第１2回原子力委員会 資　料　第　１　号

新潟県中越沖地震による柏崎刈羽原子力発電所への影響に関する国際原子力機関（IAEA）のフォローアップ調査団報告書の公表について

平成２０年３月４日
経　済　産　業　省
原子力安全・保安院

新潟県中越沖地震による東京電力柏崎刈羽原子力発電所への影響に関して、本年1月２８日から２月１日に国際原子力機関（ＩＡＥＡ）のフォローアップ調査が行われたところですが、２月２７日に、その報告書が公表されましたのでお知らせ致します。

１．フォローアップ調査の概要

目　的：原子力安全・保安院の主要検討項目（耐震安全性評価、設備健全性、防火対策）の検討状況に関する技術的な意見交換及び発電所の視察を行い、得られた教訓を国際社会に発信、共有する

団　員：ジャメ団長（ＩＡＥＡ原子力施設安全部長）をはじめ、耐震分野の専門家等、計１３名

日　程：平成２０年1月２８日（月）～２月１日（金）
（原子力安全・保安院、独立行政法人原子力安全基盤機構（ＪＮＥＳ）、東京電力と討議、及び柏崎刈羽原子力発電所においてボーリング調査等を視察）

２．調査報告書の概要

調査結果全般として次のような指摘がされています。

・前回調査（昨年８月）で発見された事実（安全上重要な機器に顕著な損傷は発見されなかった等）は今回も同様の結果。
・前回以降、地震工学、原子力安全に関する著名な機関の参加を得て、非常に多くの質の高い作業が行われており、高い透明性がもたらされている。

個別事項については、別紙をご参照ください。

３．原子力安全・保安院としての対応

当院としては、ＩＡＥＡ調査団による熱心な調査が行われ、調査終了後短期間で報告書がとりまとめられたことを歓迎するとともに、ＩＡＥＡジャメ部長を始めとする調査団メンバー、ＩＡＥＡ事務局に感謝と敬意を表します。

今後、報告書の内容を精査し、「中越沖地震における原子力施設に関する調査・対策委員会」での議論に反映させるなど、当省の今後の取り組みに活用してまいります。また、ＩＡＥＡが柏崎刈羽地域で開催予定の国際ワークショップなどの場において引き続きＩＡＥＡと協力しつつ、国際的な情報発信・共有に努めていく方針です。

【本発表資料のお問い合わせ先】
原子力安全・保安院
企画調整課国際室　八木、名倉
電　話：０３－３５０１－１５１１（内線４８４８）
０３－３５０１－１０８７（直通）

別　紙

IAEA柏崎刈羽原発フォローアップ調査団報告書について

平成２０年２月２７日
原子力安全・保安院

１月２８日～２月１日に行われたIAEAフォローアップ調査団の報告書がIAEAより２７日未明（ウィーン時間２６日）に発表されたところ、調査及び報告書の概要は以下のとおり。

１．調査概要

(1) 調査目的

・保安院の主要検討項目（耐震安全性評価、設備健全性、防火対策）の検討状況に関する主に技術的な意見交換

・前回調査（８月）には見ることのできなかった原子炉内やボーリング調査の状況の調査

・上記調査結果からIAEA加盟各国に適用でき得る教訓を抽出・整理し、国際社会に発信・共有

(2) 調査団員

ジャメ団長（IAEA原子力施設安全部長）を始め、耐震分野の専門家等計１３名（広報担当１名含む）

(3) 調査日程

１月２８日(月)～３０日(水)　原子力安全・保安院、JNES、東京電力と議論
３１日(木)　柏崎刈羽発電所施設・ボーリング調査視察
２月　１日(金)　全体会合、とりまとめ

２．調査報告書概要

本調査において日本側から良好な協力を受けた旨述べるととも

に、主に以下の点が指摘されている。

(1) 全般的事項

・前回調査（昨年８月）で発見された事実（安全上重要な機器に顕著な損傷は発見されなかった等）は今回も同様の結果。

・前回以降、地震工学、原子力安全に関する著名な機関の参加を得て、非常に多くの質の高い作業が行われており、高い透明性がもたらされている。

(2) 耐震安全性

・多数の専門的かつ著名な研究機関等が参加して得られた非常に多くの地質・地震調査の結果を集約し、基準地震動の設定等を引き続き適切に行うことが必要。

(3) 発電所設備の健全性の確認

・保安院が指示した設備健全性の確認に係る基本方針は適切である。また、それに基づく東電の点検計画は国際社会の参考となるものであるが、東電は目視点検と計算モデルによる評価を組み合わせて適切に実施すべき。

(4) 防火対策

・今回の教訓として、原発における防火対策を設計段階で考慮する必要性が認識された。また、発電所で既に多くの改善がなされている。

３．今後のＩＡＥＡの取り組み

ＩＡＥＡとしては、今後も引き続き本件の調査を行うとともに、５月下旬～６月上旬に柏崎刈羽地域で国際ワークショップを主催する予定。当院としても引き続きＩＡＥＡと協力しつつ、国際的な情報発信・共有に努めてまいる所存。

IAEA
Original English

INTERNATIONAL ATOMIC ENERGY AGENCY

MISSION REPORT
Volume I

ENGINEERING SAFETY REVIEW SERVICES
SEISMIC SAFETY EXPERT MISSION

FOLLOW-UP IAEA MISSION IN RELATION TO THE FINDINGS AND LESSONS LEARNED FROM THE 16 JULY 2007 EARTHQUAKE AT KASHIWAZAKI-KARIWA NPP

"The Niigataken Chuetsu-oki earthquake"

Tokyo and Kashiwazaki-Kariwa NPP, Japan
28 January – 1 February 2008

ENGINEERING SAFETY REVIEW SERVICES (ESRS)

DIVISION OF NUCLEAR INSTALLATION SAFETY

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY

REPORT

ENGINEERING SAFETY REVIEW SERVICES

SEISMIC SAFETY EXPERT MISSION

FOLLOW-UP IAEA MISSION IN RELATION TO THE FINDINGS AND LESSONS LEARNED FROM THE 16 JULY 2007 EARTHQUAKE AT KASHIWAZAKI-KARIWA NPP

**REPORT TO
THE GOVERNMENT OF JAPAN**

Tokyo and Kashiwazaki-Kariwa NPP, Japan

28 January – 1 February 2008

REPORT

Volume I

ENGINEERING SAFETY REVIEW SERVICES

SEISMIC SAFETY EXPERT MISSION

FOLLOW-UP IAEA MISSION IN RELATION TO THE FINDINGS AND LESSONS LEARNED FROM THE 16 JULY 2007 EARTHQUAKE AT KASHIWAZAKI-KARIWA NPP

Mission date:	28 January – 1 February 2008
Location:	Tokyo and Kashiwazaki-Kariwa NPP, Japan
Facility:	Kashiwazaki-Kariwa NPP, Units 1 – 7
Organized by:	International Atomic Energy Agency

IAEA Review Team:

JAMET, Philippe	IAEA/NSNI/Director, Team Leader
GODOY, Antonio R.	IAEA/NSNI/ESS, Deputy Team Leader.
CAMPBELL, Gregor	Doosan Babcock, UK
CAMPBELL, Kenneth	ABS Consulting, USA
DOGLIONI, Carlo	University La Sapienza, Italy
ENGEL, Robert	Leibstadt Nuclear Power Plant, Switzerland
GÜRPINAR, Aybars	Consultant, Turkey
KOSTOV, Marin	Risk Engineering Ltd, Bulgaria
SERVA, Leonello	Insubria University, Italy
SOLLOGOUB, Pierre	CEA Research Institute, France
TAYLOR, Theodore	Pacific Northwest National Laboratory, USA
VANDEWALLE, Andre	Nuclear Safety Support Services, Belgium

IAEA 2008
Issue Date: 26 February 2008

Findings, conclusions and recommendations resulting from the IAEA Programme are intended only to assist national decision makers who have the sole responsibility for the regulation and the safe operation of their nuclear power plants. Moreover, they do not replace a comprehensive safety assessment which needs to be performed in the framework of the national licensing process.

REPORT

ENGINEERING SAFETY REVIEW SERVICES

SEISMIC SAFETY EXPERT MISSION

FOLLOW-UP IAEA MISSION IN RELATION TO THE FINDINGS AND LESSONS LEARNED FROM THE 16 JULY 2007 EARTHQUAKE AT KASHIWAZAKI-KARIWA NPP

CONTENTS

SUMMARY

On 16 July 2007, a strong earthquake, the Niigataken Chuetsu-oki earthquake, with a moment magnitude of 6.6 (M_{JMA}=6.8 according to the Japanese Meteorological Agency), occurred at 10:13 h local time with its hypocentre below the seabed of the Jo-chuetsu area in Niigata prefecture (37° 33' N, 138° 37'E) in Japan, affecting the Kashiwazaki-Kariwa Nuclear Power Plant (NPP) located approximately 16 km south of its epicentre.

Kashiwazaki-Kariwa NPP is the biggest nuclear power plant site in the world. It is located in the Niigata prefecture, in the northwest coast of Japan, and it is operated by Tokyo Electric Power Company (TEPCO). The site has seven units with a total of 7965 MW net installed capacity. Five reactors are of BWR type and two reactors are of ABWR type. The five BWR units entered commercial operation between 1985 and 1994 and the two ABWRs in 1996 and 1997, respectively.

Following this event, the Government of Japan through the Nuclear and Industrial Safety Agency (NISA) requested the IAEA to carry out a fact finding mission with the main purpose of identifying the preliminary findings and lessons learned from this event in order to share them with the international nuclear community. This first mission took place from 6 – 10 August 2007 and the mission report of the August 2007 mission is available on the IAEA web page http://www.iaea.org.

The purpose of the second IAEA mission was to conduct - six months after the event - a follow-up of the preliminary findings of the August 2007 mission on the basis of the results available in January 2008 of the mission related studies and investigations performed.

In accordance with the terms of reference for the follow-up mission and the availability of results from the performed studies and investigations performed, the scope of the follow-up mission focussed on three subject areas: (1) seismic design basis – design basis ground motions, including the evaluation of the seismic hazard[1]; (2) plant behaviour – integrity assessment - structures, systems and components response; and (3) fire safety.

In general the preliminary findings and lessons learned that were reported in August 2007 were confirmed. Since August 2007 there has been a very significant amount of high quality work performed in all areas that were considered during the follow-up mission including the establishment of required regulations and the participation of recognized institutions in Japan in the area of earthquake engineering and nuclear safety. NISA, JNES, TEPCO and a large number of specialized institutions and universities as well as experts have performed activities relating to the evaluation, regulation and the review aspects of the situation of the plant after the earthquake. The participatory approach that has been chosen by NISA for the review framework provides for a transparent and consensus seeking process.

The IAEA Safety Standards relating to seismic safety have already been very useful for the follow-up mission in identifying findings and lessons learned in the areas of the evaluation of seismic hazard and of the seismic response of structures, systems and components. The

[1] *Seismic hazard*: in the context of the IAEA Safety Standards the term *seismic hazard* refers to the measure of the attributes of the manifestations of the earthquake event at a given site and to which the facility will be exposed, such as ground motion parameters (e.g. the time histories of the ground displacements, velocities or accelerations, and/or their spectral representation), seismogenic fault displacements and, in the probabilistic approach, the associated frequency of occurrence.

discussions with the Japanese counterpart confirmed that the IAEA Safety Standards can be used by NISA and TEPCO to address many of the specific findings that are detailed in Section 5 of this report. As example, in the area of seismic hazard evaluation making the adequate use of the IAEA Safety Standards will facilitate the process of integration and synthesis of the vast amount of available data.

A change in the design ground motion to be used for the complete safety re-evaluation of the existing facility is to be expected after a strong earthquake that exceeds the original design basis. In that case it appears very important to properly evaluate the relevant capacity reserves of the plant systems, structures and components. That is possible through the use of realistic assumptions, methods, modelling and acceptance criteria in all steps of the post earthquake re-evaluation process as recommended by the IAEA Safety Standards.

It was confirmed by the Japanese counterpart that the IAEA August 2007 mission and the follow-up mission achieved the objective of sharing the lessons learned with the international nuclear community in many different ways. For NISA, cooperation with the IAEA was essential given the fact that neither international regulatory guidance nor experience was available for dealing with events like this. For TEPCO (the plant operating organization), the missions provided for a clearer road map to characterize the effect of the earthquake on the plant, to update its demonstration and determine the required upgrading. For the international community, it was an invaluable chance to share the experience of Japan and learn from this event through seminars, workshops and site visits organized by the IAEA, NISA and TEPCO. It was well understood that public perception, the need for outreach and a consistent flow of information to the community are critical components for dealing with a post earthquake situation.

The main findings and lessons learned are included in Section 3 of this report while detailed information is provided in the findings sheets in Section 5.

1. BACKGROUND, OBJECTIVES AND SCOPE OF THE MISSION

1.1. BACKGROUND

On 16 July 2007, a strong earthquake, the Niigataken Chuetsu-oki earthquake, with a moment magnitude of 6.6 (M_{JMA}=6.8 according to the Japanese Meteorological Agency), occurred at 10:13 h local time with its hypocentre below the seabed of the Jo-chuetsu area in Niigata prefecture (37° 33' N, 138° 37'E) in Japan, affecting the Kashiwazaki-Kariwa Nuclear Power Plant (NPP) located approximately 16 km south of its epicentre.

Kashiwazaki-Kariwa NPP is the biggest nuclear power plant site in the world. It is located in the Niigata prefecture, in the northwest coast of Japan, and it is operated by Tokyo Electric Power Company (TEPCO). The site has seven units with a total of 7965 MW net installed capacity. Five reactors are of BWR type with a net installed capacity of 1067 MW each. Two reactors are of ABWR type with 1315 MW net installed capacity each. The five BWR units entered commercial operation between 1985 and 1994 and the two ABWRs in 1996 and 1997 respectively.

At the time of the earthquake, four reactors were in operation: Units 2, 3 and 4 (BWRs) and Unit 7 (ABWR). Unit 2 was in start-up condition but was not connected to the grid. The other three reactors were in shutdown conditions for planned outages: Units 1 and 5 (BWRs) and Unit 6 (ABWR).

The earthquake caused automatic shutdown of the operating reactors, a fire in the in-house electrical transformer of Unit 3, release of a very limited amount of radioactive material to the sea and the air and damage to non-nuclear structures, systems and components of the plant as well as to outdoor facilities, as reported by TEPCO on their web page.

Following this event, the Government of Japan through the Nuclear and Industrial Safety Agency (NISA) invited the IAEA to carry out a fact finding mission with the main purpose of identifying the preliminary findings and lessons learned from this event in order to share them with the international nuclear community. The mission took place from 6 – 10 August 2007 and the mission report (Volumes I and II) of the August 2007 mission is available on the IAEA web page http//:www.iaea.org.

As was indicated in the report of the August 2007 mission, the first visit was considered to be an initial activity that would continue the knowledge sharing in relation to this event. Thus, NISA invited the IAEA to conduct a follow-up mission from 28 January to 1 February 2008 with the objectives, scope and details as indicated below. Preparatory meetings were held in November and December 2007 and detailed terms of reference for the follow-up mission were prepared and agreed by both parties.

1.2. OBJECTIVES

Since the occurrence of the Niigataken Chuetsu-oki earthquake in July 2007, numerous studies, investigations and analyses for assessing the seismic safety of the site and the plant have been carried out by Japanese organizations.

Thus, the purpose of the second IAEA mission was to conduct – six months after the event - a follow up of the preliminary findings of the August 2007 mission on the basis of the results available in January 2008 of the related studies and investigations undertaken since the first

mission.

These investigations were performed so far by the Government of Japan and TEPCO in relation to the seismic safety of the seven units of the Kashiwazaki-Kariwa NPP which were affected by the earthquake.

In the course of the follow-up mission, the expert team received information on the progress reached to date of the ongoing work and discussed specific technical issues and lessons learned which will be shared with the international nuclear community.

1.3. SCOPE OF THE MISSION

The detailed scope of the follow-up mission is indicated in sections 1.3.1 to 1.3.4. Considering that certain findings about the impact on the international community of the experience obtained from the Niigataken Chuetsu-oki earthquake at Kashiwazaki-Kariwa NPP are still being investigated and are the subject of the ongoing cooperation between IAEA and NISA, they are not specifically included in the present report. They will be reported on in future.

The scope of the follow-up mission focussed on three subject areas:

Area 1: Seismic design basis – design basis ground motions

Area 2: Plant behaviour – integrity assessment - structures, systems and components

Area 3: Fire safety

The detailed scope of the follow-up mission was agreed as follows:

1.3.1. General approach and organizational structures set up by NISA and by TEPCO:

- Specific requirements established by NISA for the evaluations that TEPCO should perform.
- Description of the organizational structure set up by the Japanese institutions (i.e. the setting-up of subcommittees and working groups to address specific subjects).

1.3.2. Area 1 - Seismic design basis – design basis ground motions

Investigations and studies for assessing the seismic hazard at the site:

- Geophysical investigations in the offshore area;
- Integration of data from geophysical and geological investigations in the onshore area, especially relating to the folding at or near the site;
- Seismological studies for assessing specific characteristics of the Niigataken Chuetsu-oki earthquake (fault rupture, focal mechanism, directivity, etc.). The impact on Japanese national attenuation relationships used for the case of near field earthquakes as well as on those used in other countries;
- Assessment of faulting and folding at the site vicinity (~ 5 km) and the relationship with regional tectonics.

1.3.3. Area 2 -Plant behaviour – integrity assessment - structures, systems and components

a) Inspections of systems and components (SCs):

- Result of inspections of the reactor vessel and internals (including control rods), for

the seven units;

- Result of the turbine overhaul;
- Current situation of the detailed inspections of other safety related systems and components.

b) Assessment of the seismic response of systems, structures and components (SSCs) to the Niigataken Chuetsu-oki earthquake:

- Analytical simulation of structural building response to the recorded ground motions from the Niigataken Chuetsu-oki earthquake;
- Comparison between the responses of structures, systems and components that were originally calculated and those actually recorded or evaluated and the assessment of margins;
- Evaluation of the results from TEPCO and studies by the Working Group on Examination of Seismic Safety;
- Discussions on the approaches and methodologies applied and the preliminary lessons to be learned in relation to current national and international guidance. Experience obtained from the occurrence of such a high acceleration seismic event should be considered in both national and international standards.

1.3.4. Area 3 - Fire Safety - Protection and prevention

a) Progress of the study by the Subcommittee on the Review of the In-house Fire Brigade System, and Emergency Information/Public Communications Measures and the corresponding Working Group in relation to:

- Enhancement of the in-house fire brigade system and human resource development;
- Improvement of the fire fighting plan, exercises, and evaluation regarding fire extinguishing equipment;
- Improvement plan for seismic safety of fire extinguishing equipment;
- Implementation of new redundant measures such as the use of fire engines and fire extinguishing equipment for ensuring defence in depth;
- Enhancement of the licensee’s training programmes for fire prevention;

b) Discussions on current international experience of complex scenarios such as a nuclear accident combined with seismically induced fire.

2. CONDUCT OF THE MISSION

The follow-up mission was conducted by a team composed of a leader, a deputy leader and ten international experts well recognized in this domain:

1.	*Team Leader*:	Philippe Jamet, IAEA, Director of Division of Nuclear Installation Safety (NSNI).
2.	*Deputy Team Leader*:	Antonio R. Godoy, IAEA, Acting Head of Engineering Safety Section (ESS)/NSNI, responsible for the programme of external and internal events and site evaluation.

3. Team Members:

Area 1: A. Gürpinar (Turkey), C. Doglioni (Italy), K. Campbell (USA), Leonello Serva (Italy)

Area 2: Tom Taylor (USA), Gregor J. Campbell (UK), Robert Engel (Switzerland), M. Kostov (Bulgaria) and P. Sollogoub (France).

Area 3: Mr. Andre Vandewalle (Belgium).

Considering the need for proper communication to the public of the mission objectives and conclusions, Mr. Peter Rickwood, IAEA press officer from the Division of Public Information, joined the IAEA expert team as a link with the media. Mr. Rickwood collected all news that appeared daily in the press, kept the review team informed, prepared the press releases in coordination with the team leader, the deputy team leader and IAEA headquarters and organized the press interviews and conferences during the entire mission. He also participated in the site visit and walkdown of Units 3 and 7. A press release summarising the findings of the follow-up mission was distributed on the final day from Tokyo and IAEA headquarters in Vienna and an opportunity was provided for journalists, in Tokyo, to put questions to the team leader.

A document prepared by NISA in English, summarizing the investigations, studies and inspections performed and the results obtained by NISA, JNES and TEPCO, and the specialized institutions and universities involved, and the proposed future actions was sent to IAEA prior to the follow-up mission.

The mission was conducted through discussions with counterparts at NISA offices in Tokyo and observations from a one-day visit to the Kashiwazaki-Kariwa site in which the following was performed:

- Observation of reactor components, and other important facilities;
- Observation of cores from the boreholes and trenches in the site vicinity.

The mission report is composed of two volumes, Volume I and Volume II. The latter contains all supporting documentation and information collected during the mission and provided by the Japanese counterpart to the IAEA team.

The detailed mission programme and the list of participants are included in Appendices I and II of this mission report (Volume I), respectively. Appendix III provides the details of site visit on Thursday 31 January 2008.

Details of the experts are provided in Appendix II.

3. MAIN FINDINGS AND LESSONS LEARNED

3.1. GENERAL FINDINGS AND LESSONS LEARNED

These findings and lessons learned from the Niigataken Chuetsu-oki earthquake of July 2007 and its impact on the Kashiwazaki-Kariwa NPP constitute the follow up of those already reported in Volume I of the IAEA Mission Report titled "*Preliminary Findings and Lessons Learned from the 16 July 2007 Earthquake at Kashiwazaki-Kariwa NPP*" issued in August 2007.

In general the preliminary findings and lessons learned that were reported in August 2007 were confirmed through further discussions and observations during the present follow-up mission. It should be pointed out, however, that during this follow-up mission greater emphasis was given to: (a) the evaluation of the seismic hazard; (b) the integrity assessment and seismic response of structures, systems and components; and (c) the specific findings regarding fire safety. Some specific subjects such as operational management and releases have already been considered to a sufficient extent as part of the August 2007 mission. Therefore, they are not discussed further in the present report.

Since August 2007 there has been a very significant amount of high quality work performed and measures have been taken in all areas that were considered during the follow-up mission including the establishment of required regulatory guidance and the participation of recognized institutions in Japan in the area of earthquake engineering and nuclear safety. NISA, JNES, TEPCO and a large number of specialized institutions and universities as well as experts have performed activities relating to the evaluation, regulatory guidance and the review aspects of the situation of the Kashiwazaki–Kariwa NPP after the earthquake. The participatory approach that has been chosen by NISA for the review framework provides for a transparent and consensus seeking process.

The consequences of the earthquake on the plant were unique in the sense that the levels of seismic ground motion estimated in the design process were very significantly exceeded by the event. The results of the evaluation and review process presently in progress will induce changes that will be implemented in Japanese regulatory guidance and standards. It is also likely that, eventually, there will be an influence on the approaches to the seismic safety of nuclear power plants worldwide. For this reason, it is essential that findings and lessons learned are well identified and are communicated to the international scientific and technical nuclear community.

The IAEA Safety Standards relating to seismic safety have already been very useful for the IAEA follow-up mission in identifying findings and lessons learned both in the area of the evaluation of seismic hazard and for the seismic response of structures, systems and components. The discussions with the Japanese counterpart confirmed that the IAEA Safety Standards can be used by NISA and TEPCO to address many of the specific findings that are detailed in Section 5 of this report, especially in relation to the evaluations to be performed and criteria to be applied for assessing the seismic safety for a higher seismic input, as expected from the ongoing investigations. These discussions also indicated that in general the application of the IAEA Safety Standards does not contradict the Japanese regulatory guidance in force.

It was confirmed by the Japanese counterpart that the IAEA August 2007 mission and the follow-up mission achieved the objective of sharing the lessons learned with the international nuclear community in many different ways. For NISA, cooperation with the IAEA was essential given the fact that neither international regulatory guidance nor experience was available for dealing with

events like this. For TEPCO (the plant operating organization), the missions provided for a clearer road map to characterize the effect of the earthquake on the plant, to update its demonstration and determine the required upgrading. For the international community, it was an invaluable chance to share the experience of Japan and learn from this event through seminars, workshops and site visits organized by the IAEA, NISA and TEPCO. It was well understood that public perception, the need for outreach and a consistent flow of information to the community are critical components for dealing with a post earthquake situation.

3.2. SPECIFIC FINDINGS AND LESSONS LEARNED

Re-evaluation of the seismic hazard at the site

1. A large amount of work has been performed in order to understand the Niigataken Chuetsu-oki earthquake of July 2007 and to assess the possibility of future earthquakes that may affect the Kashiwazaki-Kariwa NPP. This involved geophysical, geological, geodetic and seismological investigations both onshore and offshore.

2. Many specialized and highly recognized Japanese institutions are taking part in these investigations. Considering the complexity of the problem it will be a challenge to bring together all this information and interpretations within a coherent framework so that an appropriately conservative seismic hazard evaluation can be performed.

3. Making the adequate use of the IAEA Safety Standards will facilitate the process of integration and synthesis, thus providing a unique example for the international nuclear community. In this regard, the meetings and the site visit allowed substantial discussions regarding the approach to be used for reaching this objective. Furthermore, it was recognized that the application of the IAEA Safety Standards does not present any conflict with applicable Japanese regulations.

Integrity assessment

1. Basic Integrity Assessment Policy:

- NISA developed, through the Working Group on the Operational Management and Evaluation of the Facility Integrity, a basic policy to investigate and assess the integrity of the Kashiwazaki-Kariwa NPP. This basic policy states that when conducting the assessment of integrity of facilities, the following points should be confirmed from the perspective of conforming to the technical standards applicable for nuclear facilities for power generation:
    - Functions required by the technical standards (e.g. the operability of the ECCS systems, etc.) are maintained; and
    - Large and widespread plastic deformation does not occur within the structure.
- The policy uses a combination of inspections and analyses to determine the integrity of systems and components. It was agreed that the basic policy was sound from an engineering viewpoint, as was the basic framework of the policy. It was felt that the inspection plan developed by TEPCO to comply with NISA requirements using this policy as guidance should be made available to the international nuclear community for dealing with extreme events like the Niigataken Chuetsu-oki earthquake of July 2007.

2. *Integrity Assessment of Systems and Components:*

The integrity assessment plan for systems and components that was developed by TEPCO uses a combination of analysis and inspection to develop the matrix shown below:

Comprehensive Evaluation Matrix		
Analyses	Inspections	
	No Abnormality (I-1)	Abnormal (I-2)
Enough Margin (A-1)	Judged as Sound	Restoration (Repair/Replacement)
Less Margin (A-2)	Further Analyses and/or Inspections	Restoration (Repair/Replacement)

- While discussing the analytical portion of the integrity evaluation plan, the following points were noted:
  - The simple models used in the analyses may not always provide conservative results;
  - The analysis presented used a set of assumptions that may need to be reviewed, if the plant is required to be re-evaluated to a similar or greater seismic input. It was suggested by the IAEA expert team that it would be better to adopt a more realistic set of assumptions, methods and modelling and acceptance criteria for these analyses, in order to proceed consistently during the entire re-evaluation process.
- It was noted that the conducted visual inspections conducted are adequate to detect large and widespread deformation such as bent piping. However, the visual inspections will not identify damage that may be internal to the component or localized plastic deformation. Examples where this may occur are anchor bolts or fuel elements where the damage may be localized and internal to the component or simply not visible because of the design of the component. While there is no standardized inspection method to detect localized plastic deformation in a non-destructive fashion, it was suggested that TEPCO applies the methodology through a comprehensive combination of inspections and analyses to help ensure that no internal (hidden) damage exists. As an example, detailed analytical computations using real loads will help to assess if localized plastic deformation occurred and if so to what extent.

  On the other hand, some effects of plastic deformation, e.g. cracking, can be detected. TEPCO is currently required by JMSE code to conduct periodic examinations for cracking. Therefore, it was suggested that TEPCO reviews the current JMSE requirements and, if it is determined appropriate, augment its current in-service inspection programme using a sampling scheme to inspect components important to safety to help ensure that no internal (hidden) damage exists.

Seismic response

1. The examination of the integrity of plant systems and components commenced immediately following the earthquake. The general methodology adopted is based on basic inspections and preliminary analyses. The analyses presented for this step were performed using the same methods, models and assumptions as those used in the design phase. Although this

approach may be useful for a quick evaluation of the integrity of plant SSCs immediately after the earthquake, it may not necessarily be appropriate to apply these same methods, models and assumptions in assessing the safety margins for loads higher than the ones defined at the original design stage. With this in mind, some effort to consider realistic structural parameters (e.g. the use of *as-is* values of the concrete Young's modulus) was performed. In cases where safety margins are found to be insufficient, detailed analysis will be used according to the evaluation diagram presented by NISA and TEPCO.

2. A change in the design ground motion to be used for the complete safety re-evaluation of the existing facility is to be expected after a strong earthquake that exceeds the original design basis. In that case it appears very important to properly evaluate the relevant capacity reserves of the plant systems, structures and components. That is possible through the use of realistic assumptions, methods, modelling and acceptance criteria in all steps of the post earthquake re-evaluation process as recommended by the IAEA Safety Standards. The international experience in such cases shows that in a post earthquake assessment the evaluation of the seismic response and the available safety margin based on realistic best estimates is allowable.

Fire safety

1. Seismically induced fires are frequent events after an earthquake in urbanized areas. Experience from the effects of the Niigataken Chuetsu-oki earthquake event on the Kashiwazaki-Kariwa NPP shows that seismically induced fires should be considered in the design of fire protection systems. The fire protection programme should provide for reasonable fire fighting capacity to cope with this common cause, especially for multi-unit plants. All this experience and lessons learned are being reflected in the revision by NISA of the current regulatory guidance in Japan, as presented during the meetings of the follow-up mission. Consequently, a number of improvements have been implemented, such as the deployment of an on-site fire brigade at the Kashiwazaki-Kariwa NPP.

2. It would also be helpful to give due consideration to several important aspects such as secondary effects of fire suppression systems, spurious operation of automatic fire protection systems, soil settlements and deformations due to an earthquake in the design of fire fighting system, and fire related explosion hazards which are under research internationally. The IAEA Safety Guide NS-G-1.7 on Protection Against Internal Fires and Explosions in the Design of Nuclear Power Plants provides useful guidance for improving the fire protection programme in these areas.

3. The confirmation of appropriate staffing (i.e. number of staff) of the in-house fire brigade including addressing scenarios involving the occurrence of multiple fires, will certainly improve the response capabilities. Training through appropriate exercises based on potential fire scenarios will also be helpful in this regard.

4. Communications with the local authorities, the media and the public during emergency situations can be made easier by establishing a permanent dialogue between the local stakeholders, the regulatory body and the licensee.

Other

1. During the August 2007 mission, displacements were found in the ducts connected to the main exhaust stacks at Unit 1, 2, 3, 4 and 5. However, it was not clear at that time whether these displacements led to any leakages or releases of radioactive material. In this follow-up mission it was confirmed that a few cracks were present on the bellows of Unit 1 but no radioactive contamination was found on the surface of the damaged bellows. Also, no radioactive substances were detected at the outlet of the building ventilation system or the exit of the main exhaust stack. Therefore, no radioactivity material leaked from the cracks. No cracks were found in the ducts on Units 2, 3, 4, and 5.

4. ACKNOWLEDGEMENTS

As in the previous IAEA mission in August 2007, throughout this follow-up mission, the IAEA team experienced good cooperation from all the Japanese counterparts and the institutions participating in the meetings. Detailed presentations and documentation material were provided. All questions asked by the expert team were addressed with precision and, when needed, accompanied by adequate documentation. The programme of the one-day visit to the plant allowed the team to obtain a proper impression of the ongoing inspections and integrity assessments of key safety related components that were not accessible for the previous mission in August 2007, thus complementing the findings of that time.

5. FINDINGS SHEETS

In the following pages the finding sheets for each of the areas covered by the two missions are attached.

However, during the present follow-up mission there was no activity related to some of the findings that were identified in the August 2007 mission. This is due to the definition of the scope of the mission that was agreed between NISA and IAEA based on current priorities. These finding sheets are kept in the present report for completeness. Therefore, for the items A2-01, A2-02, A2-04, A3-01 and A3-02, it is indicated on the corresponding finding sheet that there has been no action during the present follow-up mission.

In items A1-01, A1-02 and A2-03 the new findings and lessons learned from the present follow-up mission were added to the findings and lessons learned from the August 2007 mission.

The findings sheets A2-06, A2-07 and A2-08 cover new items discussed during the present follow-up mission.

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number: **A.1-01**
NPP:	**KASHIWAZAKI-KARIWA NPP**
Unit:	**UNITS 1 TO 7**
Assessment Area:	**A.1 – SEISMIC DESIGN BASIS, INSTRUMENTAL RECORDS AND RE-EVALUATION OF SEISMIC HAZARD**
Finding Title:	**A1-01 – EXCEEDANCE OF THE DESIGN BASIS GROUND MOTION BY THE EARTHQUAKE**

2. FINDINGS

2.1 - FINDING DESCRIPTION: BACKGROUND

- Recent studies for the evaluation of seismic hazard for new and operating nuclear facilities have consistently shown significantly higher values compared to those evaluated in previous decades. Also in the past two years, two nuclear power plants in Japan experienced earthquakes that exceeded the design basis response spectra without any damage to safety related structures, systems and components.

- As a result of this, the IAEA started an extra-budgetary programme on the seismic evaluation of existing nuclear power plants (hazard and design evaluation) supported by, among other Member States, Japan where TEPCO is a major contributor. Therefore, although the 16 July 2007 Niigataken Chuetsu-oki was a major earthquake that exceeded very significantly the design basis response spectra of the plant at the base mat level, its occurrence was not totally unexpected by the plant because of the awareness brought by earlier events and the related ongoing international interaction.

2.2. – FINDINGS AT KASHIWAZAKI-KARIWA NPP

- There are a multitude of reasons for the exceedance of design basis ground motions and for these reasons the Niigataken Chuetsu-oki earthquake needs to be studied in detail for a thorough understanding of the event in question and to share feedback on the experience with the international nuclear safety community. From the discussions and documents presented to the IAEA team, some of the reasons seem related to the identification and characterization of the seismogenic sources (e.g. among others, the estimate of potential maximum magnitudes) of the seismotectonic model in the near region of the site, while other reasons concern the validation of the attenuation relations for areas close to the epicentres.

- TEPCO experts have made and presented comparisons of the seismic response spectra used for the design of structures, systems and components with the response spectra that were

obtained by site accelerographs during the 16 July 2007 Niigataken Chuetsu-oki earthquake. As the records from the free field accelerographs were overwritten by aftershock records it was not possible to have a comparison of these. Instead comparisons were calculated for records that were obtained at the base mat levels for all seven units. These are provided in Volume II of this report. These comparisons show that there was significant exceedance of the design basis levels by the observed values for a very wide range of spectral frequencies. From the presentations made by TEPCO experts as well as reports by the regulatory authority NISA, and as was confirmed by plant walkdowns performed by IAEA experts, it is indicated that the safety related structures, systems and components of all seven units of the plant (in operating, start-up and shut down conditions) demonstrated exceptionally good apparent performance in ensuring the basic safety functions concerning control of reactivity, cooling and confinement.

- Therefore, it is important to understand all the elements involved in the derivation of the seismic design basis and to identify the sources of conservatism as well as sources that contributed to the exceedance of the design basis ground motions.

- The chain that makes up the process of the derivation of the seismic design basis and the actual design of the plant structures, systems and components has a multitude of links that have varying degrees of uncertainty and that are evaluated by earth scientists, hazard analysts, geotechnical, civil, mechanical, electrical and systems engineers. As the design basis response spectra and thus the seismic design is a composite product, an analytical approach is needed for this process.

3 – LESSONS LEARNED		**10/08/2007**

1. Fault mechanism and directivity:

When there are significant contributions to the seismic hazard by active faults in the site vicinity or the near region (see the IAEA Safety Guide NS-G-3.3 for definitions of the terms site vicinity and near region), source parameters such as the fault mechanism and directivity effects may play an important role. This may cause variations in the hazard even within areas very close to each other. Ways of including these effects in seismic hazard studies need to be considered when such active faults are present in close proximity to NPP sites.

2. Local Geological Conditions:

The Kashiwazaki-Kariwa NPP has seven operating units, with four units located in one part of the site and the other three units about one and a half kilometers away. However, both the intensity of damage (to non safety items) and the levels of free field acceleration are quite different at the two locations – higher in the part of the site where the four units (1 to 4) are located. Part of the explanation may be due to the differences in the age and the depth of the underlying geological formations. At the site of Units 5 – 7 the Pliocene formations has a thickness of about 120 m above the Upper Miocene to Lower Pliocene formations, while at the site of Units 1 – 4 the Pliocene formations have a thickness of over 300 m, with an anticline separating the two sites. Such differences need to be taken into account in seismic hazard evaluations.

3. Attenuation relationships:

Attenuation relationships generally play an important role in seismic hazard assessments. They have always received much attention and the data on which they are based have steadily and exponentially increased. Until about ten years ago the number of accelerograms recorded in the near vicinity of an epicentre was relatively small. For this reason this part of the attenuation relationship had large uncertainties and some extrapolation from other parts of the curve was needed. With the deployment of dense networks in some parts of the world, e.g. K-NET in Japan, there has been a dramatic increase in the records of near field earthquakes and in general these records have shown larger than expected peak and spectral accelerations compared to earlier derived attenuation relationships. When seismic sources are present in the near region or the site vicinity of a nuclear facility, it is necessary to take into consideration the recent records that have been obtained in the near field.

4. Energy contents of the ground motion:

In general, response spectra may not be representative of the energy content of the ground motion. It may be possible to have the same response spectrum for ground motions with significantly different energy content. For this reason additional representations of the earthquake ground motion are needed to account for these differences. Generally, power spectral density functions and cumulative absolute velocities (CAV) may be used to check and compare the energy content which may have played a role, as a metric of the potential of the earthquake to cause damage.

5. Soil structure interaction:

The deeply embedded structures of the Kashiwazaki-Kariwa NPP showed interaction with the soil. Especially for the aftershock record (16 July 2007, 15:37) the reduction in the peak ground acceleration is remarkable (from 298 Gals[2] free field to 60 Gals at the base mat level). This difference is much less for the main shock, possibly owing to saturation of the free field acceleration because of soil non-linearities. It should be noted that this soil structure interaction took place for the local geological conditions at Kashiwazaki-Kariwa NPP which varies from hard soil to soft rock.

6. Conservatism of the design:

Although the design basis response spectra and the observed response spectra at the base mat level show significant differences (i.e. exceedance of the observed values) the fact that design basis response spectra are not necessarily representative of the final seismic design is once again confirmed. Volume II of this report contains a comparison of the maximum response acceleration values observed at each floor where records are available with the values estimated at the design stage for the S2 earthquake level. It can be observed here that there is very little difference between the design response acceleration and the observed acceleration values. It is also noted that in Japan the design of nuclear power plants is often governed by requirements that are related to multiples of static design coefficients of the building code. It is important to understand and document the conservatism at different steps of the design process.

[2] 1 Gal = 0.01 m/s^2.

7. Accounting for uncertainties:

Regardless of the method used (deterministic or probabilistic) each step of seismic hazard evaluation contains both uncertainties that are random (i.e. aleatory) and uncertainties that are related to the modelling (i.e. epistemic). Identification and quantification of these uncertainties is very important and is usually not straightforward. The data used needs to be qualified in terms of its reliability and the method needs to allow for alternative models that are in agreement with the data. Japan has a wealth of seismic data that may be used to decrease uncertainties associated with seismic hazard evaluation.

8. Importance of seismic instrumentation:

Although part of the free field records of the 16 July 2007 earthquake were lost due to overwriting by aftershocks in the process of transmitting these to TEPCO headquarters in Tokyo, there is still considerable data that will facilitate the understanding of this earthquake at the Kashiwazaki-Kariwa NPP. Free field, downhole, base mat and in-structure records have been obtained and these are used for comparing with the response spectra and time histories used as basis for the design.

For the future, redundancies should be considered in the processing of data so that plant personnel have immediate access to this information and that loss in transmission is avoided. Experience from modern instrumentation installed in nuclear power plants in the world that provides immediate indication to the operator of the severity of earthquake using updated criteria needs to be considered.

4. FOLLOW-UP MISSION	Date:	01/02/2008

4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP

1. Summary of Findings and Lessons Learned (from August 2007 Mission):

The main findings of the IAEA August 2007 Mission related to this subject involved two major aspects:

- The first is related to the earthquake phenomena itself; that is, the understanding of the reasons why such high accelerations (both pga and spectral accelerations) were recorded even though detailed seismic hazard studies had been conducted for the site. The questions focused on the identification of the earthquake phenomena that needed to be better understood in order for these to be shared with the international scientific community. These were identified as: (1) fault mechanism and directivity, (2) local geological conditions, (3) attenuation relationships, (4) energy content of the ground motion and (5) accounting for uncertainties.
- The second aspect was more related to the apparent excellent behaviour of the safety related structures, systems and components and the reasons that made this possible so that these could also be shared by the international community. The two findings in this area were identified as: (1) soil structure interaction and (2) conservatism of the design.

In this section of the present report only the first aspect will be considered. The second aspect is

addressed in Finding Sheet A2-08 of this report.

2. Summary of investigations performed by TEPCO and other specialized institutions:

The vast amount of investigations that were performed after the Niigataken Chuetsu-oki earthquake of July 2007 can be grouped under two major headings, as follows:

- investigations that are aimed at identifying the causative fault of the Niigataken Chuetsu-oki earthquake, and
- investigations that were performed within the site area in order to identify the origins of the ground deformations such as fractures, subsidence, sand boils and slope failures.

In the following both aspects are discussed.

2.1 Summary of investigations to identify the causative fault:

- The performed investigations aimed to identify the causative fault of the Niigataken Chuetsu-oki earthquake are reported in five main documents:

(1) Current status of investigation in Seismic & Structural Design Subcommitee, by NISA.

(2) Current state of researching project for the 2007 Niigata-ken Chuetsu-oki earthquake and strong ground motions due to this earthquake, by Japan Nuclear Energy Safety Organization.

(3) The 2007 Chuetsu-oki Japan Earthquake: A case of difficulty determining the source fault plane, by Koketsu et al, Earthquake Research Institute, University of Tokyo.

(4) Offshore active faults and folds in and around the source area of the 2007 Chuetsu-oki Japan Earthquake, by Okamura Y., Geological Survey of Japan.

(5) Evaluation status of earthquake resistance safety of the Kashiwazaki-Kariwa NPS in light of the Niigata-Chuetsu-oki earthquake, December 5, 2007, TEPCO.

Evaluation status of earthquake resistance safety of the Kashiwazaki-Kariwa NPS in light of the Niigata-Chuetsu-oki earthquake, December 25, 2007, TEPCO.

Geological survey at Kashiwazaki-Kariwa NPS in light of the Niigata-Chuetsu-oki earthquake, January 25, 2008, TEPCO.

In particular, the following sections of this TEPCO report were discussed:

- o Interim report of seismic prospecting at site and in site environs
- o Interim report of geological survey of the Nagaoka plain western faults zone
- o Report of tsunami measurement record
- o Survey on faults at site (shaft excavation survey)

- The reports (1) and (2) indicate that the most probable causative fault was a thrust plane dipping to the SE. The focal depth -where the main asperity was located- was estimated at about 10-12 km, north of the site. To reach these conclusions they used aftershocks distribution, static displacement (GPS and INSAR), tsunami propagation, teleseismic records, strong motion records and seismic reflection profiles. Some seismic reflection profiles are reported at the website of the Geological Survey of Japan:

http://riodb02.ibase.aist.go.jp/db085/RIO-DB-SEISMIC/Sado/index_Sado.html

2.2 Summary of site area investigations:

- The investigations performed for the understanding of the effects of the 2007 earthquake are reported in the NISA, JNES and TEPCO document indicated in section 2.1 above. It describes all the effects occurred at the site and the investigations already carried out and ongoing. In particular the effects were ground deformation, cracks and sand boiling. These investigations consist of topographical surveys; aerial photogrammetry, various foundation surveys; excavations; shallow and deep boreholes, a large shaft for inspecting fault displacement and seismic profiles.

3. Status of the Finding:

3.1. Investigations to identify the causative fault of the Niigataken Chuetsu-oki earthquake:

- There has been a very significant amount of work performed both in the seismological and geophysical areas to study the July 2007 Niigataken Chuetsu-oki earthquake. The seismological work started with the fault plane solution of the main shock and continued with the study of the aftershock distributions. Both of the two possible planes (SE and NW dipping) have been considered by the seismologists to be credible. The plane that dips towards the site (SE) seems to have more scientific support at the moment of present mission. The Headquarters for Earthquake Research Promotion Earthquake Research Committee stated that: . . . "*In a large sense, the 2007 Niigata-ken Chuetsu-Oki earthquake was caused by reverse fault with SE dip (inclination from sea to land). Furthermore, it is estimated that the fault with of NW dip(inclination from land to sea) also ruptured in northeastern source area* ", January 11, 2008
- The offshore seismic reflection studies have concentrated on the so called F-B fault, first identified to be 7 km long but not active (during the stage of getting the construction permit of the Kashiwazaki-Kariwa NPP). Later, further investigations conducted in 2003 concluded that this fault was active and actually 20 km long. Presently, investigations performed after the Niigataken Chuetsu-oki earthquake in July 2007 provide evidence that the fault is at least 23 km long.
- Whether or not the F-B fault is the causative structure of the July 2007 Niigataken Chuetsu-oki event is not immediately obvious. This would mean that the SE dip of the fault plane would be the preferred seismological model. It should also be pointed out that the aftershock hypocenters extend to a length of approximately 30 km, that would further elongate the F-B fault, if in fact it is the causative structure of the July 2007 Niigataken Chuetsu-oki earthquake.

3.2. Site area investigations

- The site is in an area of where crustal deformation due to the earthquake was observed. This is seen in the INSAR representation of the uplift that has taken place near the site area during the earthquake. There is folding within the site area (both an anticline and a syncline structure) which is still continuing as well as faults that last moved more than 125000 years bp.
- The seismic profiles and the borehole data confirm the folding of the Neogene sediments beneath the site. The Upper Pleistocene sediments have been reported as unconformably covering the folds, unaffected by the deformation. The site is located partly above an anticline, and partly along the adjacent syncline. The anticline has a longer and less steep

western limb with respect to the eastern one, indicating that the underlying thrust is verging to the east. This thrust is very well visible in the seismic profiles provided by TEPCO.

- The investigations performed by TEPCO are aimed at understanding the behaviour of the faults (not capable, according to the IAEA NS-G-3.3 definition) during the Niigataken Chuetsu-oki earthquake. This is being done through investigating the relationship of surface fractures observed during the earthquake with the tectonic features that show no sign of deformation within the Quaternary sediments 125000 bp. TEPCO is trying to understand whether or not possible reactivation of these faults may have contributed to the large values of the ground motion recorded at the site.
- Most of the ground deformation is evident with decimetric fractures, mostly striking parallel to the walls of NPP structures in the site area. They have been interpreted as differential settlement generated by either compaction or liquefaction of the backfill sediments filling the excavated area for the construction of the NPP. Only a few of the fractures trend obliquely to the walls of the NPP structures. All deformations and fractures have been mapped. Some decimetric sand expulsions have been reported in association with the 16 July 2007 event. All these features have been analyzed in situ or in the laboratory in order to check whether or not they are related to potential deep capable faults.
- During the excavation of the plant, several faults affecting the Pliocene and the Pleistocene sediments have been reported. However these normal faults were sealed by the post 125000 years old sediments. A significant shaft with access to one of these faults (the called ß fault between Units 1 and 2) was excavated and it clearly demonstrates that this fault did not move during this earthquake.

4.2. – LESSONS LEARNED

1. Investigations to identify the causative fault of the Niigataken Chuetsu-oki earthquake:

- The causative fault of earthquakes may be difficult to determine even when good seismological and geophysical data is available. This is a particular characteristic of blind thrust faults. The fact that it is difficult to identify the causative fault of the earthquake (after the event) even with the exceptional expertise and considerable human and financial resources available is a lesson learned especially in the predictive modeling of faults for seismic hazard evaluation (see also the next finding).
- Especially in offshore investigations, it is difficult to identify the total length of a fault. This is particularly the case when the fault in question is part of a much larger system of faults (a fault zone). It is difficult to decide whether or not the identified ‘length’ represents the total length of the fault or the segment that has been recently ruptured. Again this has an implication in the seismotectonic model when these lengths are used to estimate maximum magnitudes that these structures can generate.

2. Site area investigations:

- Fault capability is an issue that depends on the seismotectonic regime in which the site is located. The time frame which needs to be considered for fault capability is much shorter for seismically active areas (such as the site of Kashiwazaki-Kariwa NPP) than areas in intraplate regions of the world. This is indicated qualitatively in the IAEA Safety Guide

NS-G-3.3. The Japanese regulatory guidance classifies active faults (capable faults in the sense of the IAEA Safety Guide) as those that moved repeatedly in recent geological age and have possibility to move in the future. In this regulation, "recent" is considered as the late Pleistocene, i.e. the last interglacial period). The results obtained so far at the Kashiwazaki-Kariwa site and the results yet to be obtained in future investigations at the site will certainly contribute to the lessons learned in this subject and provide a firmer basis for the recommendations of IAEA safety standards.

- The ongoing investigations at the Kashiwazaki-Kariwa NPP site are expected to provide a better understanding for the contribution of folded structures and buried faults to the characteristics (amplitude and frequency content) of the vibratory ground motion.

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	**A1-02**
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 - 7**	
Assessment Area:	**A.1 – SEISMIC DESIGN BASIS, INSTRUMENTAL RECORDS AND RE-EVALUATION OF SEISMIC HAZARD**	
Finding Title:	**A1-02 – RE-EVALUATION OF THE SEISMIC HAZARD.**	

2. FINDINGS

2.1 - FINDING DESCRIPTION: BACKGROUND

- Any action relating to the seismic re-evaluation or upgrading of the structures, systems and components of the Kashiwazaki-Kariwa NPP needs to be preceded by a seismic hazard re-evaluation to re-define the ground motion parameters. In September 2006, i.e. before the earthquake of 16 July 2007 earthquake occurred, NSC issued guidelines for the conduct of reviews of the seismic design of nuclear power plants in Japan with significant recommendations relating to the identification and characterization of capable and active faults. Deterministic evaluation of seismic hazards at the sites of the existing nuclear power plants will be followed by a reference probabilistic analysis (PSHA). With the occurrence of the 16 July 2007 earthquake, the investigations carried out by TEPCO at the Kashiwazaki-Kariwa NPP site have taken a new direction.

2.2. – FINDINGS AT KASHIWAZAKI-KARIWA NPP

- The September 2006 guidelines issued by NSC are very much in line with the recommendations of the IAEA Safety Guide NS-G-3.3 Evaluation of Seismic Hazards for NPPs issued in 2002. According to the programme developed by TEPCO in response to the seismic hazard re-evaluation requirement at the Kashiwazaki-Kariwa NPP site, detailed geophysical investigations are foreseen both on land and offshore with the aim of identifying and characterizing capable and active faults in the site vicinity, the near region and the region.
- The attenuation relationships to be used for faults in the near region include both empirical methods based on observed seismic data as well as analytical methods producing synthetic seismograms compatible with the fault mechanism and the travel path. It is expected to be able to address directivity issues using this methodology. It is also recommended to conduct a deterministic seismic hazard evaluation followed by a reference PSHA.
- The results of the PSHA would be used for seismic PSA studies that are now foreseen for NPPs operating in Japan. The new guidelines also address the issues relating to uncertainties and recommend that these are treated appropriately.

3. LESSONS LEARNED		10/08/2007

1. Need for strengthening of the database to decrease uncertainties:

A significant amount of investigations both on land and offshore are foreseen in the upcoming programme for the re-evaluation of the seismic hazard at the Kashiwazaki-Kariwa NPP site. It is expected that these investigations will provide information relating to the identification and the characterization of the faults in the region. This would significantly enhance the geological database and help in reducing uncertainties regarding their existence, location and characterization.

2. **Use of deterministic and probabilistic methods:**

Both deterministic and reference probabilistic methods will be used in the re-evaluation of seismic hazard. Probabilistic seismic hazard analysis will be needed for the seismic PSA study. It is important to conduct both studies for this site in order to understand the different ways of quantifying uncertainties. There is worldwide interest in conducting seismic PSA and PSHA studies are needed for this purpose for a variety of seismotectonic settings. A site such as Kashiwazaki-Kariwa NPP will attract attention owing to the close proximity of active faults to the site (16 km) and the way these are treated in a seismic hazard evaluation.

3. Faults in the near region:

The faults in the near region of Kashiwazaki-Kariwa NPP site will also be of interest for the modelling of the attenuation relationship and how new methods such as empirical Green's functions can be applied within the context of a nuclear power plant seismic hazard evaluation. Source related parameters such as fault mechanism and directivity were observed to play an important role in the recent earthquake. It is expected that new methods may provide more information relating to these issues.

4. Local geological conditions:

The variations of the geological conditions at the Kashiwazaki-Kariwa NPP site both in terms of age and depth seem to have played a role in the damage patterns to non-safety related items. Modelling of these characteristics in the seismic hazard analysis (with the knowledge of the actual damage distribution) will be a very interesting study to follow for the international nuclear safety community.

4. FOLLOW-UP MISSION	Date:	01/02/2008
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		

1. Summary of Findings and Lessons Learned (from August 2007 Mission):

The main findings of the previous IAEA August 2007 Mission related to this subject involved the following subjects:

(1) Need for strengthening of the database to decrease uncertainties;

(2) Use of deterministic and probabilistic methods;

(3) Faults in the near region; and

(4) Local geological conditions.

The finding A1-01 related to the "*Exceedance of the Design Basis Ground Motion by the Niigataken Chuetsu-oki Earthquake of July 2007*" (previous Finding Sheet A1-01) is closely linked to the re-evaluation of the seismic hazard –discussed in the present finding sheet- because the estimation of what will happen in the future is based on the past experience. In this sense, and also following the nature of the work that has already been performed, the items under this finding have been regrouped under different headings as follows.

Item 1 – Construction of a seismotectonic model

(1) Summary of investigations performed by TEPCO and other specialized institutions:

(a) Geological and geophysical investigations:

- The east verging thrusts of the region are backthrusts with respect to the west-directed vergence of the main thrusts affecting the western Japan and the eastern side of the Japan Sea. Therefore a possible explanation is that the main active geometries are triangle zones, where the basal dominant thrusts are west-vergent, cross-cutting with ramps the entire crust, as indicated by the aftershocks of the 16/7/2007 event. The wedges forming the triangle zones are completed by the east-vergent backthrusts at the top (e.g., the Nagaoka fault could be one of these). The backthrusts have likely shallower (<10 km) decollement (as evidenced by the shorter wavelength of the related fault-propagation folds), and they seem to branch at about 10 km into the opposite verging thrusts. The main shock of the 16/7/2007 event could have been determined by a SE-dipping thrust at 10 km depth. The aftershocks propagated deeper down dip, SE-ward. Therefore, the site could have been affected by the earthquake located to the north along the deeper SE-dipping thrust, and it is located also in the hanging wall of the shallower backthrust, raising E-ward beneath the NPP.
- The area shows relevant non-cylindric geometries. This supports strong heterogeneities in the structural setting, possibly generated by the inherited lateral and vertical variability in the stratigraphic and tectonic record associated to the previous geodynamic evolution of the area, such as for the example the Tertiary opening of the Japan Sea rift. Therefore the study area presents an inversion of the pre-existing grabens and horst, and is characterized by diffuse transfer zones, which are evident by the brachianticline geometries, suggesting also a fragmentation of the ramp-related thrusts. However, during the progression of the deformation, these thrusts and backthrusts should eventually (although undulating) merge in single longer fault planes, increasing the seismic risk.
- The regional setting shows active thrust tectonics and several studies have been shown to the mission in this respect. At present the seismotectonic model of the region, near region and site vicinity is still under construction. The necessary database for constructing this seismotectonic model was extensively discussed during the meetings. In this regard it is needed to integrate all the acquired data (geological – geomorphological, marine terrace analysis, geophysical, in particular seismic reflection profiles, instrumental and historical seismicity, focal mechanisms, GPS measurements, aftershock analysis, bathymetry information, structural undulations of key-reference sedimentary beds, etc.) to construct

the seismotectonic model for the site, taking into account the different scales recommended by the IAEA Safety Guide NS-G-3.3 in order to demonstrate the completeness of the information.

- This model should also help for assessing the maximum potential magnitude earthquake for each identified seismogenic source, including a complete fault characterization

(b) Seismological Investigations:

- Most of the effort applied to date by TEPCO and other investigators has been concentrated on understanding the seismological characteristics of the Niigataken-Chuetsu-oki earthquake. At the request of the IAEA Team, TEPCO provided a map of the historical and instrumental seismicity of the region, which was derived apparently from publicly available earthquake catalogues. This map showed that earthquakes up to magnitude 7.5 have occurred within 150 kilometers of the site, the most recent being the earthquake that occurred offshore Niigata City in 1964, about 100 kilometers north of the site in the same tectonic environment, which caused widespread liquefaction and shaking damage.
- Special studies of the larger earthquakes that have occurred in the site region, compilation or calculation of focal mechanisms for these earthquakes, and integration of this information with available geological and geophysical data to better understand the seismotectonic environment of the region will be an important aspect of the development of a seismotectonic model for the site region.

(2) Status of the Finding:

- The amount of information on the different topics has been summarized above. It is rare to find such abundance of high quality data -and also of related expertise- in other regions of the world. Probably –and, partly, because of this- an overarching synthesis is particularly difficult to do. Bringing together the vast amount of data in the fields of seismology (including historical seismology), geophysics and geology coming from a variety of specialized institutions is already a major challenge. Furthermore the high level of expertise in the specialized institutions provides for a multitude of credible interpretations of this data. The abundance of data may also induce a preference for using the data most relevant to the site, i.e. the data from the near region (~25 – 30 km radius), while the complete region is to be considered as a whole.
- A number of data such as heat flow, crustal thickness, and strain rate based on GPS shortening rate should be integrated in order to construct a rheological profile and to determine the maximum magnitude expected.
- Considering the wealth of data, a model of the area is recommended. Standard geological cross-sections, both at regional and site scales, dip and strike, should be prepared, integrating the seismological, geophysical and borehole prospecting.

Item 2 – Treatment of uncertainties

(1) Summary of investigations performed by TEPCO and other specialized institutions:

- The studies are not yet at the stage of incorporating the uncertainties into a seismic hazard evaluation. From the presentations, it is clear that uncertainties are reduced through the collection of a very large set of data in the relevant fields of study. There are also varying

viewpoints regarding the interpretation of these datasets.

(2) Status of the Finding:

- The construction of a reliable database is one of the most important recommendations of the IAEA Safety Guide NS-G-3.3. It is pointed out that there is a trade off between the collection of sufficient and reliable data and the uncertainty that needs to be dealt with by the analyst when performing the seismic hazard evaluation. The collection of relevant and reliable data decreases the epistemic uncertainties associated with key parameters used in the analysis because with better data it may become easier for experts to have convergent interpretations.
- This does not mean, of course, that the decrease in uncertainties will necessarily induce a decrease in the seismic hazard. In fact, the hazard may increase because of the confirmation of a negative finding through collection of more data.
- With the excellent earthquake related data that Japan possesses, it should be possible to decrease the uncertainties associated with many parameters to levels lower than in other parts of the world.

Item 3 – Characteristics of the earthquake ground motion

(1) Summary of investigations performed by TEPCO and other specialized institutions:

- TEPCO showed to the IAEA Team the accelerograms recorded at the site from the Niigataken Chuetsu-oki main shock. These ground motions were recorded in the free field, in down-hole arrays, and at the base of the reactor buildings. These ground motions included pulses that TEPCO and other investigators have interpreted as coming from at least two asperities on the source fault. In addition, these instruments recorded many of the aftershocks. TEPCO also installed several temporary instruments to better understand the distribution of ground motion over the site area from aftershock recordings. Once these recordings have been analyzed, it will be possible to use them to calibrate the models used to calculate site response from the bedrock on which the design ground motion is specified to the bedrock and backfill that forms the foundation level of the various structures at the site. They can also be used to understand the variation of ground motion over the site area and, together with the geological, geological and geotechnical data being accumulated at the site, to identify the possible causes of this variation. Such an understanding will help to better constrain the estimation of ground motions at the site from faults in the site region.

(2) Status of the Finding:

- Thanks to the increase in the number of recorded strong ground motion during earthquakes, our knowledge on the characteristics of ground motion is steadily growing. Because of the systematic instrumental coverage of the country with arrays such as the K-Net, this increase can be best felt in Japan. Therefore, it is now possible to model a multitude of parameters related to the source, pathway and the site in the empirically derived attenuation relationships. In particular, new research is indicating specific aspects related to the ground motion due to thrust faulting.

Item 4 – Potential for surface faulting at the site

(1) Summary of investigations performed by TEPCO and other specialized institutions:

- TEPCO is extensively studying the potential for surface faulting at the site taking into account the previous knowledge of the site area (e.g. faults affecting the Pleistocene sediments but not affecting the 125000 year old terrace). This was extensively discussed during the meeting held during the site visit. In particular the faults present at the site area can be related either to the external hinge of the underlying anticline, or to gravitational sliding induced by the topographic gradient between the site and the deep offshore in the Japan Sea.
- Therefore, to properly assess the fault capability, it is important to better understand the significance of these faults.

(2) Status of the Finding:

- The IAEA Safety Guide NS-G-3.3 treats the issue of capable faulting separately from the hazard due to vibratory ground motion. In the present Safety Guide, there is already an indication related to the potential hazard from capable faults in terms of the rate of activity of the fault within the context of the seismotectonic regime within which they are situated. The concept of 'rate' is closely related to the probability of the hazard that can be expected from the fault.
- The new revision (draft) of the IAEA Safety Guide (DS 422) even recommends a quantitative probabilistic evaluation of the capability of faults based not only on their rate of activity but also other characteristics that may influence their potential for causing a surface displacement that may adversely affect nuclear safety.
- The detail of the ongoing investigations at the site seems to be sufficient to enable a quantitative assessment of the potential for surface displacement. This assessment will be facilitated by the large number of investigations that have been already carried out as well as other studies that are envisaged to check if some of the features produced by the Niigataken Chuetsu-oki earthquake could be related to surface faulting effects. At present none of them can be associated to surface faulting. In this regard, studies are in progress to verify if the mapped faults, in the bedrock of the site area, affecting the Pleistocene sediments but not affecting the sediments of the last interglacial period (Late Pleistocene) have been reactivated by this event. It is important to remark that according to present knowledge, these faults were formed during the Quaternary, as shown by the fact that their offset is the same in the Pleistocene and the Pliocene sediments.
- Studies are also in progress to verify if the mapped faults in the bedrock affecting the late Pleistocene have been reactivated by this event. With the present knowledge it can be asserted that there are no signs of reactivation in the investigated area. Studies are also ongoing to understand the relationship between the local and near regional tectonics.

Item 5 – Soil failures at the site

(1) Summary of investigations performed by TEPCO and other specialized institutions:

- TEPCO has conducted a very detailed study of the soil failures that occurred at the site (such as liquefaction, subsidence, fracturing and slope failures). All these surface manifestations were mapped. Then their relationship with the material (backfill or natural

soil), water table, proximity and direction relative to NPP structures were investigated. The possible relationship of the surface fractures to the known faults at depth was also a focal point of the studies.

(2) Status of the Finding:

- Although there was widespread liquefaction, fracturing, subsidence and slope failure at the site, safety related structures, systems and components were not affected by these effects. Safety related building were founded on deep foundation (either deeply embedded or on piles) enabled them to survive the earthquake without apparent damage.
- TEPCO is now studying these phenomena in great detail. All these phenomena have been mapped and correlated with such parameters as the water table, type of material (e.g. back fill) etc.

4.2. – LESSONS LEARNED

1. A large amount of work has been performed in order to understand the earthquake of July 2007 and to assess the possibility of future earthquakes that may affect the Kashiwazaki-Kariwa NPP. This involved geophysical, geological, geodetic and seismological investigations both onshore and offshore.

2. Many specialized and highly recognized Japanese institutions are taking part in these investigations. Considering the complexity of the problem it will be a challenge to bring together all this information and interpretations within a coherent framework so that an appropriately conservative seismic hazard evaluation can be performed.

3. Making the adequate use of the IAEA Safety Standards will facilitate the process of integration and synthesis, thus providing a unique example for the international nuclear community. In this regard, the meetings and the site visit allowed substantial discussions regarding the approach to be used for reaching this objective. Furthermore, it was recognized that the application of the IAEA Safety Standards does not present any conflict with applicable Japanese regulations.

More specifically, the lessons learned may be listed as follows:

1. Construction of the seismotectonic model, specific to the Kashiwazaki-Kariwa NPP site:

- Interdisciplinary aspects of seismic hazard studies may be as important as the intra disciplinary studies. Synthetic models (such as the seismotectonic model recommended in the IAEA Safety Guide NS-G-3.3) may be useful in bringing together the various databases (seismological, geological, geophysical, geodetic, etc.) and the expertise to focus on the specific issues of the project. Often, experts coming from different disciplines may provide alternative interpretations to the same data and this may be represented as a modeling uncertainty and integrated within the scope of the seismic hazard evaluation (valid for both deterministic and probabilistic approaches).
- Regional, near-regional, site vicinity and site area studies are all part of understanding the relevant earthquake phenomena at different scales. Focusing on the prominent features that

are near or at the site in great detail is of course very important. It is also important to consider these within the wider framework of regional seismotectonics. It is possible that there may be several interpretations (i.e. issue of fault segmentation) for the length (an other characteristics) of faults to be considered in the seismic hazard evaluations. If these alternatives are all credible for different reasons and to varying degrees, their inclusion into the seismic hazard evaluation will enrich the study and bring a wider consensus to the process.

2. Treatment of uncertainties:

- As the results of the current investigations indicate, even though an impressive amount of high quality data has been collected, there are still random uncertainties associated with these. Furthermore, there are different interpretations of the data leading to various models that can be used in the seismic hazard evaluation (e.g. regarding the segmentation of faults). To understand the effects of these uncertainties on hazard values would be important because Japan possesses excellent databases in the relevant subjects and also the expertise to bring credible interpretations to these databases.
- The treatment of uncertainties is a subject that is independent of the approach used for the evaluation of seismic hazard (i.e. deterministic or probabilistic). This aspect of the treatment of uncertainties is underlined in the new revision (draft) of the IAEA Safety Guide on the Evaluation of Seismic Hazards DS422.

3. Ground motion characterization:

- The estimation of ground motions from faults in the region, near region, and site vicinity identified in the development of the seismotectonic model will require the incorporation of earthquake source characteristics, such as fault mechanism, hanging-wall effects, source directivity, radiation pattern, and three-dimensional rupture characteristics (length, width, depth and dip of the rupture plane). This can be achieved using either attenuation relationships or numerical ground motion simulation methods, or a combination of the two, as long as these methods are calibrated using strong motion recordings obtained in a tectonic environment similar to that in the site region.
- It is important that state-of-the-art attenuation relationships and numerical modeling methods be used in order to account for recent advances in ground motion estimation that have resulted from the recent availability of near-source ground motions from moderate-to-large earthquakes worldwide. This will allow a robust estimate of ground motions from both blind and surface-rupturing earthquakes that are hypothesized to occur in the site region and will help to capture the important source and site characteristics that are expected to influence the ground motion characteristics at the site.

4. Assessment of the potential for surface faulting at the site:

- Assessing the potential for surface faulting at the site will require investigations to correlating surface cracks with local tectonics and the understanding of local tectonics within the near regional framework. There is much to be learned from the final results of the ongoing investigations at the site regarding the methods for the evaluation of the potential for fault displacement.
- Similarly, there are lessons to be learned regarding the influence of the co-seismic

movement of folding at the site. How the anticline and the syncline at the site have affected the observed ground motion will be a very valuable lesson for all the international community.

- Regional, near-regional, site vicinity and site area studies are all part of understanding the relevant earthquake phenomena at different scales. Focusing on the prominent features that are near or at the site in great detail is of course very important. It is also important to consider these within the wider framework of regional seismotectonics. (Lesson learned from Item 1 repeated).

5. Soil failures at the site:

- The results of the ongoing investigations are likely to provide new insight to geotechnical and structural engineers in the understanding of hazards such as liquefaction, subsidence and surface fractures.
- One lesson learned may be related to the design and construction of backfills, the interaction (or separation) of the backfill from the structures and the foundation design of the adjacent structures.

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	A2-01
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**	
Finding Title:	**A2-01 – OFF-SITE POWER**	

2. FINDINGS

2.1 - FINDING DESCRIPTION: BACKGROUND

- It is common practice to assume that off-site power is lost when evaluating nuclear power plants for earthquakes with peak ground acceleration (PGA) values greater than about 0.25g, owing to the common cause nature of the earthquake. Even though conventional power generation plants may be operational and transmission lines may be intact, the transformer substations are vulnerable to failure during earthquakes, making power unavailable to the nuclear power unit being evaluated. This assumption has been confirmed in many observations over the past decades. In some cases, especially when applying methods to address earthquakes beyond the design basis, it has been permitted to take credit for off-site power if it can be shown with high confidence that power generation, transmission lines and substation functions are demonstrated to be operable.

2.2 FINDINGS AT KASHIWAZAKI-KARIWA

- At Kashiwazaki-Kariwa NPP, off-site power was maintained during and after the 16 July 2007 Niigataken Chuetsu-oki earthquake even though recorded ground motion on the surface of soil at the site had peak ground acceleration values approaching 1g, affecting the switchyard.

3. LESSONS LEARNED

1. A lesson of the Niigataken Chuetsu-oki earthquake is that the assumption of loss of off-site power (LOSP) for earthquake events with peak ground accelerations greater than about 0.25g may be conservative in countries like Japan where the seismic design of electrical facilities is relatively advanced. Detailed evaluations of the off-site power generation, transmission lines and switchyard may provide justification for raising the threshold of LOSP to earthquakes greater than 0.25g PGA.

4. FOLLOW-UP MISSION	Date:	01/02/2008
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		
This item was not included in present follow-up mission.		
4.2. – LESSONS LEARNED:		
As indicated in August 2007 mission.		

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number: **A.2-02**
NPP:	**KASHIWAZAKI-KARIWA NPP**
Unit:	**UNITS 1 TO 7**
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**
Finding Title:	**A2-02 – SEISMIC SYSTEMS INTERACTION**

2. FINDINGS

2.1 - FINDING DESCRIPTION: BACKGROUND

The major seismic systems interaction issues are described as follows:

- Falling interaction is a structural integrity failure of a non-safety or safety related item that can impact and damage an item classified as seismic category I (SC-I) (or in the nomenclature of Kashiwazaki-Kariwa, as seismic class A or As). In order for the interaction to be a threat to a SC-I item, the impact must contain considerable energy and the target must be vulnerable.

- A light fixture falling on a 10 cm diameter pipe may not be a credible damaging interaction to the pipe. However, the same light fixture falling on an open relay panel is an interaction, which can cause failure of the device to perform its required function. A light fixture or a series of connected light fixtures can be hazardous to personnel and structures, systems and components (SSCs). Examples of other types of falling hazards include structural or non-structural elements failing and falling on SC-I SSCs.

- Proximity interactions are defined as conditions where two or more items are close enough together that any unsafe behaviour of one of them may have consequences on the other one. The most common example of proximity interaction is the impact of an electrical cabinet containing sensitive relays by items adjacent to it that were not secured against seismic loads.

- Spray and flood can result from failure of piping, systems or vessels that are not properly supported or anchored. Inadvertent spray hazards to SC-I SSCs arise most often from the failure of non-seismic category I items containing a liquid such as water. Fire protection systems using water may also cause spray of flooding issues. Inadvertent actuation of fire protection piping systems is one such cause. If spray sources can spray equipment sensitive to water spray, then the source should be modified. For fire protection piping, this usually is accomplished by adding support to reduce deflections and impacts or stresses. Large tanks may be potential flood sources. If a flood source can fail, an assessment should be made of the potential consequences taking into account the flow paths and dispersion of the liquid through penetrations, drains, etc. Flow paths may be difficult to assess and can most appropriately be performed in the plant rather than only relying on drawings.

- Seismic systems interaction is one of the most repeatable phenomena resulting from earthquake events.

2.2 FINDINGS AT KASHIWAZAKI-KARIWA

The walkdowns of the Kashiwazaki-Kariwa NPP demonstrated that:

1. Anchorages:

Generally, the extensive use of strong anchorages for non-safety and non-seismic category items prevented falling hazards from occurring during the earthquake.

2. Housekeeping:

A general observation is that the Kashiwazaki-Kariwa units have very good housekeeping procedures, i.e. items used for maintenance or other similar activities are tied down and in designated areas even for those units under maintenance or outage conditions.

3. Falling hazards:

Examples of falling hazards during the earthquake were:

- Failure of the connection of the work platform as observed in the spent fuel pools for Units 4 and 7. Although no damage is believed to have occurred, potential consequences of this failure would be damage to the spent fuel or the support structure within the fuel pool.
- Failure of the attachments of the interconnecting multiple fluorescent light fixtures to the ceiling of the control room as observed in Units 6 and 7. No significant consequences were observed, but adverse effects to the control room electrical equipment or to the operators could have occurred. As an example, it was reported in the course of the plant walkdown that in Unit 6 a control room operator suffered a minor shoulder injury due to a falling light fixture.
- Failure of the attachments of the ventilation air conduit diffusers to the ceiling of the Unit 3 control room – partially dropped. There were no adverse consequences, but adverse effects to electrical equipment or to the operators could have occurred.
- Tipping/falling of a cabinet in Unit 2 control room impacting a non-safety related cabinet. The tipped cabinet was attached to the raised control room floor – the cabinet and a small portion of the raised floor tipped.

4. Spray or flooding hazards:

Examples of flooding hazards during the 16 July earthquake were:

- Sloshing of the spent fuel pool water onto the reactor building operating floor of Unit 6 and leakage through cable penetrations in the floor leaking water to lower elevations.
- Failure of the rubber flexible connection of the condenser B seawater box and connecting valve in Unit 4 leaking sea water onto the turbine building floor at lower elevations. The flexible connection that failed had originally been installed 13 years ago –plant personnel stated that the normal replacement schedule was 10 to 15 years – and so ageing of the flexible connection was a factor in its failure.
- Localized soil failure caused failure of fire suppression piping at a cable penetration to the Unit 1 reactor building. Water (about 2000 m^3) and soil entered the reactor building at grade elevation and flowed through floor penetrations and stairwells to lower levels, finally

reaching the B5 level at about 38 m below the plant grade level. A 40 cm deep puddle of water formed at the B5 level. It seems that this water and soil did not produce adverse consequences to SSCs. The total evaluation by TEPCO is not completed yet.

3. LESSONS LEARNED		**10/08/2007**

For all nuclear power plants:

1. Diligence is required in the design, construction and operational phases of all plants to assure that seismic systems interaction issues are minimized, as observed in the case of Kashiwazaki-Kariwa NPP.

2. Plant walkdowns performed to evaluate conditions for potential seismic vulnerabilities should extensively consider the potential consequences of failures due to non-seismically designed conditions.

4. FOLLOW-UP MISSION	**Date:**	**01/02/2008**
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		
This item was not included in present follow-up mission.		
4.2. – LESSONS LEARNED		
As indicated in August 2007 mission.		

FINDINGS SHEET

1. FINDING IDENTIFICATION		Finding Number: A2–03
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**	
Finding Title:	**A2-03 – FIRE PROTECTION**	

2. FINDINGS

2.1 - FINDING DESCRIPTION-BACKGROUND

Background:

- One of the first announcements to the public after the earthquake of 16 July 2007 that affected the Kashiwazaki-Kariwa NPP concerned the fire in the in-house electrical transformer of Unit 3. The fire was initiated by sparks from a short circuit caused by large ground displacements (settlements) of the transformer foundation (see Appendix V of Volume II of this mission report). The spark caused the ignition of oil leaked from the transformer. The fire was extinguished by the local municipality fire brigade approximately 2 hours after it began.
- Although the transformer was separated by a firewall, active actions for extinguishing the fire were not possible because the outdoor fire protection system of Units 1-4 was damaged.

Safety Significance:

- The particular fact of the fire in the in-house transformer has no safety significance for the plant. The in-house transformer is not an item of safety related equipment and does not affect the nuclear safety of the unit. Nevertheless, the fact is significant from the broad point of view of safety due to seismically induced events.
- Frequently fire protection systems are not seismically qualified and may suffer seismic damage. However, the IAEA Safety Guide NS-G-1.6 recommends that seismically induced events, such as fires, be carefully considered in the plant safety analyses and adequate counter measures be taken.
- The damage of the outside water fire protection system of Units 1 to 4 is a cause of serious concern.

2.2. FINDINGS AT KASHIWAZAKI-KARIWA NPP	Date:	10/08/2007

- The multiple failure of the fire protection system was caused mainly due to large ground deformations produced by the earthquake. The fire protection piping was not seismically qualified because this is not required by current codes. It was indicated by TEPCO that the code requires only the installation of fire protection walls and that has been provided.

  An upgrade of the fire extinguishing system is planned with increased capacity. The source of water is the filtrated water tank that is shared by Units 1 to 4. The indoor and outdoor fire systems have a total capacity of $350m^3/h$ and they are driven by motor and diesel pumps, respectively. Although the present capacity might be sufficient, the effects of the earthquake showed that the outdoor system has been affected by a common cause failure.

- The underground piping is very vulnerable to large soil deformations such as those that occurred at the Kashiwazaki-Kariwa NPP and this should have been considered as a weak link in the analyses of the fire extinguishing system. Associated counter measures should have been properly taken.

3. LESSONS LEARNED

1. Seismically induced fires are frequent events after an earthquake in urbanized areas but are relatively rare at a nuclear power plant. Although not directly related to nuclear safety, the fire in the in-house electrical transformer started as result of the 16 July 2007 earthquake demonstrated problems in the fire fighting capability of the plant. The analyses made by the plant personnel and the regulatory authority show that there is a clear understanding of the root cause of the fire, of the deficiencies in the fire management system and of the ways for improving them.

2. In any case, common cause failure should be avoided. Failure of the fire fighting system (tanks, pumps, piping, distribution system) and its consequences can be minimized by providing adequate seismic capacity, redundancy and diversification of the systems.

3. Large soil settlements often cause piping failure, as was the case at the Kashiwazaki-Kariwa NPP when subjected to the 16 July 2007 earthquake. Flexible joints, flexible penetrations, protective buried channels and other means could be used in order to minimise probability of failure.

4. FOLLOW-UP MISSION	Date:	01/02/2008

4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP

- As related to fire safety, the earthquake on 16 July 2007 had multiple effects as it was already identified during the first IAEA mission in August 2007::
  - Fire of the in-house transformer in Unit 3;
  - Multiple failures of the fire fighting water system in Units 1 to 4;
  - Failure of one of the fire fighting water storage tank;
  - Failure of other fire suppression systems;

- Communications problems to call in the fire brigade.

- The post earthquake analysis identified some weak points in the fire protection programme such as:
  - Insufficiency of in-house fire fighting capability
  - Insufficiency of training in the fire protection area
  - Areas for improvement in regulatory guidelines
- NISA set up a specific working group to investigate all those fire safety issues. The group proposed a revision to the fire safety regulations in order to better integrate fire safety aspects in nuclear safety and to improve the current guidelines in matters related to fire protection management. These regulations will incorporate the input from different sources such as the Nuclear Safety Commission and the Fire and Disaster Management Agency, as well as the comments and suggestions from IAEA OSART missions, research in fire safety and the available operating experience. These recommendations cover the following areas:
  - In-house fire brigade;
  - On-site fire extinguishing systems identifying the need to design the fire water system to earthquake loads;
  - Alert and communication systems;
  - Education, training, drills and exercises;
  - Fire prevention, operating experience feedback
  - Information and communication with the public and authorities.
- TEPCO, as presented during the mission, implemented a number of corrective actions on the site, including:
  - Fire water system improvements;
  - In-house fire fighting capabilities;
  - Training, education and prevention measures
- As mentioned above, the fire that occurred in the in-house transformer of Unit 3 showed that a fire event could be the consequence of an earthquake. In this specific case, the existing fire walls provided adequate protection to other systems and components -located close to the transformer- through proper fire separations in order to limit the damage only to the transformer itself. As discussed during the site visit, it should be confirmed that this protection mechanisms are available in all units (e.g. in Unit 6 the inlet opening to the emergency diesel generator might not be well protected and/or separated from the in-house transformer, and the in-house transformer is not provided with an automatic fire supression system).
- During the site visit, it was also discussed and identified some corrosion problems in several parts of the fire water piping systems (e.g. the supports of the fire suppression piping system welded to the oil tank of the emergency diesel generator). The effects of these corrosion problems on the integrity of the structural elements need to be confirmed. It is important to implement the planned inspection programme on these parts of the fire water system in order to provide for the necessary repairs, (Periodic inspection of fire protection system is required under the Japanese fire code).
- Since fire fighting relied on the public fire brigade, in-house fire brigade was not adequate.

Just after the earthquake, the public fire brigade was not immediately available for fire fighting on the plant site. Taking this into consideration, recently, the on-site fire brigade was established with 10 people on a permanent basis. A successful exercise was organized by this fire brigade during the site visit. Two fire fighting trucks to support the on-site fire fighting capability were available during the site visit.

- It is noted that TEPCO is improving the on-site fire water system by installing 17 buried fire water tanks. The associated fire water piping will be installed on above ground supports.

4.2. – LESSONS LEARNED

The lessons learned already identified in the first IAEA mission of August 2007 are confirmed. Regarding the present mission, the following lessons can be highlighted:

1. For nuclear power plants located in coastal areas, corrosion problems could affect the resistance of fire protection systems exposed to the exterior environment. The use of corrosion resistant material and the implementation of adequate inspection programmes will be important to prevent unexpected failures due to earthquake occurrence.

2. NISA decided to improve the fire safety guidance in order to better integrate fire safety aspects in nuclear safety and to improve the current guidelines in matters related to fire protection management, including input from different sources. It would also be helpful to give due consideration to important aspects such as secondary effects of fire suppression systems, spurious operation of automatic fire protection systems, and fire related explosion hazards which is under research internationally. The IAEA Safety Guide NS-G-1.7 on Protection Against Internal Fires and Explosions in the Design of Nuclear Power Plants provides useful guidance for improving the fire protection programme in these areas.

3. Large soil settlements and deformations due to an earthquake should be considered in the design of fire fighting system in particular in the penetration areas from outside to the buildings.

4. The confirmation of appropriate staffing (i.e. number of staff) of the in-house fire brigade including addressing scenarios involving the occurrence of multiple fires, will certainly improve the response capabilities. Training through appropriate exercises based on potential fire scenarios will also be helpful in this regard.

5. Communications with the local authorities, the media and the public during emergency situations can be made easier by establishing a permanent dialogue between the local stakeholders, the regulatory body and the licensee.

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	A2-04
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**	
Finding Title:	**A2-04 – SOIL DEFORMATION**	

2. FINDINGS

2.1 - FINDING DESCRIPTION - BACKGROUND

Background:

- TEPCO personnel reported several instances of damage caused by large soil deformation: the station road was cut off, liquefaction of soil occurred in a large area of the site, fire in the in-house transformer of unit 3 occurred due to large settlements, the fire extinguishing system was cut at five locations due to settlements, the bank protection of the north-south discharge outlet sank, the north slope of the soil disposal area collapsed, etc.

Safety Significance:

- None of the seismically induced ground failures on the Kashiwazaki-Kariwa NPP site are having any safety significance. The behaviour of the safety related structures was not affected by the settlements and the liquefaction.

- The IAEA Safety Guide NS-G-1.6 recommends attention and prevention of the seismically induced ground deformations as excessive settlements, liquefaction, etc. Although the safety related structures of Kashiwazaki-Kariwa NPP are either founded directly on base rock or on piles that reach the base rock, the large ground deformation of the near surface deposits should be taken into account.

2.2. FINDINGS AT KASHIWAZAKI-KARIWA NPP	Date:	10/08/2007

- Although not of safety significance, the large ground deformations blocked the road to the plant at a critical moment when any delay in help and access was of importance.

- The ground failures caused a common failure of the outdoor fire extinguishing system that prevented quick and immediate response to the fire in the in-house transformer of Unit 3.

- The large ground settlements caused the oil leak of several transformers on the site, as well

	as the fire in the in-house electrical transformer of Unit 3.
-	The large ground deformations around the safety related buildings most probably have caused damage in most of the piping penetrating the building walls.

3 – LESSONS LEARNED

1. In case of large seismic shaking, as was the case during the earthquake of 16 July 2007 that affected the Kashiwazaki-Kariwa NPP, large ground deformations are frequently inevitable. Nevertheless measures to limit their effects could be taken.

2. Such measures include the use of proper soil materials for backfill and proper soil compacting, protection of the penetration by expansion joints that can allow large displacements and/or concrete channels to protect the underground piping, drainage of the site in order to reduce the underground water level as well as proper handling of precipitation water, etc. The use of a combination of most of these measures may help to reduce damaging effects of large ground deformation.

4. FOLLOW-UP MISSION	**Date:**	**01/02/2008**
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		
This item was not included in present follow-up mission.		
4.2. – LESSONS LEARNED		
As indicated in August 2007 mission.		

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number: A2-05
NPP:	**KASHIWAZAKI-KARIWA NPP**
Unit:	**UNITS 1 TO 7**
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**
Finding Title:	**A2-05 – ANCHORAGE BEHAVIOUR**

2. FINDINGS

2.1 - FINDING DESCRIPTION -BACKGROUND

- The seismic qualification of nuclear power plants requires analyses, testing and care for the anchorage. Anchorages frequently shows brittle seismic behaviour. In the case of the earthquake on 16 July 2007 that affected the Kashiwazaki-Kariwa nuclear power plant some anchorage failures were reported. All reported cases refer to equipment that is not safety related; in particular anchorage failures were found for transformers (Units 1, 2 and 3) and water tanks (Units 5, 6 and 7) as well as at a heat exchanger in the turbine building of Unit 4 (walkdown finding).

Safety Significance:

- The anchorage failures found have no safety significance for the Kashiwazaki-Kariwa nuclear power plant. As the plant had been subjected to moderate earthquake in 2004, the question arises of whether the anchorages were properly investigated after that earthquake and if the ageing management programme was updated.

2.2 - FINDINGS AT KASHIWAZAKI-KARIWA NPP — Date: 10/08/2007

- Some of the failed anchorages of the service water tanks (Units 5, 6 and 7) show signs of corrosion. That may have been caused by minor cracks from previous heavy loadings. As the earthquake on 16 July 2007 exceeded the design values, it could be expected that some of the anchorages might have suffered micro damage. A proper ageing management programme should be established to prevent sudden and abrupt changes in the anchorage behaviour.

- There are long embedded anchorages where some minor longitudinal cracks in the reinforced concrete have been observed (e.g. on the turbine condenser of Unit 5). After examination, those cracks need to be properly closed as they may affect the long term behaviour of the anchorages.

3. LESSONS LEARNED		10/08/2007
1. The long term behaviour of anchorages should be guaranteed by a proper ageing management programme reflecting the safety significance of the equipment as well as the possible interactions. Because of the lack of experience for anchorage behaviour after a strong earthquake that exceeds the design values, the anchorages should be subjected to detailed evaluation and long term monitoring.		

4. FOLLOW-UP MISSION	Date:	01/02/2008
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		
This item was not included in present follow-up mission.		
4.2. – LESSONS LEARNED		
As indicated in August 2007 mission.		

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	A2-06
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**	
Finding Title:	**A2-06 – BASIC INTEGRITY ASSESSMENT POLICY**	

2. FINDINGS

2.1 - FINDING DESCRIPTION -BACKGROUND

Basic Integrity Assessment Policy

- As a post earthquake action, after the occurrence of the July 2007 earthquake, NISA developed and set up, through the Japanese Administrative Management and Facility Integrity Assessment Working Group, a basic policy to investigate and assess the integrity of the Kashiwazaki-Kariwa NPP. Part of the objective of the IAEA mission was to understand the policy developed by the working group, to discuss the policy with Japanese counterparts and to exchange information relevant to the policy.
- The basic policy guidance document uses a combination of inspection and analysis to determine the integrity of systems and components.

Safety Significance:

– The Niigataken Chuetsu-oki earthquake of July 2007 caused the shutdown of the four units at Kashiwazaki-Kariwa NPP that were operating at the time (Units 2, 3, 4 and 7). The shutdown was conducted safely and in accordance with the design of the reactors. Units 1, 5 and 6 were already in shutdown condition for planned outages. Developing a policy that ensures the structures, systems and components (SSCs) necessary to maintain the plant in a safe shutdown condition is of high safety significance.

2.2 - FINDINGS AT KASHIWAZAKI-KARIWA NPP	Date:	01/02/2008

– The basic policy guidelines state that when conducting the assessment of integrity of facilities, the following points are confirmed from the perspective to conform to the technical standards related to nuclear facilities for power generation:

  o Large and widespread plastic deformation does not occur with the structure, and

  o Functions required by the technical standards (e.g. the operability of the ECCS systems, etc.) are maintained.

– The basic policy guidelines require that the adequacy of the implementation process be

confirmed from the standpoint of the quality management system in principle as for the implementation process. Especially, when a plant manufacturer or inspection company is involved with the inspections and assessment other than the operator, the confirmation of procurement control status becomes important. It is adequate to conduct these confirmations before the basic inspection is fully in progress, .

– The basic integrity policy requires that SSCs in the facilities in the scope of inspections are to be classified according to their seismic categorization. Standard inspection methods are prepared for each classification and based on that, inspection procedures are deployed to all facilities.

– NISA issued a directive to TEPCO to formulate for each unit at Kashwazaki-Kariwa NPP, a detailed inspection and assessment plan. This plan is submitted to NISA for approval.

– NISA will evaluate the assessment results and recommendations developed by TEPCO.

3. LESSONS LEARNED		**01/02/2008**

1. The earthquake that occurred at the Kashiwazaki-Kariwa NPP significantly exceeded the design basis for this NPP. This is the first time such an event has occurred. Therefore, NISA set up a basic policy to investigate and assess the integrity of the Kashiwazaki-Kariwa NPP as a result of the earthquake. This basic policy uses a methodology based on the combination of inspections and analyses to determine the integrity of SSCs.

2. It was agreed that the basic framework of the policy was sound from an engineering viewpoint and that the consequential related inspection plan developed by TEPCO is recommended to be made available to the international nuclear community.

FINDINGS SHEET

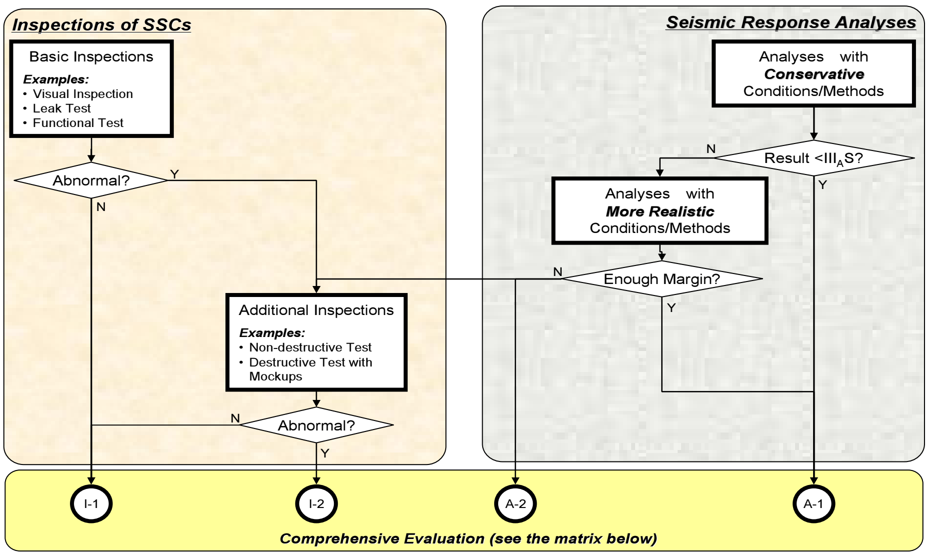
1. FINDING IDENTIFICATION	Finding Number:	**A2-07**
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**	
Finding Title:	**A2-07 –INTEGRITY ASSESSMENT OF SYSTEMS AND COMPONENTS**	

2. FINDINGS

2.1 - FINDING DESCRIPTION -BACKGROUND

Background:

The integrity assessment for systems consists of the following process:



Comprehensive Evaluation Matrix		
Analyses	Inspections	
	No Abnormality (I-1)	Abnormal (I-2)
Enough Margin (A-1)	Judged as Sound	Restoration (Repair/Replacement)
Less Margin (A-2)	Further Analyses and/or Inspections	Restoration (Repair/Replacement)

Safety Significance:

After experiencing the earthquake in July 2007 and safely shuting down all the nuclear units in operation (Units 2, 3, 4 and 7) at the Kashiwazaki-Kariwa NPP it is very important to the public safety to maintain all units in a safe shutdown condition. TEPCO has developed an integrity assessment programme that has two objectives. First, the policy helps ensure that functions required by the technical standards (e.g. maintaining the nuclear power station in a safe shutdown condition) are maintained. Second, the policy uses a combination of inspections analyses and to ensure that any widespread damage to components is detected and appropriate corrective actions are taken. This policy and the integrity assessment are of high safety significance.

2.2 - FINDINGS AT KASHIWAZAKI-KARIWA NPP	Date:	01/02/2008

- During discussions with NISA and TEPCO, it was understood that the integrity assessment plan developed by TEPCO uses both analysis and inspection to assess the integrity of SSCs. The use of both inspection and analysis to assess the integrity of components leads to separating the components into four basic categories as shown above.
- Once the components have been separated into categories, the criterion used by TEPCO to determine what additional examinations should be performed is based upon expert judgment. The expert judgment is developed using recommendations from subject matter experts and vendors.
- The inspection policy as implemented by TEPCO shows that components designated as A1/I1 could be judged sound. In practice, TEPCO has developed a programme of additional inspections for all categories of components.
- Once all components in a system are shown to be sound, TEPCO then subjects the system to a series of further inspections and analysis to demonstrate system integrity.
- The full scope of additional inspections has not been fully decided for all components at this time because the additional inspection programme is decided by expert judgment, and also, not all components have been subjected to the integrity assessment process.
- Based upon the visual inspections performed to date, no damage has been identified in safety related equipment. However, according to information presented the following abnormalities were observed.

  a. In Unit 1 Reactor Pressure Vessel Internals: one storage leg and one guide pin of the steam separator which was temporarily placed in the D/S pool, were bent.

  b. In Unit 5 Reactor Pressure Vessel Internals: a fuel bundle and a wedge of a jet pump have been displaced.

3. LESSONS LEARNED		01/02/2008

1. While discussing the analytical portion of the integrity evaluation plan developed by TEPCO, it was noted that the simple models used by TEPCO in its analysis –following the same criteria adopted at the time of the original design- may not always provide answers or explanations to the effects observed as consequence of the earthquake and may not always provide conservative results. This topic was discussed with the Japanese counterparts who agreed with the observation.

2. It was noted that some of the analyses presented by TEPCO used a set of assumptions, criteria and methods that may need to be reviewed, should the plant be re-evaluated to a higher seismic input. It was suggested to TEPCO that it would be better to adopt a more realistic set of assumptions, methods, modelling and acceptance criteria for these analyses, in order to proceed consistently during the entire re-evaluation process.

3. It was noted that while the current integrity assessment developed by TEPCO is reasonable for assessing the impact of the earthquake on the nuclear installations at Kashiwazaki-Kariwa NPP, any further action in the sense indicated above would require much more detailed policies, procedures, inspections and analyses that are based upon internationally accepted practices.

4. It was noted that the conducted visual inspections conducted are adequate to detect large and widespread deformation such as bent piping. However, the visual inspections will not identify damage that may be internal to the component or localized plastic deformation. Examples where this may occur are anchor bolts or fuel elements where the damage may be localized and internal to the component or simply not visible because of the design of the component. While there is no standardized inspection method to detect localized plastic deformation in a non-destructive fashion, it was suggested that TEPCO applies the methodology through a comprehensive combination of inspections and analyses to help ensure that no internal (hidden) damage exists. As an example, detailed analytical computations using real loads will help to assess if localized plastic deformation occurred and if so to what extent

5. On the other hand, some effects of plastic deformation, e.g. cracking, can be detected. TEPCO is currently required by JMSE code to conduct periodic examinations for cracking. Therefore, it was suggested that TEPCO reviews the current JMSE requirements and, if it is determined appropriate, augment its current in-service inspection programme using a sampling scheme to inspect components important to safety to help ensure that no internal (hidden) damage exists.

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	**A2-08**
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.2 – PLANT BEHAVIOUR – STRUCTURES, SYSTEMS AND COMPONENTS**	
Finding Title:	**A2-08 – SEISMIC RESPONSE EVALUATION**	

2. FINDINGS

2.1 - FINDING DESCRIPTION -BACKGROUND

- The seismic response analysis is one of the most important steps in the process of assessing the integrity of systems and components after the occurrence of the earthquake of July 16, 2007 that affected the Kashiwazaki-Kariwa NPP and in which the original seismic input was largely exceeded. Thus, the seismic response analysis constitutes, together with the systematic basic inspections, the approach used for integrity assessment of the structure, systems and components of the plant.
- The structural analyses conducted were aimed to reproduce the effects of the strong earthquake on all the plant components and structures using the records obtained from the strong motion recording systems.
- The integrity assessment policy adopted by NISA requires the application of conservative methods and assumptions as well as the use of assumptions, codes and standards applicable for design of new nuclear power plants. As explained by the counterpart the analyses are focused on safety related structures and components.

2.2 - FINDINGS AT KASHIWAZAKI-KARIWA NPP	**Date:**	**01/02/2008**

- The recorded strong ground motions at the foundation mat and analytically determined transfer functions are used for simulating the seismic response at various locations of the reactor building. The calculated seismic response is compared with the recorded one at places where in-structure records are available. The simple models used are adjusted by changing stiffness and damping in order to achieve best fit between floor response spectra of recorded and computed motion. In case of significant differences between the spectra response correction factors are introduced. The computed motions are further used to analytically evaluate equipment and components. The capacity evaluation results show good safety margins in most of the cases. However considering the possible future increase of the design ground motion and the international experience it is preferable to have realistic assessment of the safety margins.

- The site response analysis for the July 2007 earthquake is not yet performed. The reactor building foundations of all units are deeply embedded and placed on a Pliocene layer (designated as 'mudstone') with a shear wave velocity of about 450m/s. Despite the relatively lower shear wave velocity in the layer below the foundation in comparison to sound bedrock, the Kashiwazaki-Kariwa NPP units showed stable structural behaviour and very small gradients of the permanent structure deformations (settlement and uplift).

- Observations indicated that the safety related concrete structures most probably preserved their behaviour expected in original design during the earthquake. The very limited extent (i.e. comparatively small number) as well as the size (minor dimensions) of the cracks would tend to confirm this observation. Despite the general trend, presented by the recent analyses that indicates shear strain within the shear crack limit, it could not be excluded that, due to local cracking or to bending moments in localized areas, or due to combined multidirectional excitation (i.e. the shear strain is the result of the combined action of axial and shear forces, bending moments, etc.), etc, limited non linear behaviour may have occurred at some places of the structures of the reactor building. Discrepancies between observed and calculated spectra would suggest a similar conclusion.

- The seismic response of the equipment and components could also be assessed as elastic – linear with minor and insignificant exceptions reported. Plant safety systems were fully functional and were able to assure safe shutdown and to maintain the plant in stable conditions. The safety related equipment remained fully functional. The cranes in the Reactor and Turbine buildings that have been exposed to very strong excitation remain functional (with the exception of the crane of Reactor Building of Unit 6).

3. LESSONS LEARNED		01/02/2008

2. The plant behaviour during and after the earthquake, which exceeded the design ground motion, was safe and kept in safe conditions. The observed seismic response and the effects on the structures and components showed that considerable safety margin exists above the design strength of foundations, structures and equipment. The preliminary findings identified in this regard during the first IAEA mission in August 2007 were confirmed by the results from the integrity evaluations conducted so far and reported during the meetings.

3. There are numerous reasons for explaining the good behaviour to such extreme loads: the design was based on conservative assumptions, methods and modelling; the structural layout is regular and symmetric both in plan and elevation; the stiffness and the masses are smoothly distributed and concentration of stresses is avoided; there are no excessive eccentricities and changes in stiffness; the equipment and piping are properly anchored and there were no system interactions reported for safety related equipment.

4. As mentioned in previous Findings Sheet A2-06 of this report, the examination of the plant systems and components for integrity preservation started immediately after the earthquake. The general methodology adopted is based on: (a) basic examination (called '*basic inspections'*) and (b) preliminary analyses. The structural analyses –as presented to the mission- were performed using methods, models and assumptions as those that were used in the design phase. Although this approach may be useful for a quick evaluation immediately

after the earthquake of the integrity of plant SSCs, it may not necessarily be appropriate to apply them for assessing the safety margins for loads higher than those defined at the original design stage. With this in mind, some effort to consider realistic parameters (e.g. concrete Young's modulus) was made. In case of insufficient safety margins, detailed analysis will be used according to the evaluation diagram presented by NISA and TEPCO.

5. A change in the design ground motion to be used for the complete safety re-evaluation of the existing facility is to be expected after a strong earthquake that exceeds the original design basis. In that case it appears very important to properly evaluate the relevant capacity reserves of the plant systems, structures and components. That is possible through the use of realistic assumptions, methods, modelling and acceptance criteria in all steps of the post earthquake re-evaluation process as recommended by the IAEA Safety Standards. The international experience in such cases shows that in a post earthquake assessment the evaluation of the seismic response and the available safety margin based on realistic best estimates is allowable.

   In this regard, the use of realistic methods and assumptions are well formulated in the international community. The IAEA published a safety report document on this subject and a safety guide is being developed (presently, for comments to Member States) which reflect the current international practice in the re-evaluation of the seismic safety of existing nuclear installations for seismic input higher than the one used at the original design phase.

   In contrast with the design methods (where conservative methods are intentionally applied) the evaluation of existing nuclear facilities is based on: as-is structural and material data; as-is arrangements, loading and interactions; realistic and detailed modelling; realistic material behaviour, i.e. nonlinear behaviour (if applicable); realistic best estimate material and soil damping and other properties values; fatigue and ageing effects; etc.

6. In the design phase the site response (convolution of the outcrop design motion) caused a significant reduction of the seismic motion at foundation level. The observed strong motions and the empirically derived amplifications of the site do not support those results. An important effort has been made to adjust the soil and structure parameters in order to reproduce a simple structural model, as close as possible, to the observed in-structure records.

   However, not all the characteristics of the response have been captured, as it can be seen from the comparison of response spectra (e.g. in vertical direction for all the units and in horizontal direction for the Units 3 and 4). More refined models for site response analysis and soil structure interaction may help in this matter. These models will also be very useful for a more precise evaluation of the shear wall loads and related cracking due to the occurred earthquake, and for the seismic safety re-evaluation of the plant to a higher seismic input.

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	**A3-01**
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.3 – OPERATIONAL SAFETY MANAGEMENT**	
Finding Title:	**A3-01 – OPERATIONAL SAFETY MANAGEMENT RESPONSE AFTER SHUTDOWN**	

2. FINDINGS

2.1 - FINDING DESCRIPTION: BACKGROUND

- Operational safety management includes actions taken by the management of the power plant and the operating staff at a specific unit. Important elements in managing the response to an event are to ensure control of reactivity, removal of the decay heat from the core and confinement of radioactive material. Accident management also includes necessary communication to authorities and other organisations involved in emergency planning.

2.2 FINDINGS AT KASHIWAZAKI-KARIWA NPP

- All units in operation (Units 3, 4 and 7) and in start up (Unit 2) scrammed automatically on experiencing high seismic acceleration, as intended. For the scrammed units, the main feed water and turbine condensers were initially available as heat sinks and water make-up. The main steam isolation valves were closed manually for Unit 2 after 50 minutes and for Unit 7 after 7 hours and 55 minutes, which made the condensers unavailable in each case. The normal feed water systems were operating for all units at least the first day for all units, except for Unit 5 where the normal feed water system was stopped after 6 hours.
- The safe conditions of the plant were verified in the control room. Readiness for operation for all safety systems in all plants was first verified through visual inspection. Full testing of the safety systems with emergency diesel began on July 25.
- Operating procedures exist and were applicable, and consist of emergency operating procedures, accident operating procedures and dedicated instructions for walkdown of plant safety systems after an earthquake.
- Assistance from other units, which is usually available at unplanned unit automatic shutdown, was not possible at this time, owing to the fact that all units were affected by the earthquake and the fire at Unit 3. Resources from the technical support centre and maintenance group were also limited.
- The reporting to the authorities of the leakage of radioactive material at Unit 6 was carried out at 18:52, whilst the earthquake occurred at 10:13. The reason for taking such a long time has been explained by TEPCO. The delay was mainly caused by a lack of personnel

after the earthquake due to evacuation and other priorities. Preserving of the integrity of the communication systems is also a key issue in this respect.

3. <u>LESSONS LEARNED</u>		**10/08/2007**

1. The accident management of the event in all units was successfully carried out with respect to the operation of the reactor safety systems. The availability of both operating and safety systems and the existence of applicable accident procedures ensured the safety of the units and demonstrated the strength of maintaining several levels of defence in depth.

2. Verification of readiness for operation of the safety systems that were not activated was carried out through visual inspection. It should be carefully analysed if this procedure is sufficient or if it should be the accepted practice to test with full activation of safety systems without substantial delay after the occurrence of an earthquake.

3. There was a time delay in reporting the leakage of radioactive material to the authorities. Information from the plant should have been issued more promptly. It is of key importance to report information on releases of radioactive material to the authorities as soon as possible to provide guidance for off-site emergency organizations, even if no significant releases have occurred or are expected to occur as a result of the event.

4. FOLLOW-UP MISSION	**Date:**	**01/02/2008**
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		
This item was not included in present follow-up mission.		
4.2. – LESSONS LEARNED		
As indicated in August 2007 mission.		

FINDINGS SHEET

1. FINDING IDENTIFICATION	Finding Number:	**A3-02**
NPP:	**KASHIWAZAKI-KARIWA NPP**	
Unit:	**UNITS 1 TO 7**	
Assessment Area:	**A.3 – OPERATIONAL SAFETY MANAGEMENT**	
Finding Title:	**A.3-02 – RELEASES**	

2. FINDINGS

2.1 - FINDING DESCRIPTION: BACKGROUND

- Confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases is a fundamental safety objective in nuclear safety. It is important to detect and correct uncontrolled releases and possible pathways to the environment, even if the actual releases are very limited.

2.2 FINDINGS AT KASHIWAZAKI-KARIWA NPP:

TEPCO reported detection of iodine particulate material (Cr-51 and Co-60) during a weekly periodic measurement performed at the main exhaust stack at Unit 7. The detected radioactivity ($4x10^8$ Bq of iodine and $2x10^6$ Bq of other substances) was estimated to result in an individual dose well below the authorized limits for normal operating conditions. The release of radioactivity was found to come from the exhaust fan in the turbine gland steam ventilator. It was due to a mistake of an operator who failed to turn off a ventilator when the gland steam was no longer available. Under these circumstances, the ventilator continued to propel steam and incondensable gases from the turbine condenser to the main stack, which underwent further contamination.

- A small discharge of contaminated water into the sea occurred after the earthquake. The water spilled over from the spent fuel pool to the reactor building refuelling floor, where it filled up a cable chase. It then leaked into an uncontrolled area on the lower floor through a cable penetration that had a defective sealing. The water dripped down one additional floor along cables and a penetration. It finally collected one floor down in a pit of discharged water. The contaminated water was then sent to the sea by the discharge pump through the discharge outlet.

  The volume of discharged contaminated water was estimated by TEPCO using the records of the pump activation. The activity of the discharged water was directly measured on samples of water from puddles in rooms above the pit. It was found out that the activity released was extremely small and it was estimated to result in an individual dose well below the authorized limits for exposure of the public under normal operating conditions. The phenomenon of water spilling over from the spent fuel pool is now well known and had already been observed during previous earthquakes. It seems therefore important to devote special attention to the leak-tightness of penetrations on the floor of the reactor building where the spent fuel pool is located.

- Significant displacements were produced by the earthquake in the ducts connected to the main exhaust stacks at Units 1, 2, 3, 4 and 5. These displacements could have resulted into limited leakages and releases of contaminated air at the ground level instead of such contaminated air being exhausted and monitored at the top of the stack. - TEPCO considered that the events had a very low impact on the plant safety and individual radiation dose. The IAEA team finds this conclusion reasonable.

3. <u>LESSONS LEARNED</u>		**10/08/2007**
1. Although no releases of radioactive material from the reactor core due to the earthquake were detected, careful attention should be paid to other possible sources of releases, even if the releases are of limited low amounts.		

4. FOLLOW-UP MISSION	**Date:**	**01/02/2008**
4.1. - FINDINGS AT KASHIWAZAKI-KARIWA NPP		
This item was not included in present follow-up mission.		
4.2. – LESSONS LEARNED:		
As indicated in August 2007 mission.		

APPENDIX I - MISSION PROGRAMME

The mission programme is as follows:

Sunday, 27th January:

Arrival of experts to Tokyo, Narita Airport.

Transfer from Narita Airport to the "Akasaka Excel Hotel Tokyu".

17:30 – 18:30: Coordination Meeting with NISA, at the Hotel

18:30 – 19:30: IAEA Experts Team – Internal Meeting

19:30 Dinner at the Hotel restaurant IAEA Experts Team.

Monday, 28th January: ***"Opening Session and Integrity Assessment of the K-K NPP"***

08:00: Departure from Hotel
08:20: Arrival to NISA
08:20: Press contact: IAEA-Mr. Jamet/Mr. Rickwood.

09:00-10:00: Opening Session:

a. Opening remarks by NISA, DG Mr. Komoda
b. Opening remarks by IAEA Team Leader, Mr. Jamet
c. Introduction of IAEA Experts Team, Mr. Godoy.
d. Comprehensive explanation about KK-NPP status: Organization set up for dealing with issues related to July 2007 earthquake and Basic Safety Policy regarding Seismic Safety Assessment, by NISA.

10:00-10:30 Coffee break

10:30-11:30: ***Integrity Assessment of the K-K NPP***: – Plenary Session

1. Evaluation of Operational Management during and after earthquake occurrence, by NISA.

11:30-12:30: Lunch

12:30-14:00: ***Integrity Assessment of the K-K NPP***: (cont.) – Plenary Session

2. Result of examination of KASHIWAZAKI-KARIWA NPP after the earthquake, by TEPCO.

14:00-14:30 Coffee break

14:30:17:00: ***Integrity Assessment of the K-K NPP***: (cont.) – Plenary Session

3. Evaluation of integrity of plant systems, structures and components, by NISA and TEPCO.

17:00-17:30: General discussions o- Conclusions of the day session
18:00-19:30 Internal Meeting IAEA Experts Team at the Hotel Meeting Room.

Tuesday, 29th January: ***"Seismic Safety Evaluation*"- NISA/Tokyo**

09:30: Departure from Hotel

10:00-12:00: Seismic Safety Evaluation: – Plenary Session

1. Current situation of the discussion in study group, by NISA.
2. Current situation of evaluation of Kashiwazaki-Kariwa NPP, by JNES.
3. Comments by the member of review group, [members of study group].

12:00-13:00 Lunch break

13:00-17:30 Seismic Safety Evaluation: (cont.) –Plenary Session

1. Seismic ground motion investigations: results of the performed geological/geophysical/seismological investigations.

17:30-18:00: General discussions – Conclusions on the day session

18:30-20:30 Internal Meeting IAEA Experts Team at the Hotel Meeting Room.

Wednesday, 30th January: ***"Fire Safety*"- NISA/Tokyo**

09:30: Check-out and departure from Hotel.

10:00-12:30: Plenary Session on Fire Safety, (except WK on Geological/geophysical investigations):

1. Fire protection of Japanese NPP, by JNES.
2. Presentation of draft summary report prepared by the study group, by NISA.
3. Fire Protection Activities in Kashiwazaki-Kariwa NPP, by TEPCO.

10:00-12:30: Seismic Safety Evaluation Session on Geological/geophysical investigations (if needed): detailed discussions on results of geological/geophysical/seismological investigations between NISA/JNES/TEPCO and IAEA Experts

12:30-13:30 Lunch Break

Afternoon: Travel from Tokyo to Nagaoka
14:45: Departure from NISA to Nagaoka: transfer to Tokyo Station
15:32: Departure from Tokyo Station by Shinkansen Train
17:26: Arrival at Nagaoka Station
17:40: Check-in at "Nagaoka Grand Hotel"
18:30-19:30 Internal Meeting IAEA Experts Team at the Hotel Meeting Room.

Thursday, 31st January: *"Kashiwazaki-Kariwa NPP"*

08:00: Check-out and departure from Hotel, by bus to Kashiwazaki-Kariwa NPP

09:00-10:00: Presentation by TEPCO.

10:00-12:00 Plant walkdown:

- Team A1: Unit No 3 – Seismic Safety Examination-Inspection of components integrity.
- Team A2: Unit No 7 – Seismic Safety Examination-Inspection of components integrity.
- Team A3: Fire safety
- Team B: Geological investigations – Visit to boring investigation area.

12:00-13:00 Lunch break

13:00-15:00: Continuation

- Team A1: Cont. of plant walkdown –Unit No 7 - Seismic Safety Examination-Inspection of components integrity.
- Team A2: Cont. of plant walkdown - Unit No 3 – Seismic Safety Examination-Inspection of components integrity and fire safety.
- Team A3: Fire safety
- Team B: Geological and seismological investigations and studies: presentation by TEPCO of reports and documents of the results obtained from the performed geophysical investigations.

15:00-16:30: Plenary session: General discussions

16:30-17:00: Press interview: IAEA/Jamet and Rickwood.

17:00: Departure from Kashiwazaki-Kariwa NPP

18:37: Departure from Nagaoka Station to Tokyo by Shinkansen Train

20:12: Arrival at Tokyo Station

20:40: Arrival at the "Akasaka Excel Hotel Tokyu".

-.- IAEA Experts Team – Preparation of Mission Report

Friday, 1st February: **"*Closing meeting*" – NISA/Tokyo**

Morning: IAEA Experts Team: Internal meeting at Hotel meeting room – Preparation of Mission Report

Afternoon: 13:45: Departure from Hotel to NISA

14:00-16:00: Closing Session

- Presentation of findings and conclusions by IAEA Experts Team.
- General discussions.
- Closing remarks, by IAEA Mr. Jamet
- Closing remarks, by NISA.

16:00: Press conference: IAEA/Mr. Jamet/Mr. Godoy/Mr. Rickwood

17:00-17:30 Courtesy visit to NSC – Prof. Suzuki and Commissioners.

Adjourn

18:30-20:00 Internal Meeting IAEA Experts Team at the Hotel Meeting Room..

Saturday, 2nd February: Departure of Experts from Tokyo to home countries.

APPENDIX II - LIST OF PARTICIPANTS

A.II.1 IAEA REVIEW TEAM:

IAEA STAFF MEMBER:		
1. Mr. JAMET Philippe	Team Leader (TL)	Director, Division of Nuclear Installation Safety Department of Nuclear Safety and Security International Atomic Energy Agency Wagramerstrasse 5, P.O. Box 100 A-1400 Vienna, Austria Tel: +43 1 2600 22520 Fax: +43 1 26007 Email: p.jamet@iaea.org
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10. Mr. SERVA Leonello	External Expert	Insubria University - Professor Via dei Dauni 1 00185 Roma Italy Tel.: +39 06 4469397 E-Mail: leonello.serva@apat.it
11. Mr. SOLLOGOUB Pierre	External Expert	Pierre Sollogoub CEA/Saclay DEN/DANS/DM2S/DIR Bat 607, 91191 Gif sur Yvette Cedex France Tel: + 33 1 69 08 27 16 Email Pierre.SOLLOGOUB@cea.fr

12. Mr. TAYLOR Theodore	External Expert	Mail K5-26 2400 Stevens Richland Washington 99354 USA Tel: +1 509 375 4331 Email: tt.taylor@pnl.gov
13. Mr. VANDEWALLE Andre	External Expert	Sentier du Berger 75 B-1325 Corroy-le-Grand Belgium Tel: +32 10 688308 Email: nsss@skynet.be

A.II.2 JAPANESE ORGANIZATIONS

A.II.2.1. NISA - Nuclear and Industry Safety Agency

1-3-1 Kasumigaseki Chiyoda-ku Tokyo 100-8986 Japan

Yasuhisa KOMODA	**Director-General**
Shigeharu KATO	**Deputy Director-General for Nuclear Power**
Akira FUKUSHIMA	**Deputy Director-General for Safety Examination**
Hideshi UEDA	**Director, Policy Planning and Coordination Division**
Masahiro YAGI	**Director, International Affairs Office**
Masanobu KATO	**Deputy Director, International Affairs Office**
Kazuko NAGURA	**Assistant Director, International Affairs Office**
Tomoho YAMADA	**Director, Nuclear Safety Regulatory Standard Division**
Tadao KANDA	**Director for Safety Examination, Nuclear Safety Regulatory Standard Division**
Uichiro YOSHIMURA	**Director, Nuclear Safety Public Relations and Training Division**
Yoshinori MORIYAMA	**Director, Nuclear Power Licensing Division**
Shuuji KAWAHARA	**Director, Seismic Safety Office, Nuclear Power Licensing Division**
Hiroyuki ITO	**Deputy Director, Seismic Safety Office, Nuclear Power Licensing Division**
Yuichi SATO	**Safety Examiner, Seismic Safety Office, Nuclear Power Licensing Division**

Hisanori NEI	**Director, Nuclear Power Inspection Division**
Yukinori MAEKAWA	**Director for Safety Examination, Nuclear Power Inspection Division**
Ryo KAMITO	**Senior Examiner for Safety, Nuclear Power Inspection Division**
Tatsuya TAGUCHI	**Deputy Director, Nuclear Power Inspection Division**
Hideaki ENDO	**Deputy Director, Nuclear Power Inspection Division**
Shinji SUNOUCHI	**Deputy Director, Nuclear Power Inspection Division**
Satoshi KODAMA	**Nuclear security inspector, Nuclear Power Inspection Division**
Masahiro OKUDA	**Director, Nuclear Emergency Preparedness Division**
Nobuhiko SHIRAISHI	**Director, Fire Protection and Prevention Office, Nuclear Emergency Preparedness Division**

A.II.2.2. JNES Incorporated Administrative Agency - Japan Nuclear Energy Safety Organization
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Tel.: (+81)3 4511 1900

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Shohei MOTOHASHI	**Assistant Director-, Seismic Safety Division**
Naotaka TAKAMATSU	**Director, Seismic Safety Division**
Hideaki TSUTSUMI	**Senior Officer, Seismic Safety Division**
Hiroshi ABE	**Principal Staff, Seismic Safety Division**
Takehiro OTSUKA	**Assistant Director-General, Inspection Affaires Division**
Hideo KOIKE	**Director, Inspection Affaires Division**
Munenori HIRASAWA	**Senior Officer, Safety Information Research Division**
Yuko NOMURA	**Assistant Director, Public Relations Office**
Katsunori OGURA	**Senior Officer, Safety Analysis and Evaluation Division**
Yoshio YAMAMOTO	**Senior Officer, International Relations Office**
Masaki NAKAGAWA	**Senior Officer, International Relations Office**

Keisuke TSURUGA Senior Officer, International Relations Office

A.II.2.3. TEPCO – TOKYO ELECTRIC POWER CO:
1-3 Uchisaiwai-cho 1-Chome Chiyodaku Tokyo 100-8560 Japan

Ichiro TAKEKURO	**Executive Vice President & Chief Nuclear Officer**
Akio TAKAHASHI	**Director, Site Superintendent, Kashiwazaki-Kariwa NPP**
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Hiroto KATAOKA	**Unit Superintendent (Units 5-7), Kashiwazaki-Kariwa NPP**
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Yoshikazu SUZUKI	**Deputy Superintendent (Civil Engineering), Kashiwazaki-Kariwa NPP**
Masami ISHIKAWA	**General Manager, Quality and Safety Management Department, Kashiwazaki-Kariwa NPP**
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Hikaru KURODA	**Manager, Reactor Mechanical Group, Maintenance Department (Units 5-7), Kashiwazaki-Kariwa NPP**
Hideaki TOKUMA	**Reactor Mechanical Group, Maintenance Department (Units 5-7), Kashiwazaki-Kariwa NPP**
Takao ENDO	**Turbine Mechanical Group, Maintenance Department**

	(Units 5-7), Kashiwazaki-Kariwa NPP
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Kazuhiko YAMASHITA	**General Manager of Niigataken Chuetsu-oki Earthquake Restoration Management Center**
Jun MATSUMOTO	**General Manager, Seismic Issues Management Group, Niigataken Chuetsu-oki Earthquake Restoration Management Center**
Kenji MURANO	**Manager, Seismic Integrity Engineering Group, Niigataken Chuetsu-oki Earthquake Restoration Management Center**
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	oki Earthquake Restoration Management Center
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Kazuhiko YASHIRO	**Architectural Engineering Group, Niigataken Chuetsu-oki Earthquake Restoration Management Center**
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Kazuhiko YASHIRO	**Civil Engineering Group, Niigataken Chuetsu-oki Earthquake Restoration Management Center**
Makoto TAKAO	**Civil Engineering Group, Niigataken Chuetsu-oki Earthquake Restoration Management Center**
Satoshi ASAI	**Civil Engineering Group, Niigataken Chuetsu-oki Earthquake Restoration Management Center**
Tadayuki YOKOMURA	**General Manager of Nuclear Power Plant Management Department**
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Kazuyuki SHINODA	**Nuclear Corporate Planning Group, Nuclear Power & Plant Siting Administrative Department**

APPENDIX III – SITE VISIT

A.III.1 PROGRAMME OF THE SITE VISIT - Kashiwazaki-Kariwa NPP

Date: Thursday, 31th January, 2008

09:00-10:00 Opening remarks / Whole Body Counter

Team A

10:00-12:00 Plant Walkdown

- **Team A1: Unit No. 3 (reactor internal inspection, Recirculation system(pumps, pipe supports), turbine inspection)**
- **Team A2: Unit No. 7 (FMCRD overhaul, turbine inspection)**

Team A3: Fire-fighting equipment & facilities

12:00-13:00 Lunch break

13:00-15:00 Continuation

- **Team A1: Unit No. 7 (FMCRD overhaul, turbine inspection)**
- **Team A2&3: Unit No. 3 (reactor internal inspection, Recirculation system(pumps, pipe supports), turbine inspection)**

15:30-16:30 Team A3: Offsite Center

Team B

10:00-10:30 Explanation about geological investigations

10:30-11:30 Observation of core samples

11:30-12:30 Observation of boring investigation area

12:30-13:30 Lunch break

13:30-15:00 Discussion

15:00-16:30 Plenary session: General discussions

Explanation video about reactor internal inspection

Summary of the findings, Q&A

Closing remarks / Whole Body Counter

16:30-17:00 Press interview: IAEA

17:00 Departure from Kashiwazaki-Kariwa NPP

A.III.2 COMPOSITION OF TEAMS

Team A1: Unit No 3 & No 7– Seismic Safety Examination-Inspection of Components Integrity.

1. Jamet, P

2. Campbell, G
3. Engel, R
4. Taylor, T
5. P. Rickwood
6. Fukushima, A / DDG of NISA
7. Kato, M / International Affairs Office, NISA
8. **TEPCO: Yahagi, Kawamura, Shinoda**

Team A2: Unit No 7 & No 3 – Seismic Safety Examination-Inspection of Components Integrity.

1. Sollogoub, P

2. Kostov, M
3. Sunouchi, S / Inspection Division, NISA
4. Koike, H / Inspection Division, JNES
5. Nakagawa, M / International Relations Office, JNES
6. **TEPCO: Kataoka, Nagasawa**

TeamA3: Fire safety

1. Vandewalle, A
2. Hirasawa, M / Safety information Division, JNES
3. **TEPCO: Kawamata, Tateno, Murohoshi, Matsumoto, Zin**

Team B: Geological investigations – Visit to area of boring investigations.

1. Godoy, A

2. Campbell, K
3. Doglioni, C
4. Serva, L
5. Kawahara, S / Director Seismic Safety office, NISA
6. Ito, H / Seismic Safety Office, NISA
7. Abe, H / Seismic Safety Division, JNES
8. Nomura, Y / Public Relation Office, JNES
9. **TEPCO: Suzuki, Toba, Kubo, Takao, Asai, Mizutani**