected to maximum design earthquake S1

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Confirmation of Safety Through Seismic Proving Tests

・With respect to the facilities important for the safety of nuclear power plant, their actual or minutely simulated models have been installed on the shaking table, the largest one in the world, located in Tadotsu Engineering Laboratory of NUPEC,Kagawa Prefecture, Shikoku.

・The facilities shown below have been confirmed the safety by vibration tests subjected to simulated ground motions beyond the seismic design.

(Facilities Tested so far)

Reactor containment, reactor vessel, primary coolant system, fuel and reactor internal structure, emergency diesel generator, cooling system for reactor shutdown, etc.

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Relation with Active Fault and Basic Design Earthquake

Design Earthquake / Fault	S_1	S_2
Past earthquakes caused by active faults	All the active faults identified as having generated earthquakes in the historical age	-
Class A Fault	Clear evidence of movement within the past 10,000 years, or return period less than 10,000 years	All the class A faults other than those considered for S_1
Class B,C faults	–	Clear evidence of seismic activity within 50,000 years or return period less than 50,000 years
Relation with micro-earthquake	Active faults whose seismic activity along the fault surface clearly identified by micro-earthquake observations	–

Classification of Active Faults

Classification	Average Slip Rate(S) in Quaternary Era	Note
Class A Fault	More than 1 m during 1,000 years (1 mm/year ・・ S)	The average slip rate is defined as the total displacement in Quaternary Era divided by the years from the fault formation to present.
Class B Fault	Between 10 cm and 1 m during 1,000 years (0.1 ・・ S ・・1 mm/year)	
Class C Fault	Below 10 cm during 1,000 years (S ・・ 0.1 mm/year)	

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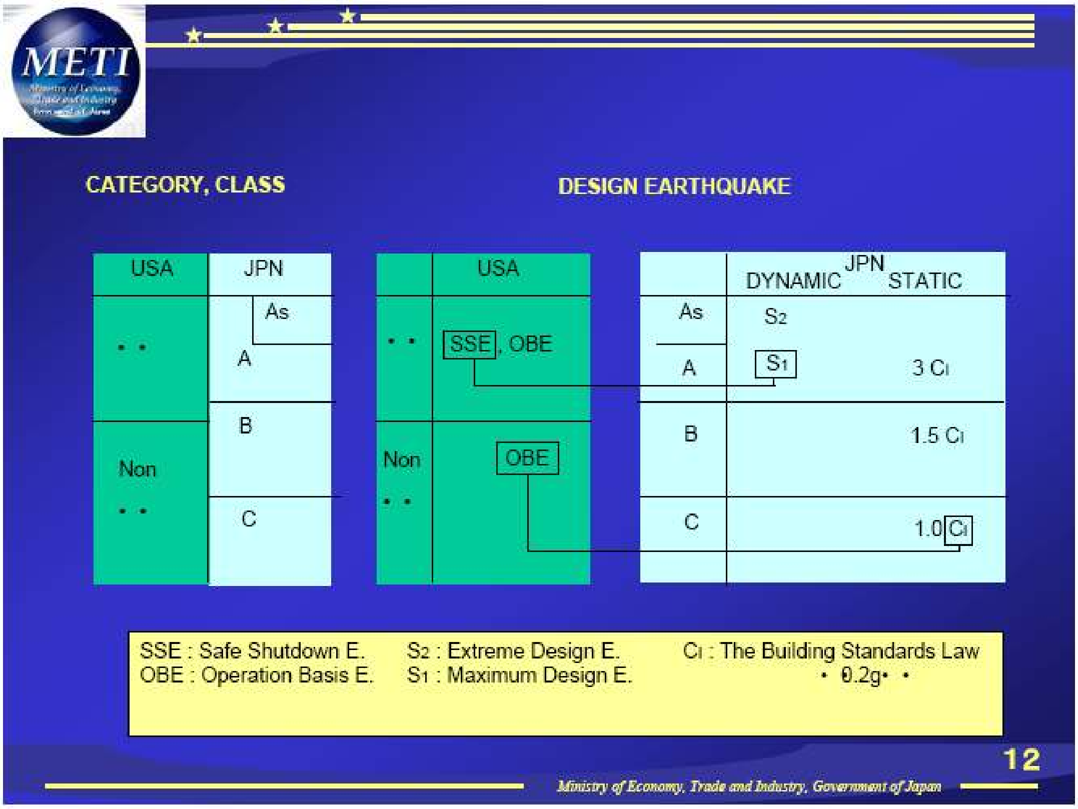

Load combination and allowable limits

Facilities	Class	Load combination	Allowable limits
Buildings and structures	As	S_1(or static seismic force) + normal load + operating load	The allowable stress in accordance with the code and standard
		S_2 + normal load + operating load	Buildings and structures shall be capable of under going deformation (margin of ductility) while maintain a safety margin to their ultimate strength
	A	Same as S_1 for As	Same as S_1 for As
	B and C	Static seismic force + normal load + operating load	Same as S_1 for As
Equipment and pipings	As	S_1 (or static seismic force) + each of the loads under normal operating, operating transient and accidental conditions	Yielding stress
		S_2 + each of the loads under normal operating, operating transient and accidental conditions	In the case a portion of the structure yields and is subject to plastic deformation, excessive deformation, cracking, rupture, etc., which would adversely affect the function of the facilities shall not occur.
	A	Same as S_1 for As	Same as S_1 for As
	B and C	Static seismic force + each of the load under normal operating and operating transient conditions	Yielding stress

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I.3. Site geology - Geological Structure of the Site Area

Plant view and cross sections (in Japanese).

Note from the IAEA Expert Team:

Please, note that the position of the cross sections in the NE-SW direction also indicate an anticline and a syncline.

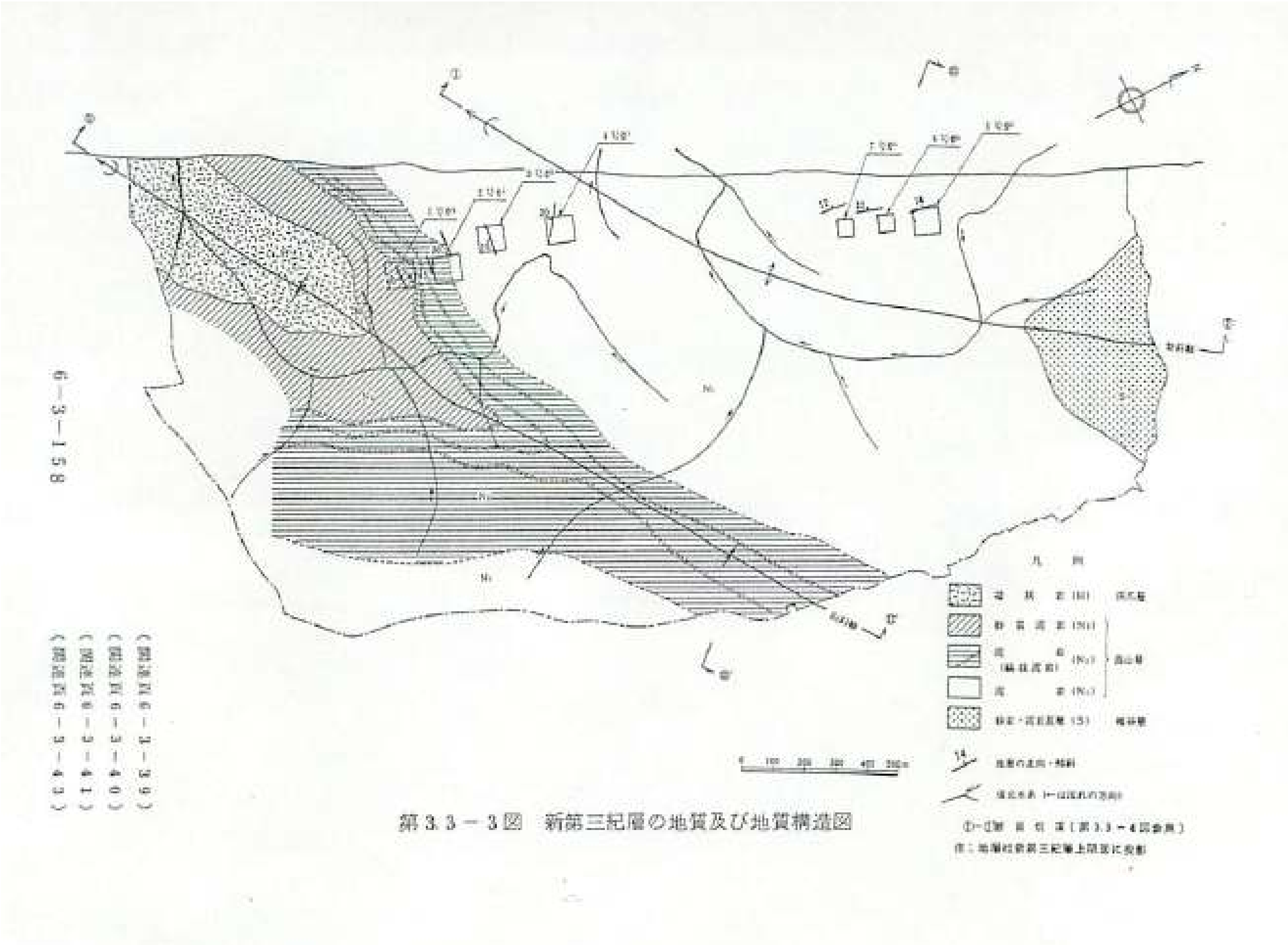


Fig. 3.3 – 3 : Geology and Geological Structure Map in Neogene layers (translated by IAEA Expert Team's support staff)

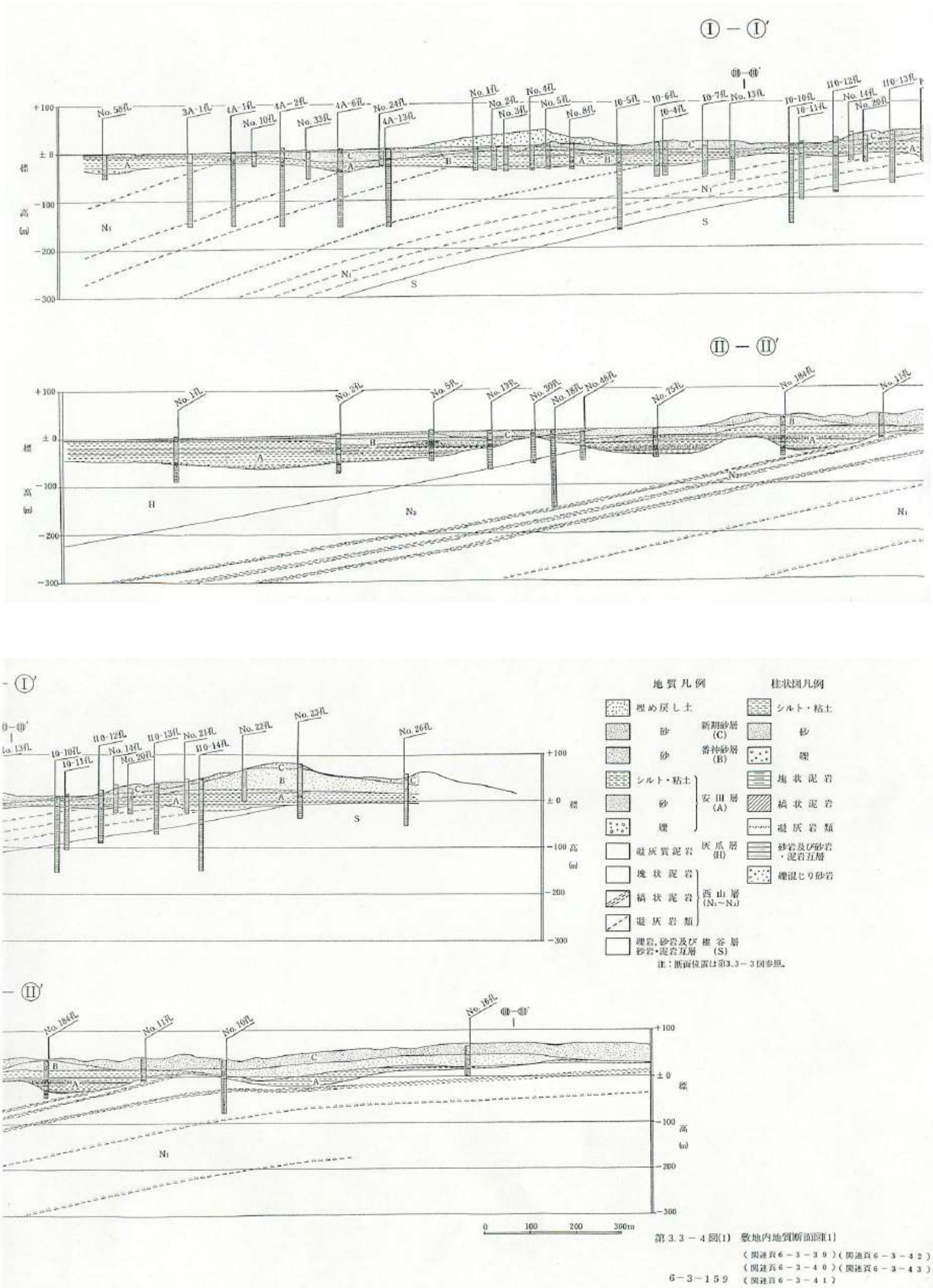


Fig. 3.3 -4 1: Geological profile in the site area. (translated by IAEA Expert Team’s support staff)

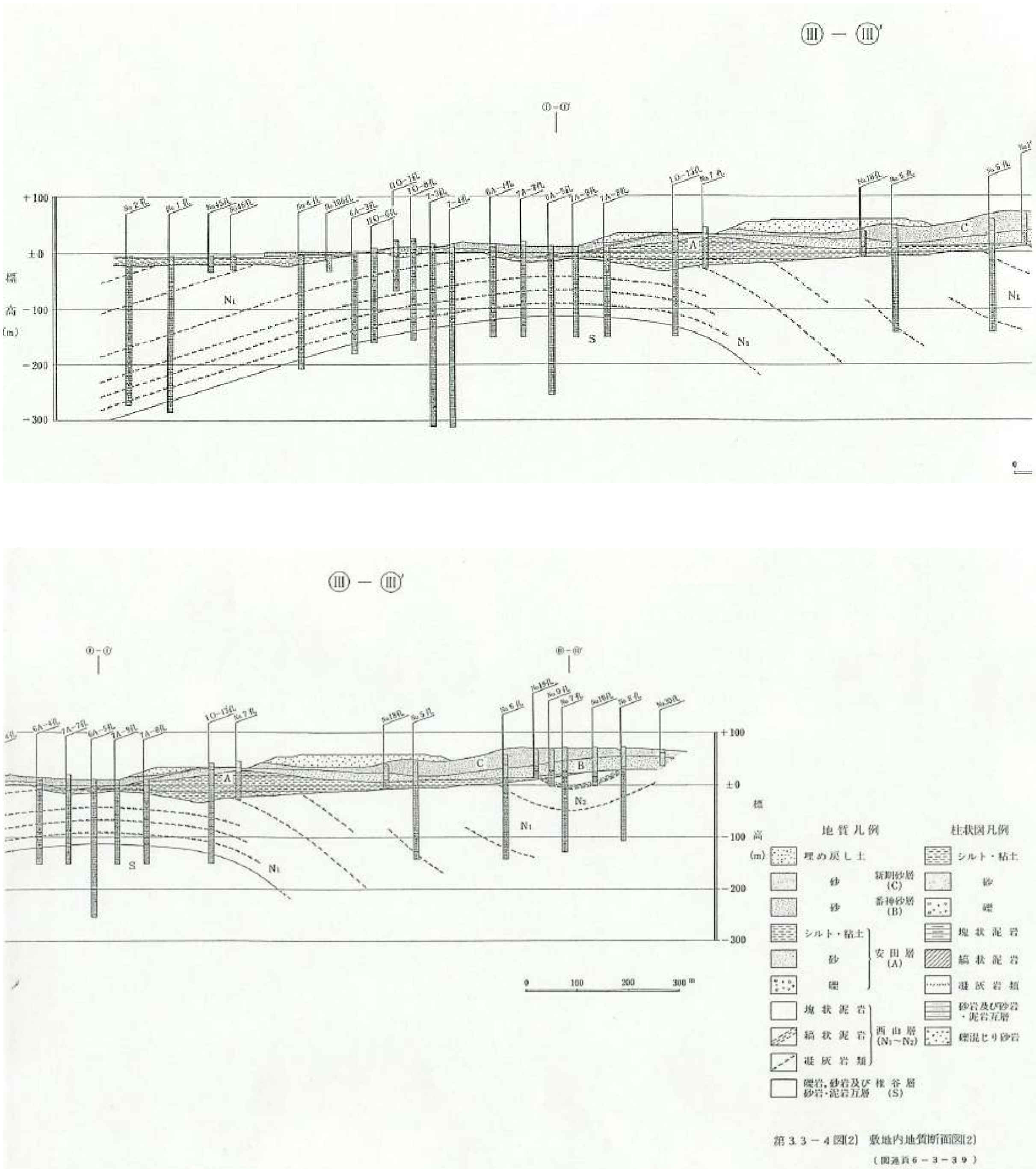
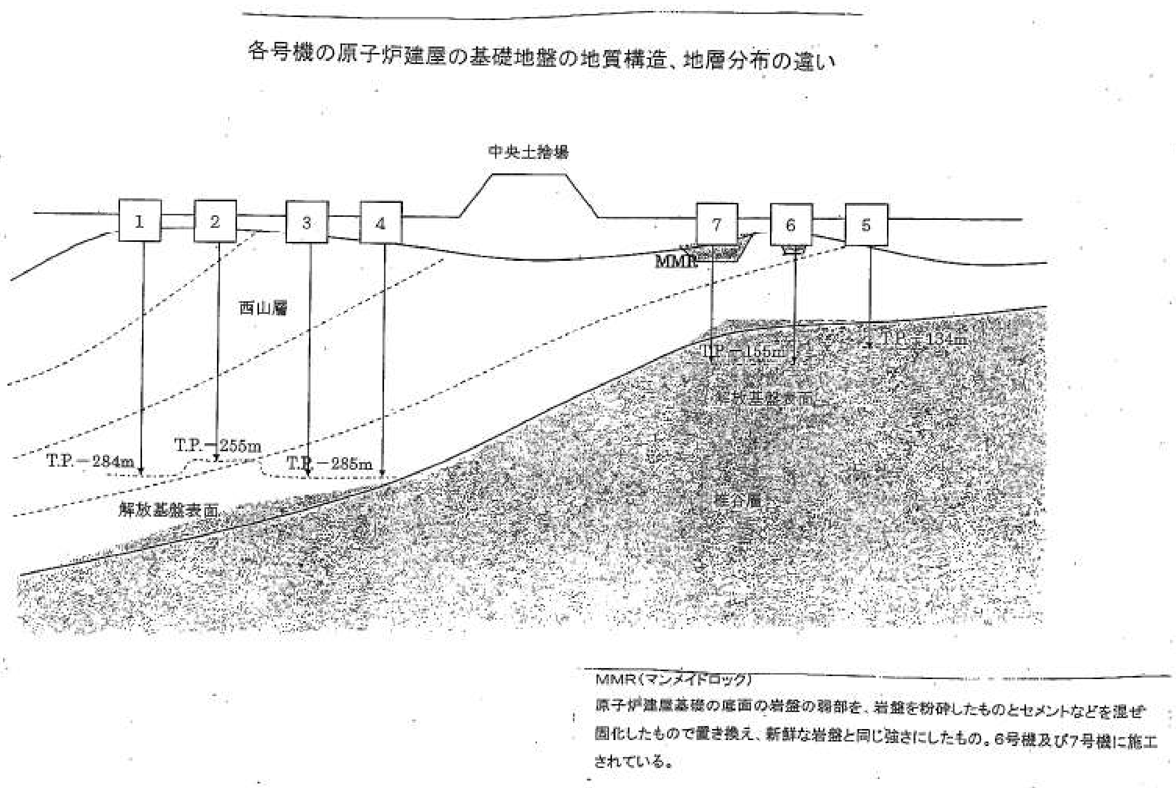


Fig. 3.3 -4 2: Geological profile in the site area. (translated by IAEA Expert Team's support staff)

Note from the IAEA Expert Team:

The “dark” substratum pertains to Lower Pliocene to Miocene.

Distribution of geological structures and soil/rock layers underlying the reactor buildings (translated by IAEA Expert Team’s support staff)



MMR (Man-Made Rock) is made of small rock mixed with cement replacing weak parts of the foundation material (Units 6 and 7), (translated by IAEA Expert Team’s support staff)

I.4. Foundation, Base Stratum and Seismic Input Levels for Units 1 -7

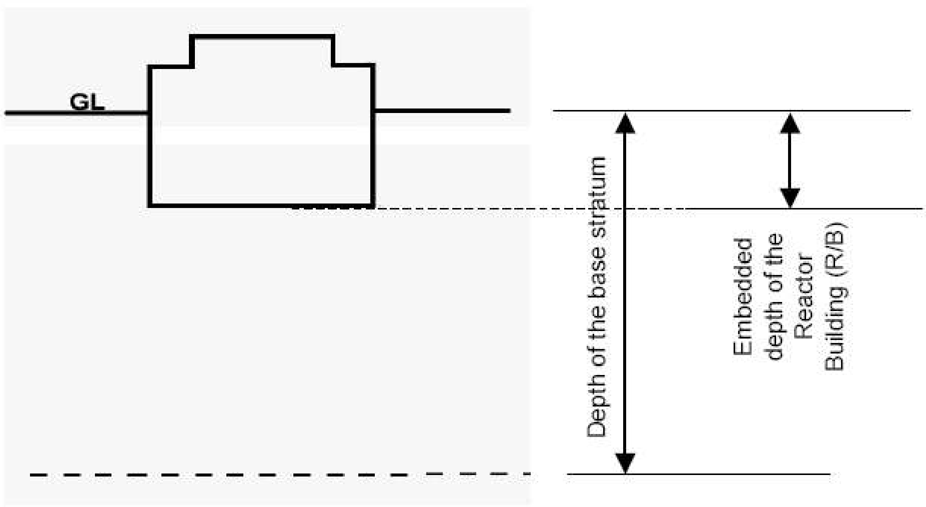
I.4.1. Embedded Depth and Depth to Base Stratum

Kashiwazaki-Kariwa NPPs

Depth of each unit's emvbedded R/B basement and the base stratum (input motion level for seismic design)

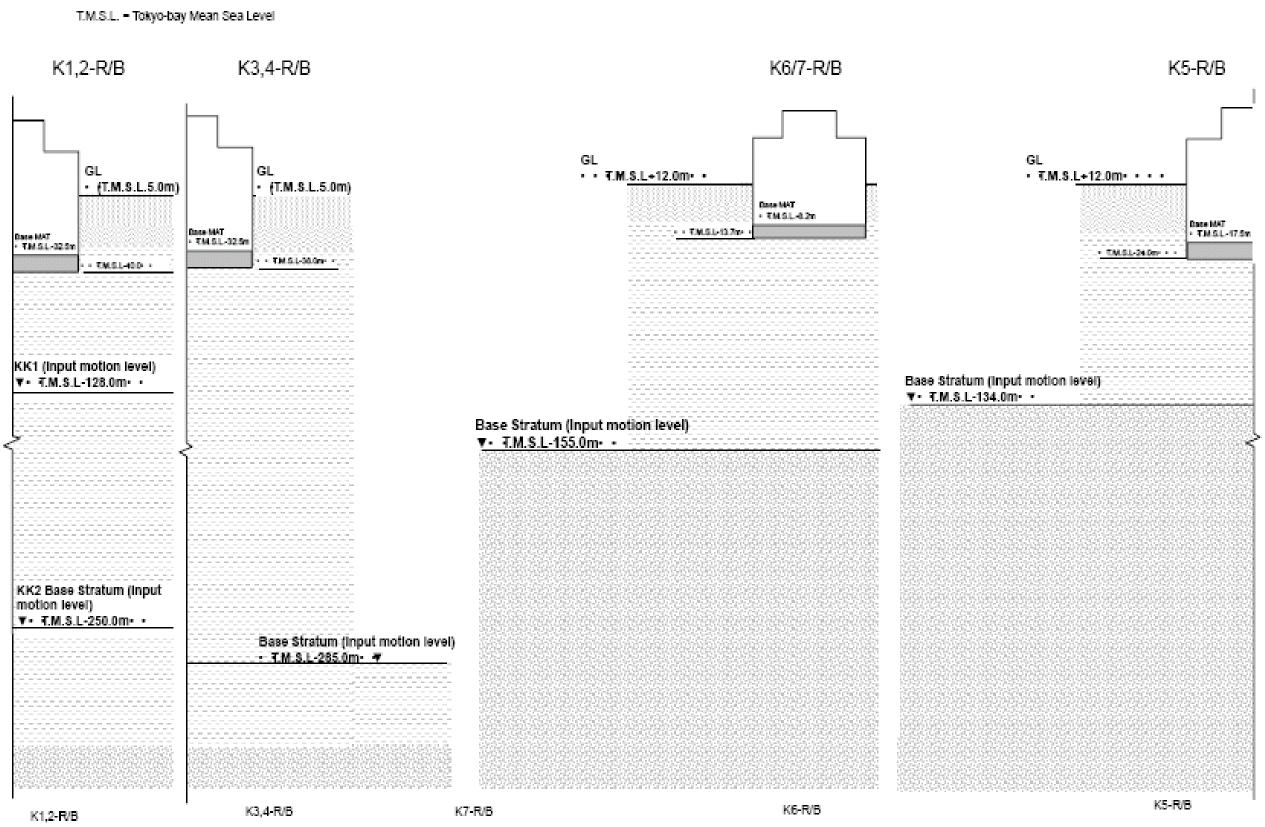
Unit	Embedded depth (m)	Depth of the base stratum (m)	GL Level
Unit 1	GL-45.0m	GL-133m	TMSL +5.0m
Unit 2	GL-44.0m	GL-255m	TMSL +5.0m
Unit 3	GL-43.0m	GL-290m	TMSL +5.0m
Unit 4	GL-43.0m	GL-290m	TMSL +5.0m
Unit 5	GL-36.0m	GL-146m	TMSL +12.0m
Unit 6	GL-25.7m	GL-167m	TMSL +12.0m
Unit 7	GL-25.7m	GL-167m	TMSL +12.0m

(TMSL=Tokyobay Mean Sea Level)



I.4.2. Input Motion and Base Stratum Levels for Units 1-7

T.M.S.L. : Tokyo Mean Sea Level



Depth of each unit's embedded R/B basement and the base stratum(Input motion level)

Note – IAEA Expert Team Comment:

Please, see also Background Document I.2 NISA presentation, slides #5 and #6. The "base stratum" (rock outcrop) is where the input position of the design basis ground motion is given. It is firm bedrock with a shear wave velocity higher than 700 m/sec as defined by the Japanese guidelines.

PART II – INFORMATION SPECIFIC TO THE THREE AREAS COVERED BY THE MISSION AS SUPPLIED BY THE JAPANESE COUNTERPART

II.A.1 - Seismic Design Basis, Instrumental Records and Re-Evaluation of the Seismic Hazard

II.A.1.1. TEPCO presentation on 06-08-2007 titled “2007 Niigataken Chuetsu-oki earthquake, Kashiwazaki-Kariwa NPP – seismic design basis and actual records”

II.A.1.2. TEPCO presentation on 07-08-2007 in response to IAEA questions on: (i) recorded in-structure response spectra, (ii) aftershock records, (iii) evaluation of active faults in the offshore area.

II.A.1.3. Location of seismic instrumentation and automatic scram sensors

II.A.1.4. Response spectra of the recorded motions (surface and down hole) at the PR Hall and Observation Houses #1 and #5.

II.A.1.5. Response spectra of the recorded vertical motions at foundation mat levels.

II.A.1.6. Technical Specification for Seismic Instrumentation

II.A.1.1. Seismic design basis and actual records – Presentation by TEPCO

2007 Niigataken Chuetsu-oki Earthquake

Kashiwazaki-Kariwa NPP
Seismic Design Basis and Actual Records

TEPCO
6 August 2007

東京電力
TEPCO

Contents

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1. Overview of the earthquake
2. Design Basis of the KK site
3. Instrumental records in the KK NPPs
4. Comparison between design basis and actual records

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1. Overview of the Earthquake (2007 Niigataken chuetsu-oki eq)

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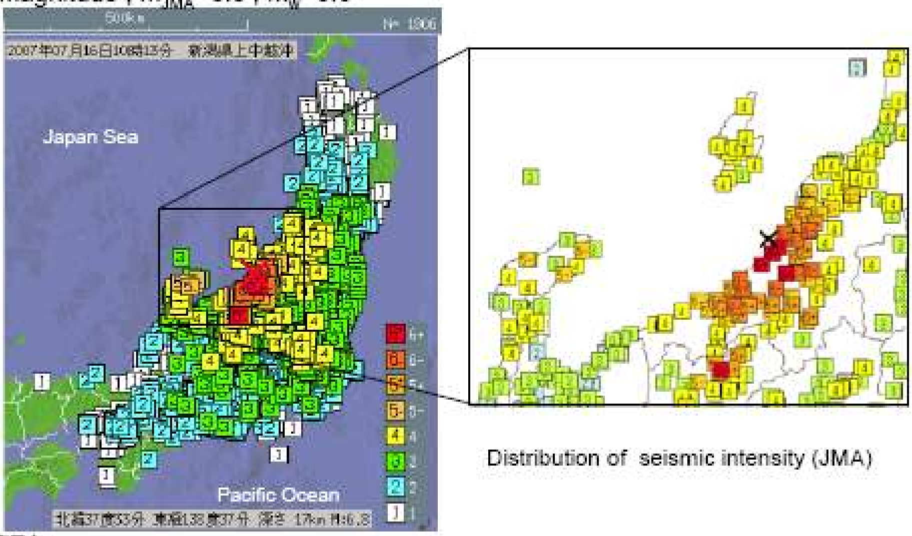
Outline of the Earthquake

- Date ; 10h13 (JMT=GMT+9h), 16 July 2007
- Hypocenter ; offshore mid Niigata prefecture
- Depth ; 17km (JMA: Japan Meteorological Agency)
- Magnitude ; M_{JMA}=6.8 , M_w=6.6



Distribution of seismic intensity (JMA)

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Epicenter and the KK site

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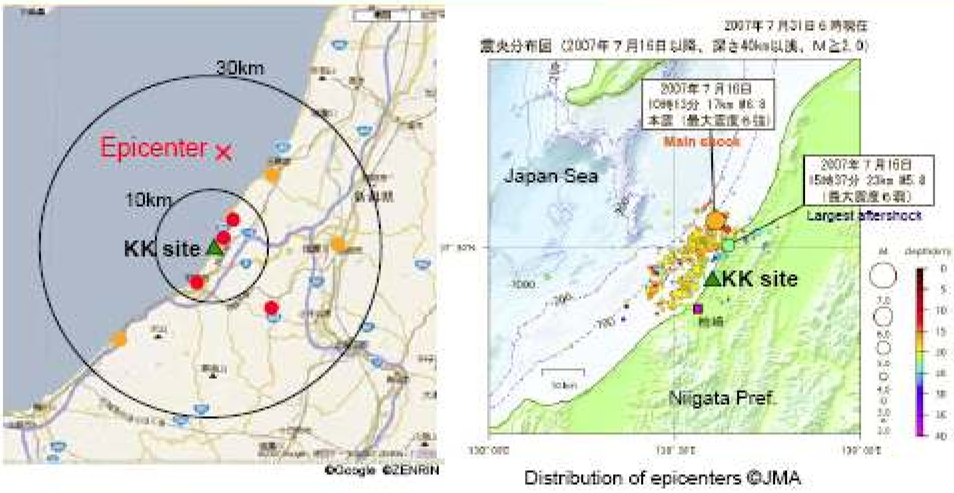

- Distance to the epicenter from KK site ; 16km
- Seismic Intensity (JMA) ;
  - 6^+ (upper) : Kashiwazaki, Kariwa, Nishiyama, Oguni
  - 6^- (lower) : Kakizaki, Izumozaki , Nagaoka

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Attenuation of amplitude

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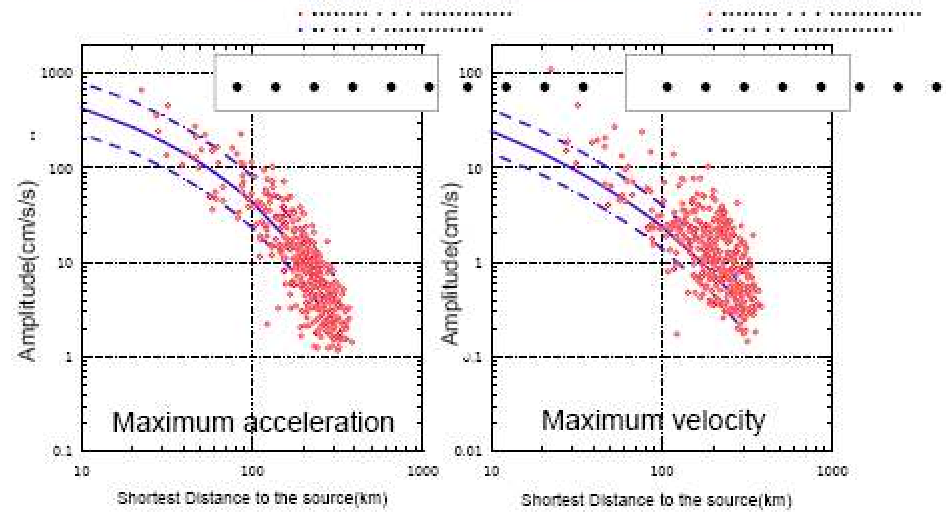

Dot (red) : Observation records (K-NET NIED)

Solid / Broken lines (blue) : Empirical attenuation relation (Si & Midorikawa) mean / SD

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2. Design Basis of the KK site

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Basic Concepts of seismic design for NPP in Japan

- Intensive **Geological and Seismological Survey**
- Consideration of **maximum earthquake** based on the survey
- **Rigid Structure** constructed directly on **solid rock**
- **3 times** as strong as general buildings
- **Automatic shutdown** in case of large shaking

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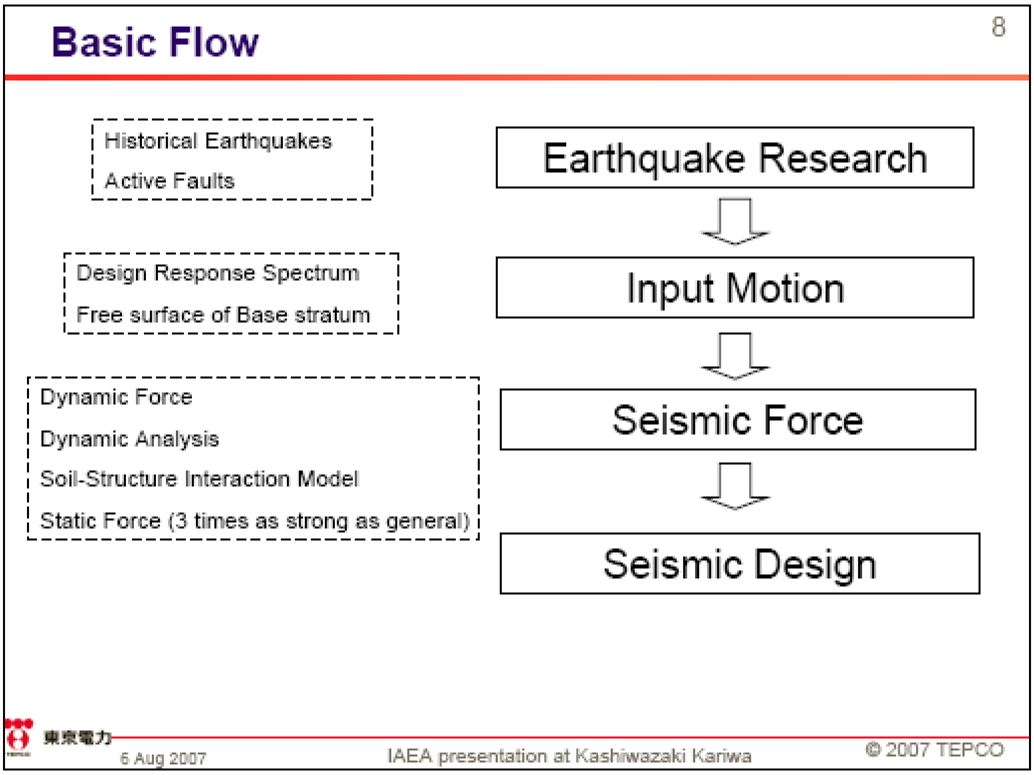
Basic Flow
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Historical Earthquakes
Active Faults
Design Response Spectrum
Free surface of Base stratum
Dynamic Force
Dynamic Analysis
Soil-Structure Interaction Model
Static Force (3 times as strong as general)
Earthquake Research
Input Motion
Seismic Force
Seismic Design
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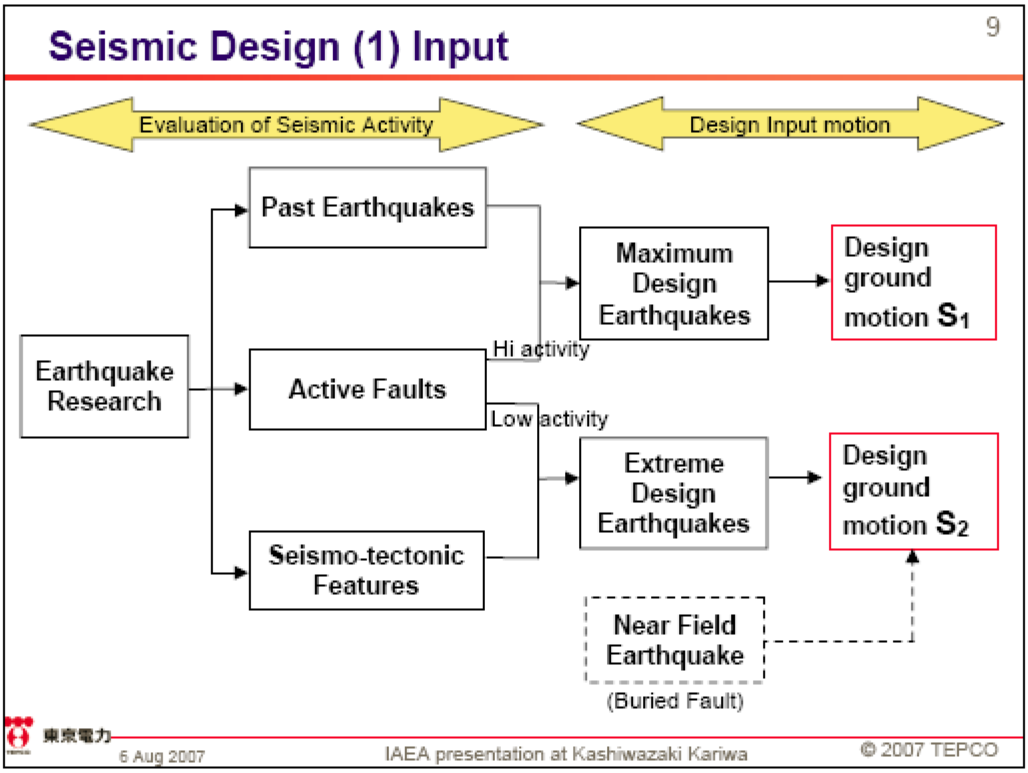
Seismic Design (1) Input
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Evaluation of Seismic Activity
Design Input motion
Earthquake Research
Past Earthquakes
Active Faults
Seismo-tectonic Features
Hi activity
Low activity
Maximum Design Earthquakes
Extreme Design Earthquakes
Design ground motion S_1
Design ground motion S_2
Near Field Earthquake
(Buried Fault)
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Design Earthquakes

Past Earthquakes

1614 and 1828 earthquakes (solid circles) are selected as Maximum Design Earthquakes for KK site.

The former is regarded as far earthquake, and the latter as near earthquake.

Many other earthquakes will cause less effect or damage in the site than MDEs.

Active Fault

Two active faults (thick lines) are selected as Design Earthquakes for KK site.

Kihinomiya Fault (M6.9)

Western margin of Chuo-kyuryo(central hills) Fault (M6.7)

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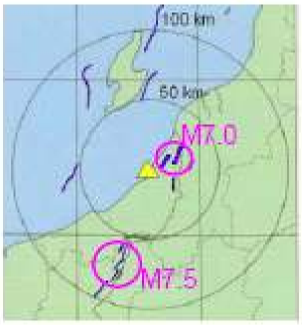
11

Design Earthquakes



Seismo-tectonic features

M7.5 : Northern Nagano pref. considering fault length and the historical earthquake occurred in 1847(Zenkoji eq. M7.4).

M7.0 : Downstream region of the Shinano River considering the Kihinomiya fault and historical quakes.

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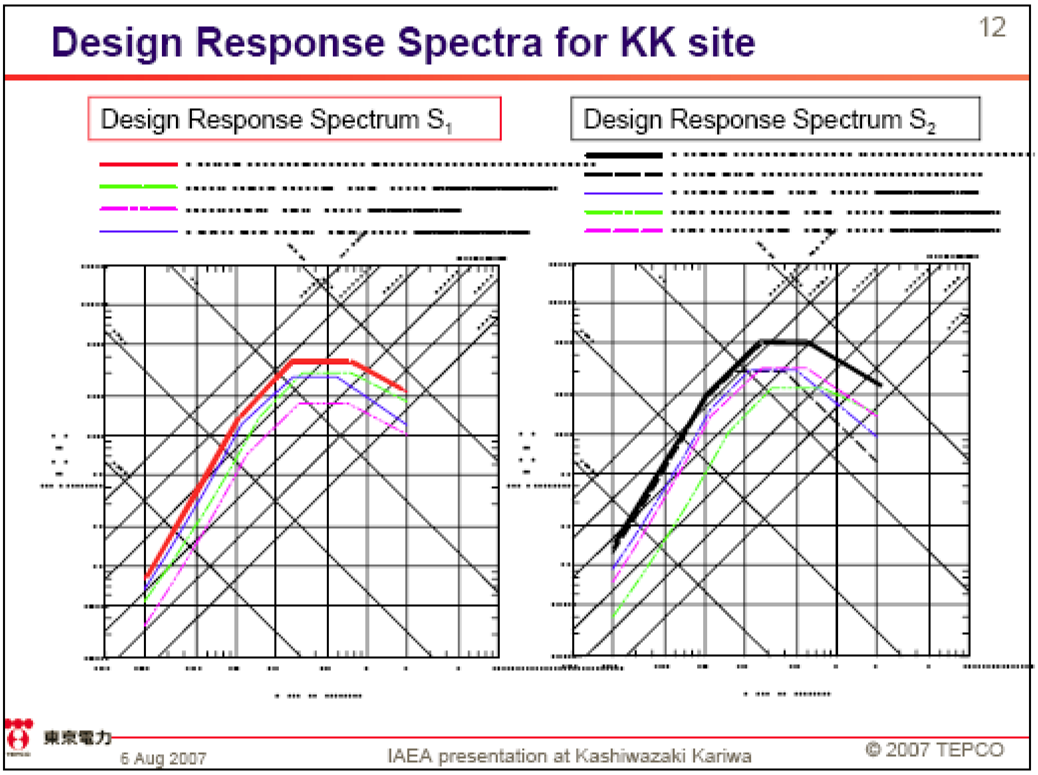
Design Response Spectra for KK site
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Design Response Spectrum S_1
Design Response Spectrum S_2
6 Aug 2007
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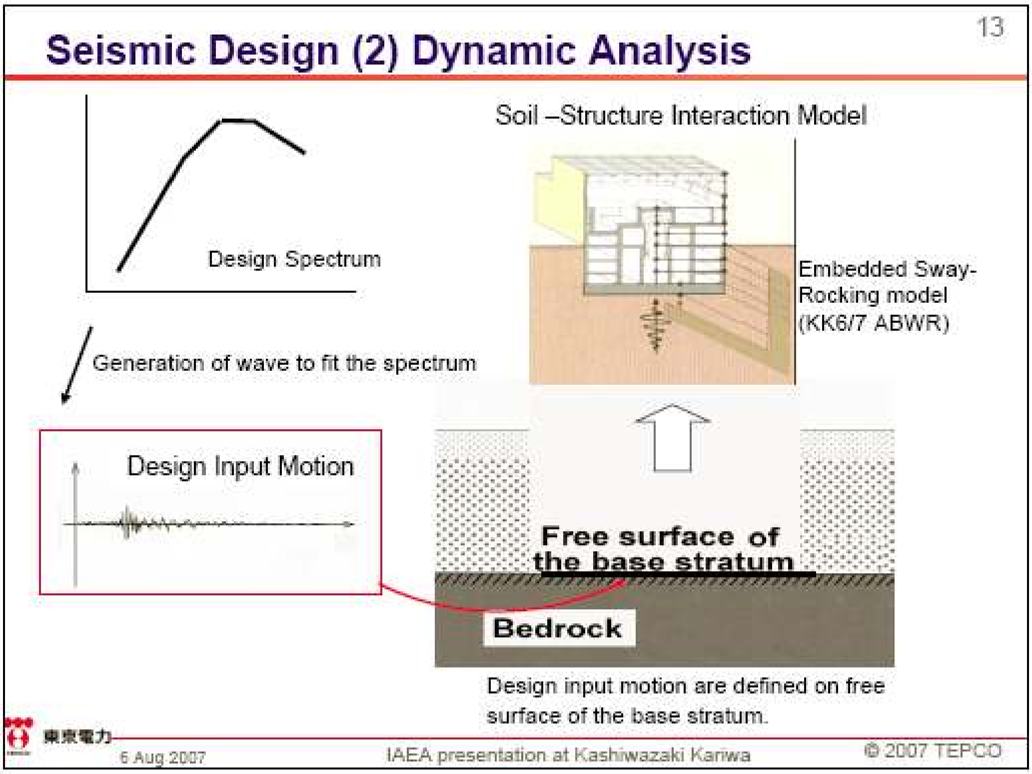
Seismic Design (2) Dynamic Analysis
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Design Spectrum
Generation of wave to fit the spectrum
Design Input Motion
Soil –Structure Interaction Model
Embedded Sway-Rocking model (KK6/7 ABWR)
Free surface of the base stratum
Bedrock
Design input motion are defined on free surface of the base stratum.
6 Aug 2007
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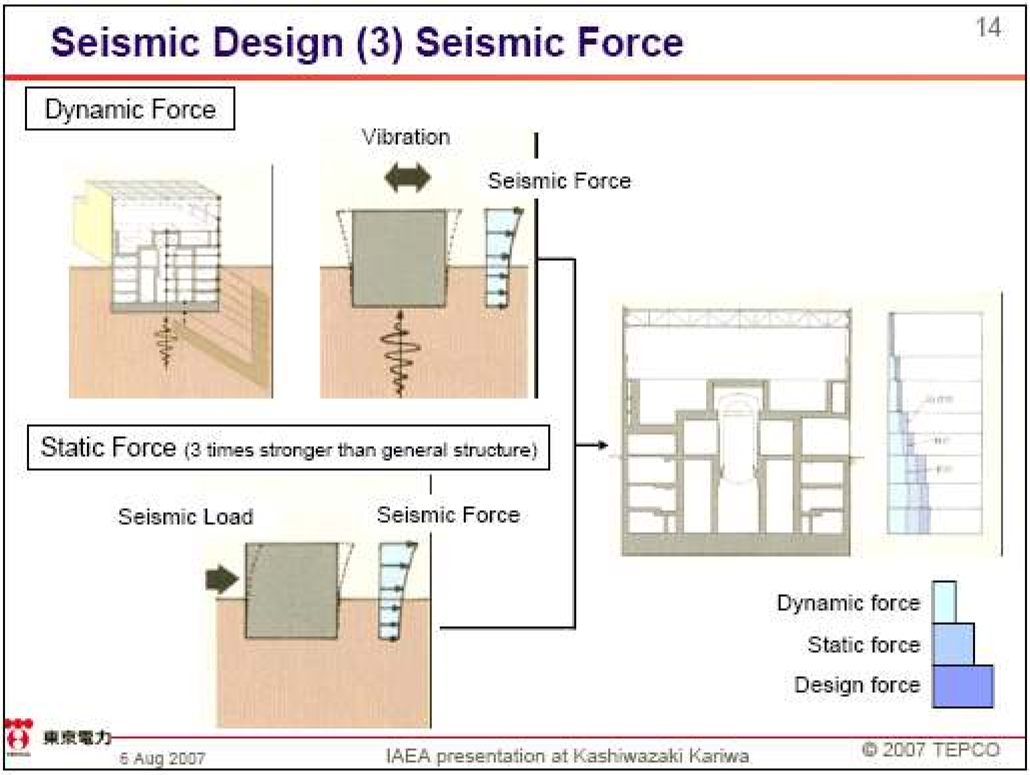

15

3. Instrumental Records in the KK NPPs

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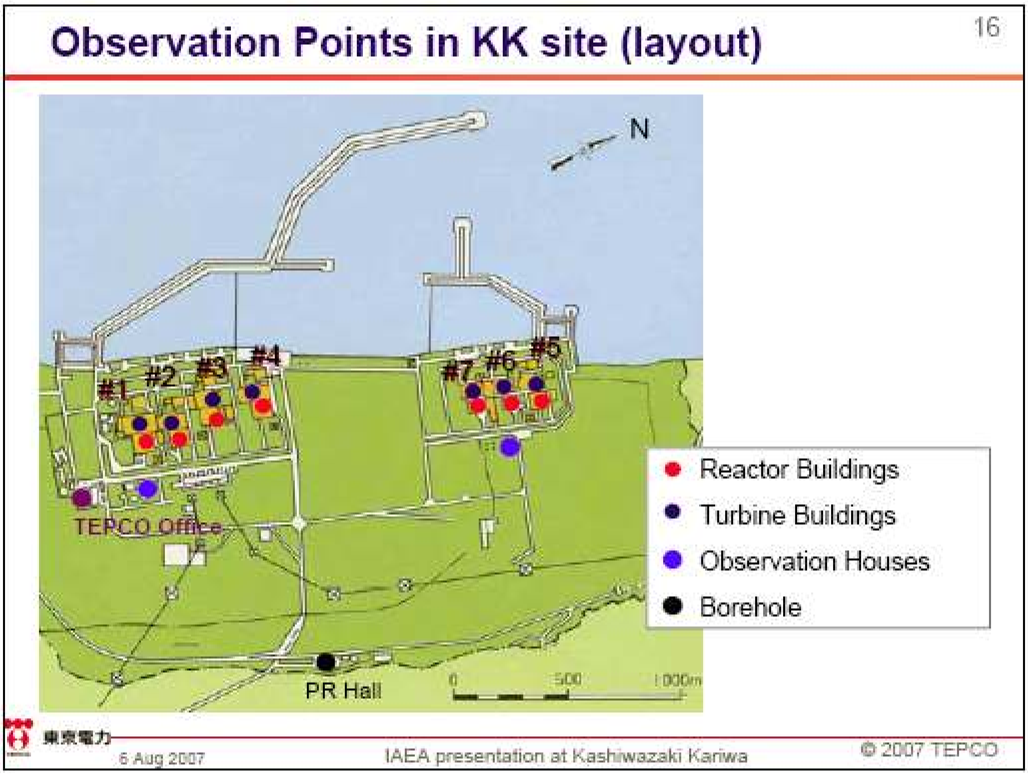
Observation Points in KK site (layout)
16
N
#1
#2
#3
#4
#5
#6
#7
TEPCO Office
PR Hall
Reactor Buildings
Turbine Buildings
Observation Houses
Borehole
0
500
1000m
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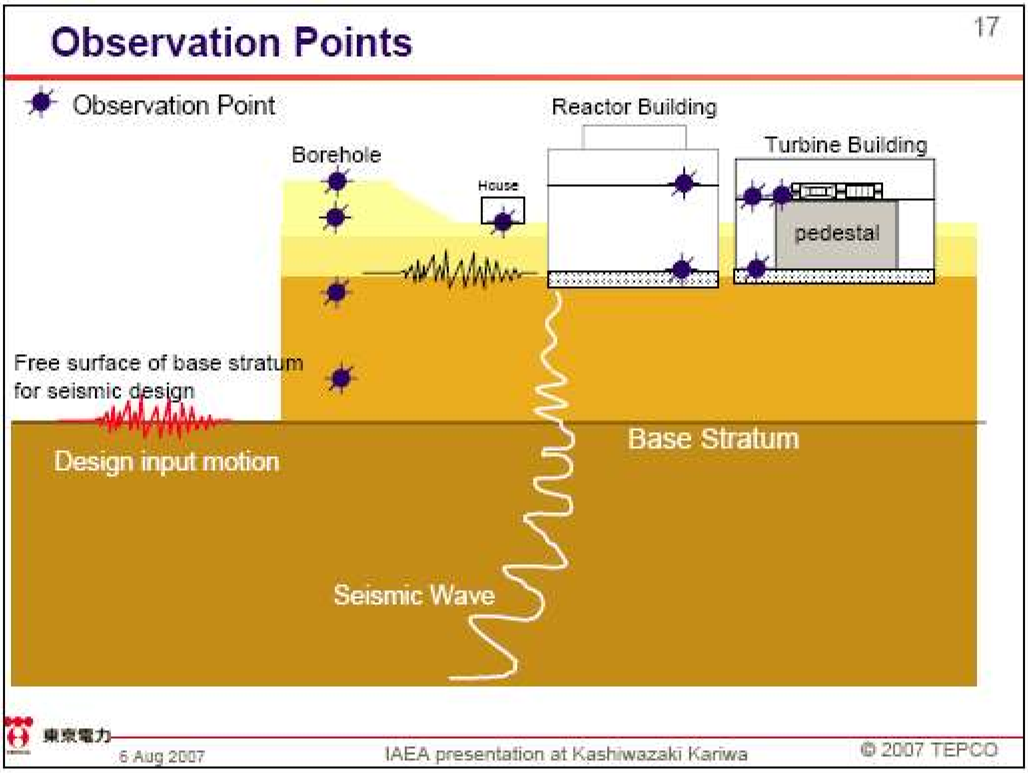
Observation Points
17
Observation Point
Reactor Building
Turbine Building
Borehole
House
pedestal
Free surface of base stratum
for seismic design
Design input motion
Base Stratum
Seismic Wave
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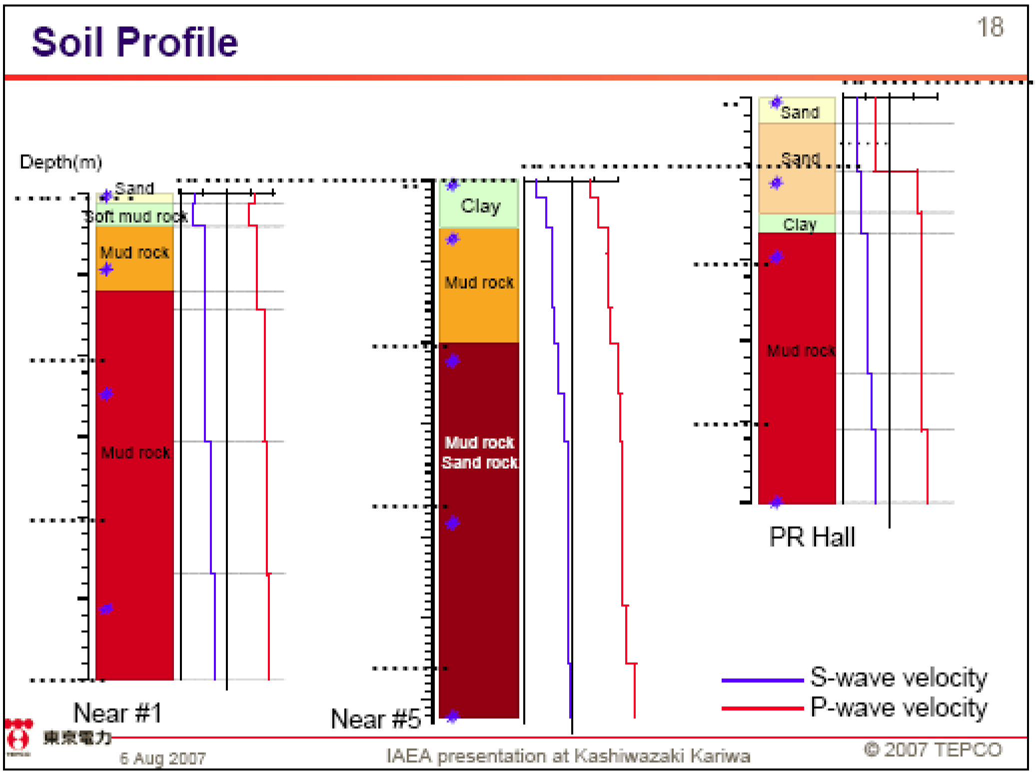
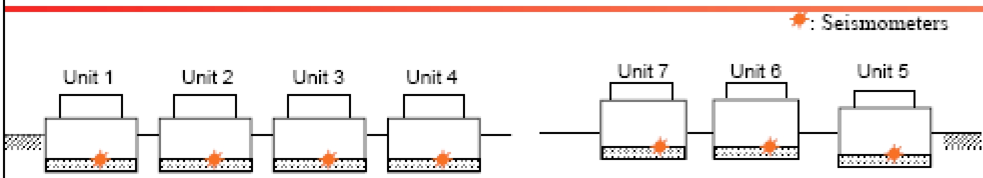


Observation Records on R/B base mat

19



Gal:cm/s/s

Observation point				Observed Maximun Acc.			Design value	
				NS	EW	UD	NS	EW
Unit1	R/B	1-R2	B5F(Base Mat)	311	680	408	274	273
Unit2	R/B	2-R2	B5F(Base Mat)	304	606	282	167	167
Unit3	R/B	3-R2	B5F(Base Mat)	308	384	311	192	193
Unit4	R/B	4-R2	B5F(Base Mat)	310	492	337	193	194
Unit5	R/B	5-R2	B5F(Base Mat)	277	442	205	249	254
Unit6	R/B	6-R2	B5F(Base Mat)	271	322	488	263	263
Unit7	R/B	7-R2	B5F(Base Mat)	267	356	355	263	263

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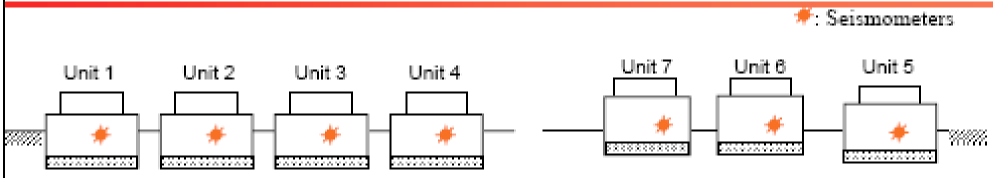
Observation Records on R/B intermediate story



Gal:cm/s/s

Observation point				Observed Maximun Acc.			Design value	
				NS	EW	UD	NS	EW
Unit1	R/B	1-R1	2F	599	884	394	460	463
Unit2	R/B	2-R1	2F	517	718	412	271	271
Unit3	R/B	3-R1	2F	525	650	518	314	309
Unit4	R/B	4-R1	2F	606	713	548	299	293
Unit5	R/B	5-R1	3F	472	697	331	354	350
Unit6	R/B	6-R1	3F	554	545	578	415	411
Unit7	R/B	7-R1	3F	367	435	464	415	411

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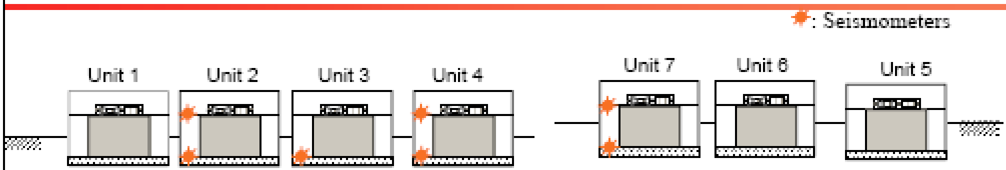
Observation Records on T/B base mat and OP floor



Gal:cm/s/s

Observation point				Observed Maximun Acc.			Design value	
				NS	EW	UD	NS	EW
Unit2	T/B	2-T3	B3F(Base Mat)	387	681	470	233	232
Unit2	T/B	2-T1	1F(Operating Floor)	431	764	594	295	259
Unit3	T/B	3-T3	B3F(Base Mat)	581	549	513	239	243
Unit4	T/B	4-T3	B3F(Base Mat)	348	442	443	238	242
Unit4	T/B	4-T1	1F(Operating Floor)	411	560	549	269	267
Unit7	T/B	7-T3	B3F(Base Mat)	318	322	336	299	312
Unit7	T/B	7-T1	2F(Operating Floor)	418	506	342	394	418

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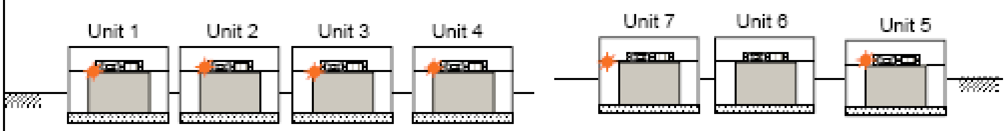
Observation Records on T/B pedestal



Gal:cm/s/s

Observation point				Observed Maximun Acc.			Design value	
				NS	EW	UD	NS	EW
Unit1	T/B	1-T2	1F (Pedestal)	1862	1459	741	(274)	(274)
Unit2	T/B	2-T2	1F (Pedestal)	642	1159	650	588	476
Unit3	T/B	3-T2	1F (Pedestal)	1350	2058	619	854	834
Unit4	T/B	4-T2	1F (Pedestal)	614	763	526	832	838
Unit5	T/B	5-T2	2F (Pedestal)	1166	1157	533	995	754
Unit7	T/B	7-T2	2F (Pedestal)	673	1007	362	1096	859

* For vertical direction, we use parameters shown in ( ) in static design.

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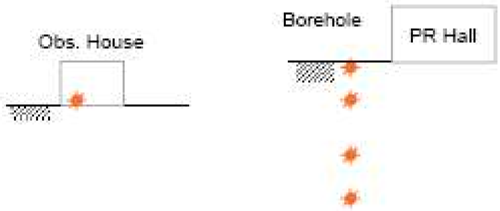
Observation Records in borehole and ground level



Gal:cm/s/s

Observation point				Observed Maximun Acc.		
				NS	EW	UD
In the Obs.House	near Unit 1		Ground Level	890	890	715
	near Unit 5			964	1223	539
Borehole	PR Hall	SG1	GL -2.4m	347	437	590
		SG2	GL -50.8m	340	411	179
		SG3	GL -99.4m	403	647	174
		SG4	GL -250m	430	728	160

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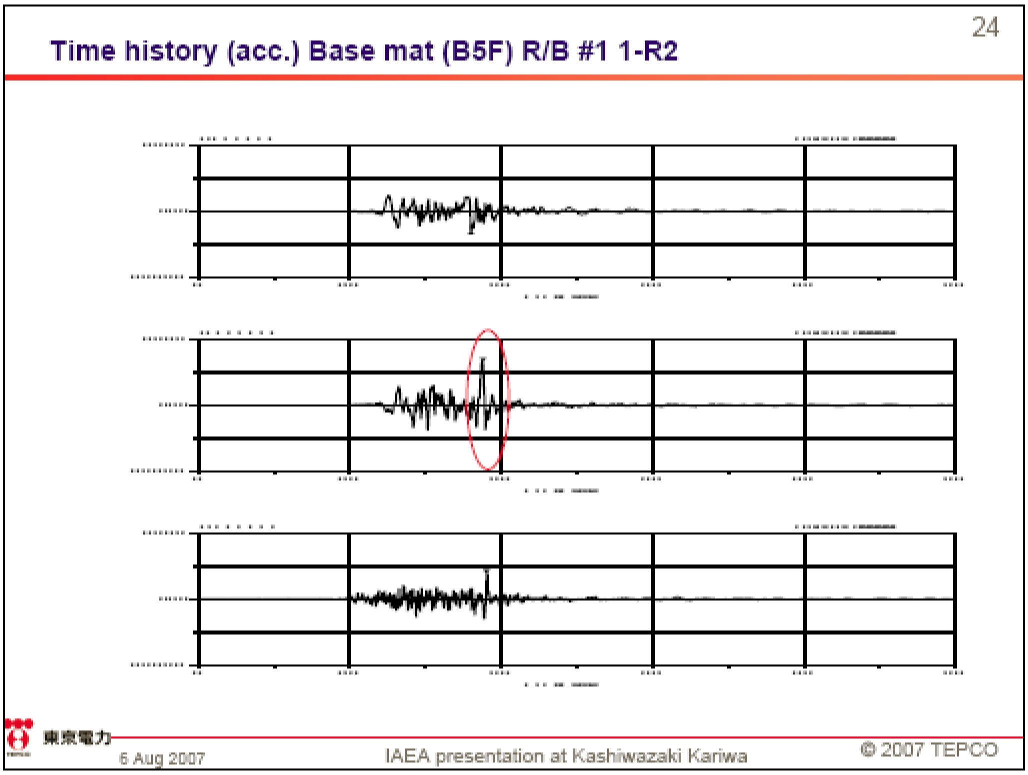
24
Time history (acc.) Base mat (B5F) R/B #1 1-R2
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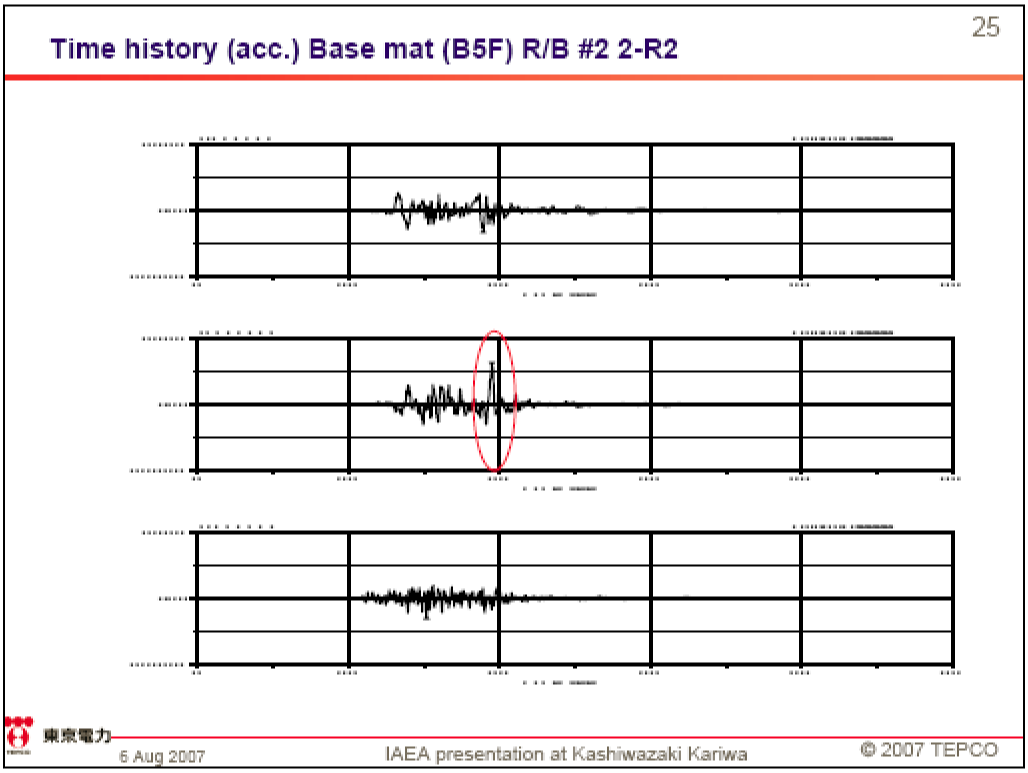
25
Time history (acc.) Base mat (B5F) R/B #2 2-R2
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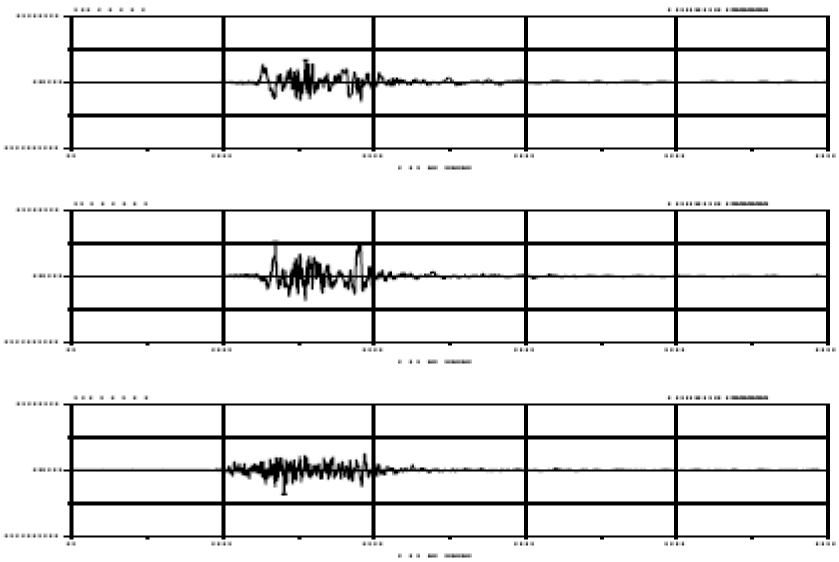
26

Time history (acc.) Base mat (B5F) R/B #4 4-R2



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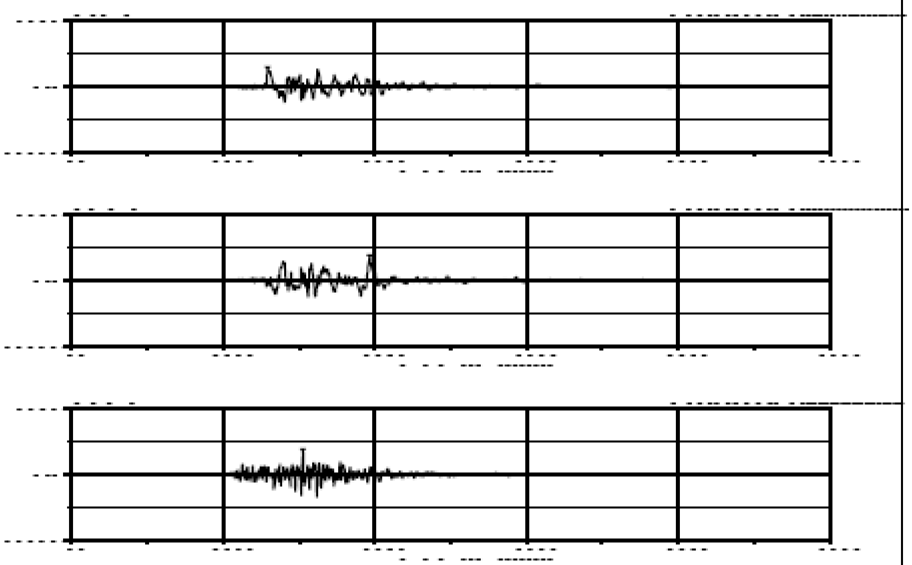
27

Time history (acc.) Base mat (B3F) R/B #7 7-R2



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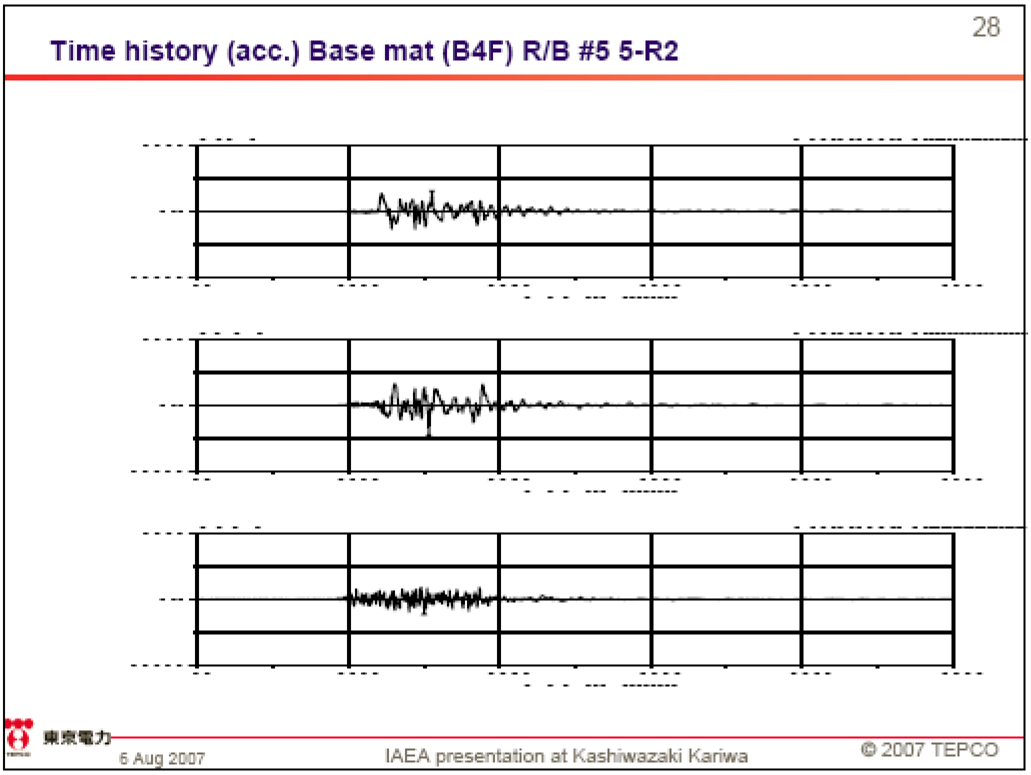
28
Time history (acc.) Base mat (B4F) R/B #5 5-R2
東京電力
6 Aug 2007
IAEA presentation at Kashiwazaki Kariwa
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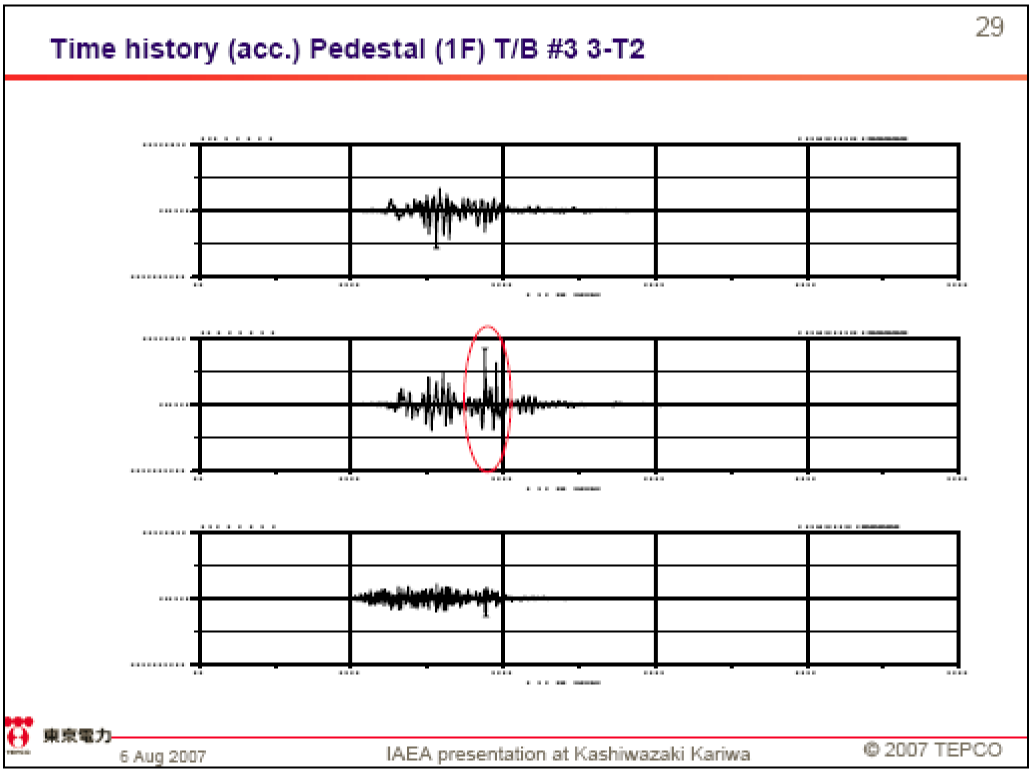
29
Time history (acc.) Pedestal (1F) T/B #3 3-T2
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6 Aug 2007
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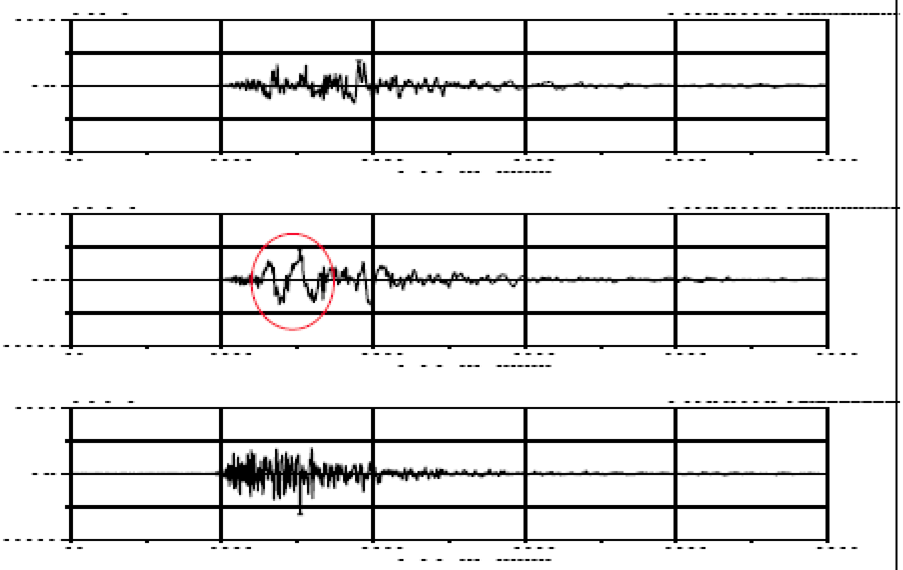
30

Time history (acc.) Borehole (G.L. -2.4m) SG1



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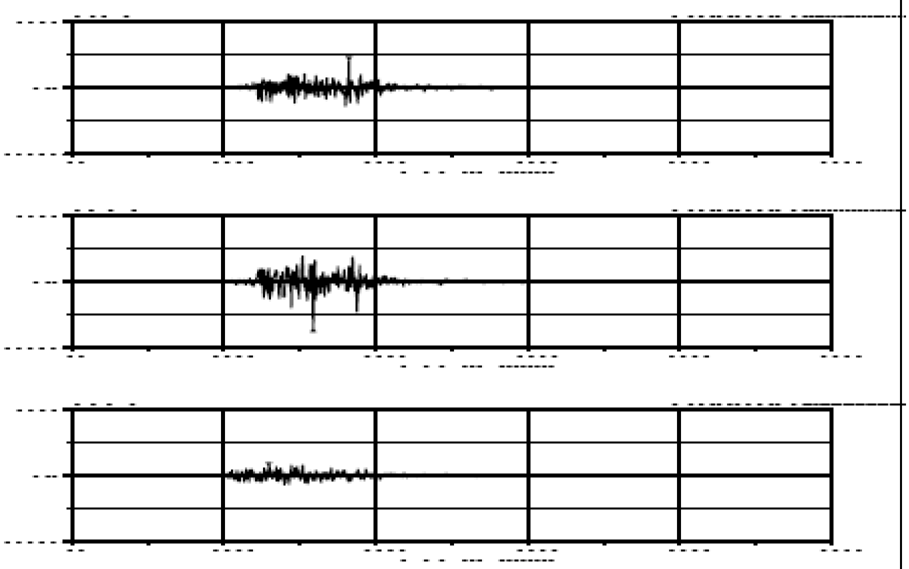
31

Time history (acc.) Borehole (G.L. -250m) SG4



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4. Comparison between design basis and actual records

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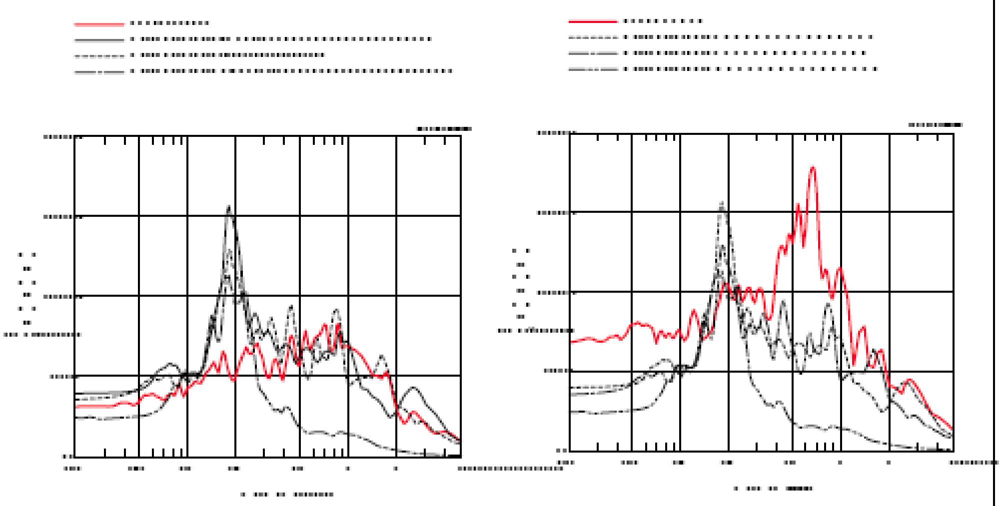
33

Response Spectra (acc.) Base mat (B5F) R/B #1 1-R2

Observed
Design



NS EW

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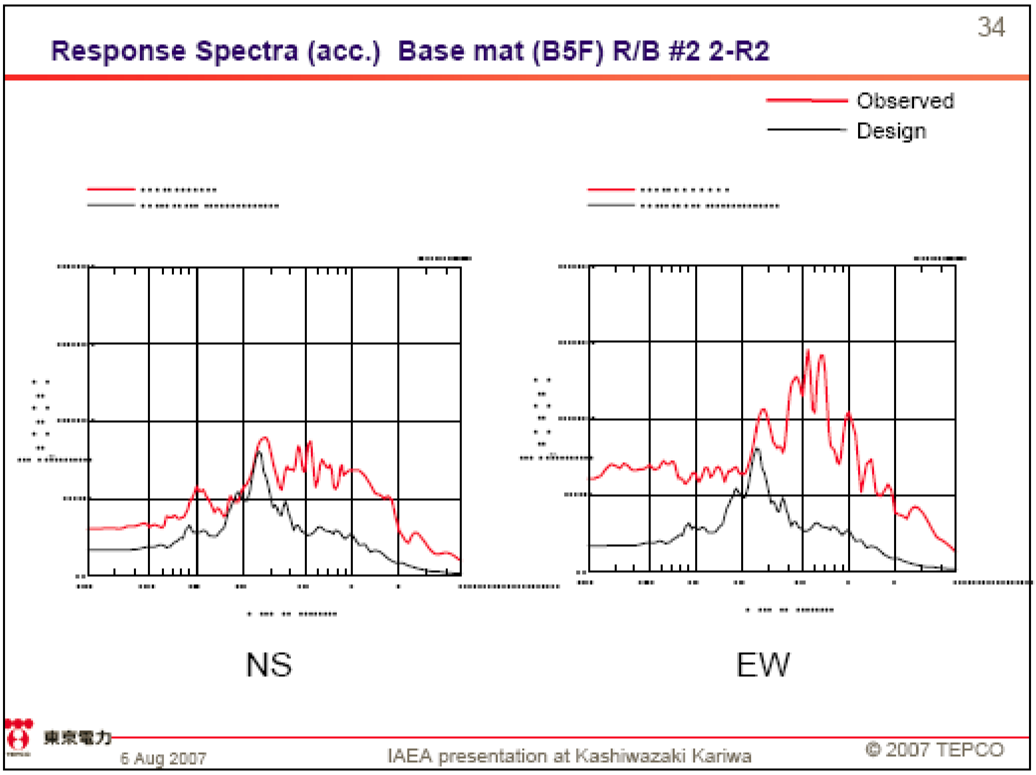
34
Response Spectra (acc.) Base mat (B5F) R/B #2 2-R2
Observed
Design
NS
EW
東京電力
6 Aug 2007
IAEA presentation at Kashiwazaki Kariwa
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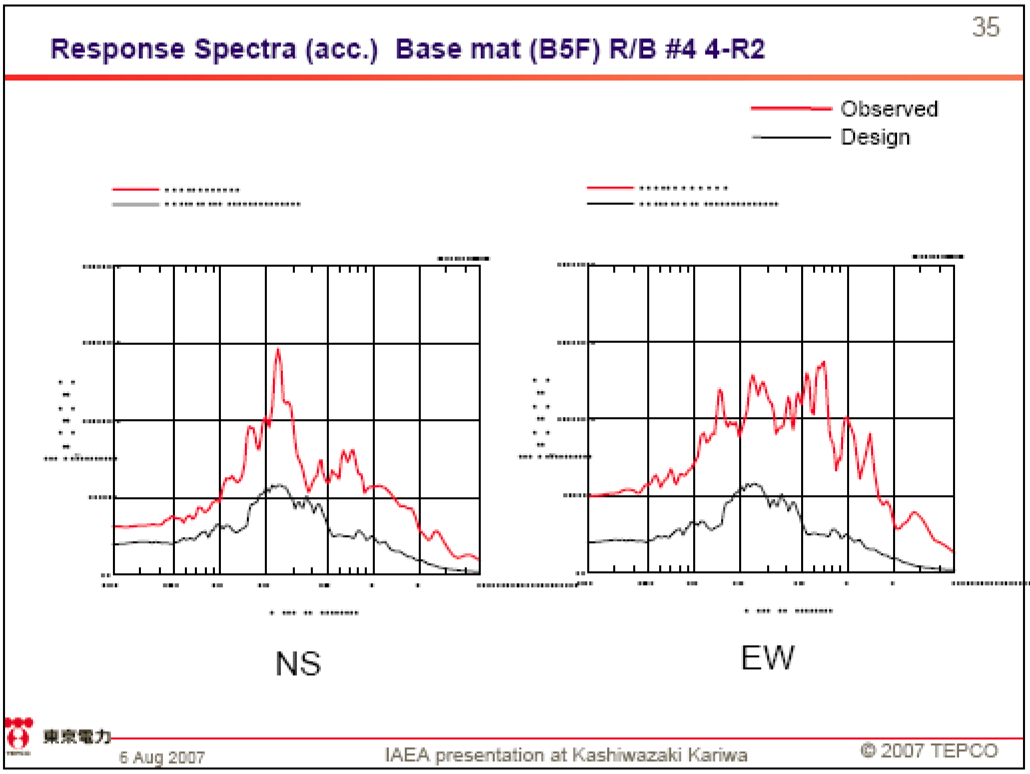
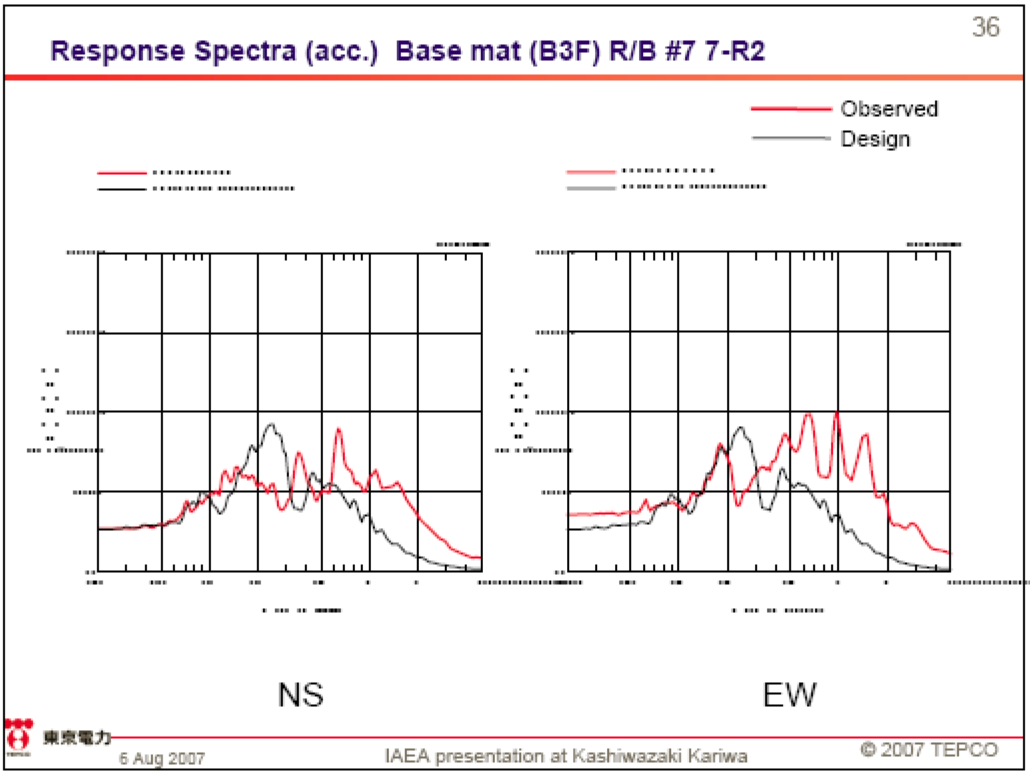
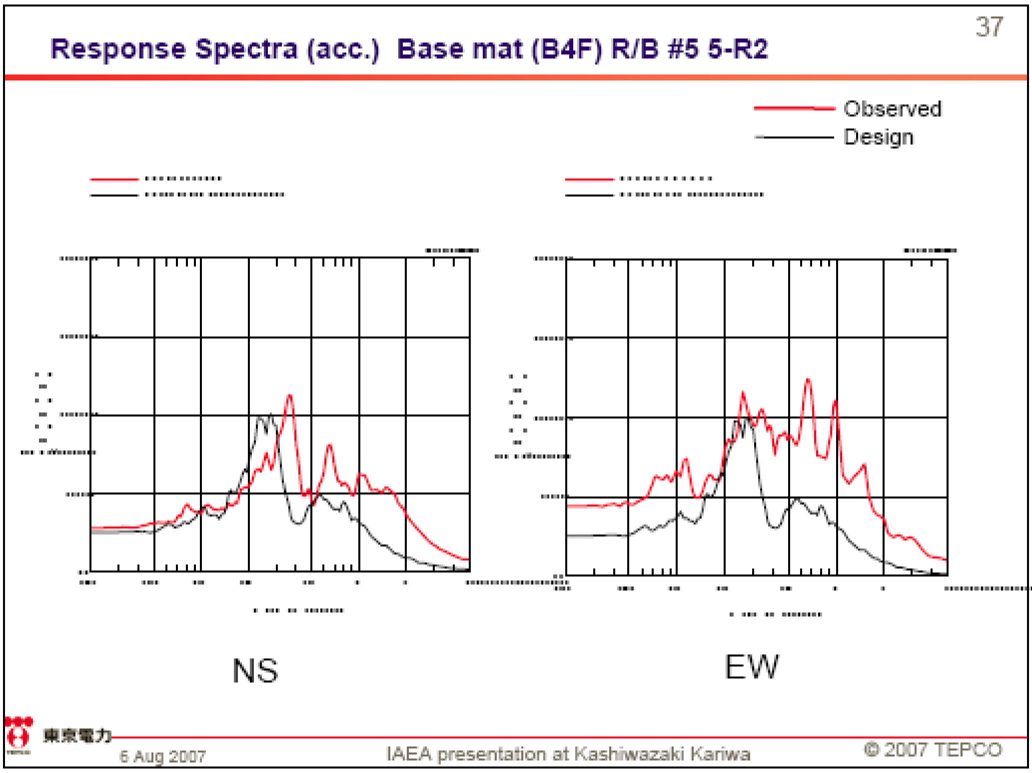

35
Response Spectra (acc.) Base mat (B5F) R/B #4 4-R2
Observed
Design
NS
EW
東京電力
6 Aug 2007
IAEA presentation at Kashiwazaki Kariwa
© 2007 TEPCO


36
Response Spectra (acc.) Base mat (B3F) R/B #7 7-R2
Observed
Design
NS
EW
東京電力
6 Aug 2007
IAEA presentation at Kashiwazaki Kariwa
© 2007 TEPCO


37
Response Spectra (acc.) Base mat (B4F) R/B #5 5-R2
Observed
Design
NS
EW
東京電力
6 Aug 2007
IAEA presentation at Kashiwazaki Kariwa
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II.A.1.2. Seismic design basis for K-K NPP - Presentation by TEPCO.

In following pages is included the TEPCO presentation in response to IAEA questions on:

(i) recorded in-structure response spectra,

(ii) aftershock records,

(iii) evaluation of active faults in the offshore area.

contents

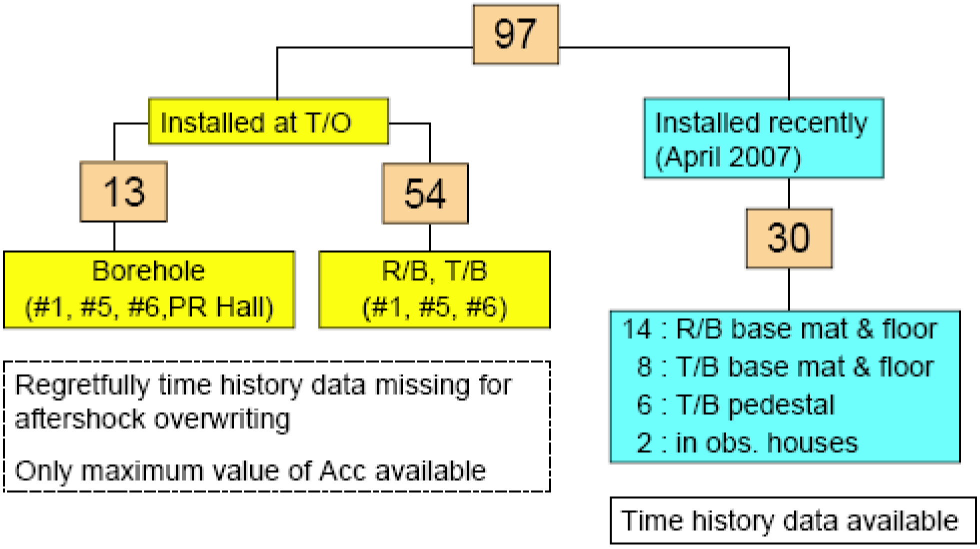
1. In-structure spectra
2. Aftershock records
3. Evaluation of Active faults including offshore investigation

Tue 7th August 2

1. In-structure spectra
   1.1 Observation points
   1.2 Records

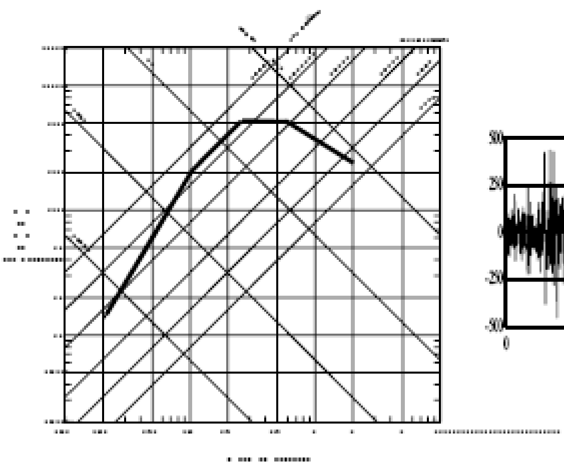
Tue 7th August 3

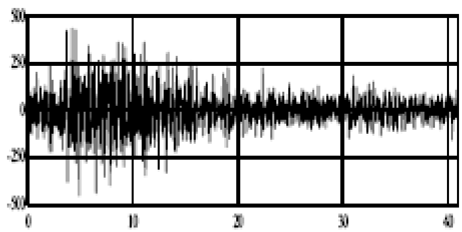
Number of seismometers in KK site



Tue 7th August 4

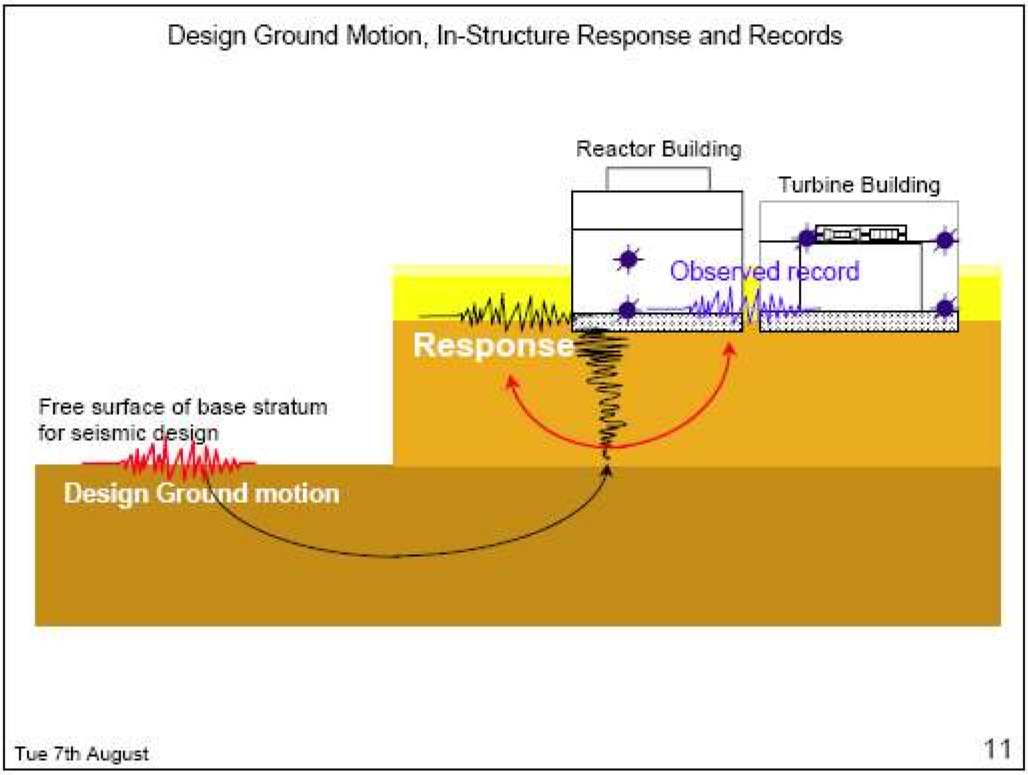
Design Ground Motion S_2

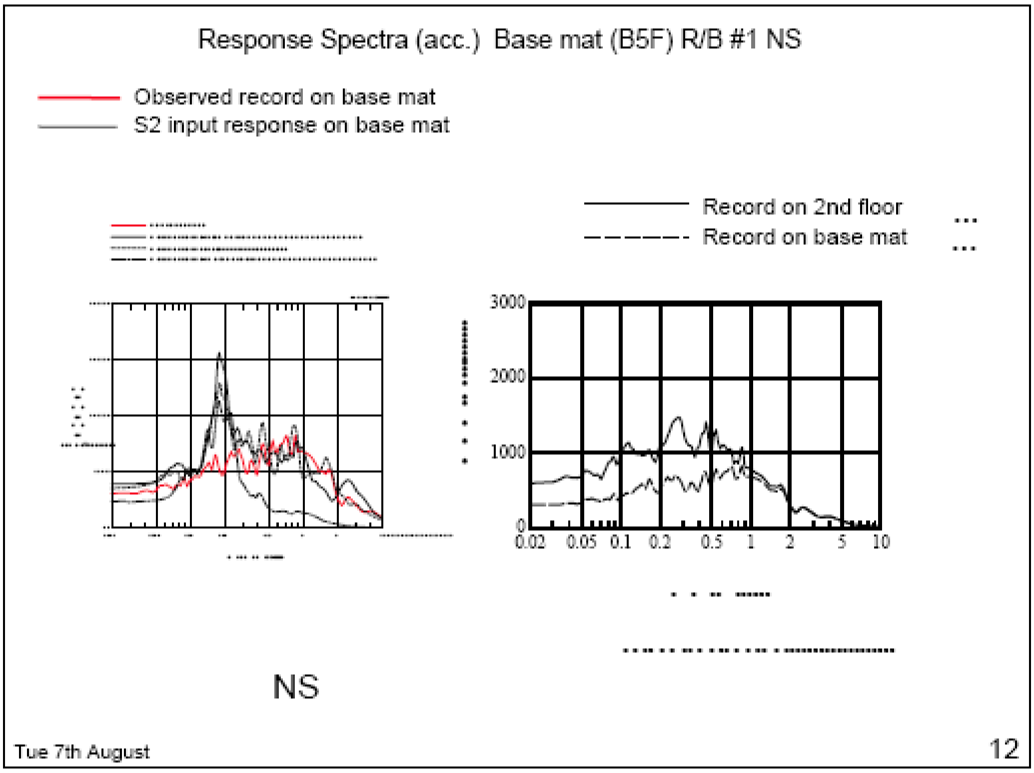




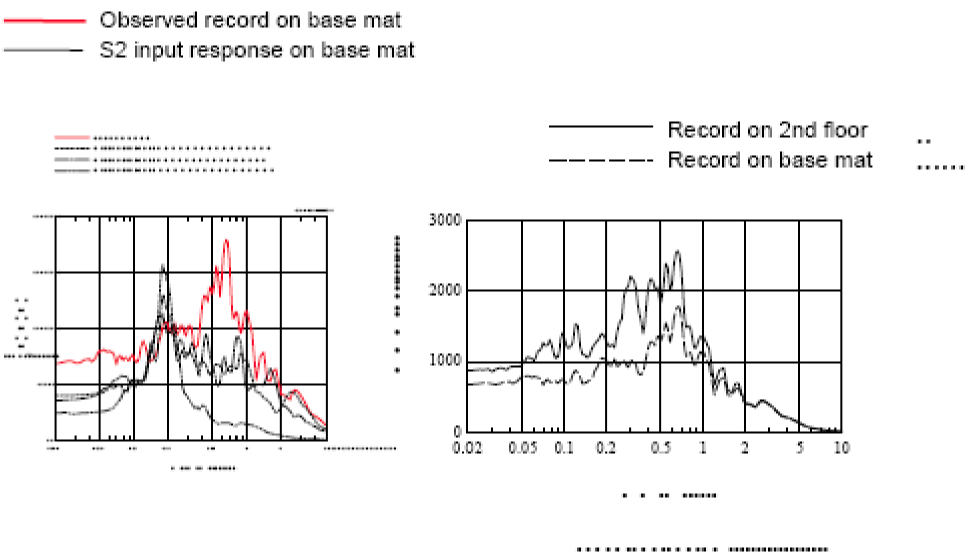
Design Spectrum Design Ground Motion

Tue 7th August 10


Design Ground Motion, In-Structure Response and Records
Reactor Building
Turbine Building
Observed record
Response
Free surface of base stratum
for seismic design
Design Ground motion
Tue 7th August
11


Response Spectra (acc.) Base mat (B5F) R/B #1 NS
Observed record on base mat
S2 input response on base mat
Record on 2nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
NS
Tue 7th August
12

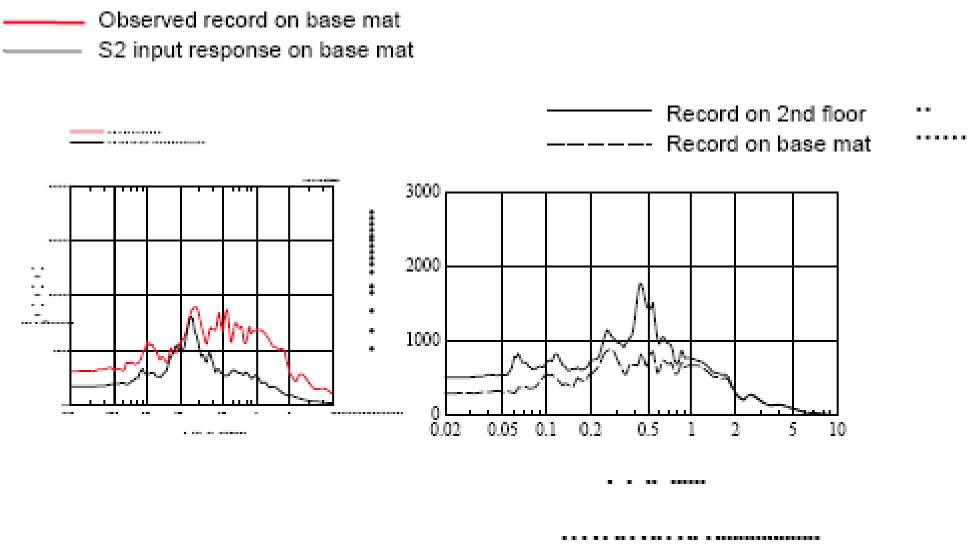
Response Spectra (acc.) Base mat (B5F) R/B #1 EW



EW

Tue 7th August 13

Response Spectra (acc.) Base mat (B5F) R/B #2 NS

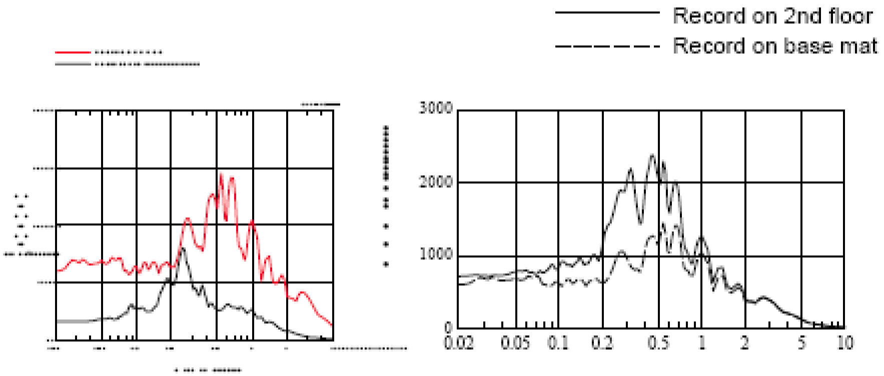


NS

Tue 7th August 14

Response Spectra (acc.) Base mat (B5F) R/B #2 EW

Observed record on base mat
S2 input response on base mat



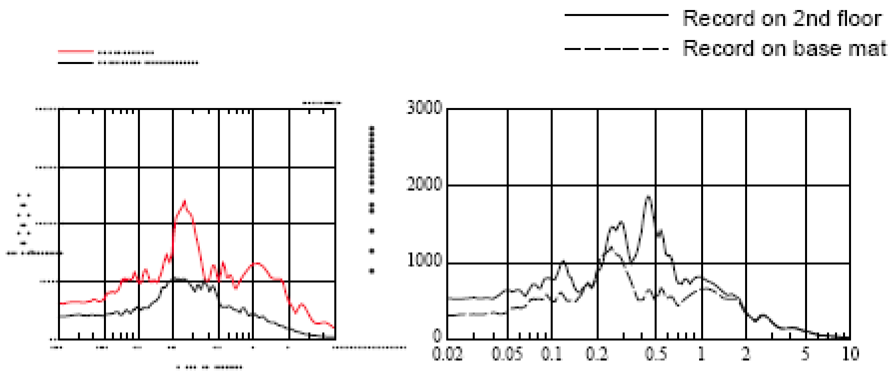
EW

Tue 7th August

15

Response Spectra (acc.) Base mat (B5F) R/B #3 NS

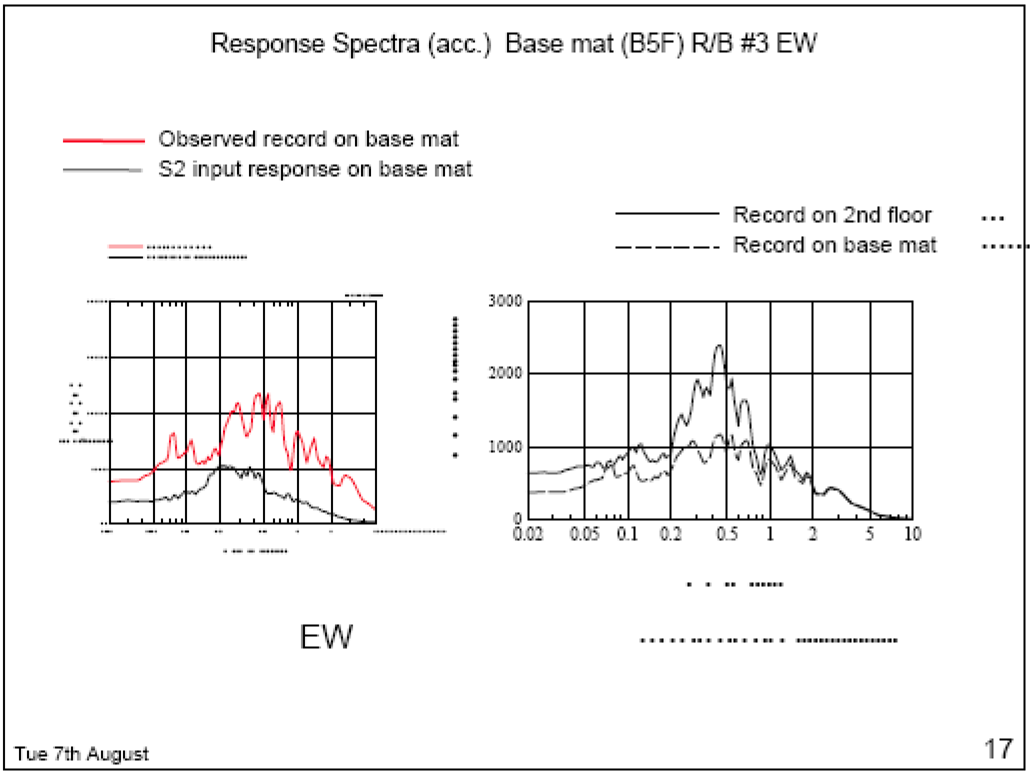
Observed record on base mat
S2 input response on base mat

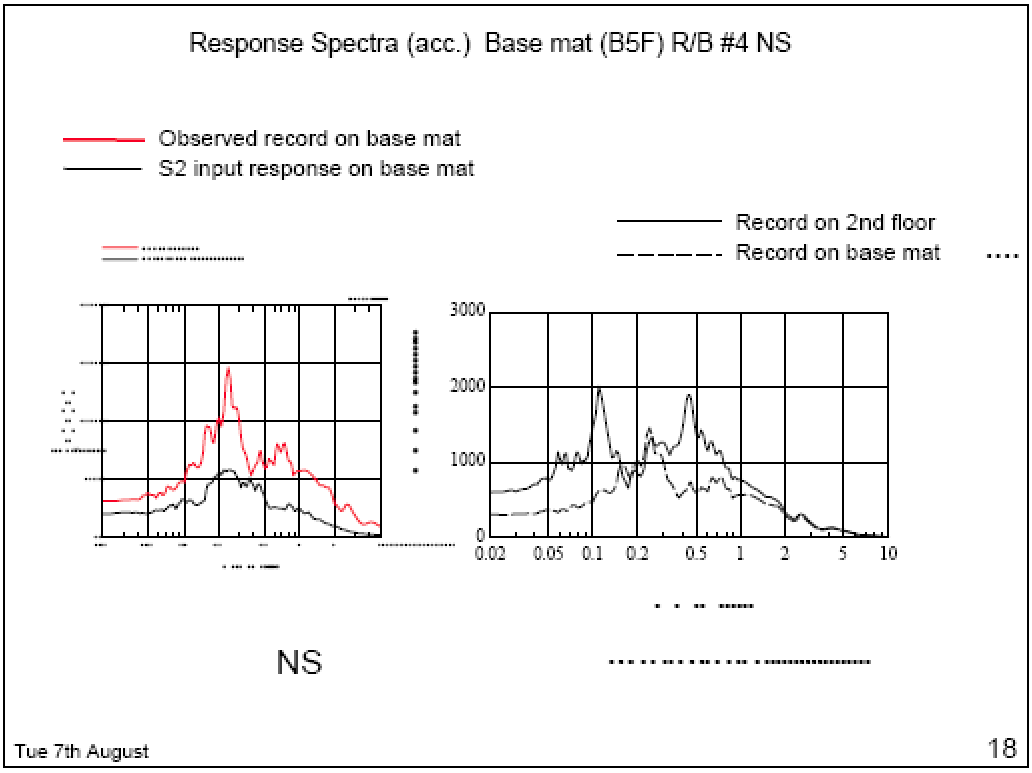


NS

Tue 7th August

16

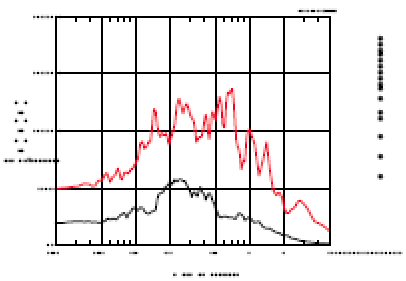

Response Spectra (acc.) Base mat (B5F) R/B #3 EW
Observed record on base mat
S2 input response on base mat
Record on 2nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
EW
Tue 7th August
17

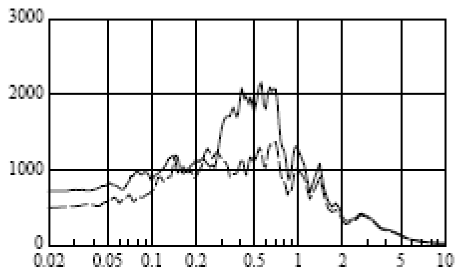

Response Spectra (acc.) Base mat (B5F) R/B #4 NS
Observed record on base mat
S2 input response on base mat
Record on 2nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
NS
Tue 7th August
18

Response Spectra (acc.) Base mat (B5F) R/B #4 EW

Observed record on base mat
S2 input response on base mat

Record on 2nd floor
Record on base mat





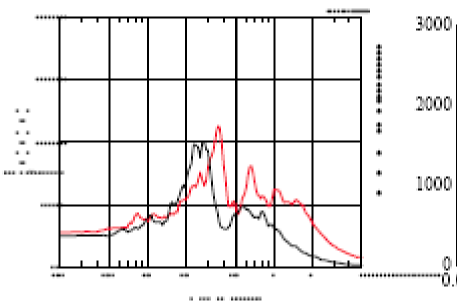
EW

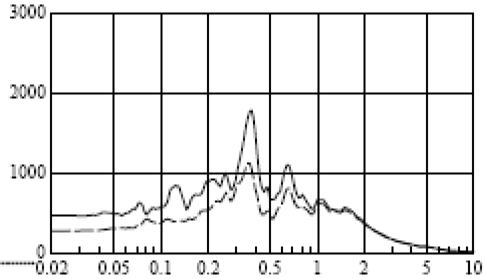
Tue 7th August 19

Response Spectra (acc.) Base mat (B4F) R/B #5 NS

Observed record on base mat
S2 input response on base mat

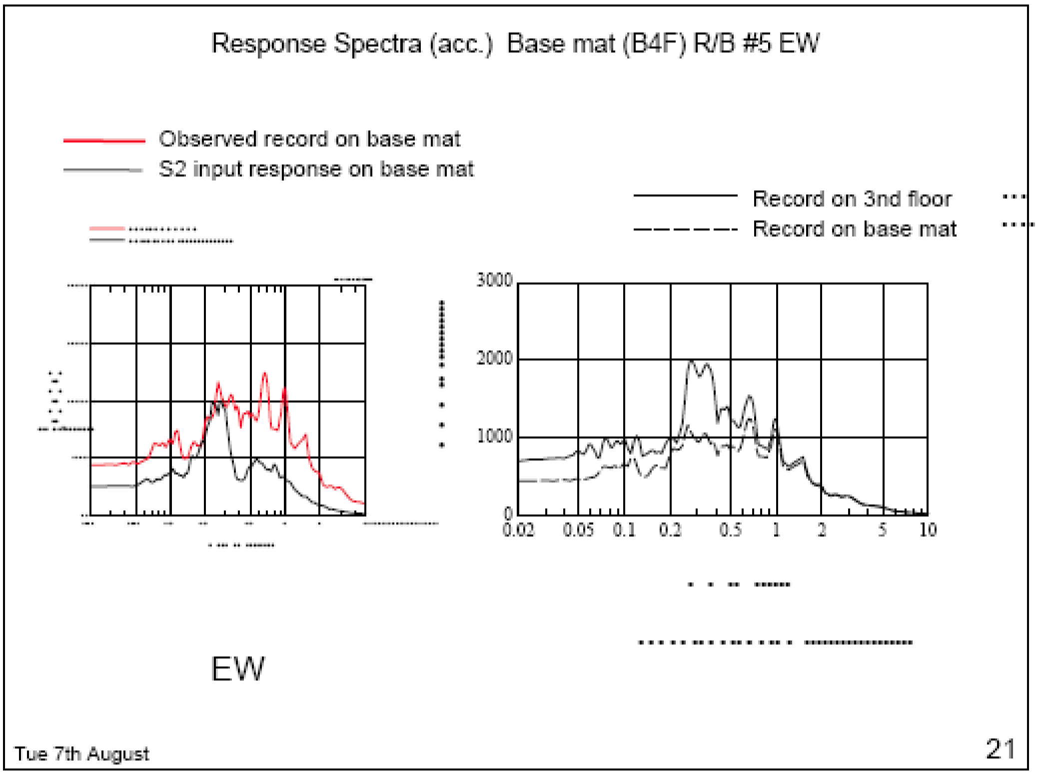
Record on 3nd floor
Record on base mat

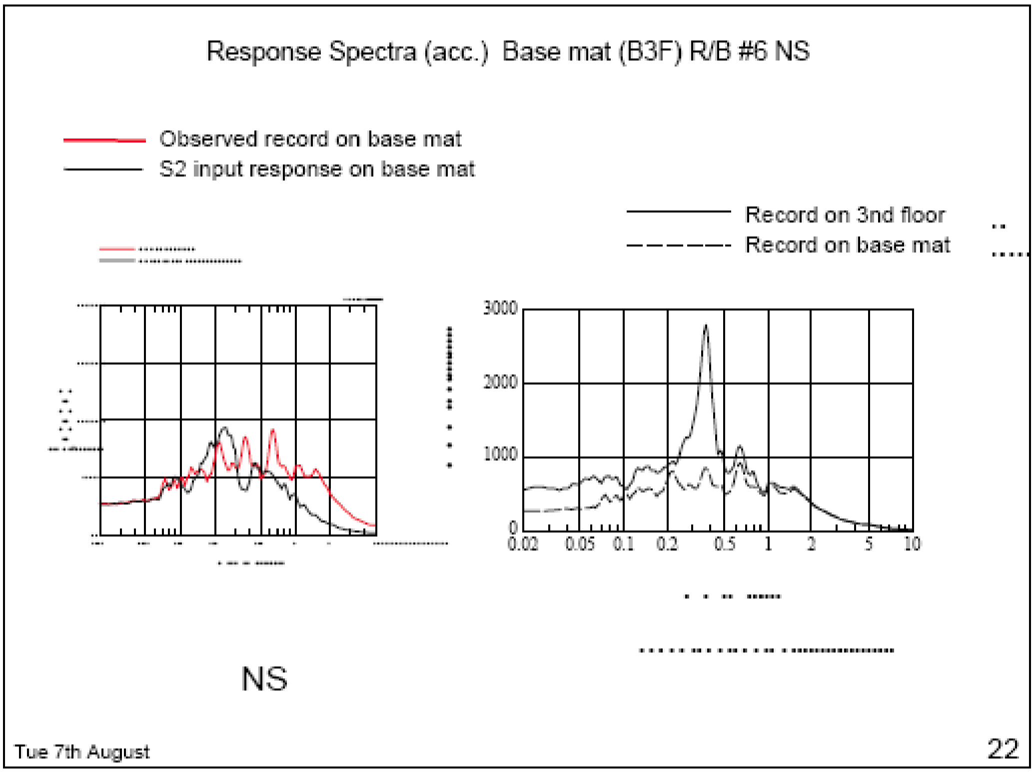


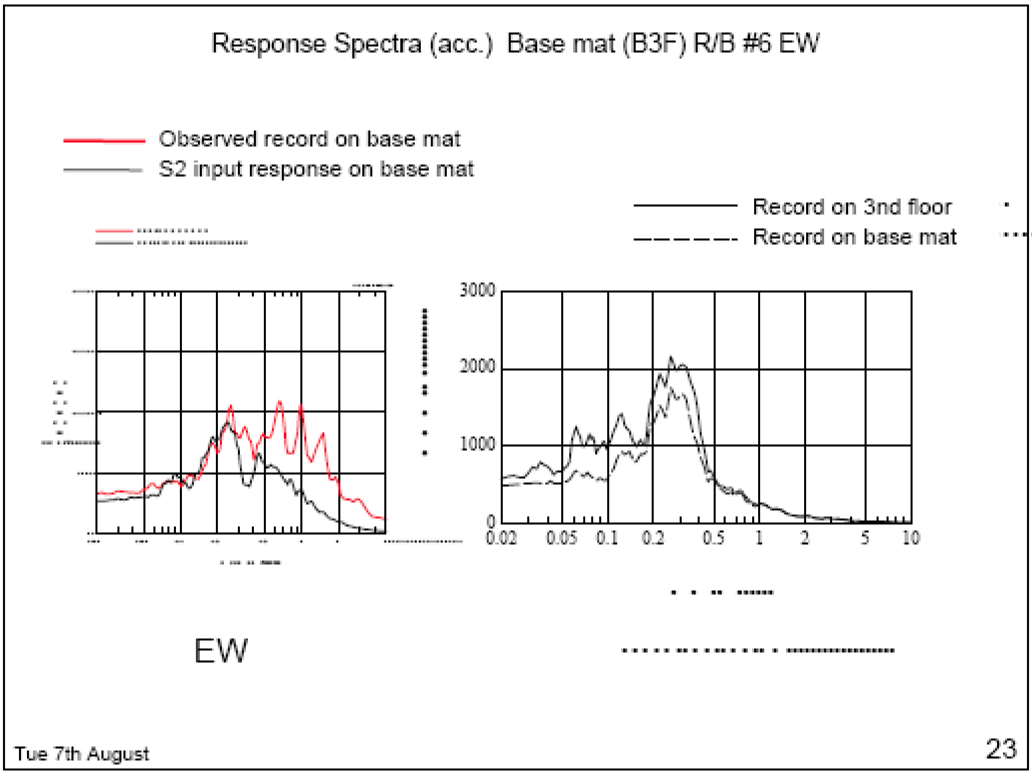


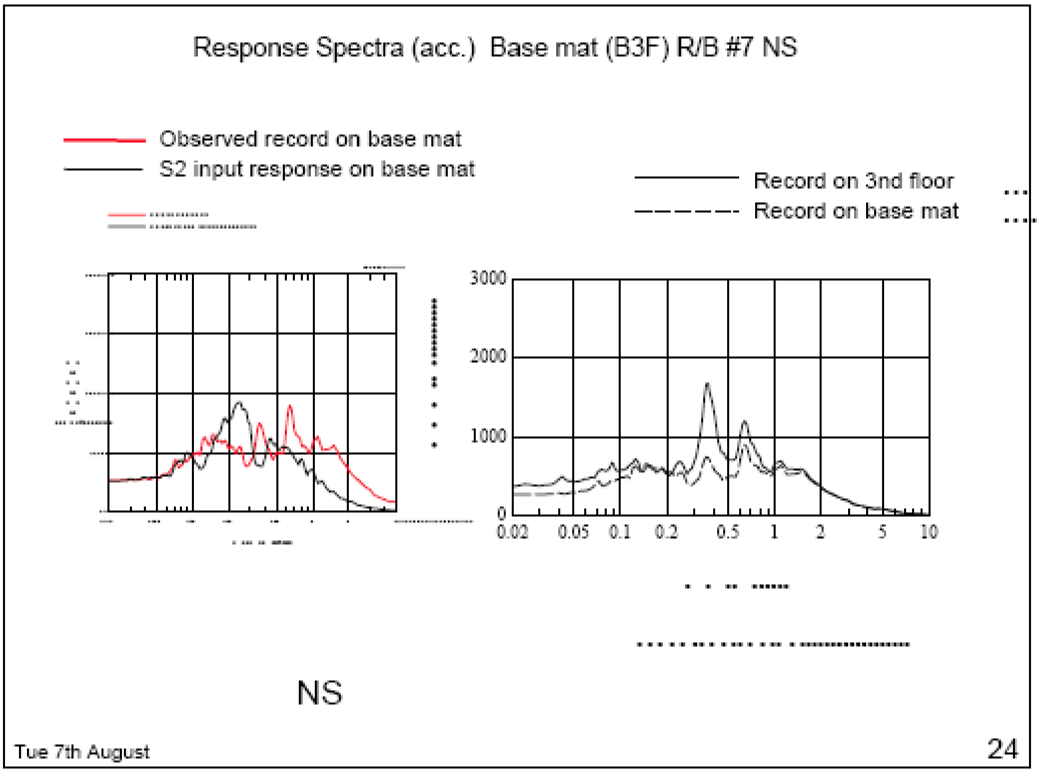
NS

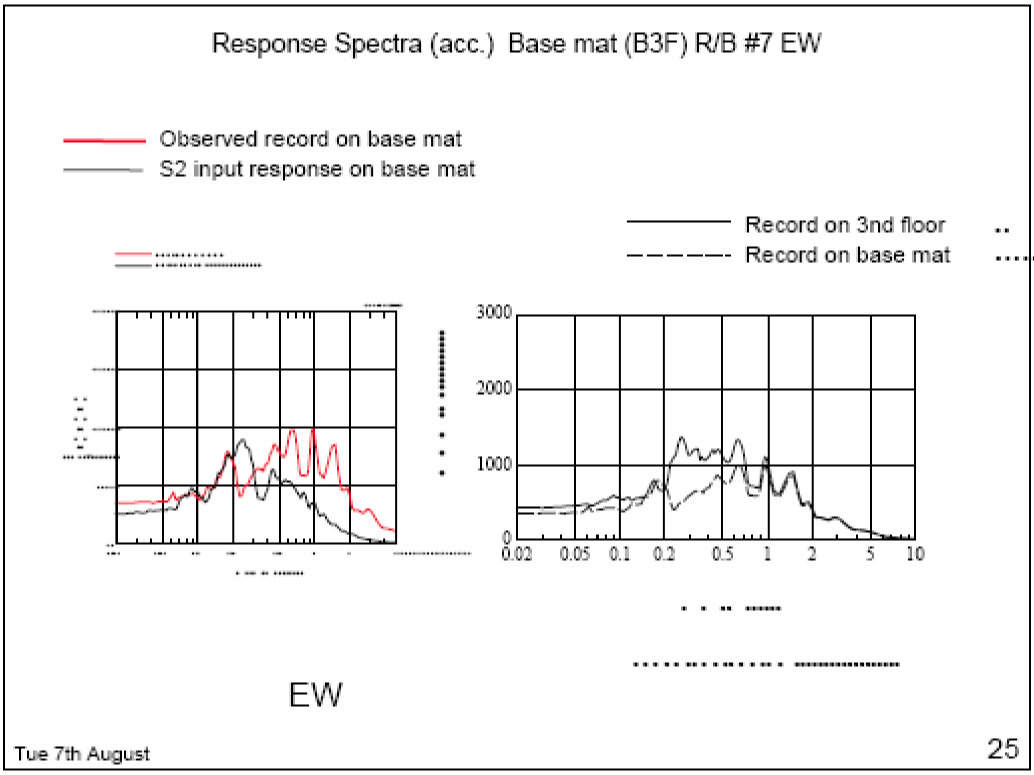
Tue 7th August 20


Response Spectra (acc.) Base mat (B4F) R/B #5 EW
Observed record on base mat
S2 input response on base mat
Record on 3nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
EW
Tue 7th August
21

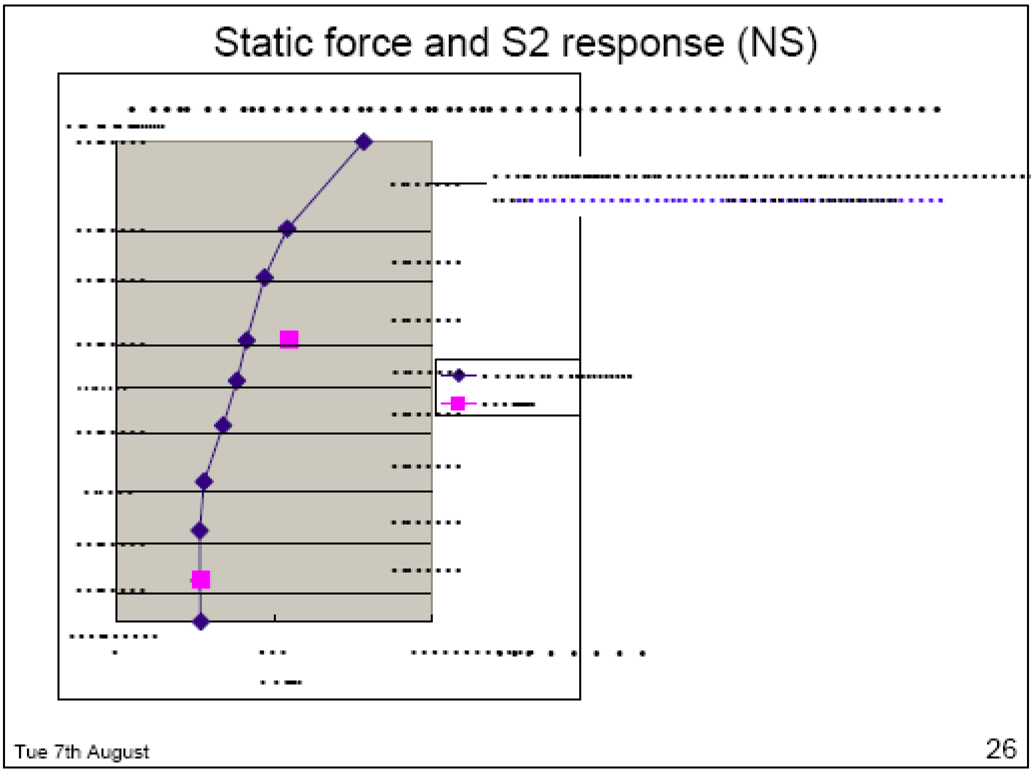

Response Spectra (acc.) Base mat (B3F) R/B #6 NS
Observed record on base mat
S2 input response on base mat
Record on 3nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
NS
Tue 7th August
22


Response Spectra (acc.) Base mat (B3F) R/B #6 EW
Observed record on base mat
S2 input response on base mat
Record on 3nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
EW
Tue 7th August
23


Response Spectra (acc.) Base mat (B3F) R/B #7 NS
Observed record on base mat
S2 input response on base mat
Record on 3nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
NS
Tue 7th August
24

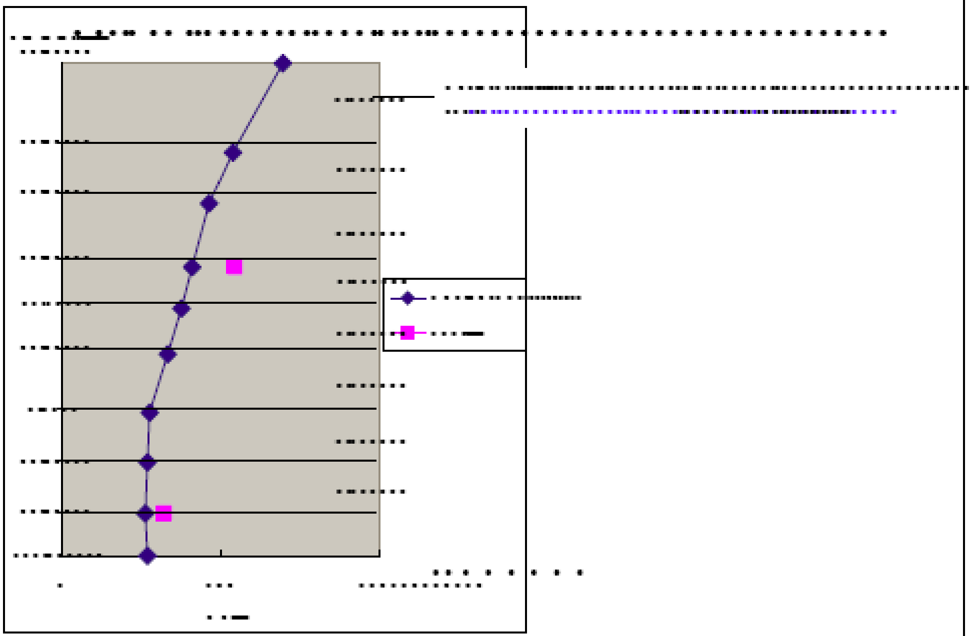


Response Spectra (acc.) Base mat (B3F) R/B #7 EW
Observed record on base mat
S2 input response on base mat
Record on 3nd floor
Record on base mat
3000
2000
1000
0
0.02
0.05
0.1
0.2
0.5
1
2
5
10
EW
Tue 7th August
25



Static force and S2 response (NS)
Tue 7th August
26

Static force and S2 response (EW)

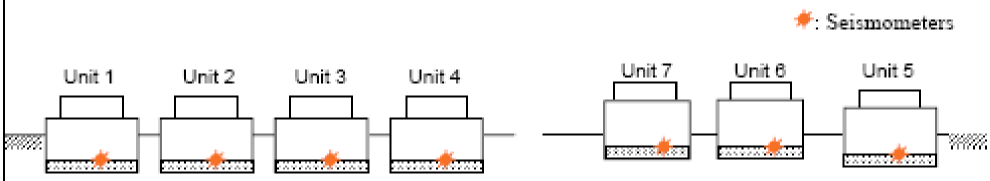


Tue 7th August 27

2. Aftershock records

Tue 7th August 28

Observation Records (aftershock) on R/B base mat

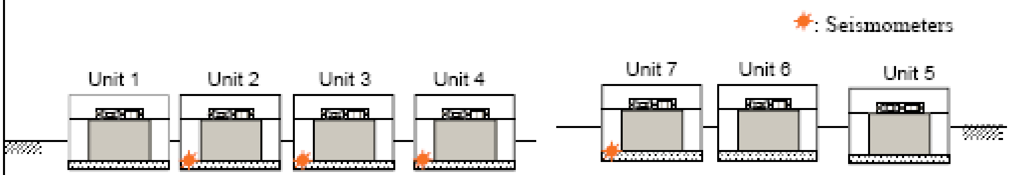


Gal:cm/s/s

Observation point				Observed Maximun Acc.			Obs. Max Acc. (aftershock)			Design value	
				NS	EW	UD	NS	EW	UD	NS	EW
Unit1	R/B	1-R2	B5F(Base Mat)	311	680	408	52	60	57	274	273
Unit2	R/B	2-R2	B5F(Base Mat)	304	606	282	48	59	41	167	167
Unit3	R/B	3-R2	B5F(Base Mat)	308	384	311	66	73	52	192	193
Unit4	R/B	4-R2	B5F(Base Mat)	310	492	337	74	94	61	193	194
Unit5	R/B	5-R2	B4F(Base Mat)	277	442	205	126	102	57	249	254
Unit6	R/B	6-R2	B3F(Base Mat)	271	322	488	159	114	82	263	263
Unit7	R/B	7-R2	B3F(Base Mat)	267	356	355	170	135	74	263	263

Tue 7th August 29

Observation Records (aftershock) on T/B base mat



Gal:cm/s/s

Observation point				Observed Maximun Acc.			Obs. Max Acc. (aftershock)			Design value	
				NS	EW	UD	NS	EW	UD	NS	EW
Unit2	T/B	2-T3	B3F(Base Mat)	387	681	470	70	82	65	233	232
Unit3	T/B	3-T3	B3F(Base Mat)	581	549	513	108	111	82	239	243
Unit4	T/B	4-T3	B3F(Base Mat)	348	442	443	97	103	93	238	242
Unit7	T/B	7-T3	B2F(Base Mat)	318	322	336	182	129	78	299	312

Tue 7th August 30

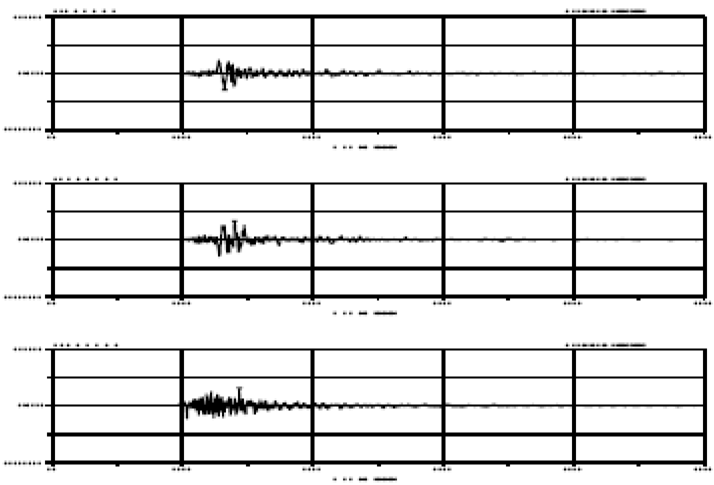
Observation Records (aftershock) borehole and obs. house

Gal:cm/s/s

Observation point				Observed Maximun Acc.			Obs. Max Acc. (aftershock)		
				NS	EW	UD	NS	EW	UD
In the Obs.House	near Unit 1		Ground Level	890	890	715	258	298	248
	near Unit 5			964	1223	539	386	362	108
Borehole	PR Hall	SG1	GL -2.4m	347	437	590	163	186	194
		SG2	GL -50.8m	340	411	179	128	117	70
		SG3	GL -99.4m	403	647	174	138	123	60
		SG4	GL -250m	430	728	160	140	111	52

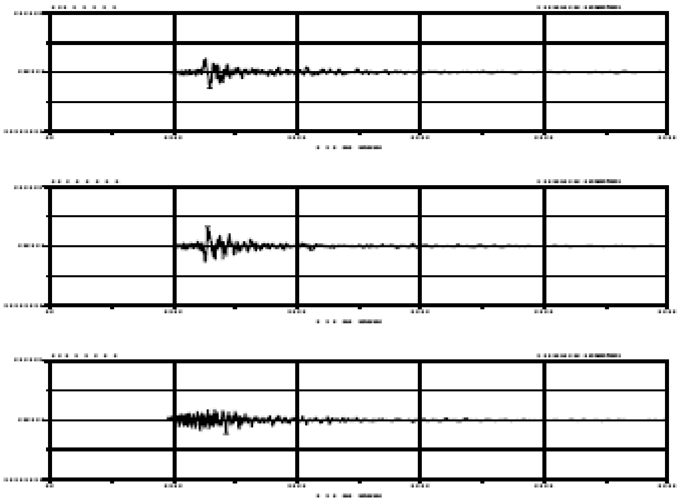
Tue 7th August 31

Time history (acc.) Base mat (B5F) R/B #1 1-R2
15h37 16 July 2007



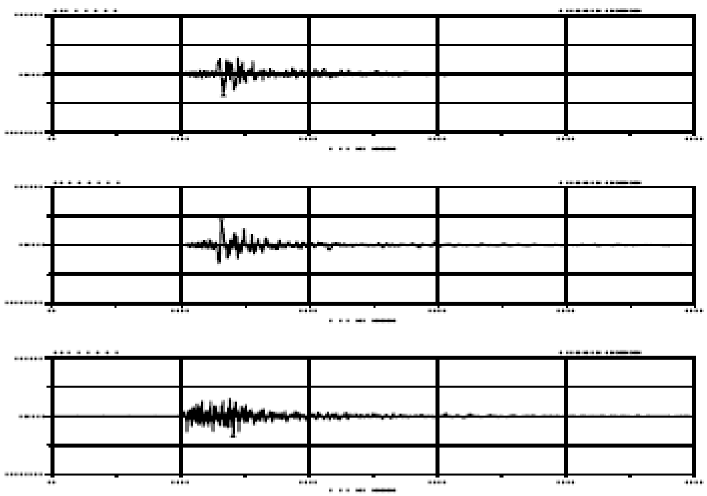
Tue 7th August 32

Time history (acc.) Base mat (B5F) R/B #2 2-R2
15h37 16 July 2007



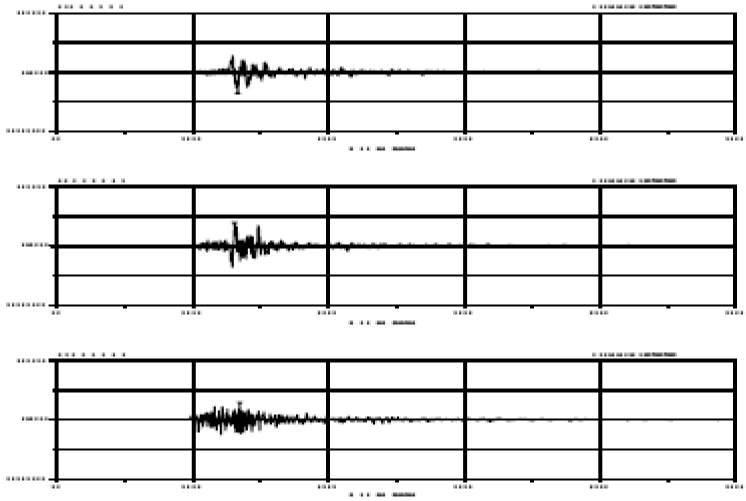
Tue 7th August 33

Time history (acc.) Base mat (B5F) T/B #2 2-T3
15h37 16 July 2007



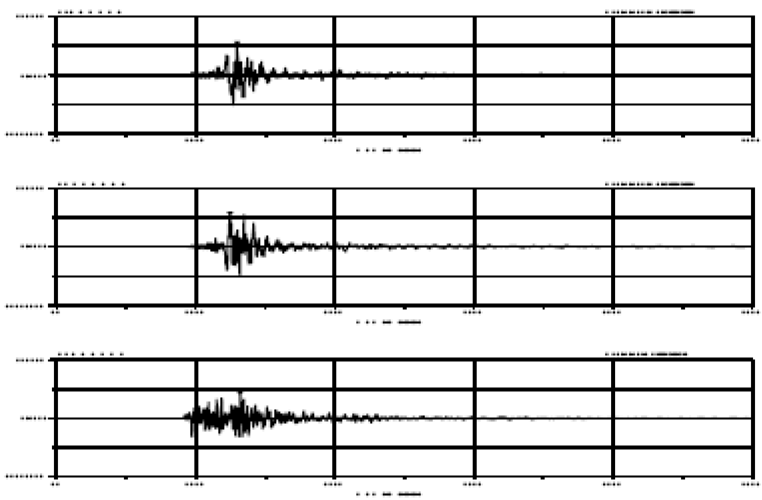
Tue 7th August 34

Time history (acc.) Base mat (B5F) R/B #3 3-R2
15h37 16 July 2007



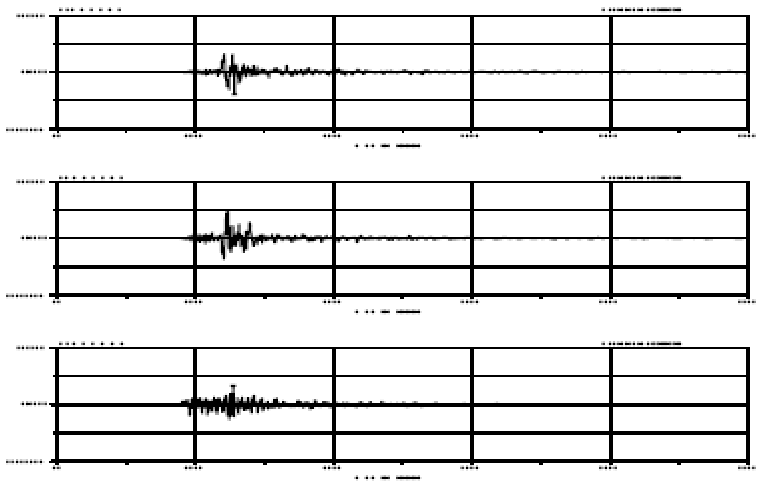
Tue 7th August 35

Time history (acc.) Base mat (B5F) T/B #3 3-T3
15h37 16 July 2007



Tue 7th August 36

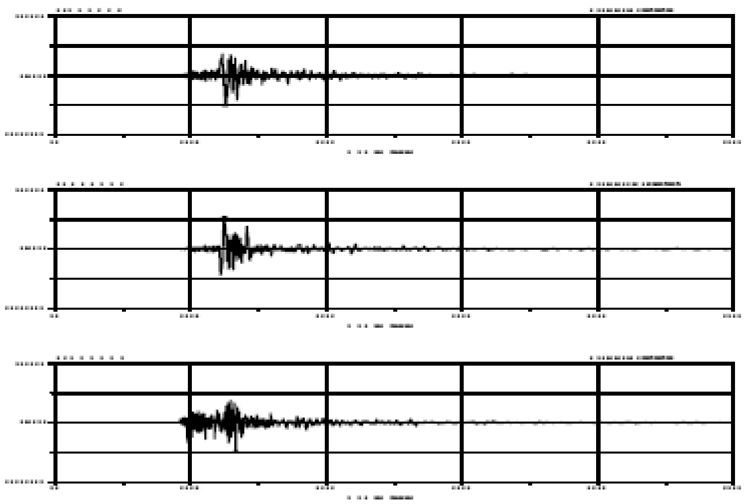
Time history (acc.) Base mat (B5F) R/B #4 4-R2
15h37 16 July 2007



Tue 7th August

37

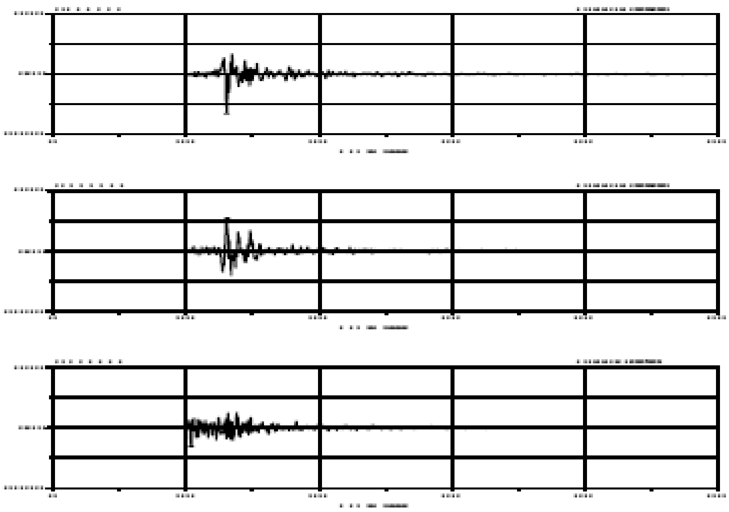
Time history (acc.) Base mat (B5F) R/B #4 4-T3
15h37 16 July 2007



Tue 7th August

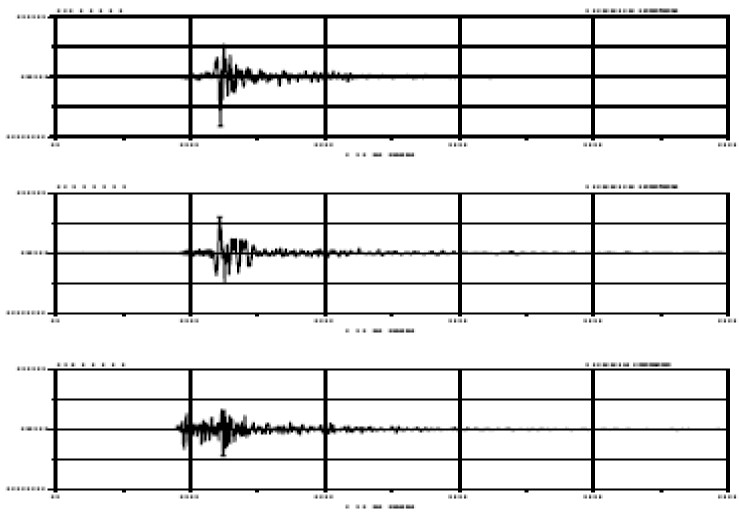
38

Time history (acc.) Base mat (B4F) R/B #5 5-R2
15h37 16 July 2007



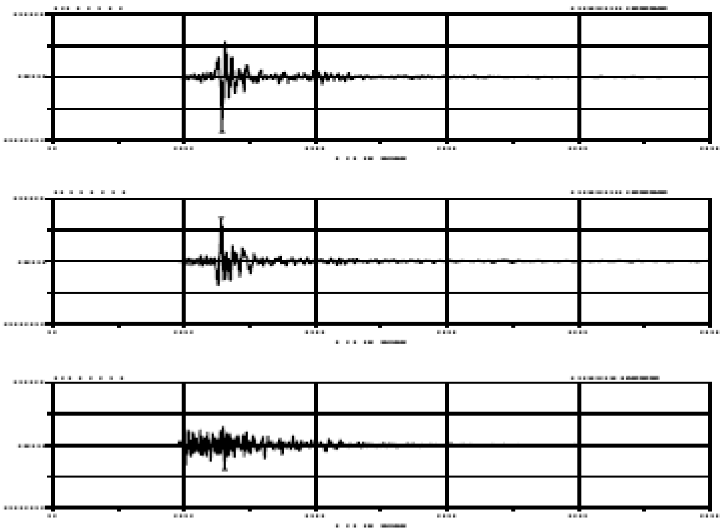
Tue 7th August 39

Time history (acc.) Base mat (B3F) R/B #6 6-R2
15h37 16 July 2007



Tue 7th August 40

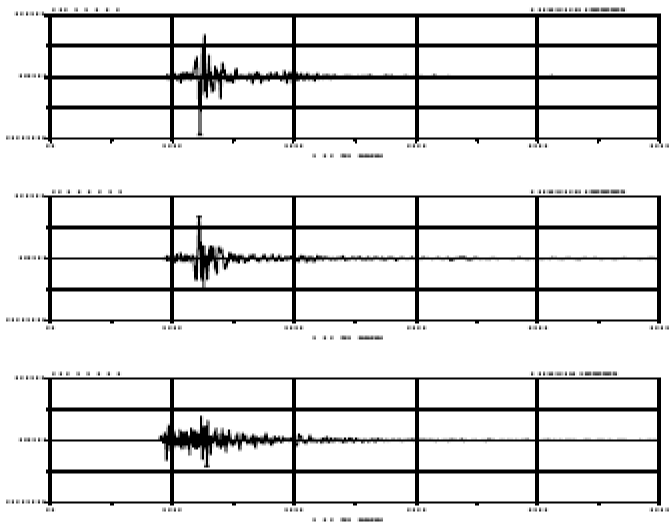
Time history (acc.) Base mat (B3F) R/B #7 7-R2
15h37 16 July 2007



Tue 7th August

41

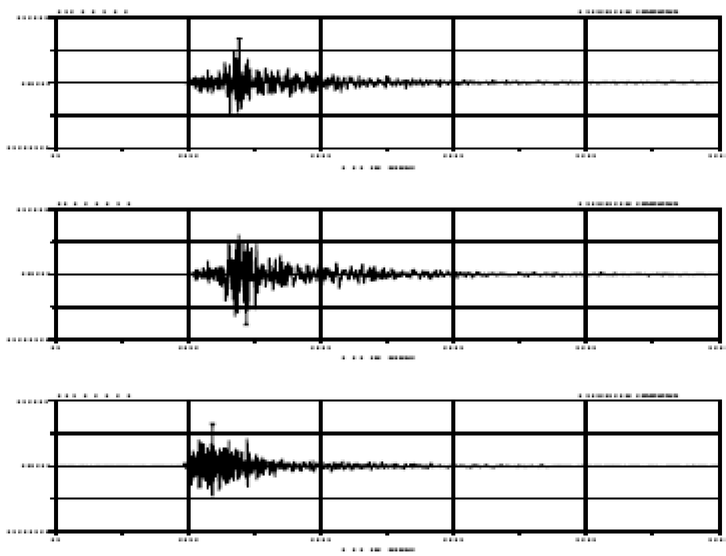
Time history (acc.) Base mat (B3F) R/B #7 7-T3
15h37 16 July 2007



Tue 7th August

42

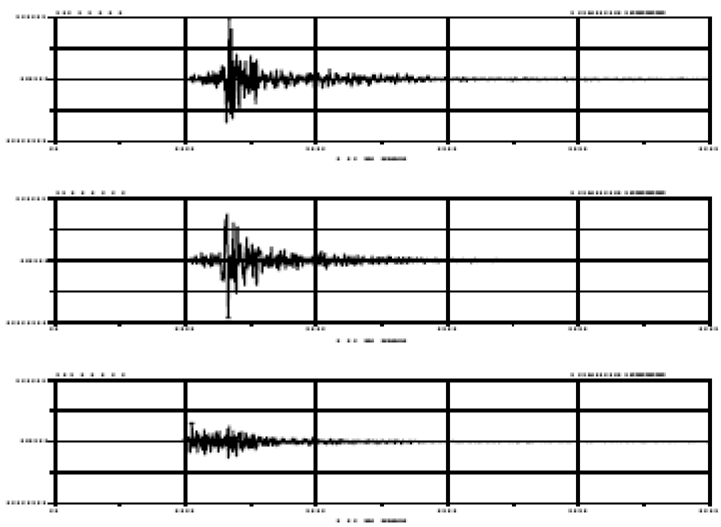
Time history (acc.) #1 Obs.House 1G1
15h37 16 July 2007



Tue 7th August

43

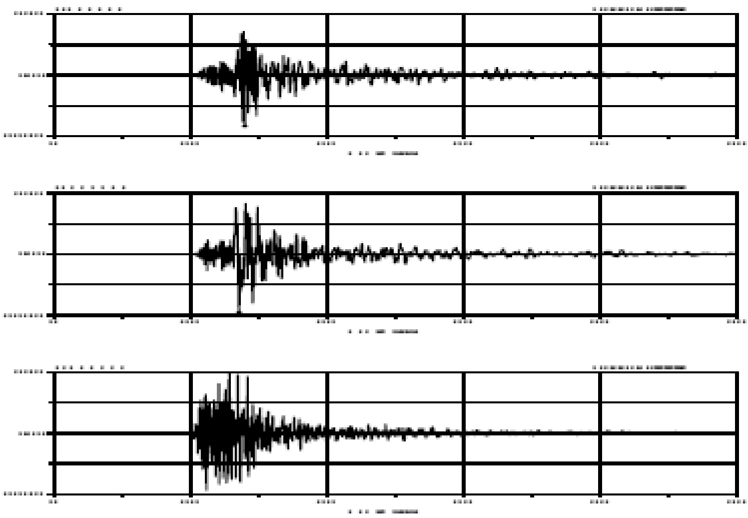
Time history (acc.) #5 Obs.House 1G5
15h37 16 July 2007



Tue 7th August

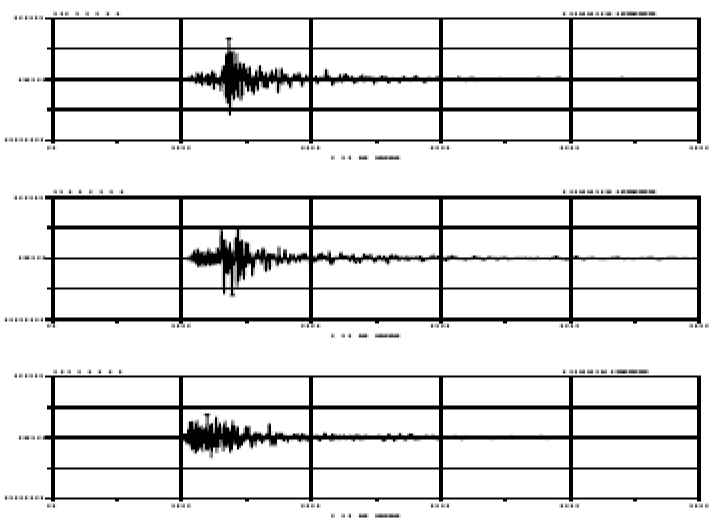
44

Time history (acc.) PR Hall (T.M.S.L.+65.1m) SG1
15h37 16 July 2007



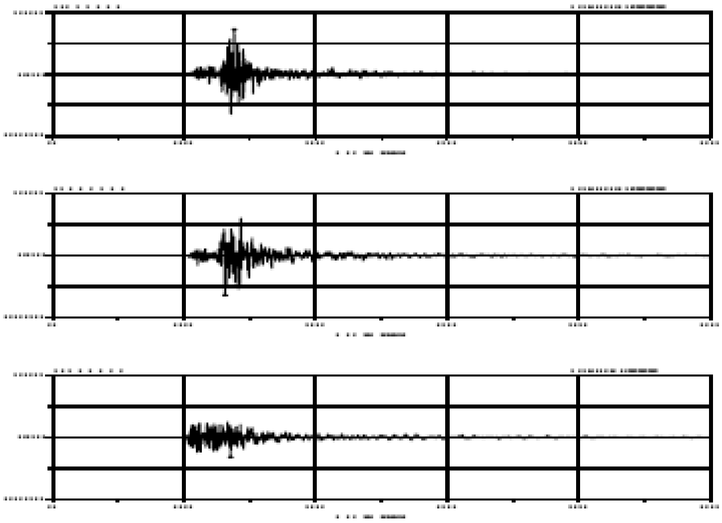
Tue 7th August 45

Time history (acc.) PR Hall (T.M.S.L.+16.7m) SG2
15h37 16 July 2007



Tue 7th August 46

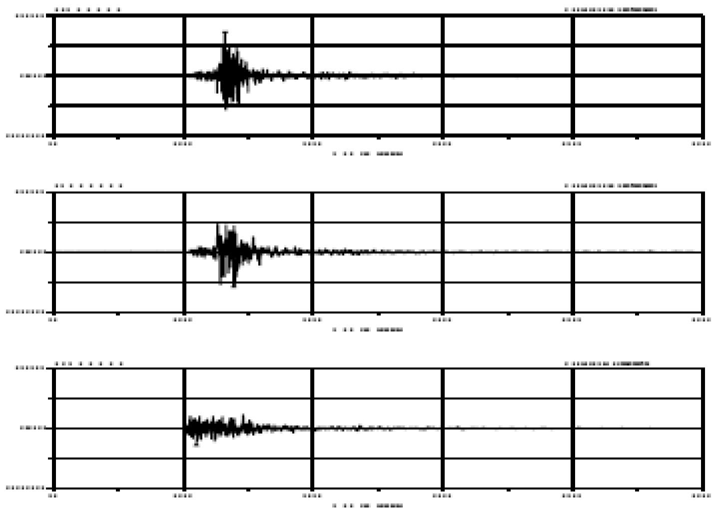
Time history (acc.) PR Hall (T.M.S.L.-31.9m) SG3
15h37 16 July 2007



Tue 7th August

47

Time history (acc.) PR Hall (T.M.S.L.-182.3m) SG4
15h37 16 July 2007



Tue 7th August

48

3. Evaluation of Active faults including offshore investigation

Tue 7th August 49

Evaluation of Active Faults in “Regulatory Guide” and “Guide-Line”

- “Regulatory Guide for Aseismic Design of Nuclear Power Reactor Facilities” (September 1978, revised edition July 1981)
- “Guide-Line on Licensing Examination for Geology and Ground Condition of Nuclear Power Plants” (August 1978)

[Evaluation of active Faults]
For earthquakes generating the basic design earthquake ground motions, faults at the proposed site and surrounding region shall be considered.

S1:faults having the evidence of movement within the past 10,000 years
S2:faults having the evidence of movement within the past 50,000 years

[Requirements]

In the area within 30km(minimum) from the center of the site, necessary requirements are as follows.

In the land area: literature survey, topography survey and surface geological survey

In the sea area : literature survey, and sonic prospecting

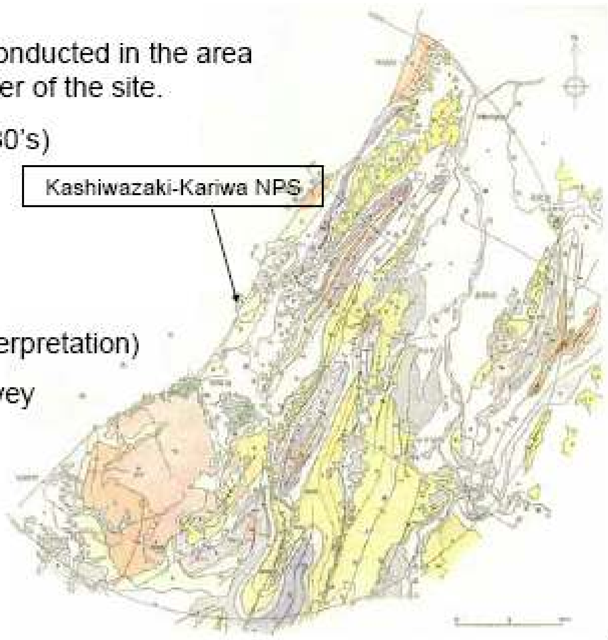
Tue 7th August 50

Surveys of Active Faults in the Land Area

Following surveys were conducted in the area within 30km from the center of the site.

(the late 1960's ~ late 1980's)

- Literature survey
- Topography survey
  (Aerial photograph interpretation)
- Surface geological survey



Tue 7th August

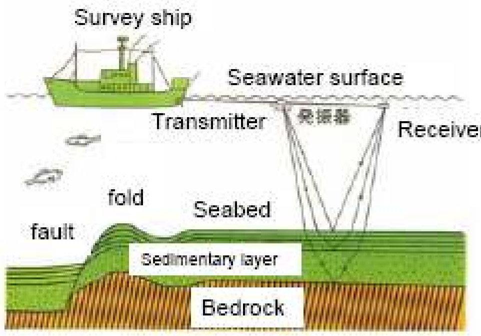
51

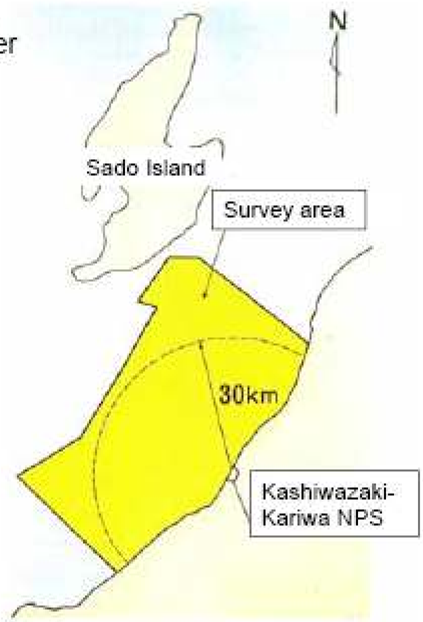
Surveys of Active Faults in the Sea Area

In the sea area within 30km from the center of the site.

•Literature survey

•Sonic prospecting (1979,1980,1985)





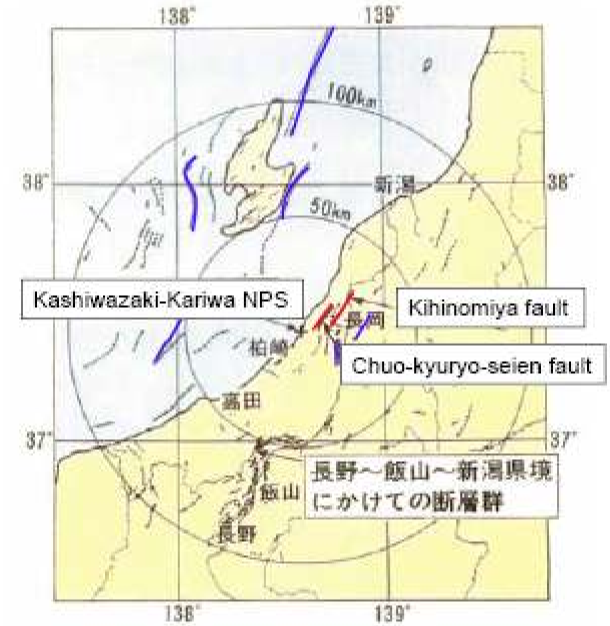
Tue 7th August

52

Evaluation of Active Faults (land area)

Active faults considered to evaluate basic design earthquake ground motion

- Kihinomiya fault
  M6.9, • ≒20km, S1
- Chuo-kyuryo-seien-bu fault
  M6.7, • ≒12km, S2



Tue 7th August

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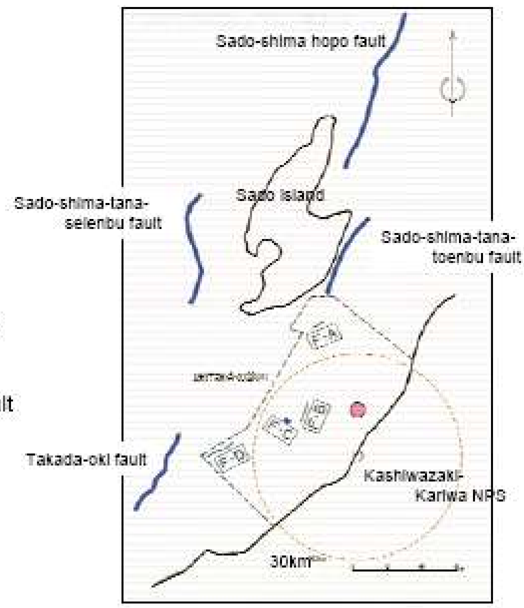
Evaluation of Active Faults (sea area)

Active faults in the sea area

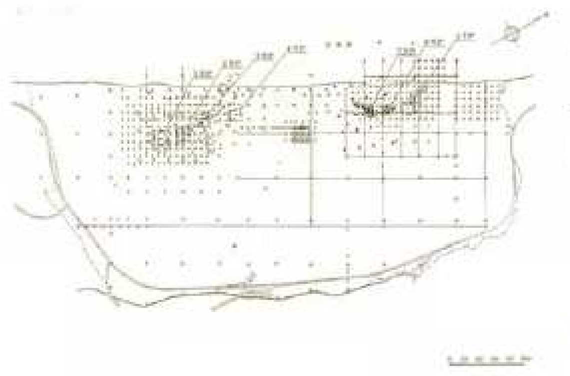
- In the vicinity of NPS
  F-C fault : L=1.5km, • ≒21.5km
- Farther area from NPS
  Areas surrounding Sado Island
  north: Sadoshima-hopo fault
  M7.7, • ≒109km
  east : Sadoshima-tana-toenbu fault
  M7.2, • ≒61km
  west : Sadoshima-tana-seienbu fault
  M7.4, • ≒78km
  Off the coast of Takada
  Takada-oki fault
  M7.3, • ≒58km



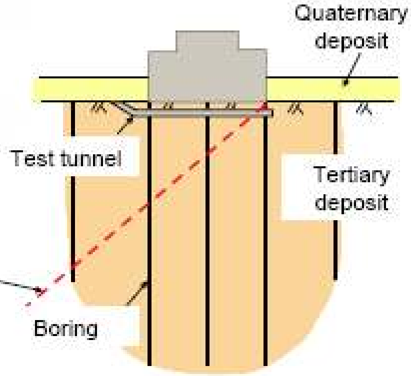
Tue 7th August

54

Surveys of Active Faults in the Site



- Boring survey
N =8 hundred (approx.)
Total length
=60 thousand meters (approx.)
(the late 1960's ~ late1980's)



Active faults were not found under the reactor building by boring survey, adit survey etc..

Tue 7th August 55

Revise Points of the Evaluation of Active Faults in Revised Regulatory Guide for Aseismic Design

- "Regulatory Guide for Aseismic Design of Nuclear Power Reactor Facilities" (revised edition September 2006)

Point 1: revise of geological survey method in near-field the site

Within 5km area from the site, further investigation is required.

[Required investigation items]

•Tectonic geomorphological investigation

•Geophysical investigation

Point 2: revise of the standard for the evaluation of active faults (latest activity age)

movement within the past 50,000 years

➔movement after late Diluvium (within the past 120,000~130,000)

evaluation can be done by using the stratum of latest interglacial period(past 80,000~130,000).

Tue 7th August 56

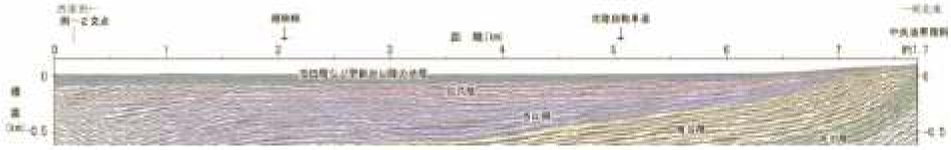
Geological Survey in accordance with
Revised Guide,

- seismic reflection method

near site (2006.9~2006.10)

in the site (2007.5~)

Result of the survey line



Tue 7th August

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Survey Plan based experience of Niigataken-Chuetsu-oki Earthquake

[in the sea area]

- seismic sonic prospecting

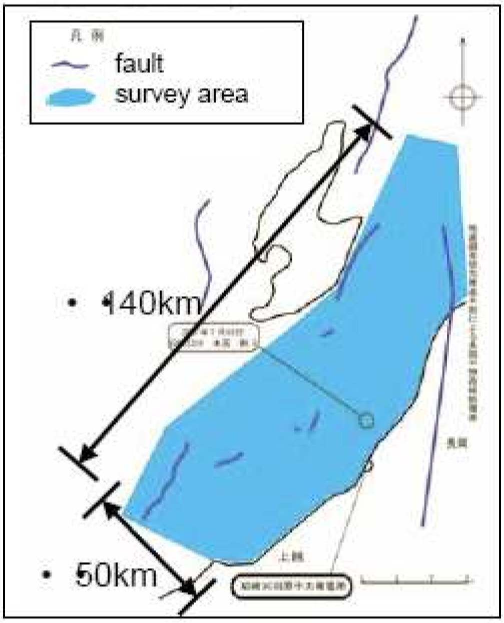
As highlighted area in right figure

(2007.8~2007.10)

[in the land area]

- seismic reflection method etc.

(now,planning)



Tue 7th August

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II.A.1.3. Location of seismic instrumentation and automatic scram sensors

Note from the IAEA Expert Team:

Please note that the main shock of the Niigataken Chuetsu-oki earthquake was registered only with the newly (April 2007) installed seismic instruments. The records from the original seismic instruments were overwritten due to saturation of memory capacity, therefore, only maximum values are available from these.

The technical specifications for these instruments are provided in Section II.A.1.6 of this Volume II.

The seismic sensors for triggering the automatic scram of the reactors are part of the safety systems of the plant. They do not provide time histories.

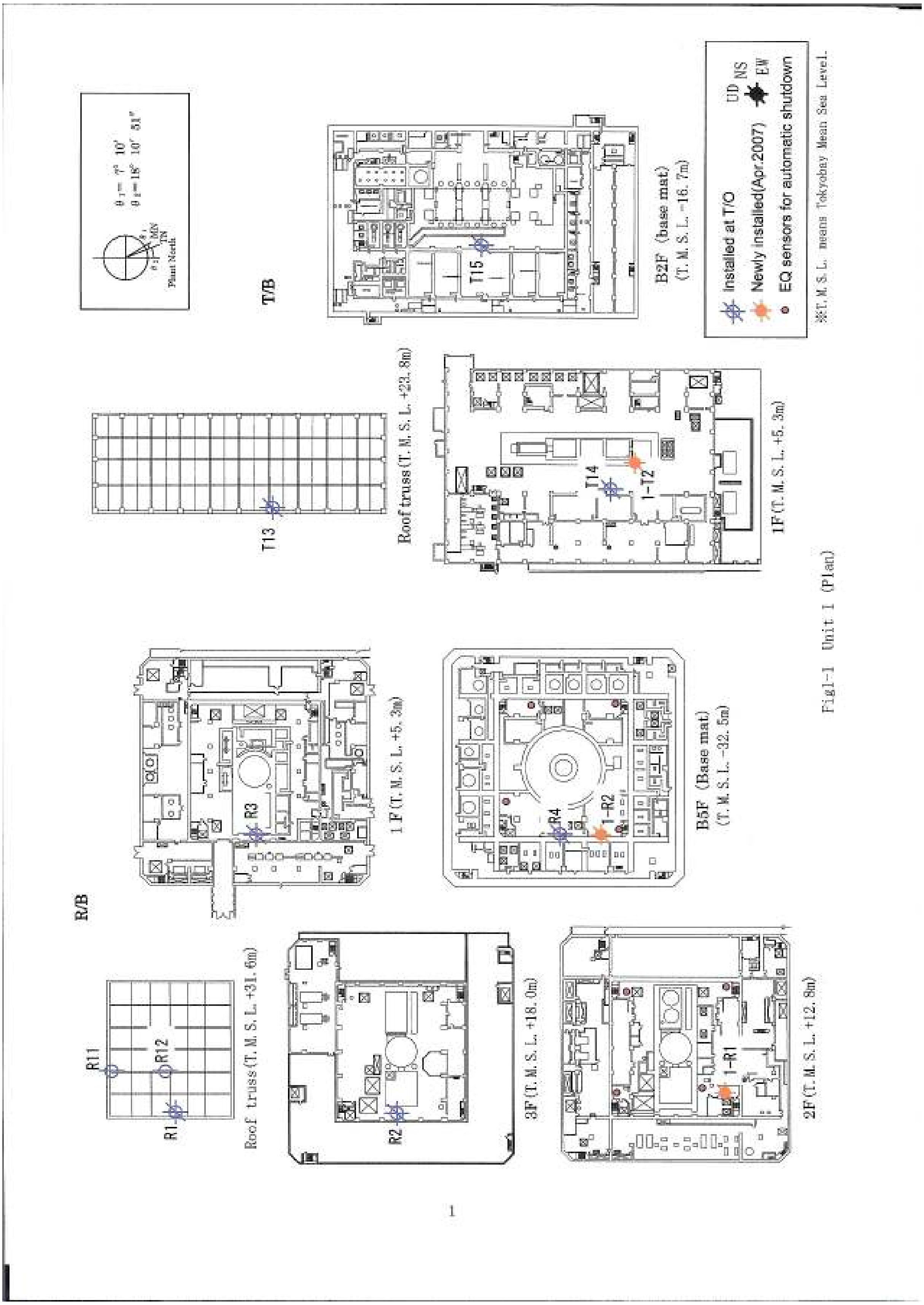


Fig1-1 Unit 1 (Plan)

1

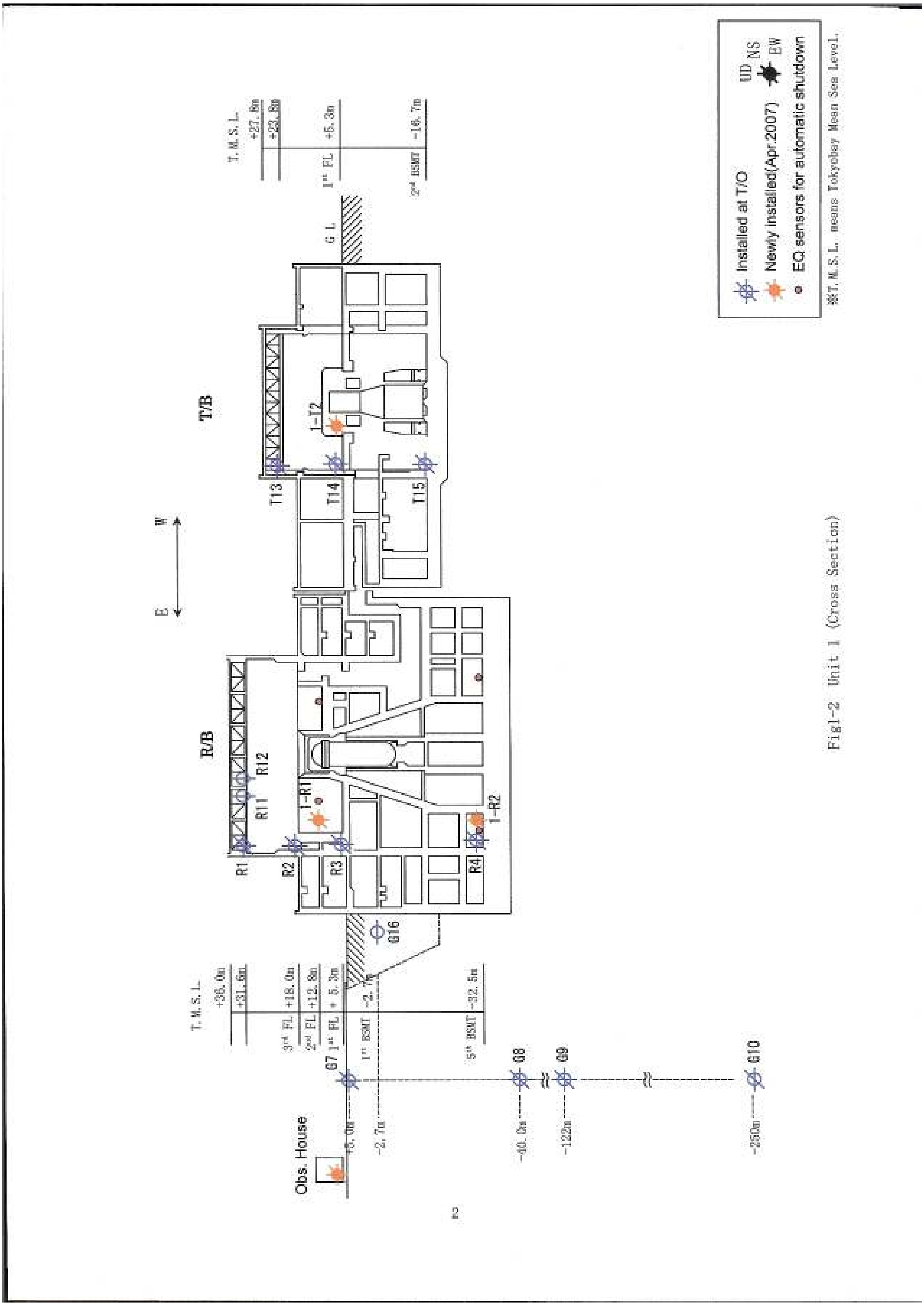


Fig1-2 Unit 1 (Cross Section)

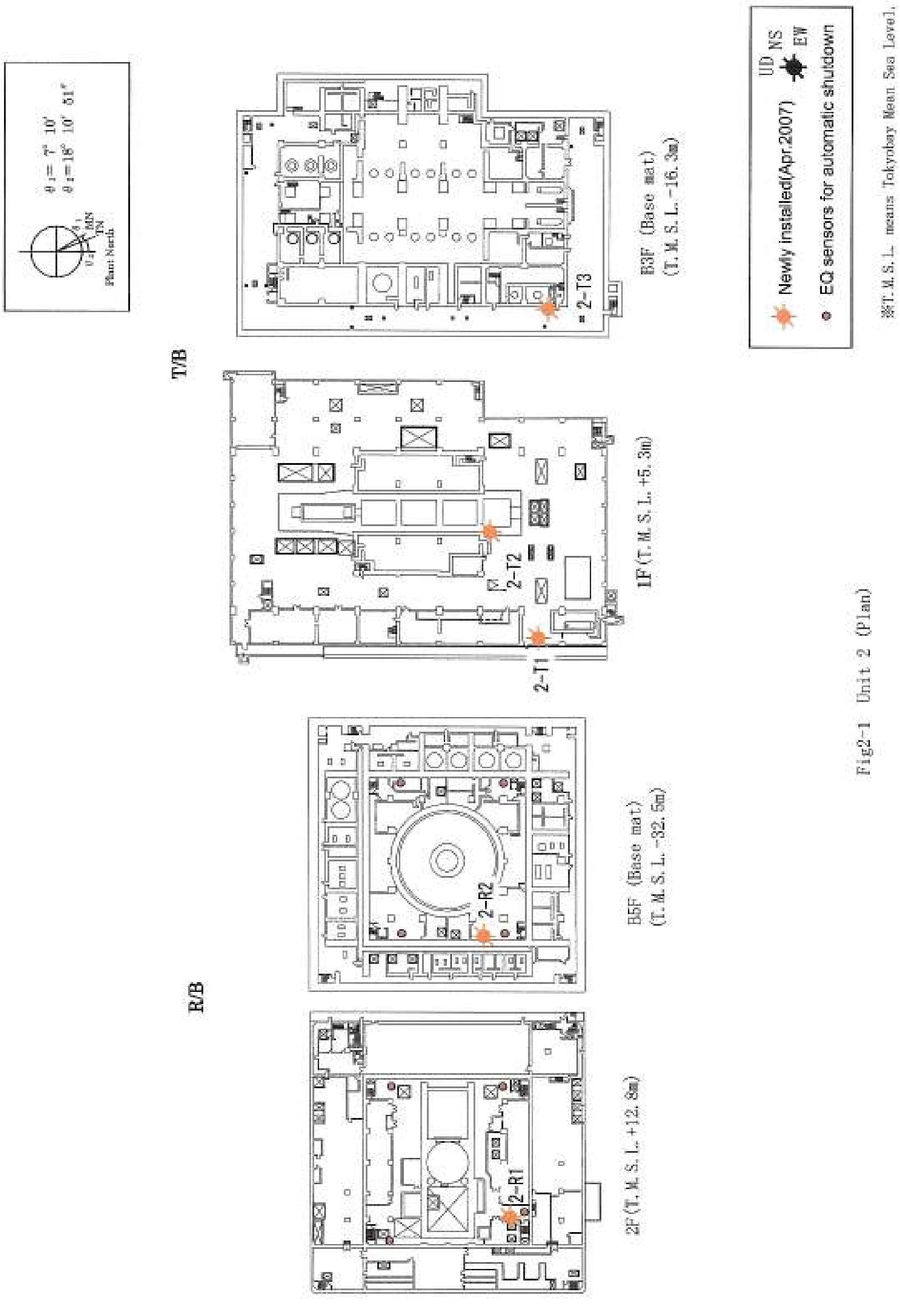


Fig2-1 Unit 2 (Plan)

3

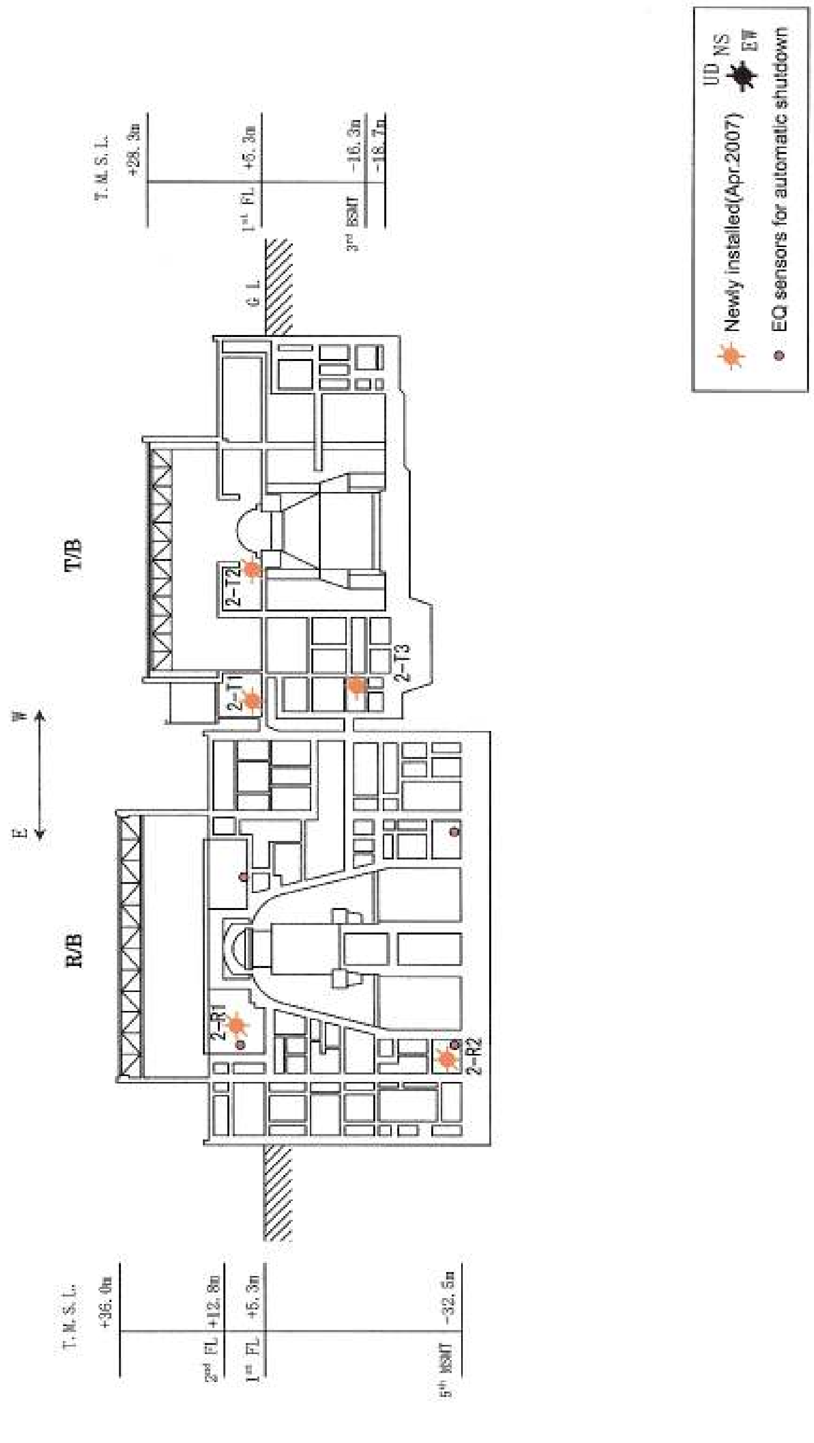


Fig2-2 Unit 2 (Cross Section)

4

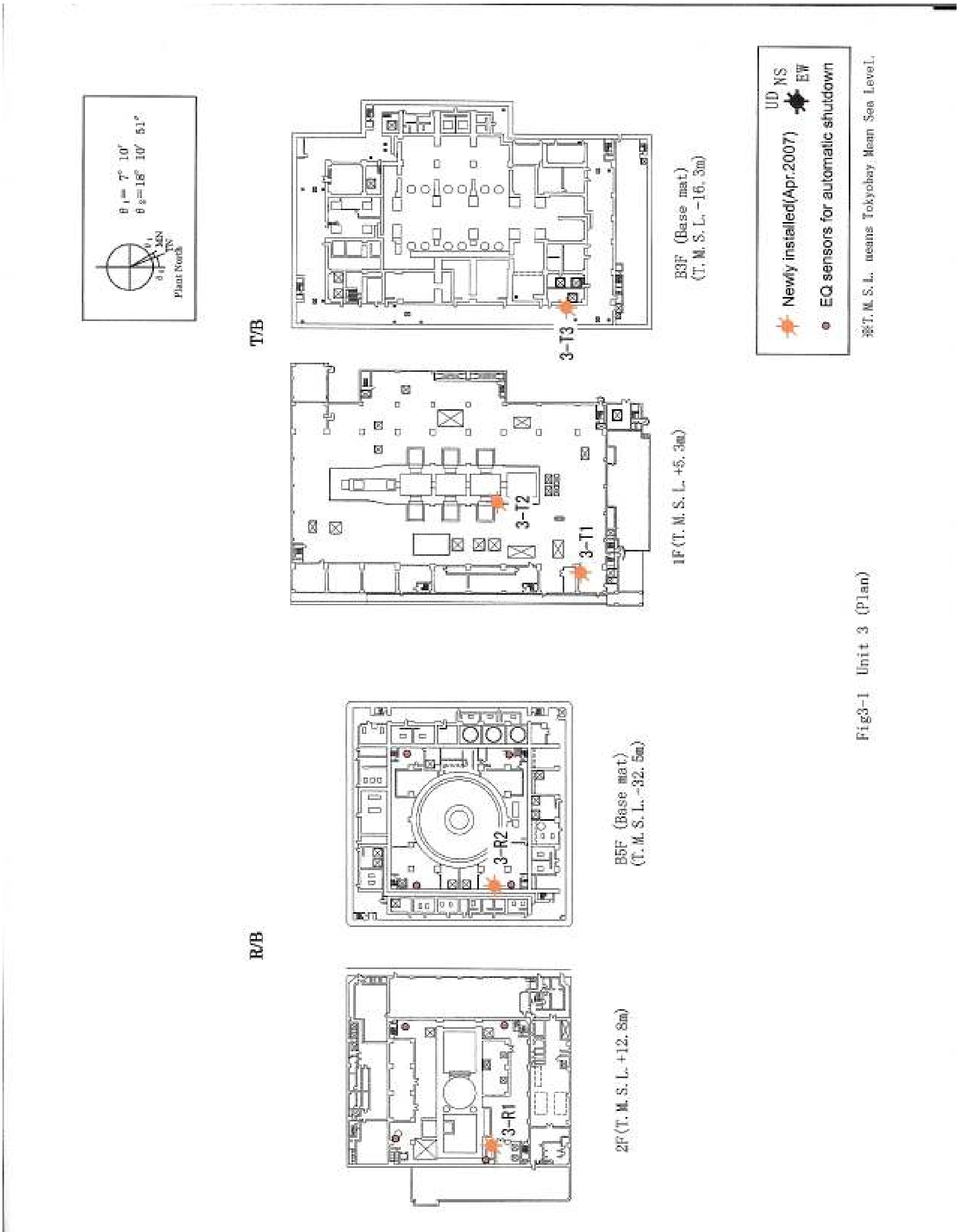


Fig3-1 Unit 3 (Plan)

5

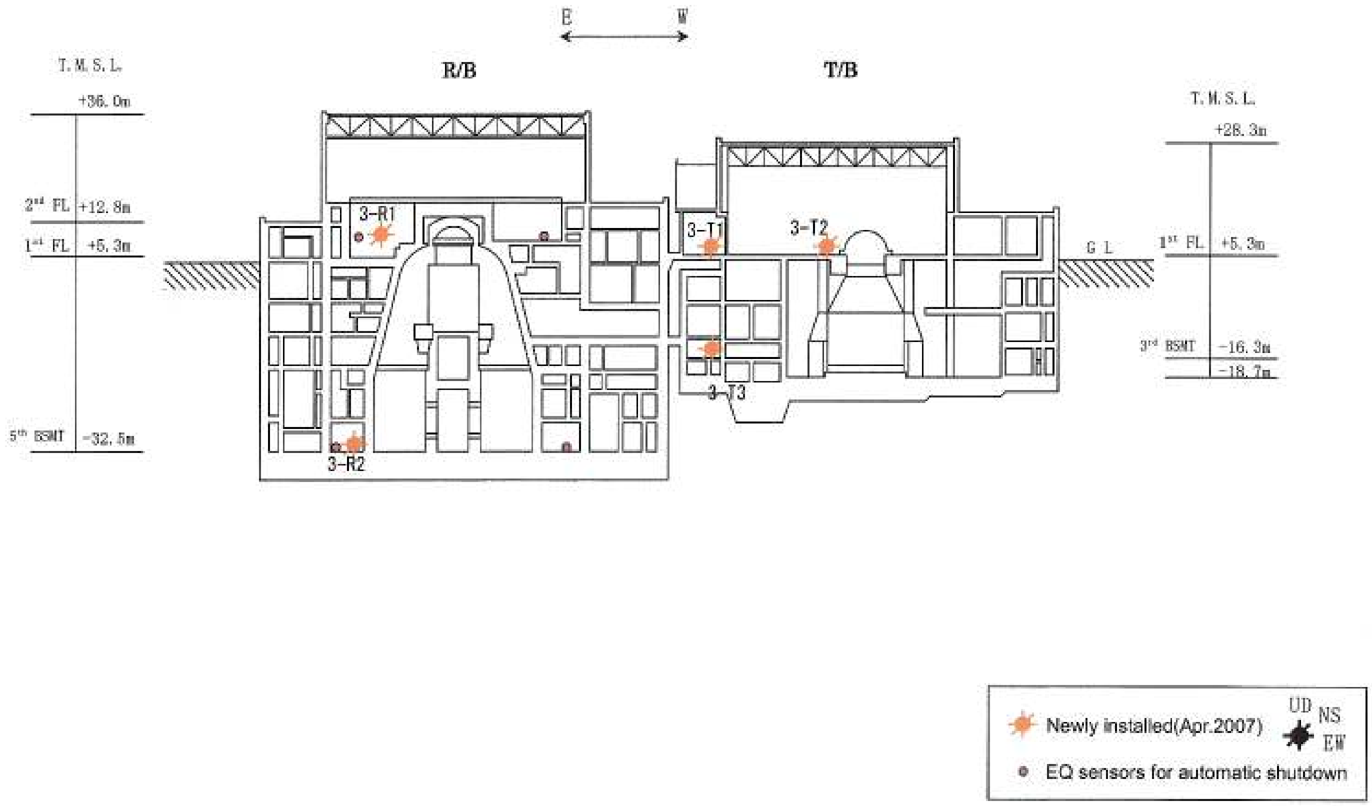
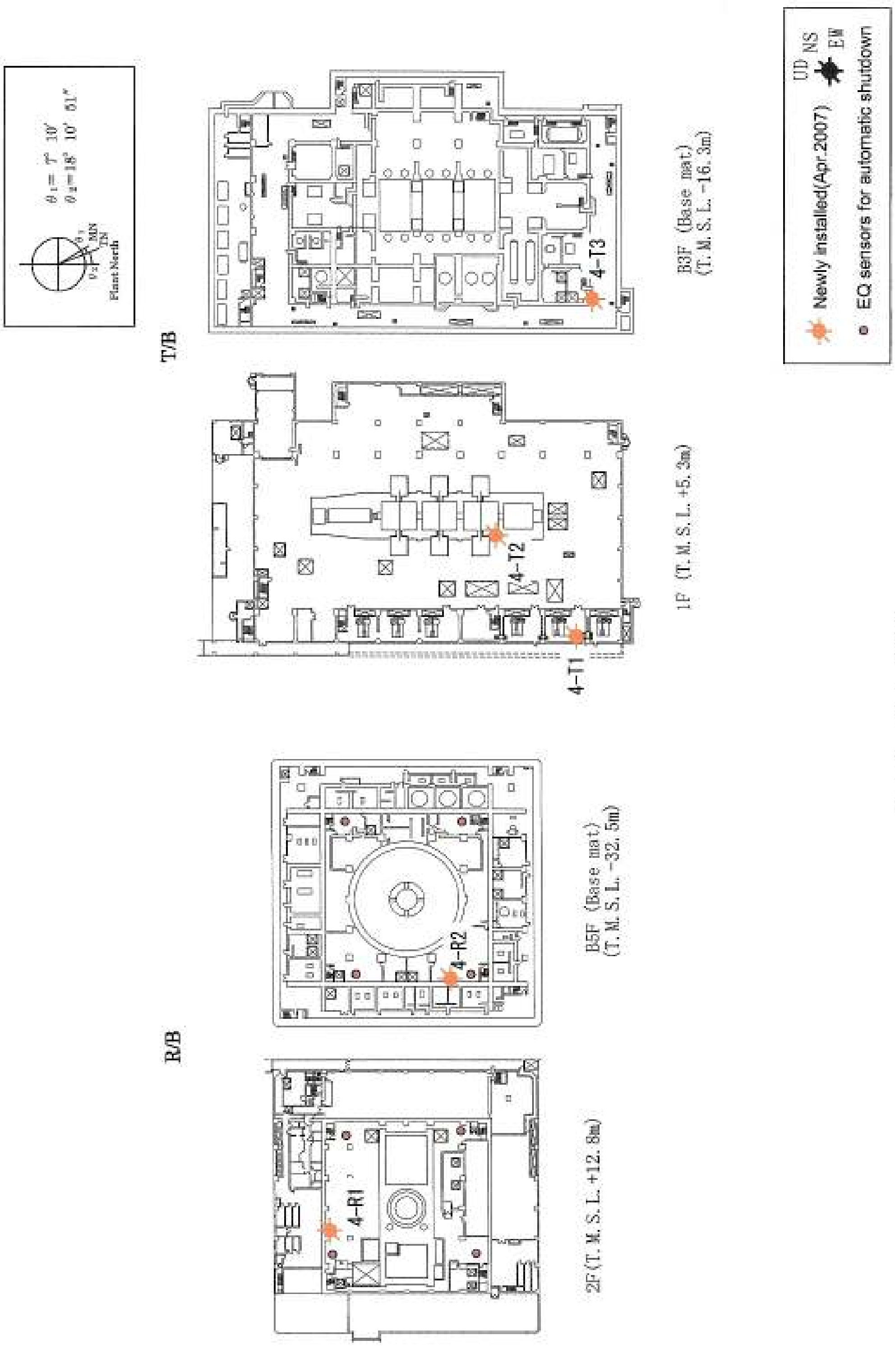


Fig3-2 Unit 3 (Cross Section)

※T.M.S.L. means Tokyobay Mean Sea Level.

6



※T. M. S. L. means Tokyobay Mean Sea Level.

Fig4-1 Unit 4 (Plan)

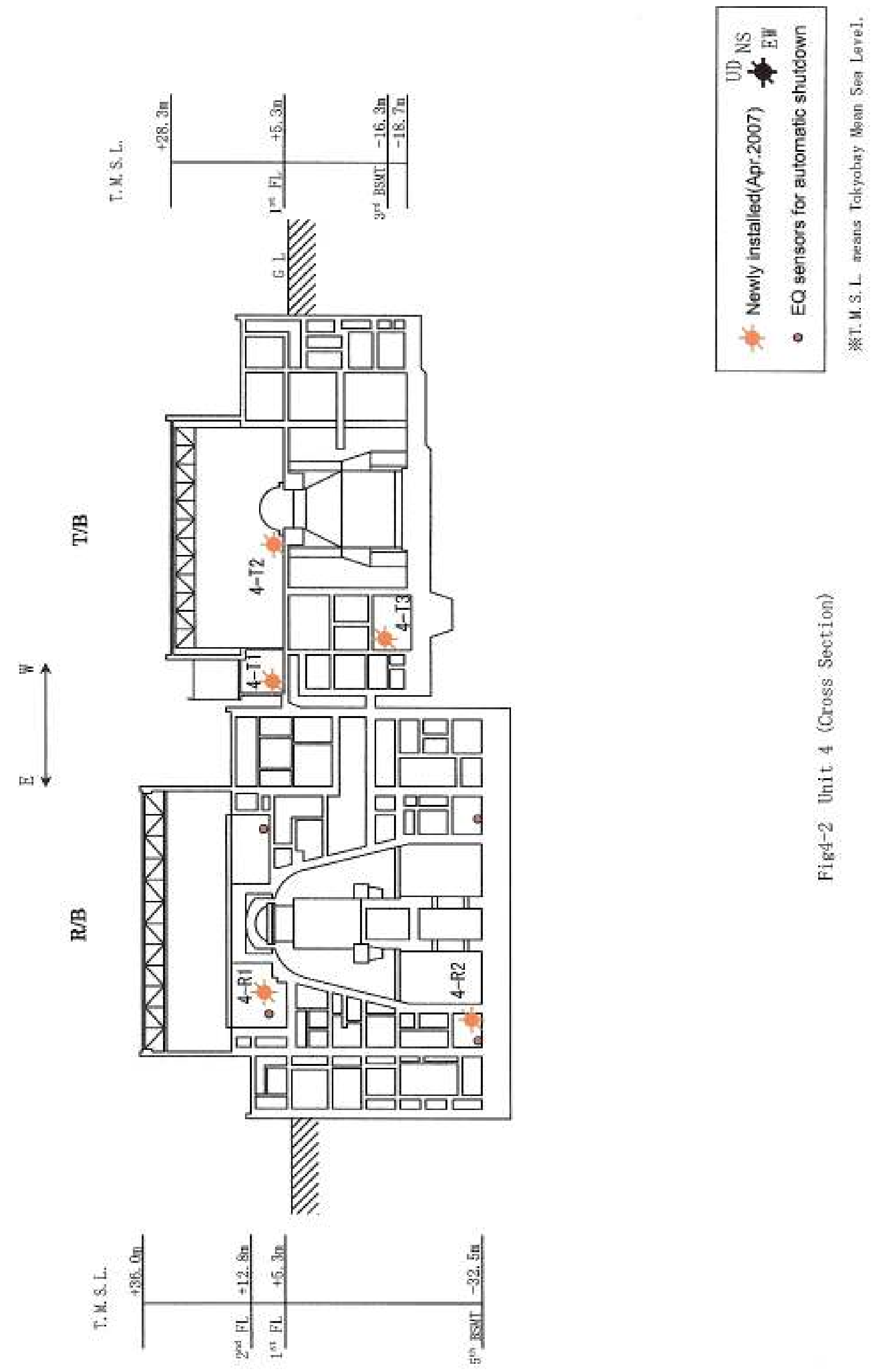


Fig4-2 Unit 4 (Cross Section)

8

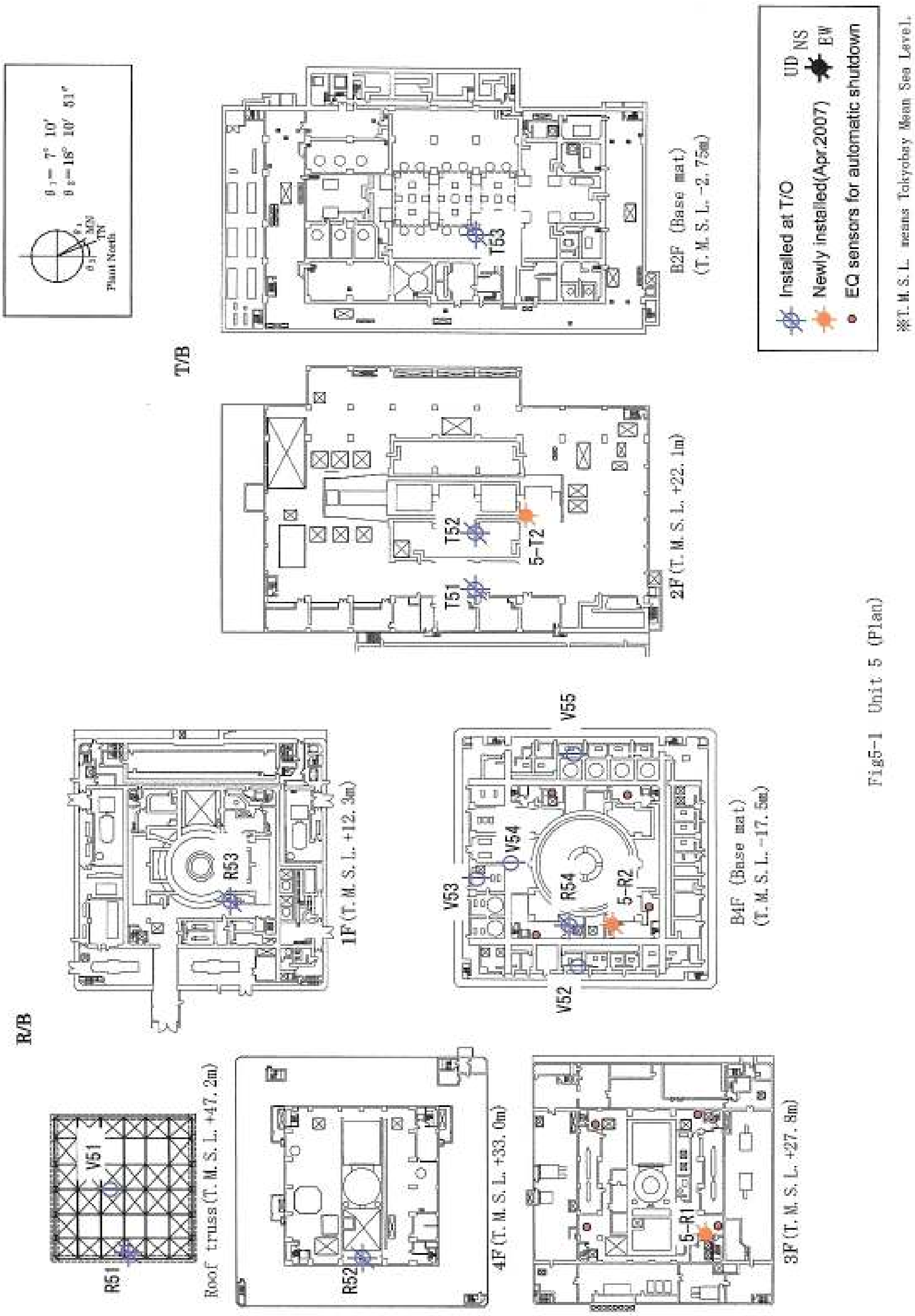


Fig5-1 Unit 5 (Plan)

9

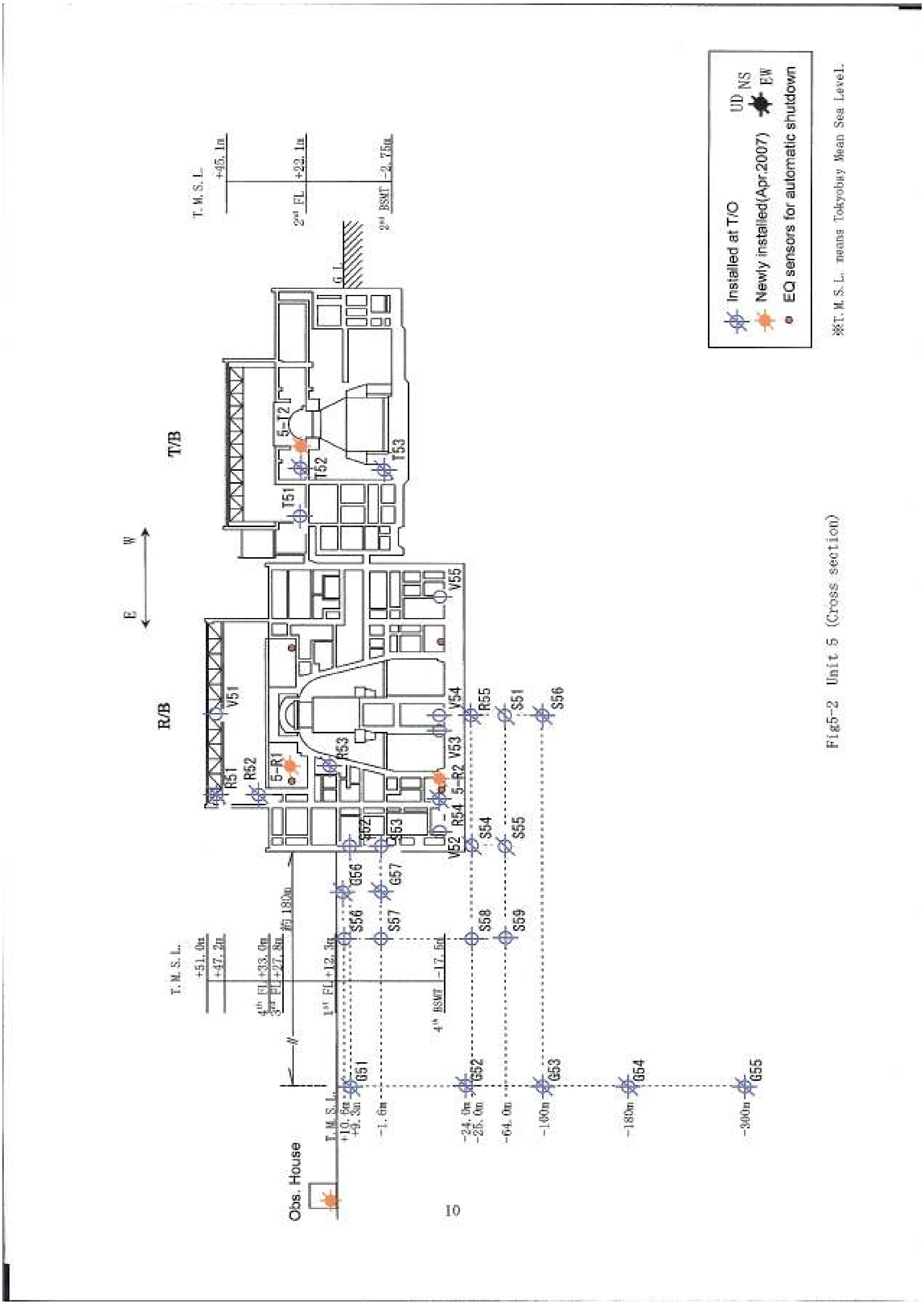


Fig5-2 Unit 5 (Cross section)

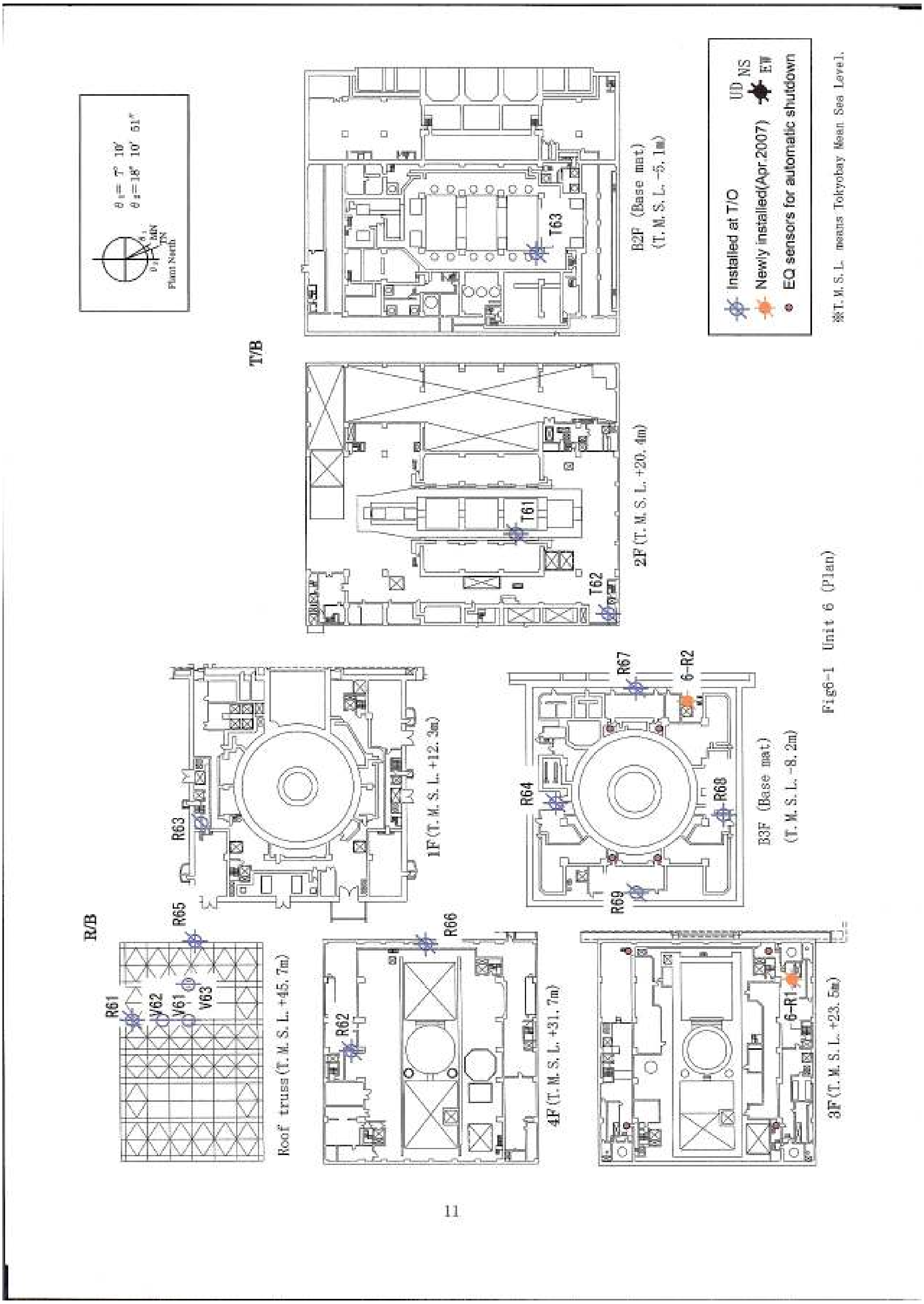


Fig6-1 Unit 6 (Plan)

11

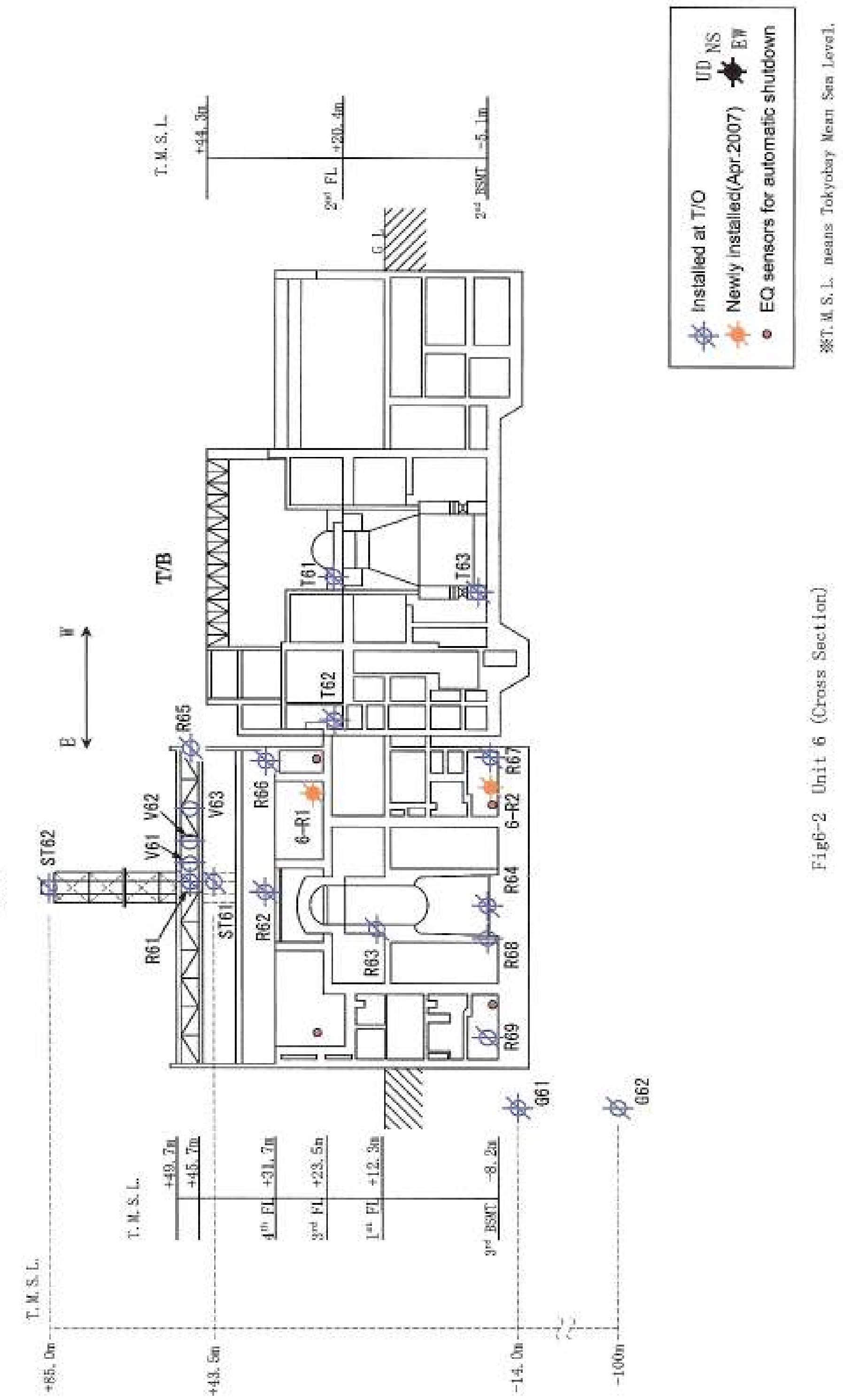


Fig6-2 Unit 6 (Cross Section)

12

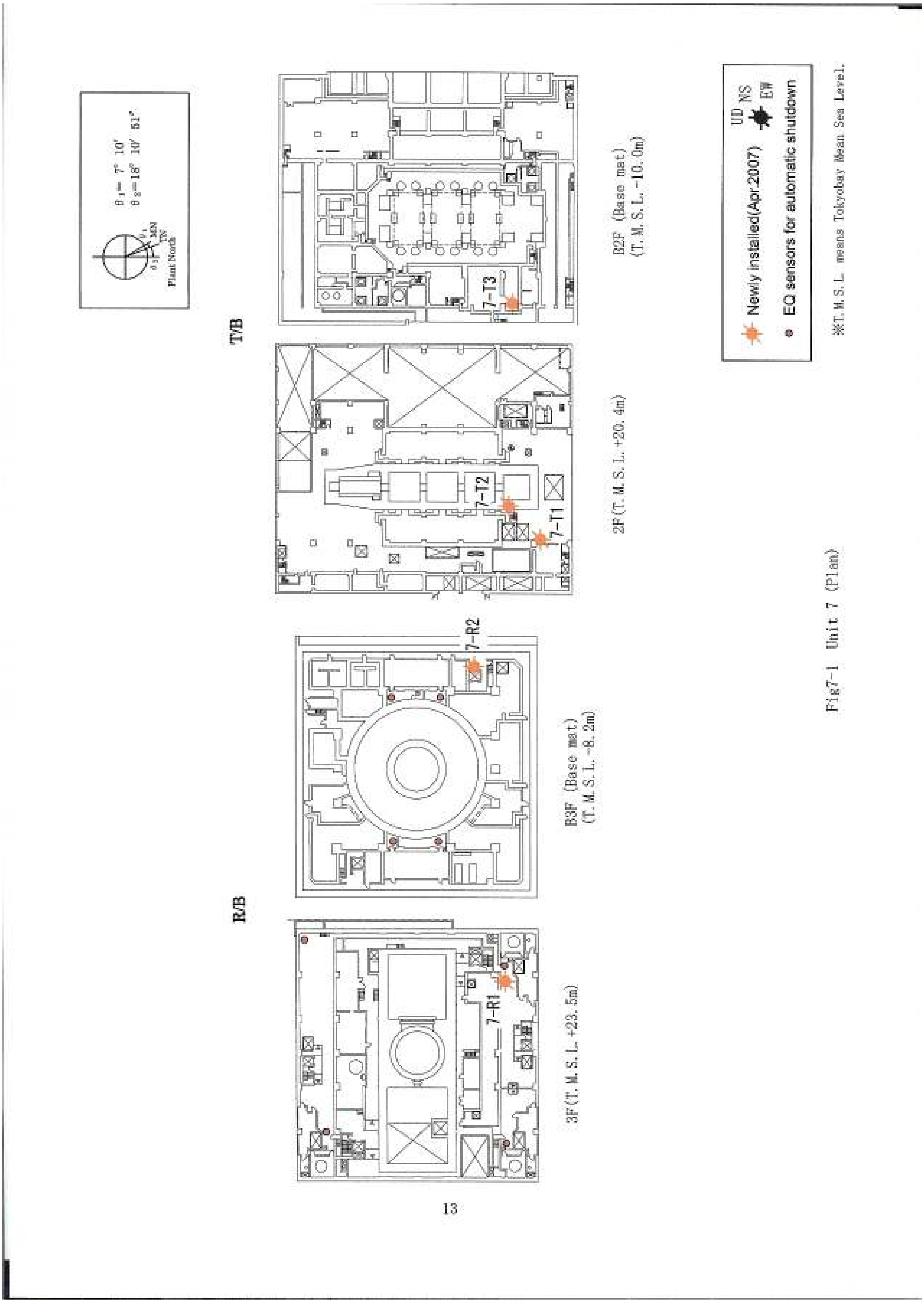


Fig7-1 Unit 7 (Plan)

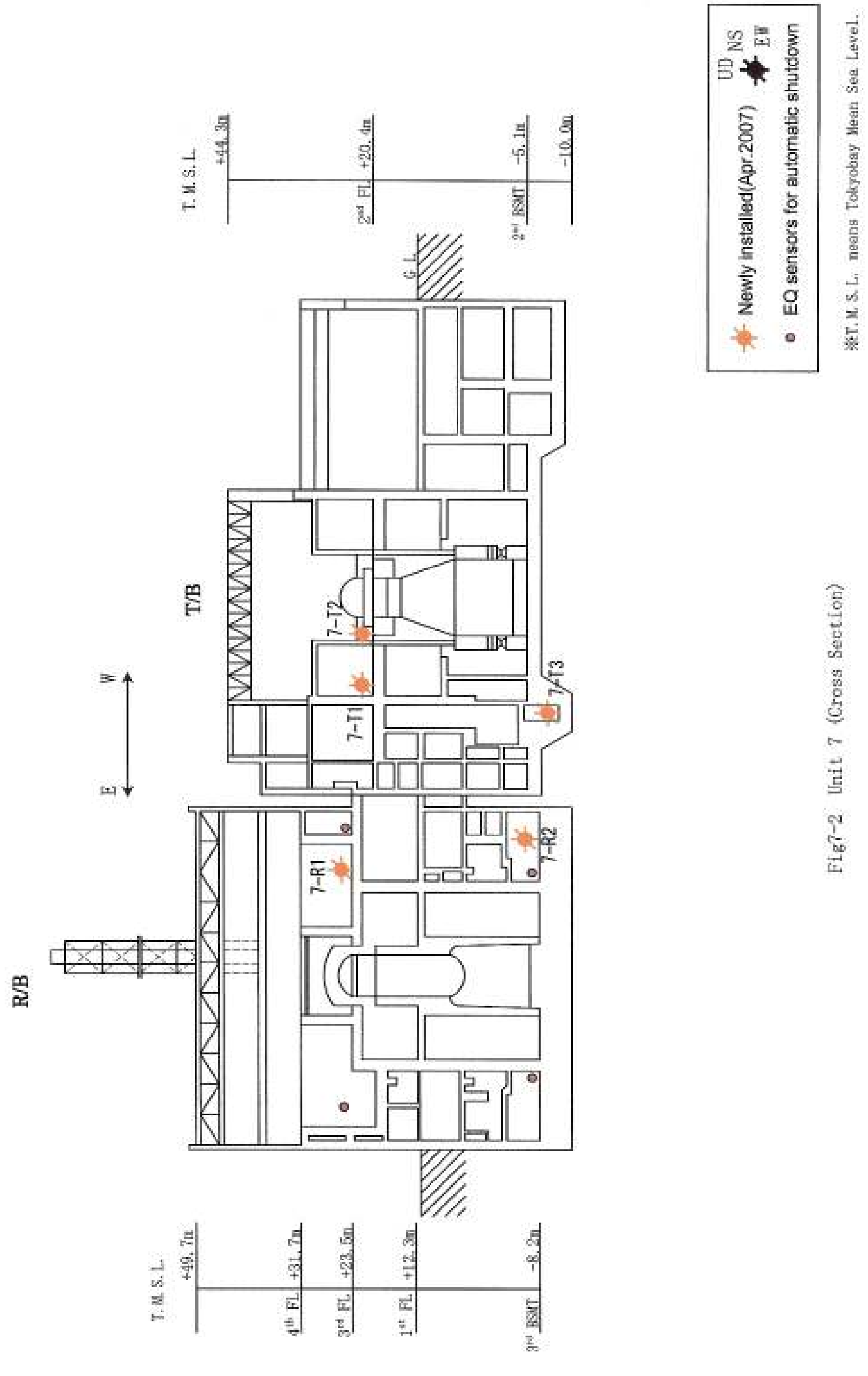
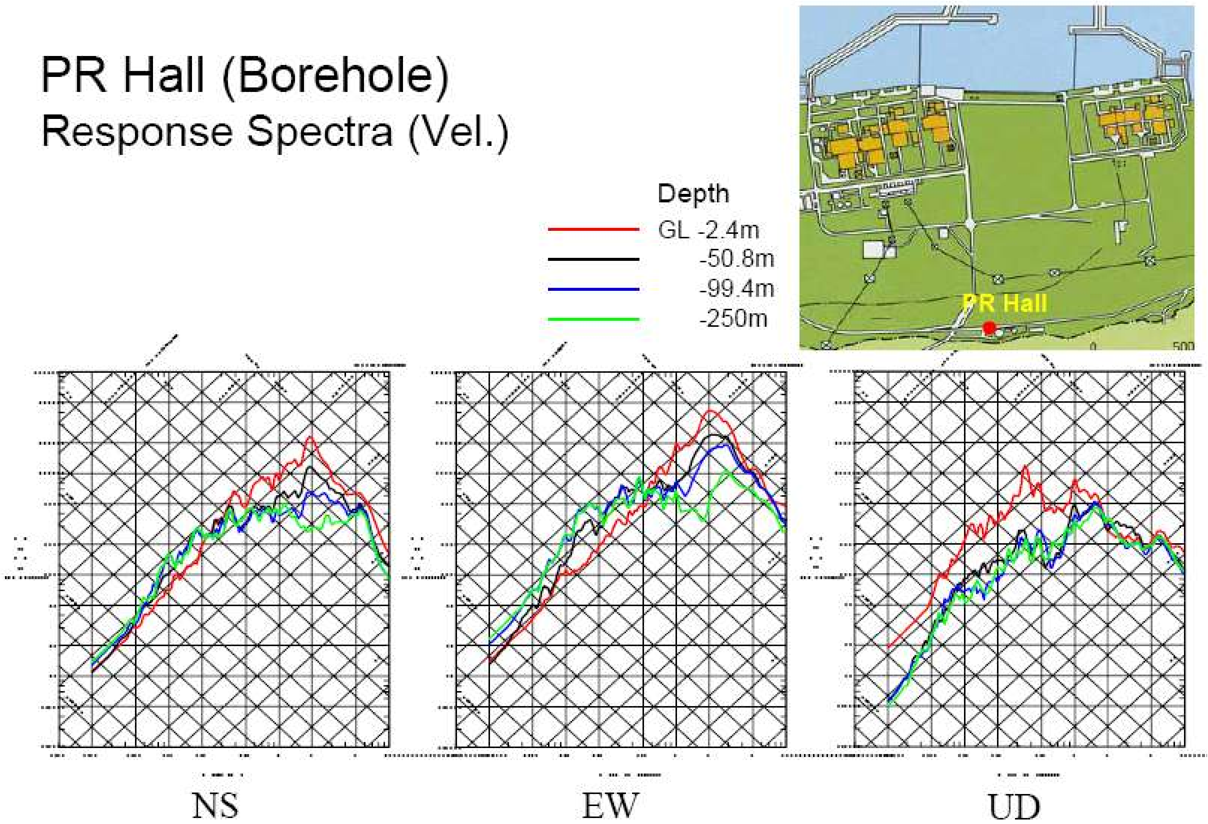


Fig7-2 Unit 7 (Cross Section)

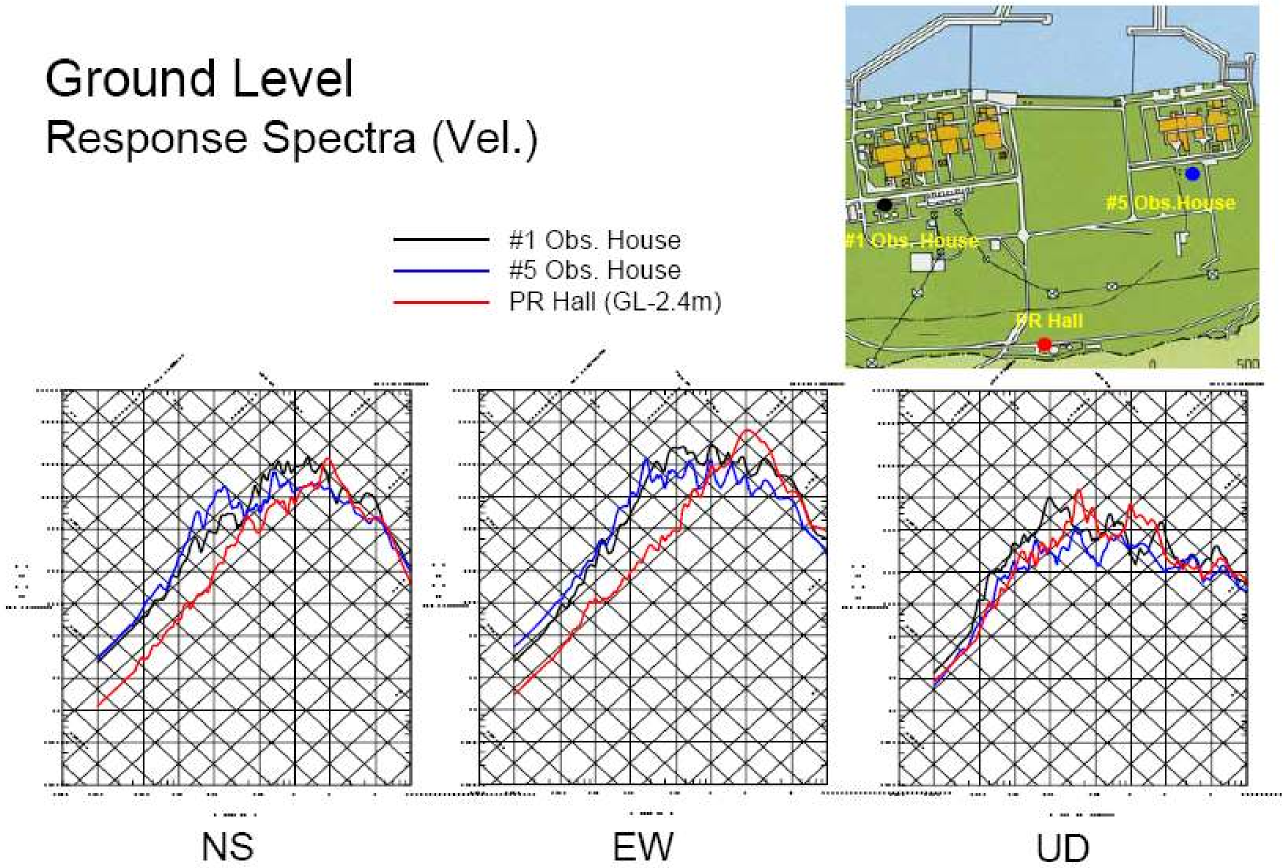
14

II.A.1.4. Response spectra of the recorded motions (surface and down hole) at the PR Hall and Observation Houses #1 and #5

a. Response spectra of the recorded motions at the borehole located at the PR Hall, at ground level and at 3 depths



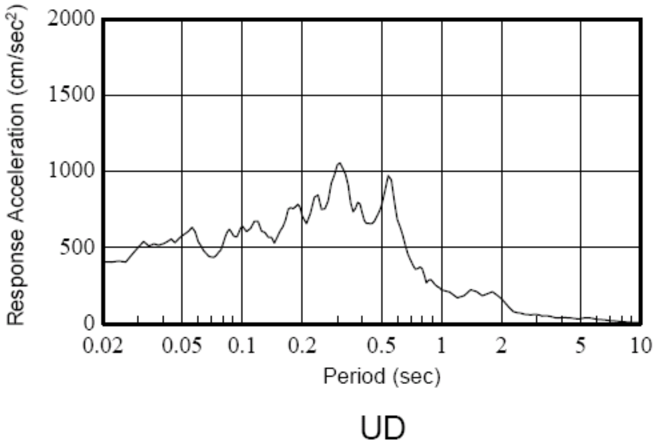
b. Response spectra of the recorded motions at the PR Hall and at Observation Houses #1 and #5 at the ground level



II.A.1.5. Response spectra of the recorded vertical motions at foundation mat levels

1. Unit 1:

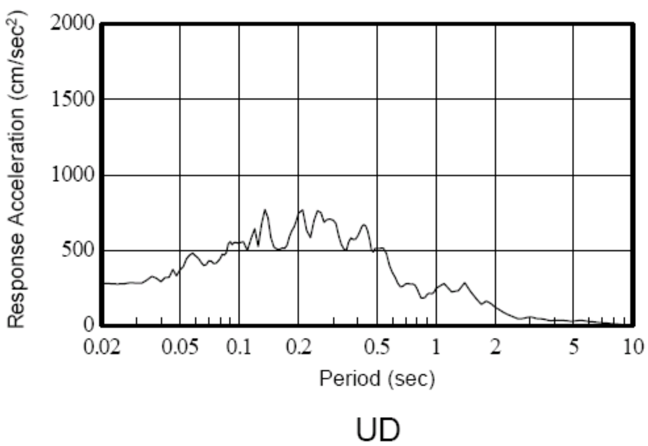
Response Spectra (acc.) Base mat (B5F) R/B #1 1-R2



東京電力 IAEA presentation at Kashiwazaki Kariwa

2. Unit 2:

Response Spectra (acc.) Base mat (B5F) R/B #2 2-R2



東京電力 IAEA presentation at Kashiwazaki Kariwa

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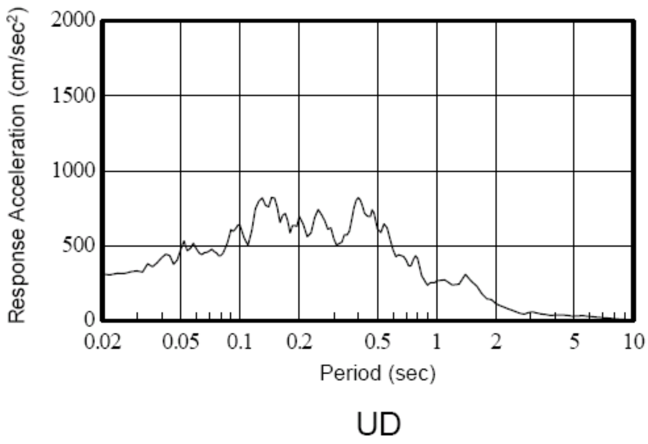
3. Unit 3:

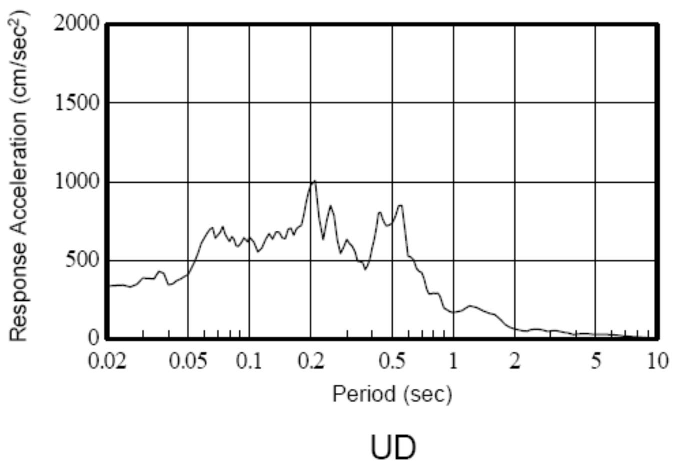
Response Spectra (acc.) Base mat (B5F) R/B #3 3-R2



東京電力 IAEA presentation at Kashiwazaki Kariwa

4. Unit 4:

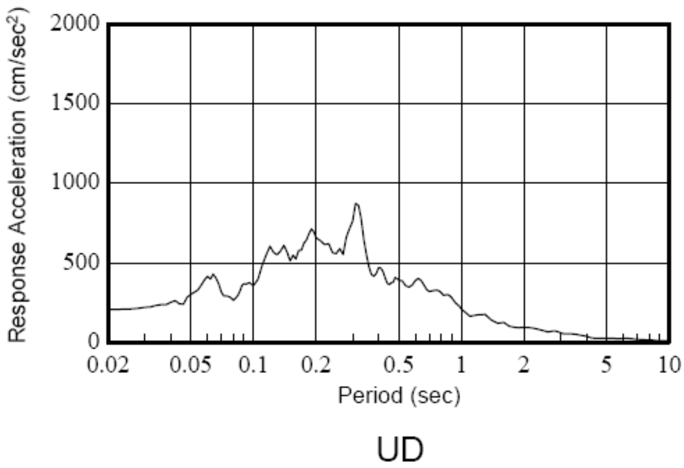
Response Spectra (acc.) Base mat (B5F) R/B #4 4-R2



東京電力 IAEA presentation at Kashiwazaki Kariwa

5. Unit 5:

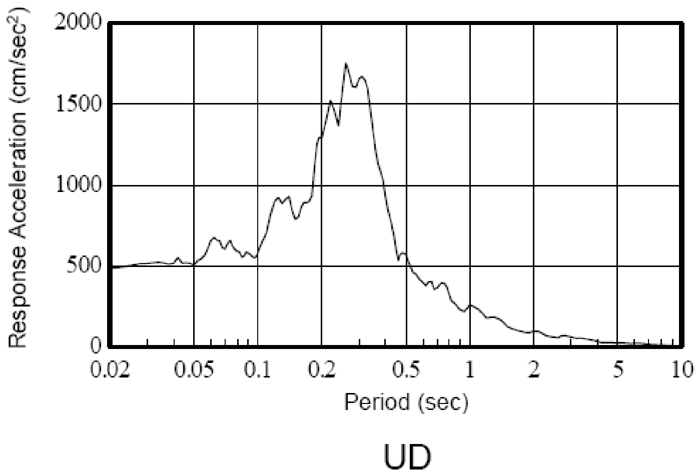
Response Spectra (acc.) Base mat (B4F) R/B #5 5-R2



東京電力 IAEA presentation at Kashiwazaki Kariwa

6. Unit 6:

Response Spectra (acc.) Base mat (B3F) R/B #6 6-R2



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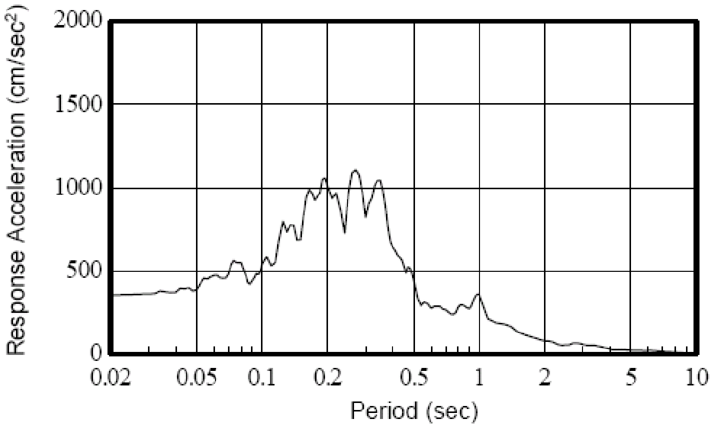
7. Unit 7:

Response Spectra (acc.) Base mat (B3F) R/B #7 7-R2



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IAEA presentation at Kashiwazaki Kariwa

II.A.1.6. Technical specifications for seismic instrumentation (in Japanese)

Note from the IAEA Expert Team:

The technical specifications of the old (original) and new (April 2007) seismic instruments are provided in following two pages, respectively.

The amplification curves are given at the bottom of the page.

The most notable differences between the two types of instruments may be observed for the frequency ranges (0.005~40 Hz for the old one and DC~450 Hz for the new) and the maximum amplitudes (± 1000 gals for the old and ± 2097 gals for the new instruments).

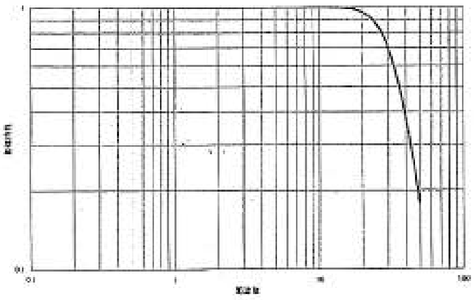
表５　新設地震計の計器特性

部　位	項　目	仕　様
検出器	方式	電磁式負帰還方式加速度計（変位帰還型）
	周波数範囲	DC ～ 450 Hz
	測定可能範囲	± 2097 Gal
増幅器	周波数特性	DC ～ 30 Hz
	ハイカットフィルタ	f_0 = 30Hz, ３次IIRバタワースLPF＋f_0 = 50Hz, 2次IIR LPF
	フルスケール	2097 Gal
制御部 （記録器）	A / D 変換	24 bit（実行20bit, ﾀﾞｲﾅﾐｯｸﾚﾝｼﾞ：114 dB）
	最小分解能	4.00 mGal
	サンプリングレート	100 Hz（50 Hz, 200 Hz切替可能）
	遅延時間	30 秒
	記録時間	90 秒以上（遅延時間含む）
	キャリブレーション	１日１回 〔１号機（１時05分）～７号機（１時35分） 各号機５分おきに実施, 地表（１時40分）〕
	記録媒体	現地：ICメモリー（256MB）
	最大収録時間	現地：約80時間（100 Hzサンプリング時）
	停電復帰対策	自動復帰
	時計精度	誤差±１ppm以下 （観測室のPCの時計により通信を通じて校正）
無停電電源装置	停電保証時間	３時間

起動及び記録時間

項目	仕様	現在の設定
起動レベル	0.1～99.9Gal（0.1Galステップ）	〔原子炉建屋〕基礎版上：１Gal, 中間階：２Gal 〔タービン建屋〕基礎版上：１Gal, ペデスタル：20 Gal, 中間階：２Gal 〔地震観測小屋〕４Gal
起動方式	OR, AND	OR
起動チャンネル	―	―
記録時間長	起動レベルに達した30秒前より記録を開始し, 起動レベルを下回った後60秒間継続し記録する。１地震当たりの最大記録時間は, 600秒。	

（参考）　周波数特性図



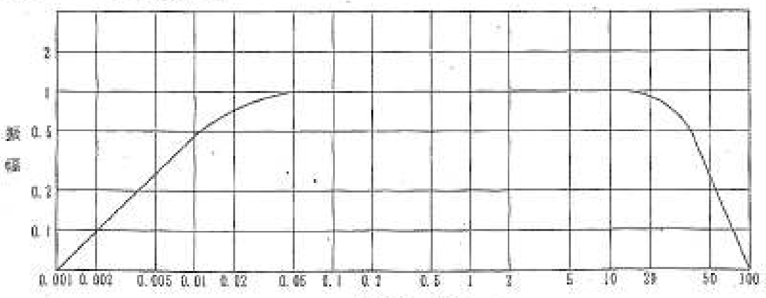
5

表１　既設地震計の計器特性（１号機）

部位	項目	仕様
検出器	方式	電磁式負帰還方式加速度計（速度帰還型）
	周波数範囲	0.05 ～ 40 Hz
	測定可能範囲	± 1000 Gal
増幅器	周波数特性	0.02 ～ 30 Hz
	ハイカットフィルタ	f_0 = 30Hz　-18 dB/oct
	フルスケール	1000 Gal
制御部（記録器）	A / D 変換	16 bit（14bit＋(2bit<AGC３段>，ﾀﾞｲﾅﾐｯｸﾚﾝｼﾞ：102 dB)
	最小分解能	7.63 mGal
	サンプリングレート	100 Hz（200 Hz切替可能）
	遅延時間	30 秒
	記録時間	90 秒以上（遅延時間含む）
	キャリブレーション	１日１回（８時）
	記録媒体	現地：ICメモリー（40MB）
	最大収録時間	現地：約54分（100 Hzサンプリング時）
	停電復帰対策	自動復帰
	時計精度	±10^{-6} sec以上（NHK-FMにより時報毎に校正）
無停電電源装置	停電保証時間	60 分

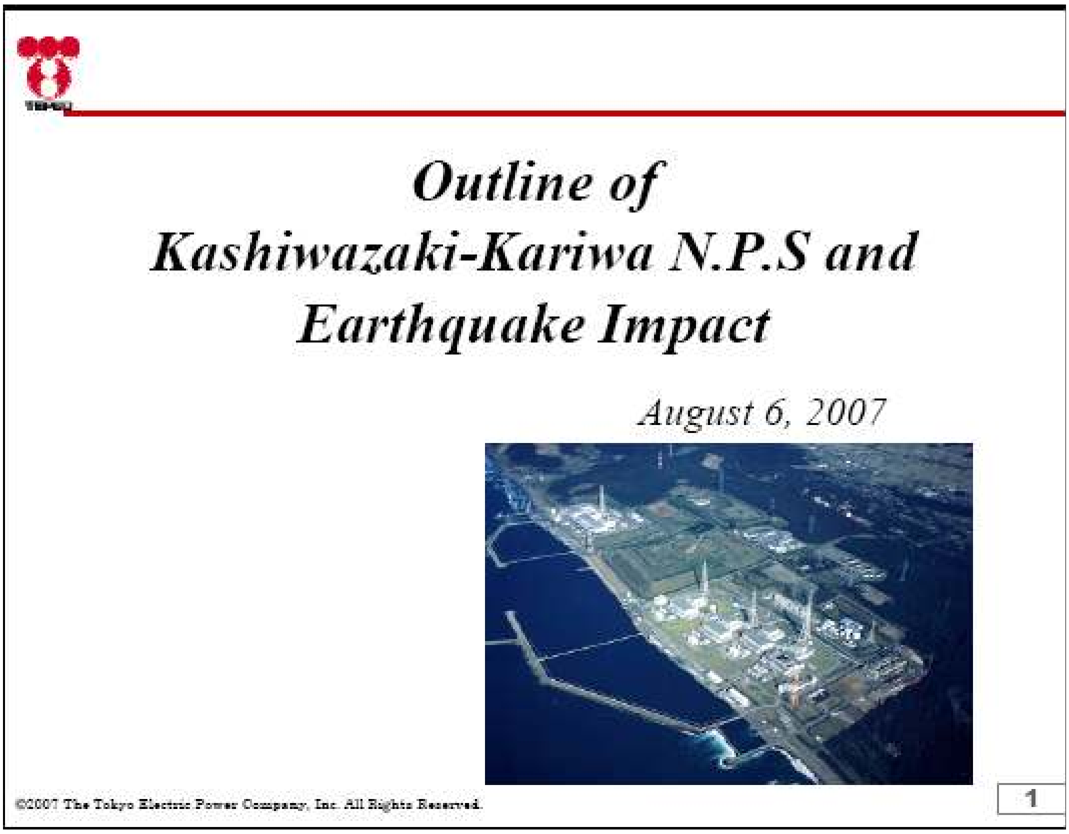
起動及び記録時間		
項目	仕様	現在の設定
起動レベル	0.5, 1, 2, 4, 8, 16, 32Gal	0.5 Gal
起動方式	OR, AND	OR
起動チャンネル	任意の3成分	G9観測点（T.M.S.L. －122m）の３成分
記録時間長	起動レベルに達した30秒前より記録を開始し，起動レベルを下回った後60秒間継続し記録する。１地震当たりの最大記録時間は，メモリ残量分（最大約54分）。	

（参考）　周波数特性図



1

II.A.2. Outline of Kashiwazaki-Kariwa NPP and earthquake impact



Note:
NISA and TEPCO have approved the release of following information.

Analysis and evaluation of plant behavior in Earthquake Impact

August 6, 2007

TEPCO

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TEPCO proprietary INFO

1• OBJECT

- In consideration of Earthquake Impact on July 16, We are analyzing and evaluating the plant data of Kashiwazaki-Kariwa units No.2/3/4/7 (shutdown by automatic scram).
- The plant data for analysis and evaluation are as follows ;
  - •Chart of safety important plant parameter
  - •Plant trip sequence by process computer
  - •Alarm message by process computer
  - •Transient recorder
  - •Operator logbook
  - •Alarm status in main control room
- Our Goal is to confirm : the plant after scram because of "Large seismic acceleration" ensured to shut-down safely and to shift the status of Reactor Shutdown Cooling (Rx WTR TEMP < 100•) by the analysis and evaluation of the safety important plant parameter data.
- • The data analysis-team consists of the experts of TEPCO and plant maker (Toshiba,Hitachi) for the mission.

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2. Plant status before Earthquake impact

Plant status	NSSS						Radiation monitor		
	Avaraged	APRM	Rx WLV (Narrow)	Rx WLV (Upset)	Rx Prssure	Rx TEMP	STACK	SGTS	SEA WTR
	(MW)	(%PWR)	(mm)	(mm)	(MPa)	(•)	• • • • •	• • • • •	• • • • • • •
UNIT • •	-	-	-	-	-	30	4	2.2	396
UNIT • (*1)	0	0	921	590	3.38	242.6	4.8	4	385
UNIT • •	3290	100.3	921	-	6.85	278.1	5.3	2.5	390
UNIT • •	3286	100.4	923	-	6.85	276.5	5.3	3.6	392
UNIT • •	-	-	-	-	-	41.5	6	6	382
UNIT • •	-	-	-	-	-	30.4	5.5	5.5	380
UNIT • •	3907	100	1181	-	7.1	278	4.3	4	371

• • •OPERATOR LOGBOOK (data of July 16th at 10:00am)

Unit 1-5 : BWR5 Rated thermal power : 3293 MW
Unit 6-7 : ABWR Rated thermal power : 3926 MW

The meaning of the color :
Blue • Starting-up operationYellow• Full power operation White• Annual outage

*1 Unit 2 :Starting-up operation
Rx feed water system : 1• MDRFP+2• CP
Neutron flux monitoring : SRM/IRM
CR in full drawing : 22 / 185

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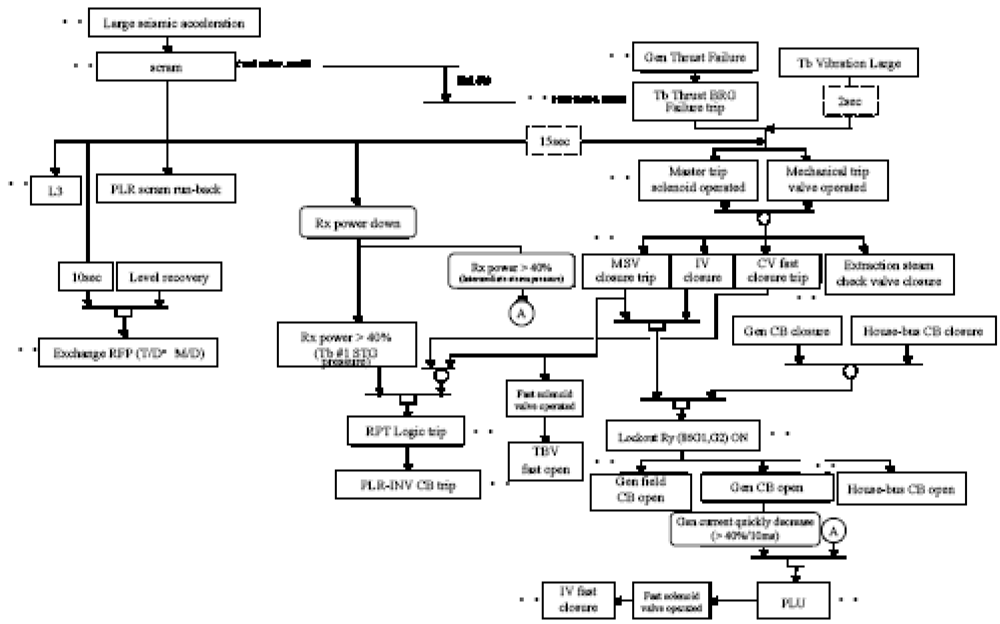
3. Example of trip sequence • •unit No.3 • •



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4• Analysis of the safety important plant parameter

Control of Reactivity

- Neutron flax (SRM/IRM/SRNM/APRM)
- SCRAM speed

Removal of the decay heat

- Reactor Water Temperature
- Reactor Pressure
- Reactor Water Level •K2• used upset range water level••
- Core Flow
- Feed Water Flow
- Main Steam Flow

Confinement of radioactive material

- D/W pressure
- D/W temperature
- Stack radiation monitor
- SGTS radiation monitor

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4. Analysis and Evaluation

1.Control of Reactivity

(1) Neutron flax

- UNIT2 • SRM/IRM signal was stable immediately
- UNIT3,4,7• APRM signal decreased immediately

(2) SCRAM speed (measured value)

- UNIT2 • 0.905• 0.955s at 75% < 1.62s (design basis)
- UNIT7 • 0.714• 0.807s at 60% < 1.44s (design basis)
- UNIT3,4 • SCRAM timing recorder was not available

(3)CR condition

- UNIT3,7• ALL CR full insertion according to alarm message
- UNIT2,4• ALL CR full insertion according to Operator log

The reactivity was safely controlled

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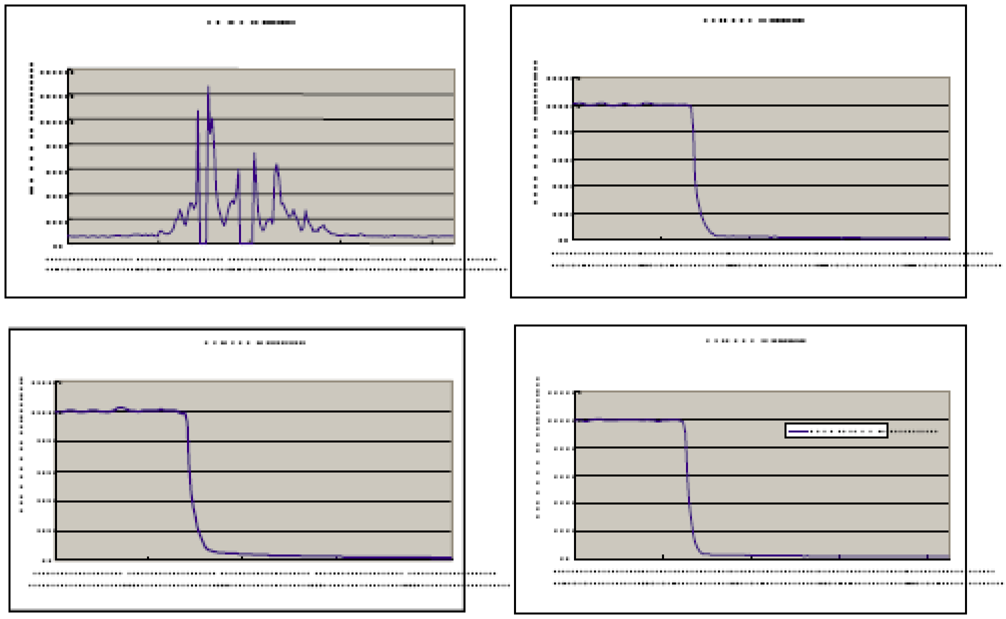
Behavior of main plant parameter (Neutron flax monitor)



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4. Analysis and Evaluation (cont.)

2. Removal of the decay heat

(1) Rx water level

- UNIT2 : Increase trend caused by CUW(A) trip
- UNIT3,4,7 : Stable and moderate trend in general

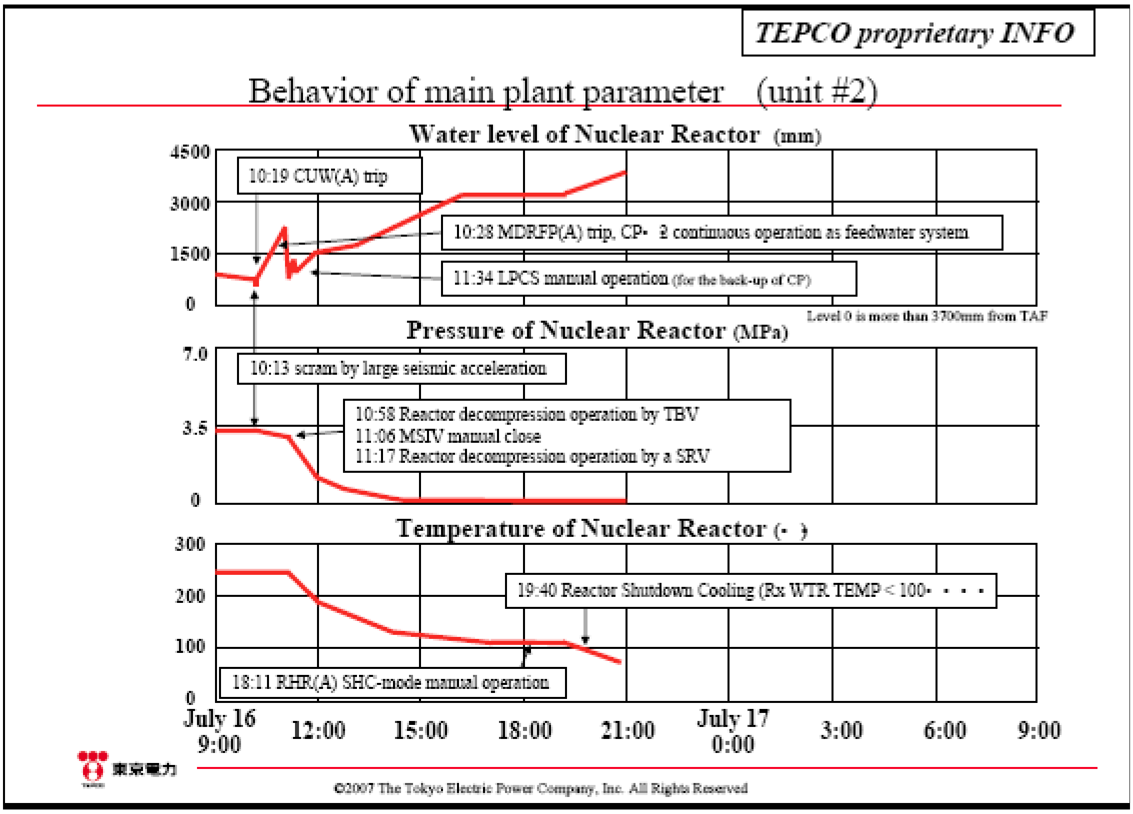
(2)Rx pressure

- UNIT2 : Stable and moderate trend in general
- UNIT3,4,7 : Stable and moderate trend in general

(3)Rx water temperature

- UNIT2 : Stable and moderate trend in general
- UNIT3,4,7 : Stable and moderate trend in general

The decay heat was safely removed


TEPCO proprietary INFO
Behavior of main plant parameter (unit #2)
Water level of Nuclear Reactor (mm)
10:19 CUW(A) trip
10:28 MDRFP(A) trip, CP• 2 continuous operation as feedwater system
11:34 LPCS manual operation (for the back-up of CP)
Level 0 is more than 3700mm from TAF
Pressure of Nuclear Reactor (MPa)
10:13 scram by large seismic acceleration
10:58 Reactor decompression operation by TBV
11:06 MSIV manual close
11:17 Reactor decompression operation by a SRV
Temperature of Nuclear Reactor
19:40 Reactor Shutdown Cooling (Rx WTR TEMP < 100•
18:11 RHR(A) SHC-mode manual operation
July 16 9:00
12:00
15:00
18:00
21:00
July 17 0:00
3:00
6:00
9:00
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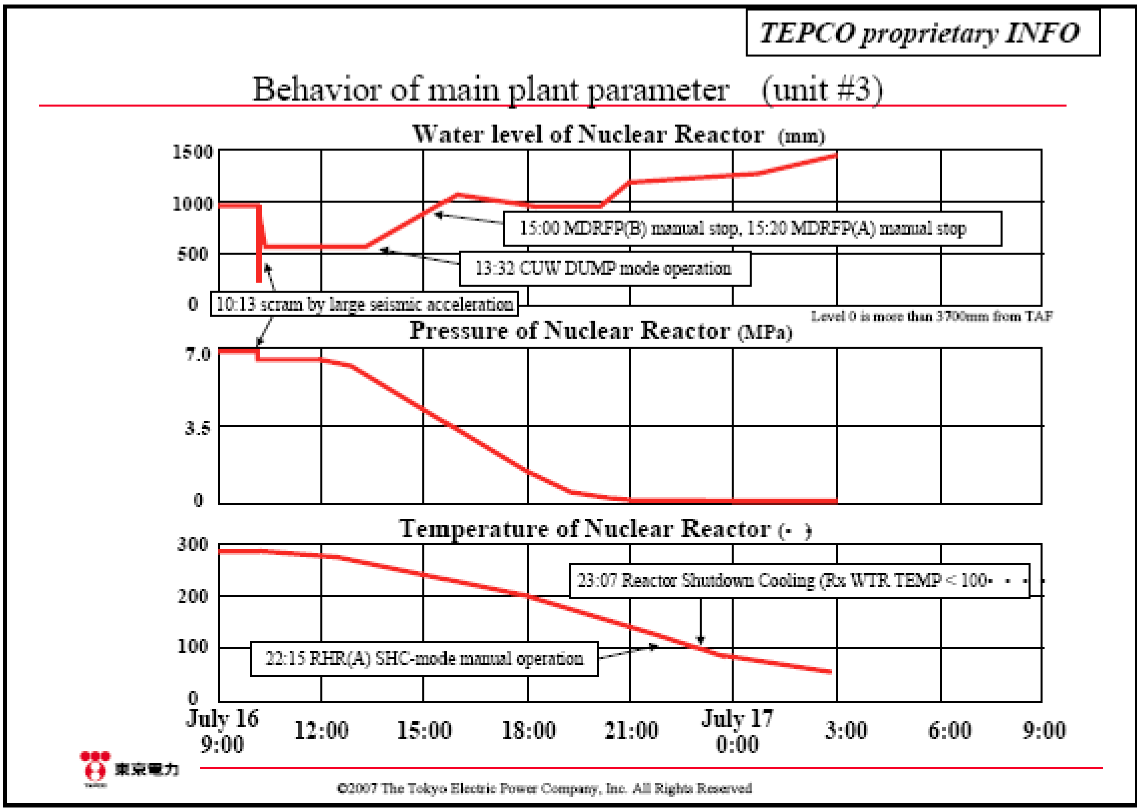
TEPCO proprietary INFO
Behavior of main plant parameter (unit #3)
Water level of Nuclear Reactor (mm)
15:00 MDRFP(B) manual stop, 15:20 MDRFP(A) manual stop
13:32 CUW DUMP mode operation
10:13 scram by large seismic acceleration
Level 0 is more than 3700mm from TAF
Pressure of Nuclear Reactor (MPa)
Temperature of Nuclear Reactor
23:07 Reactor Shutdown Cooling (Rx WTR TEMP < 100•
22:15 RHR(A) SHC-mode manual operation
July 16 9:00
12:00
15:00
18:00
21:00
July 17 0:00
3:00
6:00
9:00
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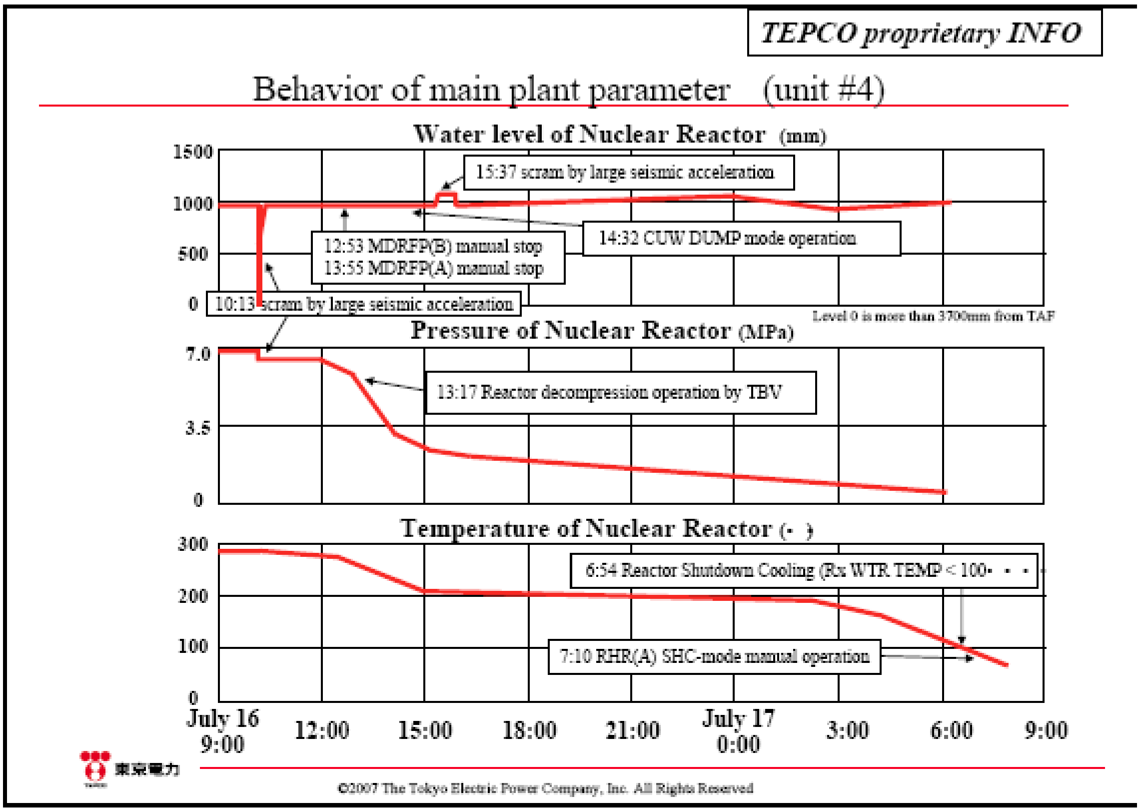
TEPCO proprietary INFO
Behavior of main plant parameter (unit #4)
Water level of Nuclear Reactor (mm)
1500
1000
500
0
15:37 scram by large seismic acceleration
14:32 CUW DUMP mode operation
12:53 MDRFP(B) manual stop
13:55 MDRFP(A) manual stop
10:13 scram by large seismic acceleration
Level 0 is more than 3700mm from TAF
Pressure of Nuclear Reactor (MPa)
7.0
3.5
0
13:17 Reactor decompression operation by TBV
Temperature of Nuclear Reactor
300
200
100
0
6:54 Reactor Shutdown Cooling (Rx WTR TEMP < 100
7:10 RHR(A) SHC-mode manual operation
July 16 9:00
12:00
15:00
18:00
21:00
July 17 0:00
3:00
6:00
9:00
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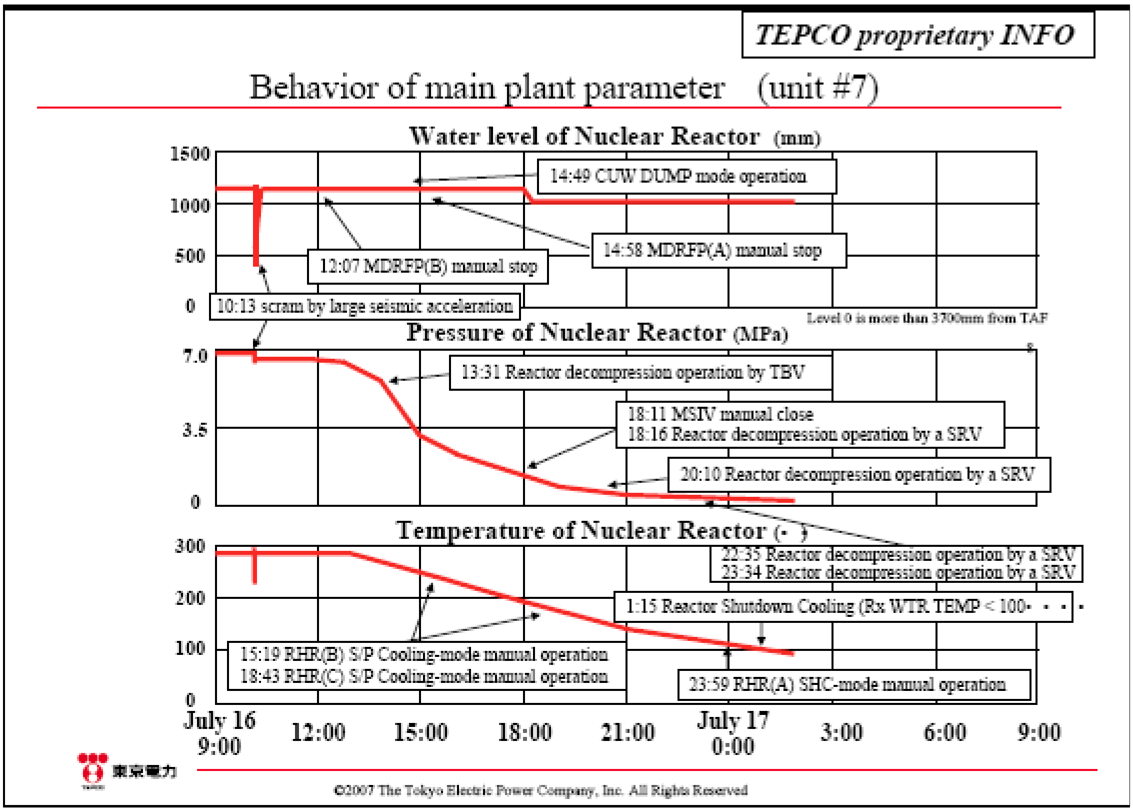
TEPCO proprietary INFO
Behavior of main plant parameter (unit #7)
Water level of Nuclear Reactor (mm)
1500
1000
500
0
14:49 CUW DUMP mode operation
14:58 MDRFP(A) manual stop
12:07 MDRFP(B) manual stop
10:13 scram by large seismic acceleration
Level 0 is more than 3700mm from TAF
Pressure of Nuclear Reactor (MPa)
7.0
3.5
0
13:31 Reactor decompression operation by TBV
18:11 MSIV manual close
18:16 Reactor decompression operation by a SRV
20:10 Reactor decompression operation by a SRV
Temperature of Nuclear Reactor
300
200
100
0
22:35 Reactor decompression operation by a SRV
23:34 Reactor decompression operation by a SRV
1:15 Reactor Shutdown Cooling (Rx WTR TEMP < 100
15:19 RHR(B) S/P Cooling-mode manual operation
18:43 RHR(C) S/P Cooling-mode manual operation
23:59 RHR(A) SHC-mode manual operation
July 16 9:00
12:00
15:00
18:00
21:00
July 17 0:00
3:00
6:00
9:00
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4. Analysis and Evaluation (cont.)

3. Confinement of radioactive material

(1) D/W pressure : Stable and moderate trend in general
(2) D/W temperature : Stable and moderate trend in general
(3) Stack radiation monitor : Stable and moderate trend in general
(4) SGTS radiation monitor : Stable and moderate trend in general

The radioactive material was safely confined

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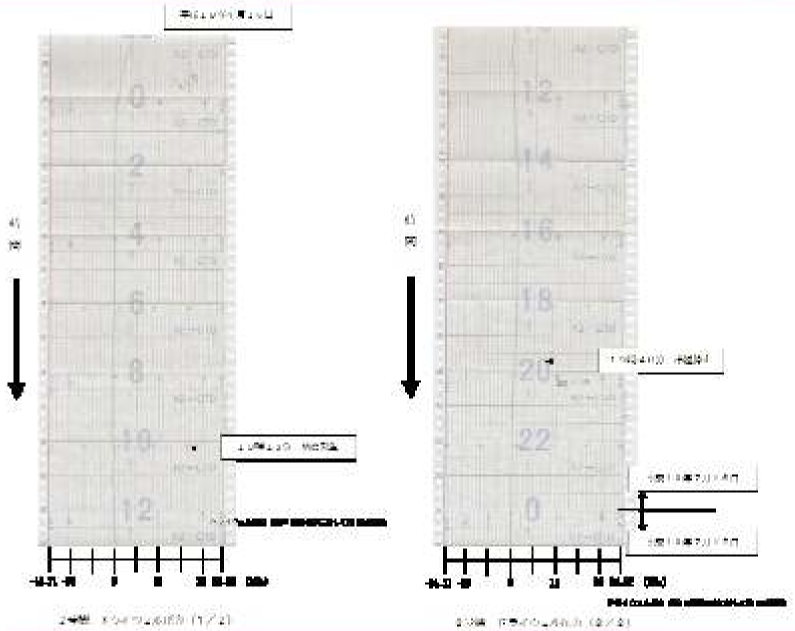
Behavior of main plant parameter (#2 D/W pressure)



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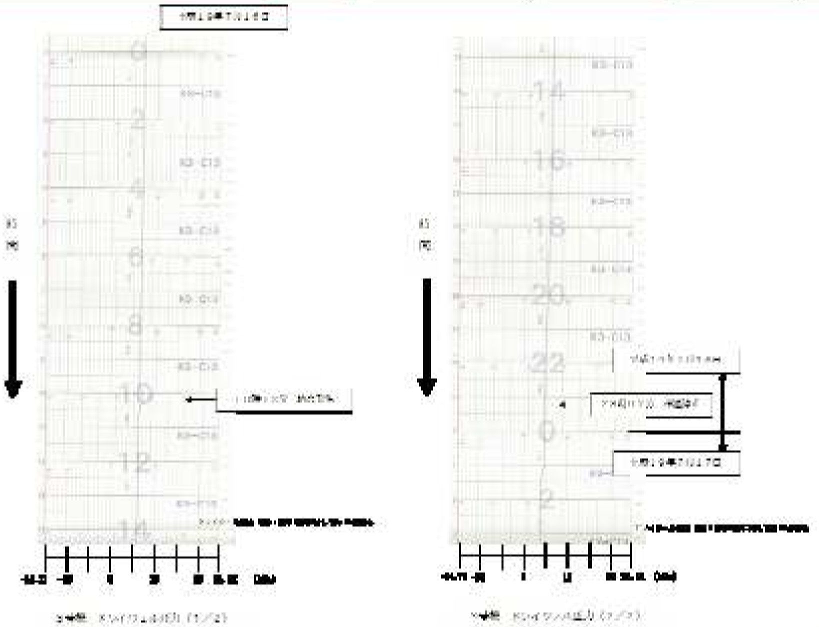
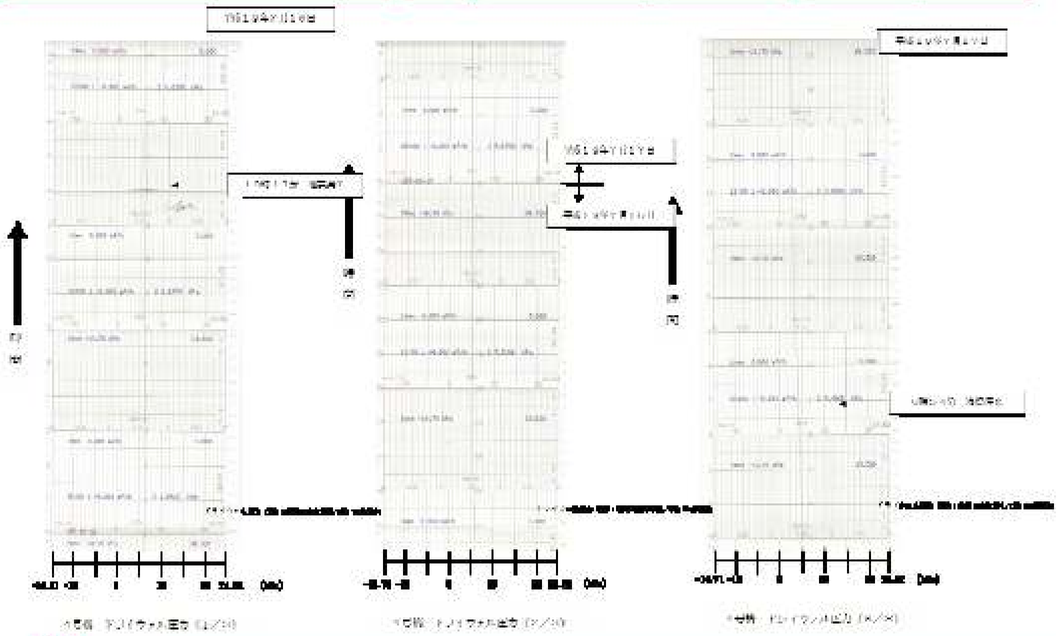
Behavior of main plant parameter (#3 D/W pressure)



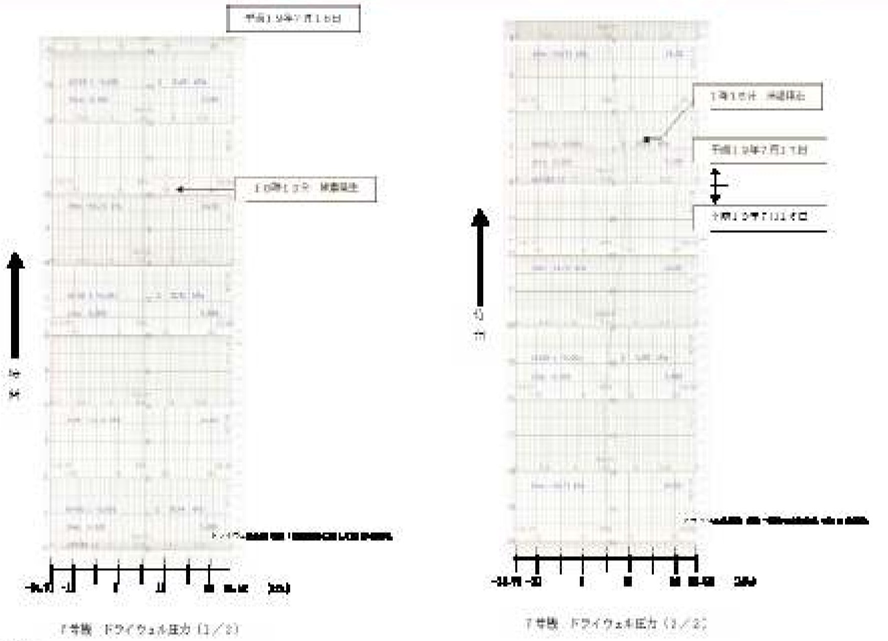
TEPCO proprietary INFO

Behavior of main plant parameter (#4 D/W pressure)



TEPCO proprietary INFO

Behavior of main plant parameter (#7 D/W pressure)



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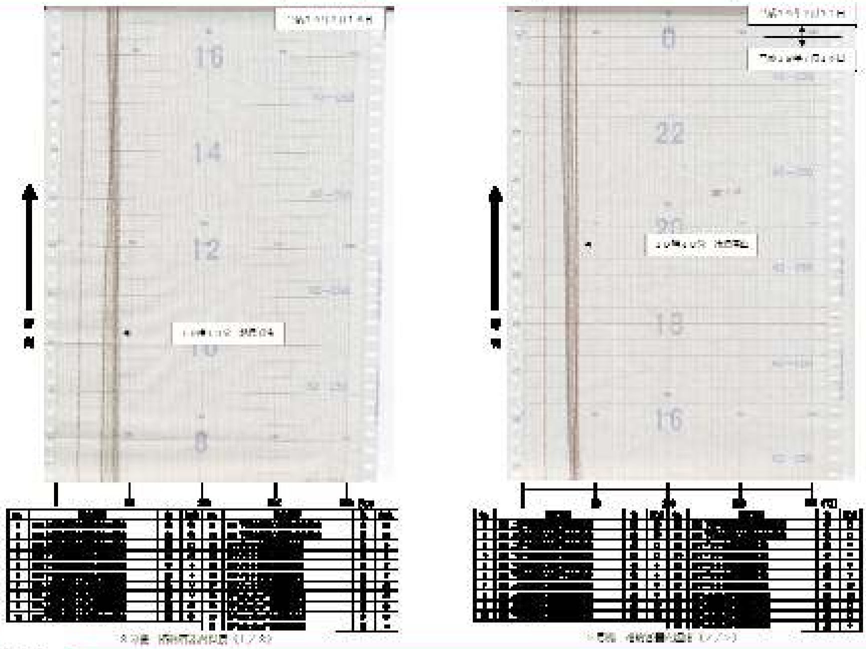
TEPCO proprietary INFO

Behavior of main plant parameter (#2 D/W temperature)



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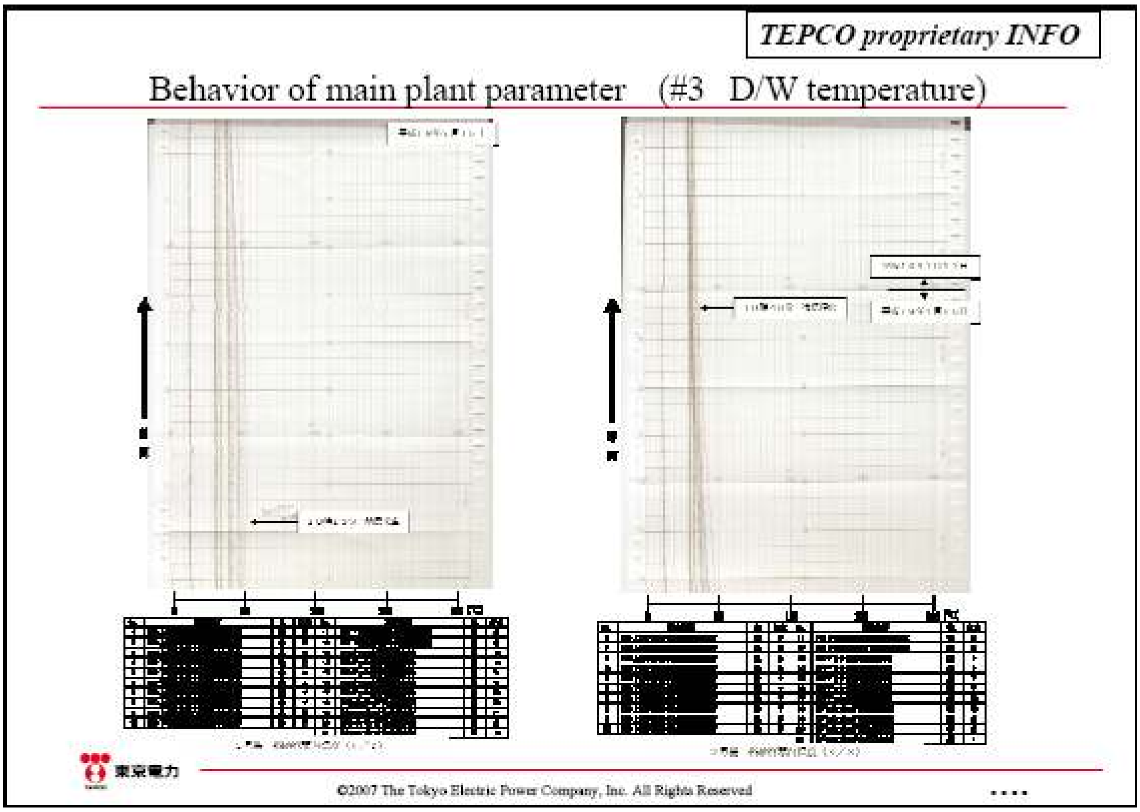
TEPCO proprietary INFO
Behavior of main plant parameter (#3 D/W temperature)
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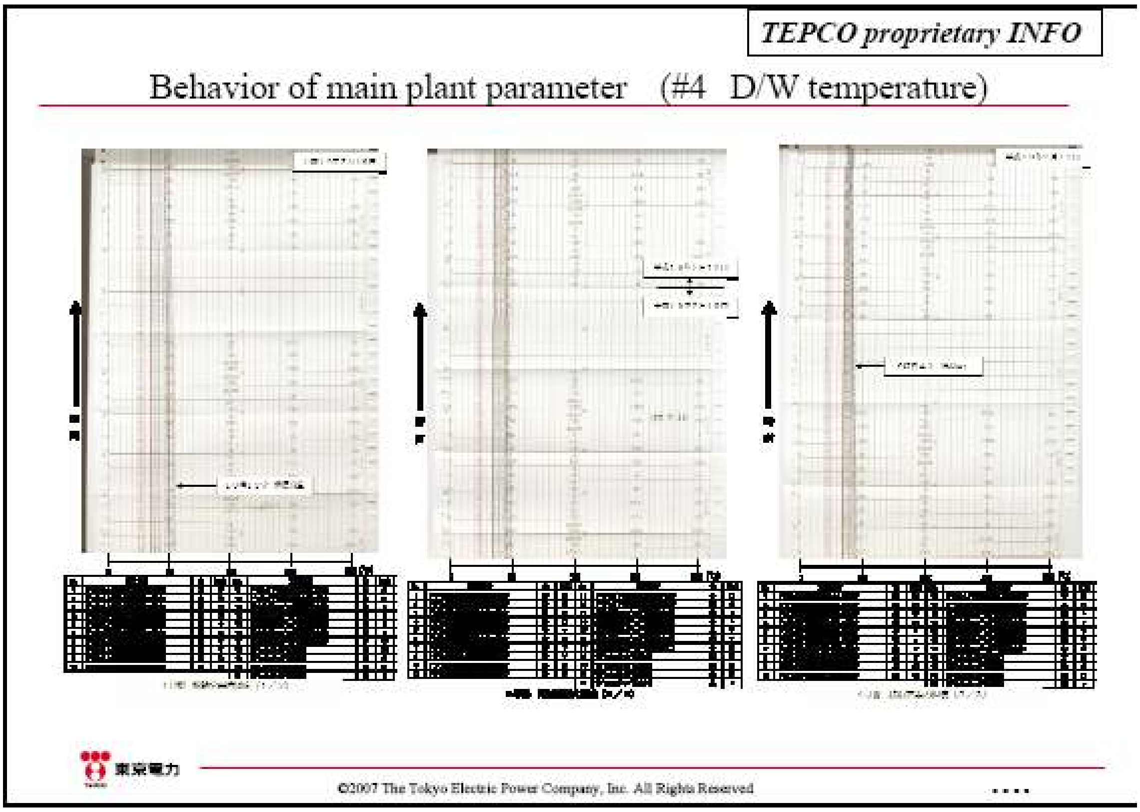
TEPCO proprietary INFO
Behavior of main plant parameter (#4 D/W temperature)
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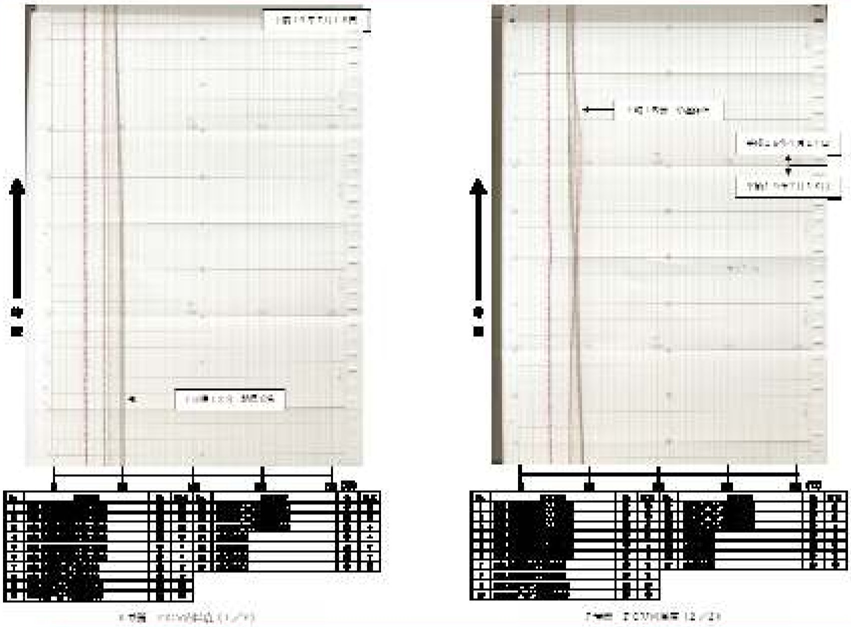
TEPCO proprietary INFO

Behavior of main plant parameter (#7 D/W temperature)



TEPCO proprietary INFO

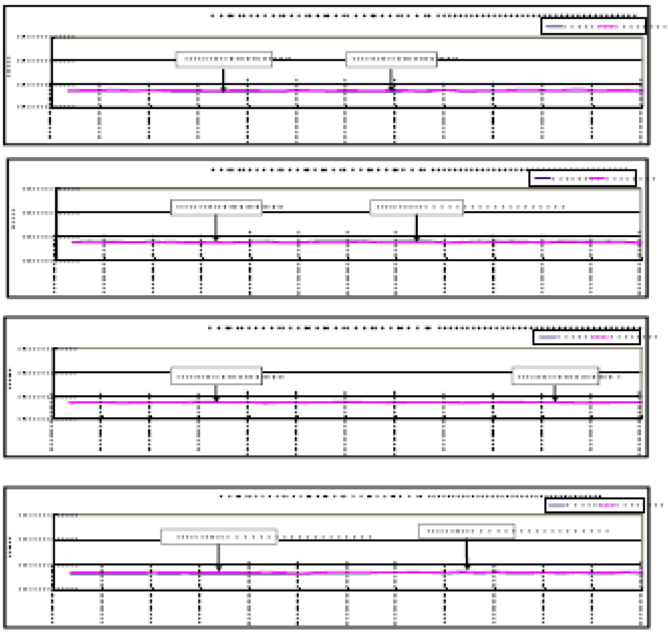
Behavior of main plant parameter (main stack monitor)

#2

#3

#4

#7



Plot by 1hour from operation data book

TEPCO proprietary INFO

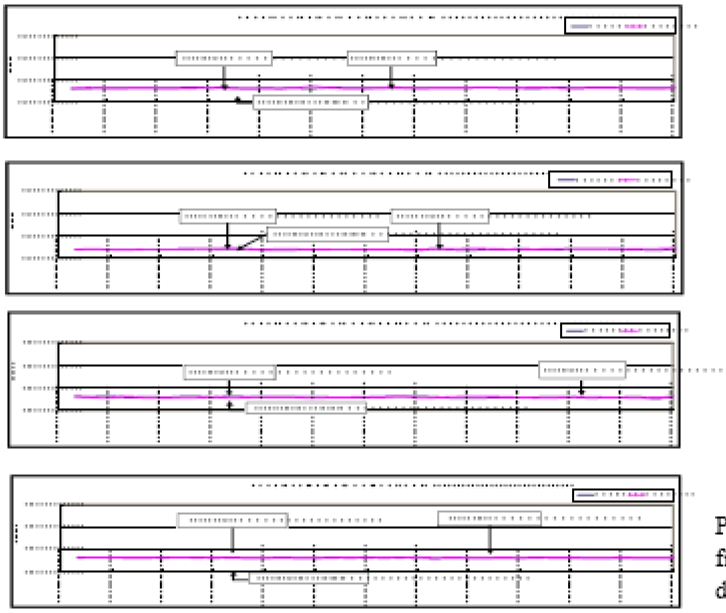
Behavior of main plant parameter (SGTS radiation monitor)

#2

#3

#4

#7



Plot by 1hour from operation data book

TEPCO proprietary INFO

5. Others

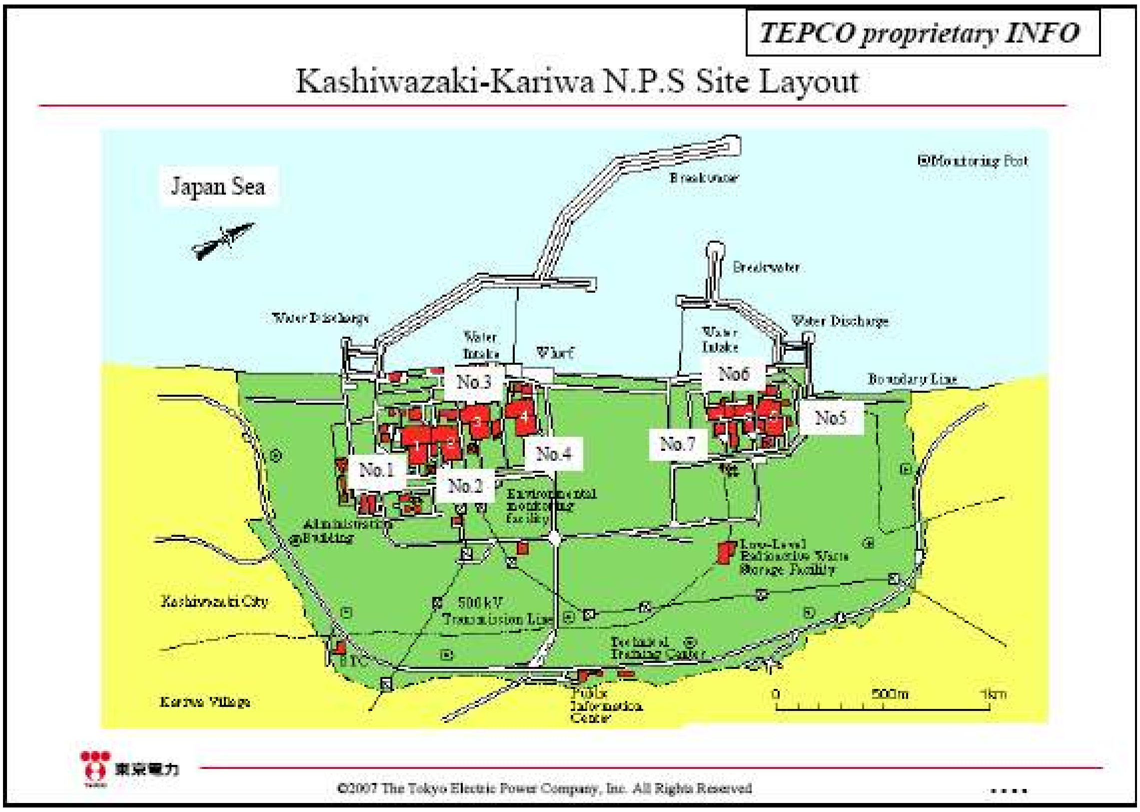
- As for the outside power supply system, more than two lines were always secured.
- As for the emergency power supply system, all diesel generator were always secured. (except for unit 1A DG which stopped for inspection)
- As for the reactor feed water system, we were able to always use normal pump system.
- Before and back of the earthquake impact, the iodine density of reactor water did not have the meaningful difference.

6. Conclusion

As a result of having analyzed and evaluated the safety important plant parameter. We got the following conclusion.

- • Control of Reactivity was carried out safely
- • Removal of the decay heat was carried out safely
- • Confinement of radioactive material was carried out safely

Reference Information


TEPCO proprietary INFO
Kashiwazaki-Kariwa N.P.S Site Layout
Japan Sea
Monitoring Post
Breakwater
Breakwater
Water Discharge
Water Intake
Wharf
Water Intake
Water Discharge
Boundary Line
No.3
No.6
No.5
No.7
No.4
No.1
No.2
Environmental monitoring facility
Administration Building
Low-Level Radioactive Waste Storage Facility
Kashiwazaki City
500kV Transmission Line
Technical Training Center
Kariwa Village
Public Information Center
0
500m
1km
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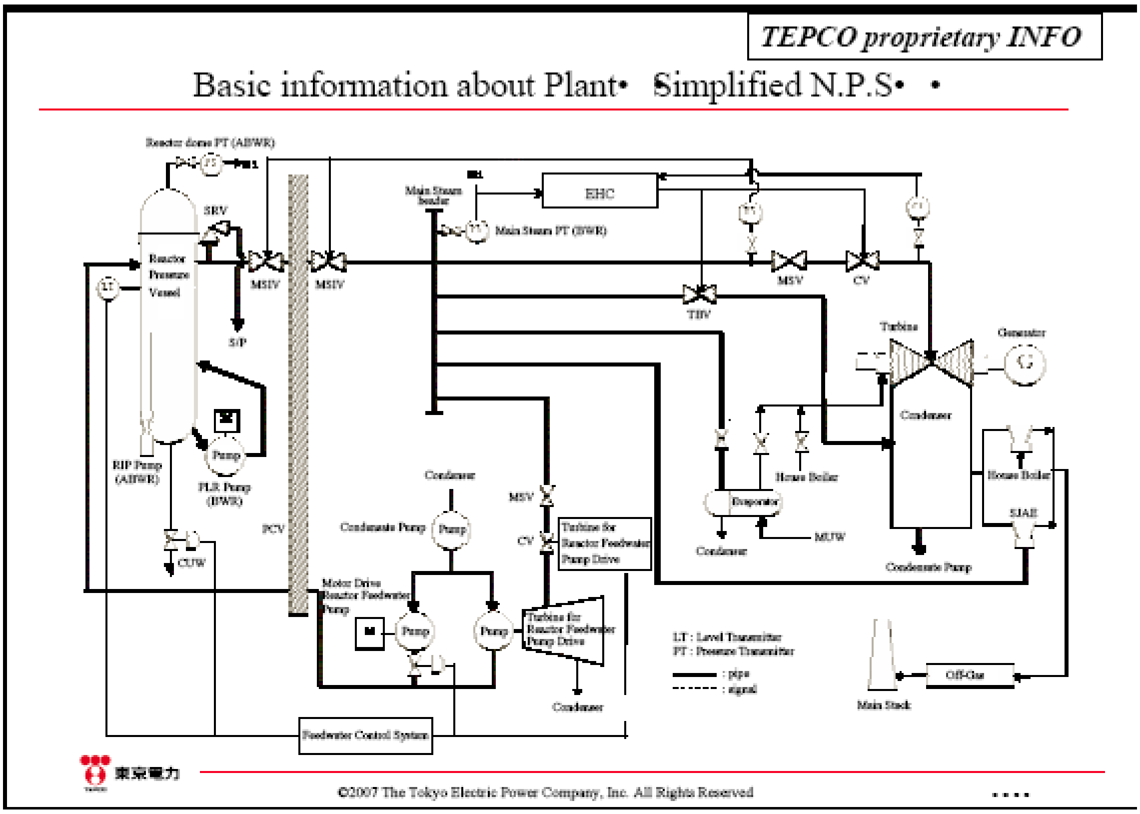
TEPCO proprietary INFO
Basic information about Plant• Simplified N.P.S• •
Reactor dome PT (ABWR)
SRV
Reactor Pressure Vessel
MSIV
MSIV
S/P
Main Steam header
EHC
Main Steam PT (BWR)
MSV
CV
TBV
Turbine
Generator
Condenser
RIP Pump (ABWR)
Pump
PLR Pump (BWR)
PCV
CUW
Condenser
Condensate Pump
Pump
MSV
CV
Turbine for Reactor Feedwater Pump Drive
House Boiler
Evaporator
Condenser
MUW
House Boiler
SJAE
Condensate Pump
Motor Drive Reactor Feedwater Pump
M
Pump
Pump
Turbine for Reactor Feedwater Pump Drive
Condenser
LT : Level Transmitter
PT : Pressure Transmitter
: pipe
: signal
Off-Gas
Main Stack
Feedwater Control System
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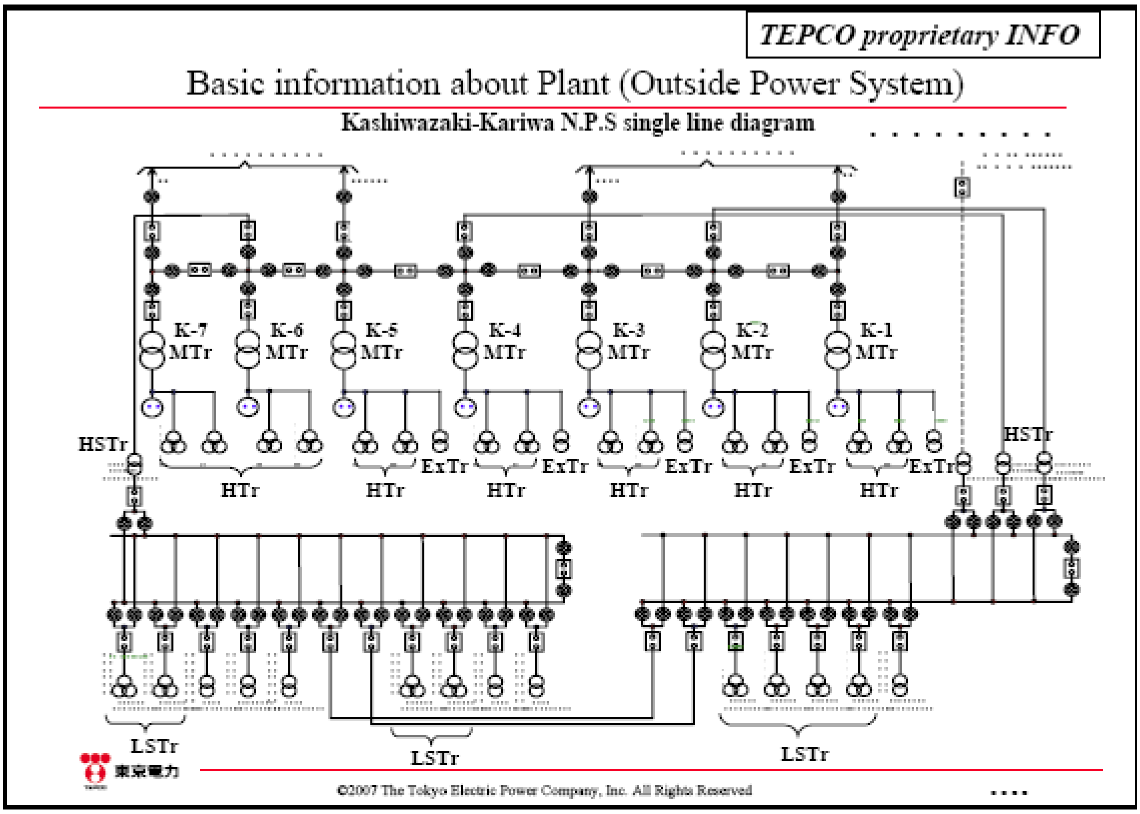
TEPCO proprietary INFO
Basic information about Plant (Outside Power System)
Kashiwazaki-Kariwa N.P.S single line diagram
K-7 MTr
K-6 MTr
K-5 MTr
K-4 MTr
K-3 MTr
K-2 MTr
K-1 MTr
HSTr
HTr
ExTr
LSTr
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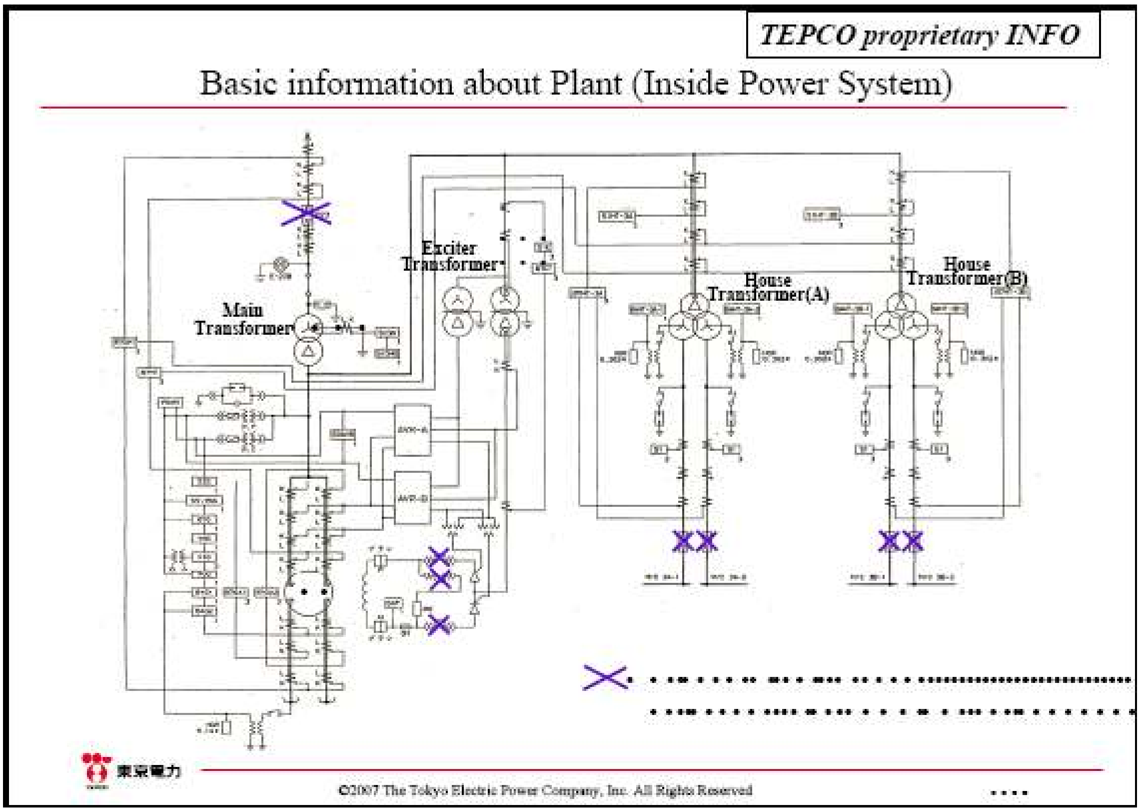
TEPCO proprietary INFO
Basic information about Plant (Inside Power System)
Exciter Transformer
Main Transformer
House Transformer(A)
House Transformer(B)
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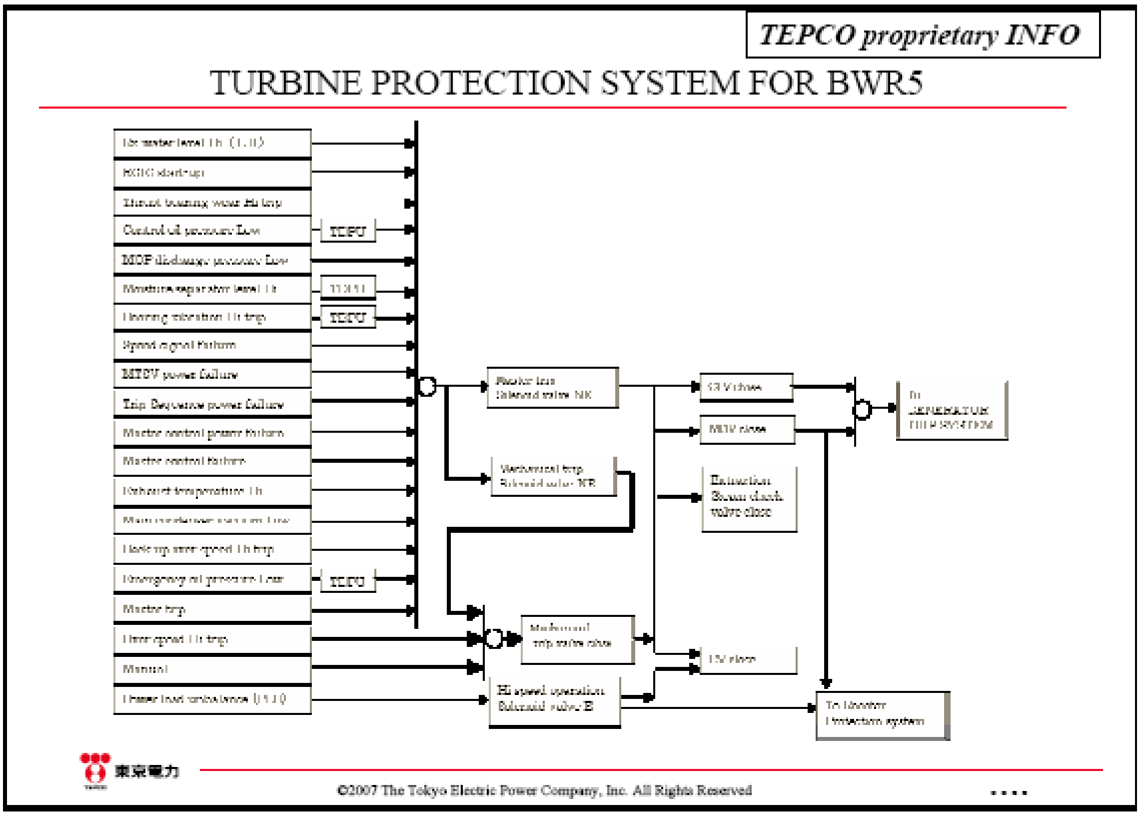
TEPCO proprietary INFO
TURBINE PROTECTION SYSTEM FOR BWR5
RCIC start-up
Thrust bearing wear Hi trip
Control oil pressure Low
TEPU
MOP discharge pressure Low
Bearing vibration Hi trip
Speed signal failure
MTPV power failure
Trip Sequence power failure
Master control failure
Master trip
Manual
Mechanical trip Solenoid valve NE
Mechanical trip valve close
Hi speed operation Solenoid valve B
Extraction Steam check valve close
To Reactor Protection system
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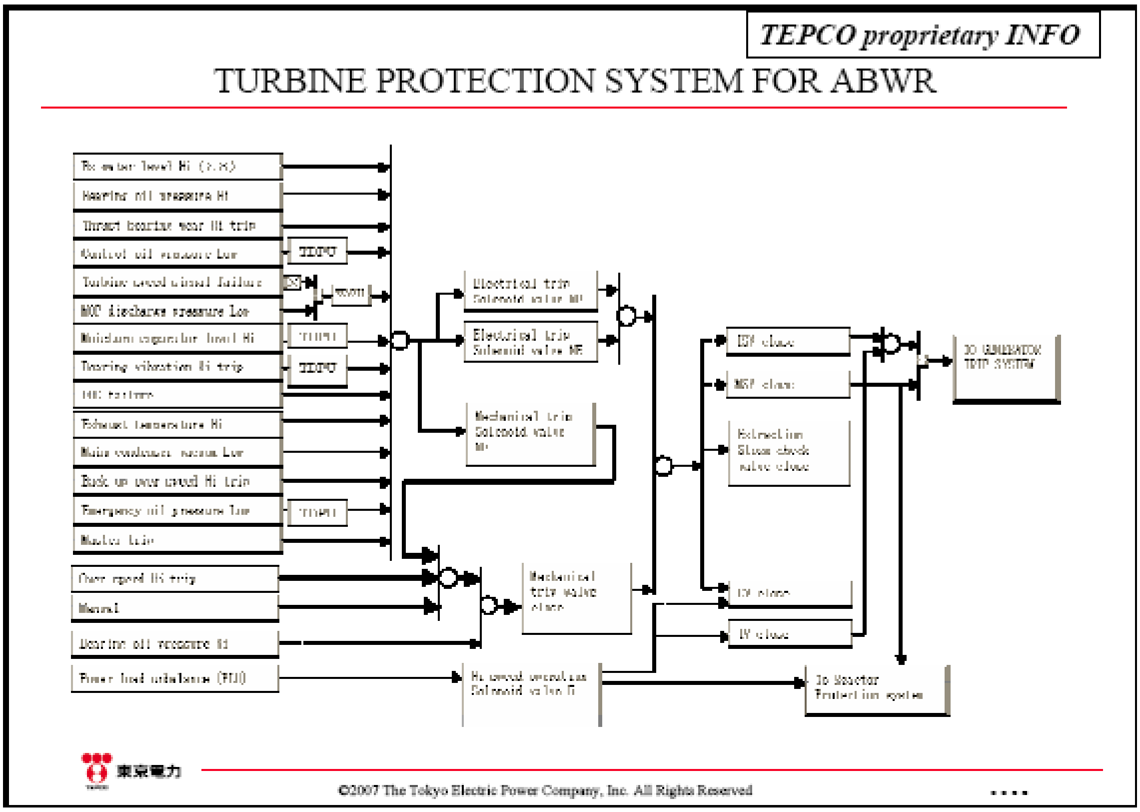
TEPCO proprietary INFO
TURBINE PROTECTION SYSTEM FOR ABWR
Bearing oil pressure Hi
Thrust bearing wear Hi trip
Control oil pressure Low
MOP discharge pressure Low
Bearing vibration Hi trip
Exhaust temperature Hi
Main condenser vacuum Low
Back up over speed Hi trip
Emergency oil pressure Low
Master trip
Over speed Hi trip
Manual
Bearing oil pressure Hi
Power load unbalance (PLU)
Electrical trip Solenoid valve NE
Mechanical trip Solenoid valve
Mechanical trip valve close
Hi speed operation Solenoid valve B
Extraction Steam check valve close
TO GENERATOR TRIP SYSTEM
To Reactor Protection system
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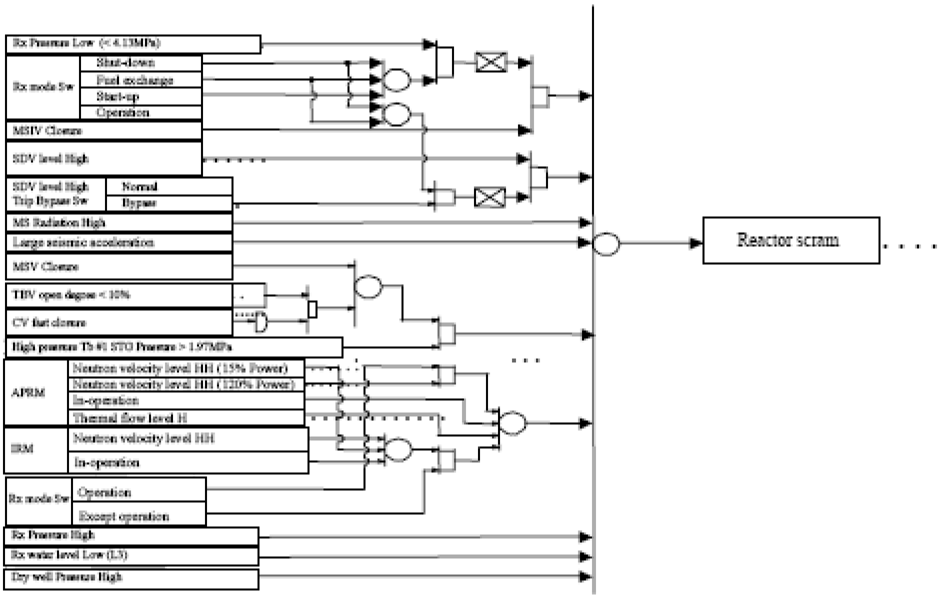
TEPCO proprietary INFO

Reactor protection system for BWR5



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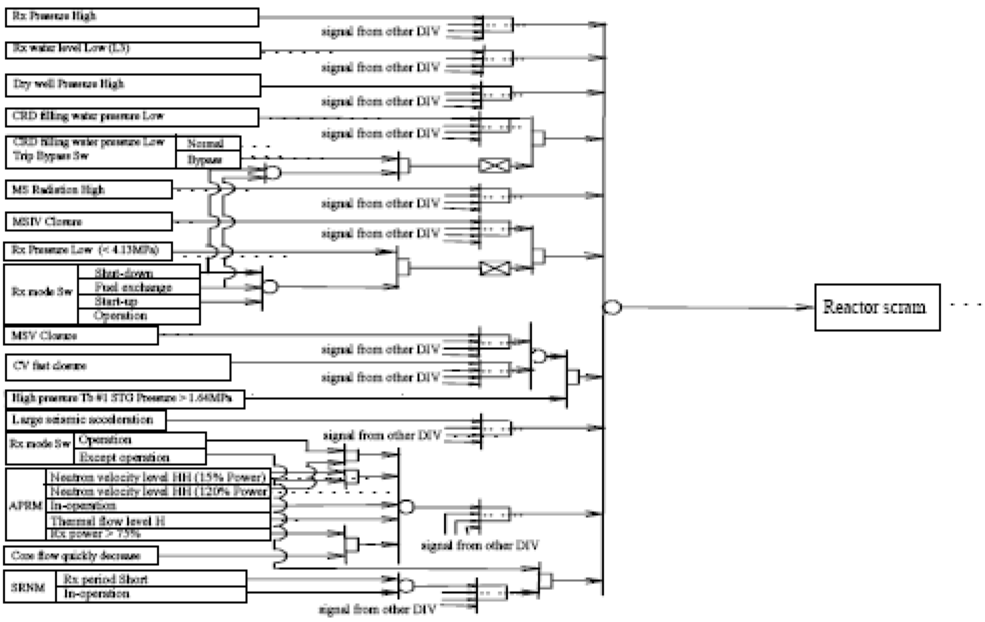
TEPCO proprietary INFO

Reactor protection system for ABWR



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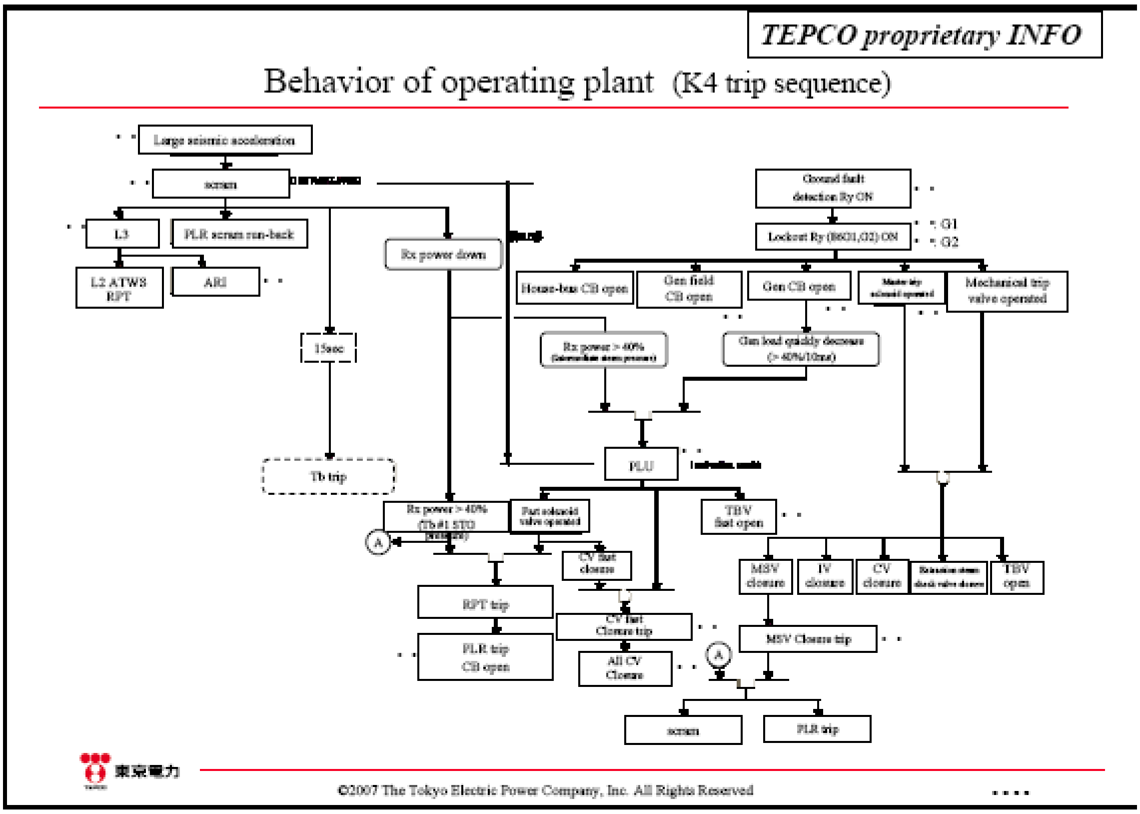
TEPCO proprietary INFO
Behavior of operating plant (K4 trip sequence)
Large seismic acceleration
scram
L3
PLR scram run-back
Rx power down
L2 ATWS RPT
ARI
15sec
Tb trip
Ground fault detection Ry ON
Lockout Ry (86G1,G2) ON
G1
G2
House-bus CB open
Gen field CB open
Gen CB open
Mechanical trip valve operated
Rx power > 40%
Gen load quickly decrease (> 40%/10ms)
PLU
Rx power > 40% (Tb#1 STG)
Fast solenoid valve operated
TBV fast open
CV fast closure
MSV closure
IV closure
CV closure
TBV open
RPT trip
CV fast Closure trip
MSV Closure trip
PLR trip CB open
All CV Closure
A
scram
PLR trip
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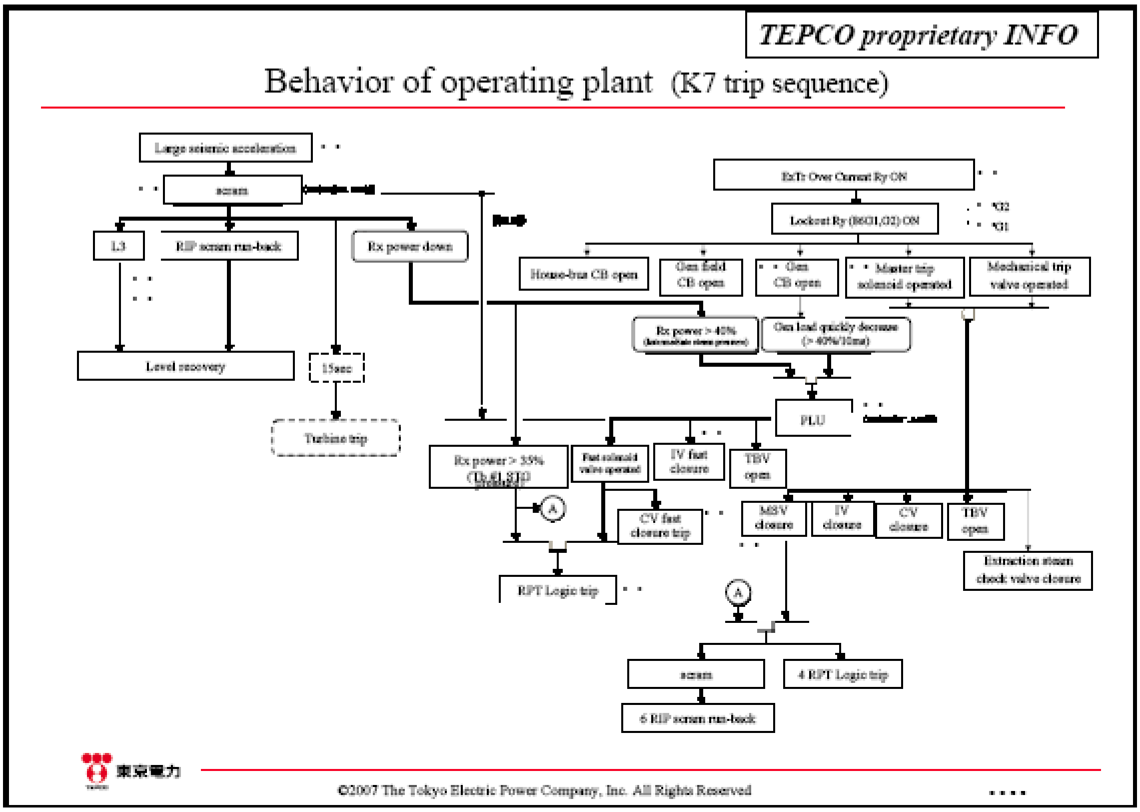
TEPCO proprietary INFO
Behavior of operating plant (K7 trip sequence)
Large seismic acceleration
scram
L3
RIP scram run-back
Rx power down
Level recovery
15sec
Turbine trip
ExTr Over Current Ry ON
Lockout Ry (86G1,G2) ON
G2
G1
House-bus CB open
Gen field CB open
Gen CB open
Master trip solenoid operated
Mechanical trip valve operated
Rx power > 40%
Gen load quickly decrease (> 40%/10ms)
PLU
Rx power > 35% (Tb#1 STG)
Fast solenoid valve operated
IV fast closure
TBV open
CV fast closure trip
MSV closure
IV closure
CV closure
TBV open
Extraction steam check valve closure
A
RPT Logic trip
scram
4 RPT Logic trip
6 RIP scram run-back
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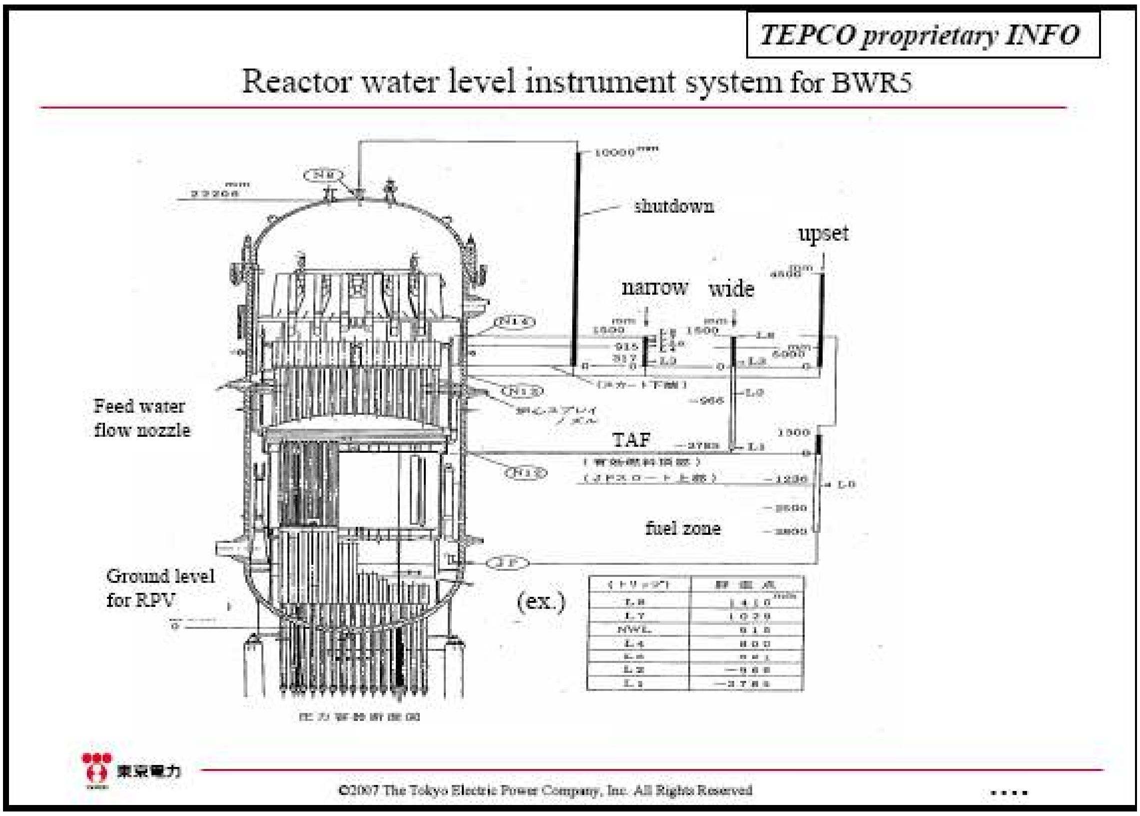
TEPCO proprietary INFO
Reactor water level instrument system for BWR5
shutdown
upset
narrow
wide
Feed water
flow nozzle
TAF
fuel zone
Ground level
for RPV
(ex.)
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II.A.3 Plant status of Kashiwazaki-Kariwa NPP after the Niigata Chuetsu-oki earthquake (as of August 7th)

Plant Status of Kashiwazaki-Kariwa Nuclear Power Station after the Niigata-Chuetsu-Oki Earthquake (as of August 7th)

Plant Status: All units were shutdown after the occurrence of the earthquake.
1. Visual Inspection Results After the Earthquake: A total of 65 incidents have been confirmed to date (excluding 4 incidents of reactor automatic scram due to the earthquake).

(1) Incidents related to radioactive materials (15 cases).

Unit	Status Prior to Earthquake	No	Status at the Time of Earthquake	Current Status
Unit 1	Shutdown (in an outage)	1	Displacement of the duct connected to the main exhaust stack. Detailed investigation underway.	Investigation on the size of the displacement and whether there had been a leakage of radioactivity is being conducted.
		2	Damage to fire protection system piping leading to a 40 cm-deep puddle of water on the B5 floor (the lowest floor, controlled area) of the Reactor Combination Building.	Amount of leakage: about 1,670m^3. Confirmed re-leakage with radioactivity. After repairing the fire protection system piping, depth of water is Maximum amount of leakage: about 2,000m^3.
		3	Water puddle on the reactor building refueling floor.	Completed soaking up water from the floor on July 27th.
Unit 2	Starting up	4	Displacement of the duct connected to the main exhaust stack. Detailed investigation underway.	Investigation on the size of the displacement and whether there had been a leakage of radioactivity is being conducted.
		5	Water puddle on the reactor building refueling floor.	Completed soaking up water from the floor on July 24th.
Unit 3	Operating	6	Displacement of a duct connected to the main exhaust stack. Detailed investigation underway.	Investigation on the size of the displacement and whether there had been a leakage of radioactivity is being conducted.
		7	Water puddle on the reactor building refueling floor.	Completed soaking up water from the floor on July 20th.
Unit 4	Operating	8	Displacement of a duct connected to the main exhaust stack. Detailed investigation underway.	Investigation on the size of the displacement and whether there had been a leakage of radioactivity is being conducted.
		9	Water puddle on the reactor building refueling floor.	Completed soaking up water from the floor on July 23rd.
Unit 5	Shutdown (in an outage)	10	Displacement of a duct connected to the main exhaust stack. Detailed investigation underway.	Size of the displacement: about 4cm. Investigating whether there had been a leakage of radioactivity.
		11	Water puddle on the reactor building refueling floor.	Completed soaking up water from the floor on July 24th.
Unit 6	Shutdown (in an outage)	12	Minuscule amount of radioactivity found on the 3rd floor of the reactor building (0.6 liter; 2.8x10^2 Bq) and mezzanine 3rd floor of the reactor building, which is an uncontrolled area (0.9 liter; 1.6x10^4 Bq). Leaked water discharged to the sea via water discharge outlet (Total amount of discharged water: 1.2 m^3; radioactivity: 9x10^4 Bq; no change observed on the seawater radioactivity monitor.) No water is discharged at this moment.	Radionuclides discharged to the sea is as follows: Cobalt-58: 7.7 x 10^3 Bq Cobalt-60: 4.3 x 10^4 Bq Antimony-124: 3.5 x 10^4 Bq
		13	Water puddle on the reactor building refueling floor.	Completed soaking up water from the floor on July 23rd.
Unit 7	Operating	14	Detected Iodine and particulate material (Cr-51 and Co-60) during a weekly periodic measurement of the main exhaust stack. Detected radioactivity: 3x10^8 Bq.	The measurements made on July 18th detected the release of iodine-131 and iodine-133. However, for the period of July 19th to July 23rd, no radioactive material has been detected.
		15	Water puddle on the reactor building refueling floor.	Detected radioactivity on July 20th. Completed soaking up water from the floor on July 21st.

(2) Incidents NOT related to radioactive materials (54 cases).

Unit	Status prior to earthquake	No	Events	
Unit 1	Shutdown (in an outage)	16	Departure from Limiting Condition of Operation (LCO) due to low water level of spent fuel pool and subsequent return to normal level.	
		17	Small amount of oil leakage (still continuing) from the exciter power transformer; displacement from the foundation base.	Unknown amount of oil leakage. Small amount of leakage continues.
		18	Double door of the reactor building kept open due to power loss.	No departure from LCO since the unit is in cold shutdown condition. Closed the double door after the power had been restored on July 24th (returned to normal condition).
		19	A puddle of water extending from the electrical instrument room of the emergency diesel generator (A) controlled room boundary door to non-controlled area.	Amount of leakage: about 4 liters. Leakage ceased. No radioactivity.
		20	Power loss of liquid waste treatment system control room control panel.	No impact on plant monitoring.
		21	Displacement at the connection between house transformers 1A and 1B and isolated phase bus. Breakage of foundation bolt.	Investigating the size of the displacement.
		22	Subsidence, slant, crack and abruption of concrete, opening of the joint on the oil protection bank of transformer.	Opening of the joint: 10 locations; maximum width 7cm.
		65	C shoes (red shoes) found on top of the bulk head inside the reactor well at the unit 1 reactor building refueling floor.	C shoes placed near the reactor well opening fell into the reactor well at the time of the earthquake. Planned to be picked up. (Upgraded non-conformance grade from C to B on Aug. 3rd.)
Unit 2	Starting up	—	Reactor automatic scram due to earthquake.	
		23	Departure from LCO due to low water level of spent fuel pool and subsequent return to normal level.	
		24	Oil leakage from between the main transformer and its cooler main piping (still continuing). Breakage of foundation bolt.	Unknown amount of oil leakage. Considering oil removal. Leakage stopped by covering with filler.
		25	Lateral displacement of exciter power transformer foundation and duct for power bus.	Investigating the size of the displacement.
		26	Water intake screen washing pump unable to start.	
		27	Displacement of the turbine building blowout panel.	No leakage of radioactivity. Temporarily restored on July 20th.
		28	Oil leakage in the oil tank room of the turbine driven reactor feedwater pump (B).	Amount of oil leakage: about 800 liters. Leakage ceased. Completed oil recovery on July 19th.
		29	Subsidence and lateral displacement of the oil protection bank of transformer.	Lateral displacement: one location; 2cm wide.

Unit	Status prior to earthquake	No	Events	
Unit 3	Operating	—	Reactor automatic scram due to earthquake.	
		30	LCO due to low water level of spent fuel pool and subsequent return to normal level.	
		31	Departure from the LCO due to displacement of the reactor building blowout panel and subsequent return to within the LCO.	Returned within the LCO since the unit came to a cold shutdown condition. Temporarily replaced the blowout panel on July 21st.
		32	Displacement of the turbine building blowout panel.	Temporarily replaced on July 20th.
		33	House transformer 3B caught on fire.	On July 16 at 10:15AM, house transformer 3B was found on fire. Fire extinguished at 12:10PM on the same day.
		34	Oil leakage from oil exhaust piping of K-3/4 low voltage start-up transformer (3SB).	Unknown amount of oil leakage. Leakage continuing. Low voltage start-up transformer shutdown due to continuing oil Confirmed that oil leakage ceased on July 23rd.
		35	Displacement in the exciter power transformer foundation and power bus duct.	Investigating the size of the displacement.
Unit 4	Operating	—	Reactor automatic scram due to earthquake.	
		36	Leakage of seawater from a crack occurred in rubber flexible joint between condenser B seawater box and connecting valve.	Size of the crack: 3.5m. Amount of leakage: $24m^3$. Leakage ceased on July 19th.
		37	Service platform in the spent fuel pool fell on the spent fuel storage rack with spent fuels. No damage to the fuels.	Spent fuel pool water analyses confirmed there is no damage to fuels.
		38	Subsidence and tilt of the oil protection bank of transformer (partial opening of the joint).	Opening of the joint: one location; maximum width 20cm.
Unit 5	Shutdown (in an outage)	39	Leakage from No. 4 filtered water tank.	Amount of oil leakage: about 900 m^3. Leakage ceased. No radioactivity.
		40	Water intake screen washing pump unable to start.	
Unit 6	Shutdown (in an outage)	41	Oil leakage from low voltage start-up transformer (6SB).	Low voltage start-up transformer shutdown due to small amount of continuing oil leakage. Confirmed that oil leakage ceased on July 23rd.
		42	Dislocation of the service platform in the spent fuel pool.	Spent fuel rack is underneath the dislocated service platform; however the platform is fixed on a wire. Considering how to handle the situation. Stabilization measures, such as fixing the wire to a handrail, have been taken on July 25th.
Unit 7	Operating	—	Reactor automatic scram due to earthquake.	
		43	Degradation of water tightness of the water-tight doors of the Reactor Core Isolation Cooling System and Residual Heat Removal Systems (A) and (C).	
		44	Subsidence, slant, opening of the joint on the oil protection bank of transformer.	Opening of the joint: 2 locations; maximum width 4cm.
		45	Service platform in the spent fuel pool fell on the spent fuel storage rack with spent fuels. No damage to the fuels.	Spent fuel pool water analyses confirmed there is no damage to fuels.
		66	Dropping of light fixture, dropping of ceiling decorative sheet, crack, displacement of emergency lighting, and opening of inspection door in the units 6/7 main control room.	(Upgraded non-conformance grade from C to B on Aug. 3rd.)

Unit	Status prior to earthquake	No	Events	
Switch yard	–	46	500kV New Niigata 2L shut down.	
		47	Slight gas leakage from breaker of 500kV New Niigata 2L.	Temporarily repaired with rubber bands.
		48	Oil leakage from 500kV South Niigata 2L black phase bushing (South Niigata 2L shut down.)	Unknown amount of oil leakage. Considering oil removal.
		49	Slippage of soil from the east-side slope.	Crack with width of about 10 cm.
Solid Waste Storage Warehouse	–	50	Several hundred drums in the solid waste storage warehouse tipped over and several tens of drums were found with their lids open.	No radioactive material detected from measurement of airborne radioactive material concentration in 4 locations of the solid waste storage warehouse. Confirmed water leakage from tipped over drums. Amount of leakage: 16 liters. No radioactivity. Soaked up leakage from the Although no impact on external environment has occurred, all intake and exhaust opening of the warehouse were sealed on July 20th.
Administration Office Building	–	51	Normal power supply to the main office building were shut down. Power is supplied from emergency power source for the emergency response room.	Power supply to the emergency response room has been restored to normal power.
		52	No damage occurred to the building structure (columns and beams) of the office and information buildings. An expansion joint was damaged; many cracks occurred; many glass panes broke; the rooftop air conditioning unit was damaged; the waterproof tank was damaged; ducts fell; cooking equipment fell.	
Site and others	–	53	Partial damage to the diagonal steel frame of the lightning arrestor tower.	No damage found on main frame.
		54	Penetration of the joint in the bank of heavy oil tank.	Restored on July 20th.
		55	Part (north slope) of the soil disposal area collapsed.	
		56	Water leaked from the drinking water tank.	
		57	Fire protection system: the pipe was damaged at five locations, resulting in water leaks. KK-1: Northeast side of the reactor building KK-1: West side of the turbine building KK-1: Near the fire hydrant adjacent to the diesel oil tank KK-2: Feed line to the service building KK-2: Feed line to the heat exchanger building	KK-1: Northeast side of the reactor building—restored on July 18th. KK-1: West side of the turbine building— restored on July 20th. KK-1: Near the fire hydrant adjacent to the diesel oil tank—restored on July 19th. KK-2: Feed line to the service building— restored on July 17th. KK-2: Feed line to the heat exchanger building— restored on July 20th.
		58	The environmental minicomputer (Unit 1 service building) and telemeter transmission to the prefecture became disabled.	Restored telemeter transmission to the prefecture on July 17th at Restored all system on July 18th 18:00.
		59	The station road was cut off. Soil liquefaction occurred in a wide area of the site.	Currently travelable.
		60	A 50 cm difference in road level occurred in the approach road, making it impassable. Repair work begun.	Currently travelable.
		61	Bank protection of the north-south discharge outlet sunk.	
		62	Water intake bank protection joint crack.	Size of crack: maximum about 8 cm.
		63	Onsite control panel of heavy oil tank fire protection system damaged.	Restored on July 19th.

2. Incidents found after start of detailed inspection.

Unit	Status Prior to Earthquake	No	Incidents Found after Start of Detailed Inspection	Current Status
Unit 6	Shutdown (in an outage)	64	Breakage found on the coupling of the drive axis of the unit 6 reactor building ceiling crane.	

[Other Information]

・Total number of injured person at the Kashiwazaki-Kariwa site since the occurrence of earthquake: 11 (no radiation exposure)

・Reactor water analyses for units 2 through 7, which have fuels in the reactor core, confirmed there is no damage to fuels in the reactor core.

・Periodic measurements for radioactivity from the main exhaust stacks for units 1, 2, 3, 4, 5, and 6 confirmed there is no radioactivity.

・Periodic manual start-up surveillance testing of emergency diesel generators for each unit--totaling 20 diesel generators excluding one for unit 1 that has been under inspection since before the earthquake--were conducted and all were confirmed to be functional.
(Published on July 27th.)

・The following incidents, all of which are presumed to be effects of rainfall, were found in the controlled area:

(Unit 1) A water puddle was found in the Low Pressure Condensate Pump Room at the B2 floor of the turbine building. Rainfall is suspected to have flowed in from the connection passage between the turbine building and the support building and subsequently flowed into the B2 floor via B1 floor of the turbine building. No radioactivity has been detected. Completed transferring the water from the puddle to the waste processing system on July 26th. Confirmed no more inflow into the B1 floor of the turbine building on July 27th. Small amount of water continues to dribble into the connection passage between the turbine building and the support building.
Recovery of water in the connecting passage underway on July 30th.

(Unit 3) Water inflow found from the wall in the B1 floor of the turbine building. This water is presumed to have pooled in the pit adjacent to the turbine building and subsequently flowed into the turbine building via the penetration of electrical cable conduits, etc. No radioactivity has been detected. Collected water that flowed in on July 26th. Confirmed no more inflow into the turbine building on July 27th.

(Solid Waste Storage Warehouse) A water puddle suspected to have occurred from ground water due to rainfall was found near the boundary of the 1st building in the B1 floor of the solid waste storage warehouse and the administrative building. No radioactivity was detected. Completed soaking up water from the floor on July 26th. Confirmed no more inflow on July 27th.

(Support Building) A water puddle suspected to have occurred from ground water due to rainfall was found in the B1 floor of the support building. No radioactivity was detected. Confirmed no more inflow on July 27th.
Completed soaking up water from the floor on July 27th.

・The following oil leakage incidents were identified inside the power station:

– Small amount of oil film found at the unit 1 turbine building sub-drain and at the discharge outlet of units 1 to 4. Discharge from the sub-drain has been ceased and preparation is underway to process the drainage in a temporary tank. Oil film at the discharge outlet will continued to be monitored as the sub-drain drainage has been ceased.(Published on July 31st.)
On July 31st, a temporary oil separation tank was installed and two-fold oil protection fences with adsorption mats were installed at the discharge outlet. (Published on August 1st.)

– Crack found at the base of oil protection banks of units 1 to 3 transformers. Insulating oil is suspected to have infiltrated into the soil. Maximum estimated amount of insulating oil leakage: about 200 kl including those from transformers of other units that are yet to be examined thoroughly. Recovery of soil under and surrounding the oil protection banks is considered.

PART III – INFORMATION SPECIFIC TO THE THREE AREAS COVERED BY THE MISSION AS COMPILED BY THE IAEA EXPERT TEAM

The main information compiled by the IAEA Review Team was the information obtained from the visit to the facilities and the plant walkdowns performed during the three days at Kashiwazaki-Kariwa NPP. During the walkdowns of the seven units numerous photographs were taken of damage encountered as well as evidence of the plant response to the earthquake. Therefore, in this Section of the Volume II are compiled those photographs that are considered representative of the findings obtained during the mission.

The following photographs have been organized in sequence of the findings that were identified in Volume I. The list of findings with the corresponding numbering is given in the following. Each photo is identified with the appropriate finding number. In some cases more than one finding can be associated with the photograph.

The final fourteen photos are not associated with any one particular finding from Volume I. They illustrate the general good behaviour of the structures, systems and components to the earthquake.

LIST OF FINDINGS (from Volume I)

A.1 Seismic design basis, instrumental records and re-evaluation of seismic hazard

- A.1-1 Exceedance of the design basis ground motion by the earthquake
- A.1-2 Re-evaluation of the seismic hazard

A.2 Plant behaviour – Structures, systems and components

- A.2-1 Off-site power
- A.2-2 Seismic systems interaction
- A.2-3 Fire protection
- A.2-4 Soil deformation
- A.2-5 Anchorage behaviour

A.3 Operational safety management

- A.3-1 Response after shutdown
- A.3-2 Releases

Photo 1: Seismic instrumentation to record in-structure response (A.1-1)

Photo 2: One of the seismic instruments used for automatic scram (A.1-1)

Photo 3: Seismic instrumentation Unit 1 at foundation mat level (A.1-1)

Photo 4: Unit 4-TB-Level: -16.300 – Sliding of the foundation plates of Heat Exchanger (A.2)

Photo 5: Unit 4-TB: Failure of the rubber flexible joint between condenser B seawater box and connecting valve, causing seawater leakage. (A.2)

Photo 6: Differential settlement between adjacent buildings. (A.2)

Photo 7: Minor cracking in shear walls was observed in a few cases (A.2)

Photo 8: First day group touring outside the structures. Note soil displacements. Also note in the background the undamaged switchyard connecting to the grid. Off-site power was not lost during the seismic event. (A.2-1, A.2-4)

Photo 9: Colour difference at the top, showing differential settlement of building. (A.2-2)

Photo 10: Unit 1: A buried fire fighting pipe failure caused mud to penetrate into the reactor building through cable tray penetrations. Maximum amount of water leakage ~2000m3; depth of water/mud in floors ~0.48m (A.2-2)

Photo 11: Unit 1 - The route of the mud that went all the way down to the lowest levels of the R/B. (A.2-2)

Photo 12: Unit 1 – Cleaning operation of leakage mud/water in lowest levels of R/B. (A.2-2)

Photo 13: Blow-out panels (A.2-2)

Photo 14: Unit 6 - Falling of temporary service platform into the spent fuel pool (A.2-2)

Photo 15: Failure of portions of ceiling panels with potential for interaction effects (A.2-2)

Photo 16: Control room panels behaved well. No interactions were reported. (A.2-2)

Photo 17: **Control room: Ceiling panels that fell due to the earthquake (A.2-2)**

Photo 18: **Ceiling panel that fell into the control room floor and panels (A.2-2)**

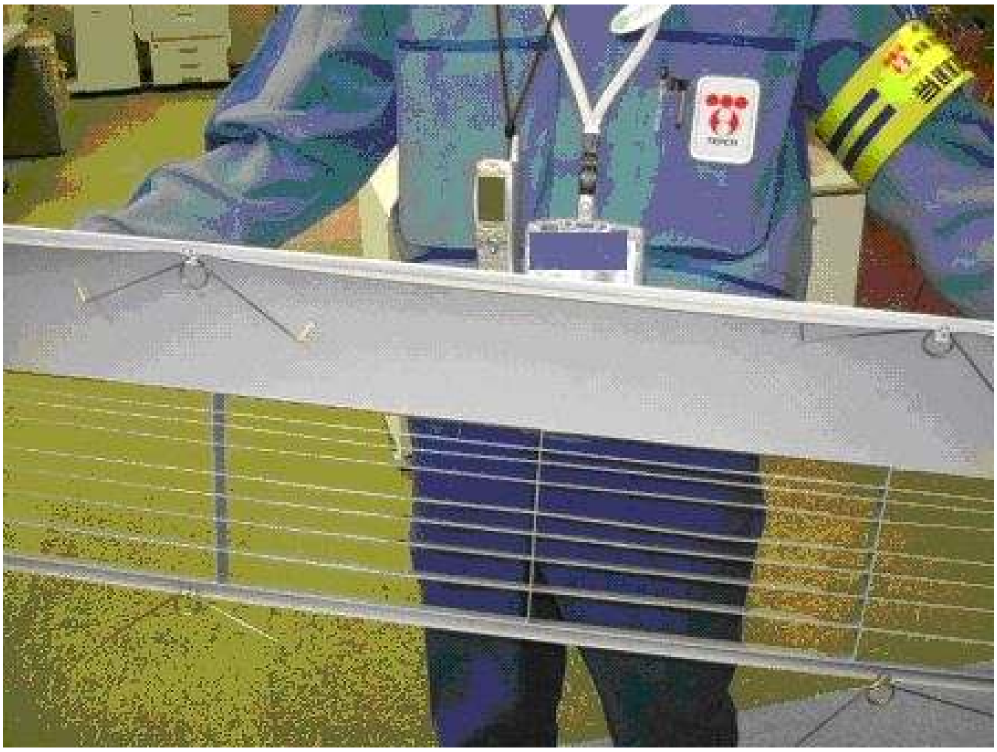

Photo 19: **A ceiling panel that fell, reflecting a weak connection, a maintenance problem, etc. (A.2-2)**

Photo 20: **Bolt failure surface shows variation in colouring and corrosion, indicating possible previous damage. The bolt was anchoring the service water tank (non safety related) for the fire extinguishing system which were not functional after the earthquake (A.2-3, A.2-5)**

Photo 21: The fire fighting system was not operational after the earthquake (A.2-2)

Photo 22: The failure of house transformers was also due to the foundation settlement of connecting structures. (A.2-3, A.2-4)

Photo 23: The fire at the in-house transformer was caused by the ignition of the transformer insulation oil that leaked from the broken porcelain, ignited by the sparks from a short circuit at the bus duct all due to the different displacement between the connecting structure (on shallow foundation) that settled and the transformer built on piles. (A.2-3, A.2-4)

Photo 24: Soil surrounding structures on deep foundation showed significant settlement (A.2-4)

Photo 25: A good indication of the order of magnitude of soil settlement which caused damage to non-safety SSCs on shallow foundation. (A.2-4)

Photo 26: Landslide on a man-made hill at the site (A.2-4)

Photo 27: **Damage to the foundation plate of the house transformer caused by the settlement of the connecting structure. (A.2-4)**

Photo 28: **A detail of the damage at the connection of the foundation slab of the transformer and the connecting structure. (A.2-4)**

Photo 29: Failure of part of the water intake structure near the pump house (A.2-4)

Photo 30: Failure of the anchorage for the water tank for the fire extinguishing system – note also the elephant foot buckling of the tank itself (A.2-5)

Photo 31: Lateral displacement of the foundation beams that failed the anchor bolts – transformer building (A.2-5)

Photo 32: Local buckling of piping insulation cover at penetration point (A.2-5)

Photo 33: Lateral movement of unanchored cabinet (A.2-5)

Photo 34: Relative sliding between concrete foundation pad and component leg support. (A.2-5)

Photo 35: **Unit 2-Failure of steel structure connection of the concrete base – water intake building structure. This structure was seriously damaged. (A.2-5)**

Photo 36: **Typical damage of the duct (shallow foundation) connecting to the exhaust stack which is on piles. Soil settlement caused differential displacements to these structures. This is the pathway for the releases to the atmosphere (A.3-2, A.2-4)**

Photo 37: **Cable penetrations on the floor, through which the water overflowed from the sloshing in the spent fuel pool flowed to the lower floors. This is on the pathway for the radioactive release to the sea. (A.3-2, A.2-2)**

Photo 38: **Spent fuel pool that overflowed due to sloshing (A.3-2, A.2-2)**

Photo 39: **Spent fuel area, floor channel from which the water flowed through cable penetrations. (A.3-2, A.2.2)**

Photo 40: **Falling of barrels containing low level radioactive waste – there was no release related to this incident (A.3-2, A.2-2)**

Photo 41: The diesel generator fuel tank with undamaged bolts shows the contrast in the performance of components of different seismic design.

Photo 42: The diesel generator fuel tank with undamaged bolts shows the contrast in the performance of components of different seismic design.

Photo 43: In general, visual inspections did not provide evidence of recent earthquake on safety related SSCs.

Photo 44: Safety related piping of all sizes generally showed very good performance

Photo 45: **Safety related tanks generally performed very well**

Photo 46: **A great majority of safety related structures showed no visual evidence of damage due to the earthquake**

Photo 47: **A variety of pipe supports and spans-all behaved very well. See anchors. No interactions**

Photo 48: **Example of a horizontal vessel (HEx) showing very good performance**

Photo 49: Good performance of well supported Nitrogen tubes of the hydraulic control units for Control Rod Drive System, (Level ~-1.00).

Photo 50: Emergency Batteries in well designed racks showed very good performance.

Photo 51: Emergency Batteries in well designed racks showed very good performance

Photo 52: Well braced and supported electrical cabinets in general showed very good performance

Photo 53: Well braced cable trays in general showed very good performance

Photo 54: Details for cable connection and pipe support that performed very well