NUCLEAR ENERGY AGENCY
COMMITEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

PROCEEDINGS OF THE OECD/NEA WORKSHOP ON SEISMIC RISK

Committee on the Safety of Nuclear Installations PWG3 and PWG5

Hosted by the Japan Atomic Energy Research Institute under the Sponsorship of the Science and Technology Agency, 10-12 August, 1999, Tokyo, Japan
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The CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of the programme of work. It also reviews the state of knowledge on selected topics on nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus on technical issues of common interest. It promotes the co-ordination of work in different Member countries including the establishment of co-operative research projects and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences and specialist meetings.

The greater part of the CSNI’s current programme is concerned with the technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the nuclear fuel cycle, conducts periodic surveys of the reactor safety research programmes and operates an international mechanism for exchanging reports on safety related nuclear power plant accidents.

In implementing its programme, the CSNI establishes co-operative mechanisms with NEA’s Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA’s Committee on Radiation Protection and Public Health and NEA’s Radioactive Waste Management Committee on matters of common interest.

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ABSTRACT

This is the proceedings from the Workshop on Seismic Risk organized by the OECD/NEA/CSNI/PWG3 and PWG5. The Workshop was held from the 10th-12th August 1999 in Tokyo, Japan, and was hosted by JAERI under the sponsorship of STA.

Twenty-four technical papers were submitted on methodology and data for, uses of, and insights gained from seismic PSA/margin studies, and development of risk-goal oriented seismic design procedure. The proceedings contain a summary of the papers presented, conclusions made by the Workshop Participants and copies of the papers presented.
FOREWORD

The main objective of the Workshop was to provide a forum to review recent advances in methodology and application of seismic probabilistic safety assessment and seismic margin analysis of nuclear installations. Emphasis was placed on the exchange of ideas on effective ways for using seismic PSA rather than the numerical PSA results such as core damage frequencies or seismic hazard for specific plants.

The Workshop was held in Tokyo, Japan, and was hosted by Japan Atomic Energy Research Institute (JAERI) and sponsored by the Science and Technology Agency (STA). Members of the Organising Committee wish to acknowledge the excellent planning and arrangements made by Dr. Kiyoharu Abe of JAERI and Mr. Ken Muramatsu of JAERI. Professor Shunsuke Kondo of the University of Tokyo presided as Workshop Chairman.

These proceedings were prepared under the guidance of the Workshop Organising Committee listed in the body of the report. Special acknowledgement is given to the following experts who provided their time and considerable knowledge to the success of the Workshop: Dr. Robert P. Kennedy, Dr. Robert J. Budnitz, Prof. Hiroyuki Kameda, Dr. Karl N. Flemming, Dr. Nilesh Chokshi and Dr. Heki Shibata. Additional thanks are given to the Session Chairpersons for their work during the Workshop.

This activity was jointly sponsored by PWG3 (Integrity of Systems and Components) and PWG5 (Risk Assessment).

PWG3 has a sub-group on the Seismic Behaviour of Structures. This group has issued a report on Seismic Re-Evaluation, organised a workshop on Finite Element Analysis, an International Standard Problem on Seismic Shear Wall Analysis, and a workshop on the Engineering Characterisation of Seismic Input. This last topic is particularly important for seismic PSA as being a major component of the input data.

PWG5 issued a state-of-the-art report on the current status of methodologies for seismic PSA. It is in the process of developing a technical opinion paper of seismic PSA based on the report and the results of this workshop.
1. BACKGROUND

The OECD/NEA Workshop on Seismic Risk was planned by the two principal working groups of the Committee on the Safety of Nuclear Installations (CSNI), PWG3, the group on the Integrity of Structures and Components, and PWG5, the group on risk assessment, on the basis of the following preceding activities:

- The PWG3 subgroup on the seismic behaviour of structures was formed in 1996 adding to the mandate of PWG3. A status report initiating the activities of the subgroup identified Uncertainties (issues related to seismic margins and PSA) as a topic that was important.
- PWG5 prepared a report on current status of methodologies for seismic PSA, which was issued in March 1998.

2. OBJECTIVES

The objectives of the Workshop were:

- To provide a forum to review the recent advances in methodology and application of seismic probabilistic safety assessment and seismic margin analysis of nuclear installations,
- To discuss the effective uses of the seismic PSA/margin analysis with consideration of merits and limitations of probabilistic methods,
- To review the state of the art methodology to provide guidance for conducting seismic PSA, and
- To discuss methodological issues and identify areas in which further research is needed for enhancing the usefulness of seismic PSA.

The emphasis of the Workshop was placed on the exchange of ideas on effective ways of using seismic PSA rather than the numerical PSA results for specific plants such as core damage frequencies or seismic hazard.

3. ORGANIZING COMMITTEE

Dr. Shunsuke Kondo, U. Tokyo, Japan (Chairman)  
Dr. Medhat Elghohary, AECL, Canada  
Dr. Mitsumasa Hirano, NUPEC, Japan  
Mr. Ken Muramatsu, JAERI, Japan  
Dr. Heki Shibata, ADEP, Japan  
Dr. José Sanchez-Cabañero, CSN, Spain  
Dr. Charles Shepherd, NSD UK  
Dr. Robert Budnitz, Consultant, USA  
Dr. Nilesh Chokshi, NRC, USA  
Mr. Joseph Murphy, NRC, USA  
Dr. Alex Miller, OECD/NEA (PWG-3 secretary)  
Mr. Barry Kaufer, OECD/NEA (PWG-5 secretary)  
Mr. Akira Omoto, Tokyo Electric Power Company, Japan
4. PARTICIPANTS

About 90 persons participated from nuclear power industries, universities, regulatory authorities, and research institutes of 11 countries/international organisation including: Canada, Czech (Paper submittal), Finland, Germany, Hungary, Korea, Japan, Spain, United Kingdom, and the United States.

5. PRESENTATIONS AND DISCUSSIONS

24 technical papers were submitted and presented in 9 technical sessions.

- 11 papers on Methodology and Data (Hazard, Fragility, and Correlation/Dependency)
- 8 papers on Uses of Seismic PSA/Margin Study,
- 3 papers on Insights Gained from Seismic PSA/Margin Studies,
- 2 papers on Development of Risk-Goal Oriented Design Procedure and Data.

In order to stimulate effective discussions, the following five experts were invited to provide a review talk on generic and/or topical issues.

- Dr. Robert P. Kennedy: An overview of methodology including recent innovations,
- Dr. Robert J. Budnitz: PWG5 Topical Opinion Paper on the current status of seismic PSA,
- Prof. Hiroyuki Kameda: An overview on the development of seismic hazard evaluation methodology in Japan,
- Dr. Karl N. Fleming: Technical issues in the treatment of dependencies in seismic risk analysis,
- Dr. N. Chokshi: Lessons learned from IPEEE and a regulatory application in seismic area using risk insights.

The final session of the Workshop was devoted to summarising the current status and progress to draw conclusions. Participants of the Workshop made extensive discussions based on summary reports by three experts and session chairs.
6. SUMMARY OF THE WORKSHOP

In the summary session, which was chaired by Drs. N. Chokshi (USNRC) and K. Abe (JAERI), the discussion on technical papers were divided into three groups of sessions, for which three experts (main reporters) contributed a brief summary followed by additional comments from session chairs and discussions by all participants.

6.1 Groups

Group 1: Methods and Data  (Main reporter: Dr. M. K. Ravindra. EQE, USA)

- Session I. Generic Reviews on Methods and Applications, Chaired by C. Shepherd and H. Shibata
- Session II. Seismic Hazard Analysis and its Application, Chaired by Sanchez-Cabanero and J. P. MacFarlane
- Session VI. Treatment of Dependency/Correlation in Seismic PSA, Chaired by M. K. Ravindra and W. Mizumachi
- Session VII. Fragility Evaluation Using Vibration Tests, Chaired by R. P. Kennedy and J. Hirose

Group 2: Uses of Seismic PSA/Margin Study  (Dr. J. G. Sanchez-Cabanero, CSN, Spain)

- Session III. Use of Seismic PSA/Margin Study I, Chaired by M. Sakagami and T. Matsuoka
- Session IV. Use of Seismic PSA/Margin Study II, Chaired by A. Yamaguchi and T. Oikawa
- Session V. Use of Seismic PSA/Margin Study III, Chaired by M. Elgohary and A. Bareith

Group 3: Insights, and Risk Goal Oriented Approaches (Dr. R. J. Budnitz, Consultant, USA)

- Session VIII. Insights Gained from Seismic PSA/Margin Studies, Chaired by K. Fleming and S.K. Kang
- Session IX. Development of Risk-goal Oriented Design Procedures and Criteria), Chaired by R. Budnitz and J. Kanda
6.2 Summaries and Comments

6.2.1 Methods and Data

SESSION I. OVERVIEW OF CURRENT STATUS OF METHODOLOGY

Two papers gave generic reviews of methods.

1) Overview of Methods for Seismic PSA and Margin Analysis Including Recent Innovations, R. P. Kennedy, USA

- Seismic PSA and Margin Methods were compared to clarify the limitations in the Margin Method.
- A Hybrid Method was proposed for extending a margin study to obtain risk information such as CDF at a reasonable cost by estimating HCLPF Capacity and using generic uncertainty parameter on fragility.
- Uncertainty in seismic hazard is large so that the use of generic fragility is acceptable for most "normal" cases.
- The proposed method is a good way to do “sanity check” by reviewers.

2) PWG5 Topical Opinion Paper – Consensus Statement on the Current Status of Seismic PSA, R. Budnitz (USA)

- “Maturity” of seismic PSA methods was emphasised based on the experiences that uncertainty in bottom line numbers generally does not invalidate the key insights on potential vulnerabilities.
- It is important to consider non-seismic failures.
- Open issues include consideration of ageing, “gross errors”(errors in design and construction), relay chatter, operator actions after earthquakes, and “correlation” among failures of equipment.
- Walkdown is an important part of seismic PSA.
- Peer review is important.

SESSION II. SEISMIC HAZARD ANALYSIS

Two papers presented seismic hazard analysis in Japan and Finland. Both analyses used multiple expert opinions.

3) Study on Methodology of Seismic Hazard Evaluation in Japan, H. Kameda, K. Hagio and M. Sakagami, Japan

- Probabilistic seismic hazard analysis was made for two sites in Japan.
- Expert opinion was systematically sought and incorporated involving many “seismological” experts.
- Use of expert opinion is able to obtain PGA seismic hazard curves with “reduced uncertainty”. 
4) **Estimation of Seismic Hazard in Territory of Southern Finland, Pentti E. J. Varpasuo, Finland**

- Seismic hazard study was made for the purpose of establishing seismic design basis for a new plant in Finland.
- Multiple expert opinions on interpretation of seismicity and attenuation were used for this study.
- Example of how data from other regions can be used to augment sparse earthquake data in Finland.

**SESSION VI. TREATMENT OF CORRELATION**

5) **Technical Issues in the Treatment of Dependence in Seismic Risk Analysis, K. Fleming and T. J. Mikschl, USA**

- Poses questions regarding sources of dependency.
- Recommends a better conceptual framework for treating correlation for uses in non-power plant applications (“Glove box”).

6) **Reappraisal of the Effect of Correlation of Component Failures on Core Damage Frequency in Seismic PSA Using DQFM Method, Y. Watanabe, T. Oikawa and K. Muramatsu, Japan**

- A new method by Direct Quantification of Fault Tree using Monte Carlo Simulation (DOFM) was developed.
- Several examples showed that the effect of correlation on CDF may not be significant as was pointed out in the SSMRP.

**SESSION VII. FRAGILITY EVALUATION USING VIBRATION TABLE TESTS**

Based on the methodology used in the seismic PSA of USA, fragility analyses have been performed in the other countries respectively. In high seismic regions, however, this resulted in providing a large uncertainty to fragility data for components and piping systems.

7) **Component Fragility Evaluation for Seismic PSA on Japanese LWR, A. Shibuya, M. Nishihata, M. Izumi, and W. Mizumachi, Japan**

- The response factor method and the safety factor one were improved in order to derive more realistic fragility data and to perform more efficient evaluation.
- Generic fragility data was developed as a first attempt and merits and drawbacks of these data were identified.

8) **Fragility Data Derived from Seismic Proving Tests, H. Abe, Y. Sasaki, N. Tanaka and M. Nishihata, Japan**

- Seismic proving tests have been performed for a variety of structures, components and piping systems using the large-scale high-performance shaking table in Japan.
- Although the maximum accelerations of these tests were insufficient to cause damage to test specimens, these test data were valuable to examine adequacy of the procedures for fragility evaluation.

- A utility group recently performed vibration tests of safety-related electric components up to the high acceleration level.
- These tests will be used to supplement fragility data for the same type of NPPs.

10) Generation of Fragility Curve of Components by Using Shaking Table, H. Shibata and H. Asada, Japan

- A concept to generate fragility curve using Bayesian Analysis from the test results performed by a shaking table was proposed.

11) The Test Methodologies to Provide Data for Evaluating Seismic Fragility of NPP Building and Equipment, Y. Kitada and N. Tanaka, Japan

- A new type of vibration test methodologies using artificial earthquake motion by blasting in a coal mine in the USA and a vibration amplification device to a shaking table, which enable evaluation of ultimate strength of structures or components, were proposed to verify adequacy of extrapolation from existing test data.

PRESENTATION BY REPORTER AND DISCUSSIONS BY THE PARTICIPANTS EMPHASIZED FOLLOWING POINTS

- Seismic PSA method has matured and is able to provide important risk insights
- Uncertainty of seismic hazard can be better estimated through systematic elicitation of expert opinion.
- Correlation of component failure may not be important for risk estimation.
- Further discussions and examinations of real data are desirable to clarify the issue.
- Generic fragilities developed in US may be used with caution for PSAs in other countries. Difference in culture and design philosophy should be considered.
- Obtaining test data is important for fragility analysis and, considering the cost of such tests, international exchange of data and experience are highly recommended.
- Wider distributions of existing good guidance for fragility analysis will enhance transparency and credibility in seismic PSA results as well as their quality.
- Development of procedure standards such as those being developed by ASME would be useful for assuring quality of seismic PSAs.
- Potential importance of operator actions should be further discussed.

SEVERAL ADDITIONAL COMMENTS WERE MADE ON ONGOING STUDIES.

- A research program on the effect of ageing of structural components in the USA.
- An activity by seismologists in Japan after the Kobe earthquake for improvement of prediction method for seismic input motion for buildings and structures.
6.2.2. Uses of Seismic PSA/Margin Studies

**SESSION III, IV, AND V. USE OF SEISMIC PSA/MARGIN STUDY (., II, III)**

PSA/Margin study is very important because it is the only way to calculate CDF; and we may use CDF results linked to different accident initiating events in order to implement risk management/reduction efforts in a cost-effective manner. In this Group it has been shown that there are practical ways to perform a PSA/Margin study. Papers from Czech Republic, Hungary, Korea, Spain, the United Kingdom, and Japan presented activities in their countries:

12) **Seismic Safety Evaluation and Enhancement at the PAKS Nuclear Power Plant, T. Katona and A. Bareith, Hungary**
   - Overview of the seismic assessment and upgrading of Paks NPP is presented.
   - Emphasised future activities concerned with seismic which will estimate the level of plant safety with respect to seismic hazard representative for Paks site. Another important objective of the seismic PSA for Paks NPP was to identify seismic vulnerabilities and develop recommendations for improvements as feedback to the seismic safety re-evaluation program, if required.

13) **Seismic Margin Study for the Korean Standard Nuclear Power Plant, Kyu Ho Hwang and Sun-Koo Kang, Korea**
   - PSA-based Seismic Margin study was carried out to demonstrate the SM of Korean standard design plant.
   - Review Level Earthquake was defined by 0.5g median USNRC NUREG/CR-0098 rock horizontal spectra.
   - The results show shear capacity of the containment is controlled by Ogakis shear strength limitation and there is some relationship between HCLPF84 and HCLPF50. HCLPF84 to meet the 84th confidence, SM earthquake spectra should be decided taking into account input material properties, construction quality, and predictive formula used in Korea.

14) **Integrated Program on PSA, Seismic Categorisation of Spanish NPP's Sites, Sanchez-Cabanero J.G. and Jimenez Juan A., Spain**
   - Current status of seismic part of Spanish Integrated Program on PSA and the seismic categorisation of Spanish NPPs sites approved by CSN to use SM methodologies was presented.
   - Regulatory review was not delayed because the NPP owners have performed jointly a PSHA, and as result all plant have been assigned to the 0.3g bin and none of the Spanish plant was required to be checked against the reduced scope.
   - Highlighted was the benefit of performing a peer review and the seismic hazard research necessity.

15) **Seismic Assessment of British Energy NPPs, G. Lawrence, UK**
   - Seismic design philosophy and how Periodic Safety Review adopted a deterministic approach to seismic assessment was explained.
   - As part of a large program of backfitting taking place on older plant, investigations into the feasibility and benefits of seismic PSA have been performed.
   - It was emphasised that development of an approach appropriate to the seismic activity in the United Kingdom and the nature of the plant and safety systems is important.
16) Seismic Margins Analysis for Japanese ABWR Plant, T. Zama, Japan

- A seismic margin analysis was performed for Japanese ABWR as a first step to evaluate plant seismic capacity against design basis earthquake and to discuss the improvement of safety.

17) Study on Importance of Systems and Components by Seismically Induced Accident Sequence Analysis in BWR, M. Sakagami and M. Hirano, Japan

- Seismic PSA methodology was used to perform a phase 1 preliminary analysis for Japanese representative BWR by using seismic hazard curves of a typical site and domestic plant components fragility data.
- Point-estimate analysis showed that dominant accident sequences are LOSP sequences with loss of function of emergency electric power, or with loss of function of residual heat removal.
- Sensitivity analysis showed that CDF is sensitive to the capacity of several component categories.

18) Sensitivity Analyses for the Effect of Uncertainty Issues on Risk Contributors in a Seismic PSA of the BWR Model Plant at JAERI, T. Oikawa, M. Kondo, Y. Watanabe, I. Shiraishi, J. Hirose and K. Muramatsu, Japan

- A sensitivity analysis was performed in a PSA of a BWR “model plant” to examine the robustness of the insight on risk contributors.
- Although large uncertainty in hazard analysis affect the absolute value of CDF, it does not affect the robustness of risk contributors such as dominant initiating events, important sequences and relative importance of components obtained from seismic PSA.

19) The Use of Leak Before Break in Piping Assessment, L. Pecinka, Czech (Paper submittal only)

- An assessment of break probability of piping with circumferential through wall crack was made.
- Calculated probability values may be used as input for PRA of NPPs with WWER 440 type 213 reactors.

FOLLOWING OBSERVATIONS WERE EMPHASIZED IN THE SUMMARY PRESENTATION:

Potential Benefits of seismic PSA

- To help identify reasonable and practicable enhancements,
- To avoid unnecessary cost-expenditure which does not improve safety
- To provide a framework for a comparison between different design practices

Some Limitations

- Large uncertainty in the analysis (seismic hazard, fragilities, capacity) pose challenges to the interpretations.
- Unless the SM analysis has full logic structure and good HCLPF capacities, SM analysis is not integrated to generate PSA type results. (A method to do this at a relatively low cost was presented by Kennedy in this workshop.)
6.2.3 Insights Gained from Seismic PSA/Margin Studies, and Risk Goal Oriented Approaches

SESSION VIII. Insights Gained from Seismic PSA/Margin Studies

20) Lessons Learnt from Seismic PSA Research at JAERI and Issues to be Resolved in Future, H. Shibata, T. Oikawa, J. Hirose and K. Muramatsu, Japan

- Overview of experiences and lessons learned at JAERI and on-going research activities were presented.
- From the experience at JAERI where core damage frequency was significantly influenced by uncertainties in response and capacity evaluation, it is recommended to use detailed response analysis methods to reduce uncertainty and to develop generic fragility data based on Japanese design practices for use with plant specific capacities.
- On-going studies include development of methods for seismic risk management such as method for operator assistance after earthquake, application of seismic PSA onto quaternary deposit site, and examination of method for using seismic hazard analysis for design.

21) Seismic PSAs - Issues, Resolutions and Insights, M. K. Ravindra, USA

- Recent issues in seismic PSA were reviewed based on the authors wide experiences in the IPEEE program in USA and seismic PSAs in Europe and Asia.

   Following issues were discussed:

   - Correlations
   - Min-Max approach in Margin Method
   - Salogate elements method
   - Importance of Peer Review

22) Lessons Learned from Seismic PSA/Margin and IPEEE Studies and Some Regulatory Applications, N. Chokshi, A. Rubin, J. Chen, A. Murphy and R. Kenneally, USA

- Experiences and lessons learned from the USNRC/IPEEE program were presented.
- A large number of improvements were made based on seismic PSA or Margin studies. (Not all of them have been reported in the final submittal.)
- This paper also described the concept of the method to determine the design basis seismic input (SSE) adopted by the USNRC.

It was pointed out in the summary session that:

- Engineering insights are very plant specific.
- Several “generic” insights have been obtained.
- Extensive methodology guidance exists. Such guides should be widely shared and used.
- Plant walkdown is important.
- Peer review is important.
23) Probabilistic Scenario Earthquakes for Seismic Design – Comparison of Two Identification Procedures, T. Takada, J. Hirose, K. Muramatsu, T. Okumura, S. Taki and K. Ishii, Japan

- Two methods for selecting design basis earthquake using probabilistic hazard analysis were compared based on application to one specific site in Japan.

24) Development of Risk-Based Seismic Design Criteria, R. P. Kennedy, USA

- A risk-based design criterion that does not require very drastic change in existing design methods was proposed.

*It was pointed out that:*

- These studies are important and should have wider international and/or interdisciplinary reviews such as reviews by seismic design experts in non-nuclear industry.
7. CONCLUSIONS

From the presentations and discussions in this workshop, it can be concluded that the seismic PSA/Margin methods have been and are being used world-wide, providing useful information for safety improvement or decision making, and great amount of experience has been accumulated, although the status of programs in member countries vary widely.

The objectives of such studies include the following:

- To examine whether there are cost effective ways to improve safety from ALARP point of view
- To assist in decision making in backfitting by identifying cost effective improvements
- To demonstrate the seismic margin of existing or future plants
- To examine the vulnerabilities in protection against severe accident
- To improve design of future reactors by identifying relatively weak points
- To assist in selection of new sites for NPPs.

Although numerical results from seismic PSA have not been directly used in seismic design as an alternate or supplement to current deterministic analysis methods, some countries have already adopted the use of probabilistic seismic hazard analysis for determining design basis earthquakes (SSE in USA) and some activities are ongoing to develop methods for wider use of seismic PSA technology for design of NPPs.

Improvements in methodology and database and examinations of the importance of issues in the following areas will further enhance the usefulness of seismic PSA/Margin studies:

- Database and guidance for evaluation of seismic capacities of components (with consideration of differences in design philosophy and practice)
- Correlations
- Effect of ageing of structures and components
- Analysis of post-earthquake operator actions
- Use of seismic PSA for identifying effective strategy for accident management
- Risk goal oriented design methodology including the use of probabilistic seismic hazard analysis
- Extension of the scope of seismic PSA to consider unique situations of other operating modes such as low power/shutdown state.

It was also pointed out that the importance of seismic risk is strongly dependent on the geological conditions and design practices of countries and that analysts should select appropriate methodology for their objectives and scope of the seismic PSA/Margin studies with consideration of such conditions in their countries.

Efforts by countries and international organisations such as NEA to promote international information exchange in the above areas as well as the experiences in applications and reviewing of seismic PSA/Margin studies are highly recommended.
AGENDA

Opening Session
OECD/NEA Workshop on Seismic Risk (B. Kaufer, OECD)

Opening Address (S. Kondo, Chairman of the Organising Committee)

SESSION I. GENERIC REVIEWS ON METHODS AND APPLICATIONS

Chaired by C. Shepherd and H. Shibata

I-1 Overview of Methods for Seismic PRA and Margin Analysis Including Recent Innovations (Invited)
R. P. Kennedy, USA

I-2 Topical Opinion Paper Consensus Statement on the Current Status of Seismic PSA (Invited)
R. J. Budnitz, OECD

SESSION II. SEISMIC HAZARD ANALYSIS AND ITS APPLICATION

Chaired by Sanchez-Cabanero and J. P. MacFarlane

II-1 Study on Methodology of Seismic Hazard Evaluation in Japan (Invited)
H. Kamedo, K. Hagio and M. Sakagami, Japan

II-2 Estimation of Seismic Hazard in Territory of Southern Finland
Pentti E. J. Varpasuo, Finland

SESSION III. USE OF SEISMIC PSA/MARGIN STUDY I

Chaired by M. Sakagami and T. Matsuoka

III-1 Integrated Program on PSA. Seismic Categorisation of Spanish NPP’s Sites
Sanchez-Cabanero J. G. and Jimenez Juan A. M., Spain

III-2 Seismic Assessment of British Energy’s NPPs
G. Lawrence, UK

III-3 Seismic Safety Evaluation and Enhancement at the PAKS Nuclear Power Plant
T. Katona and A. Bareith, Hungary
SESSION IV. USE OF SEISMIC PSA/MARGIN STUDY II

Chaired by A. Yamaguchi and T. Oikawa

IV-1 Seismic Margin Study for the Korean Standard Nuclear Power Plant
Kyu Ho Hwang and Sun-Koo Kang, Korea

IV-2 Seismic Margin Analysis of Japanese ABWR Plant
T. Zama, S. Visweswaran, M. Fujii and K. Hisamochi, Japan

IV-3 The Use of Leak Before Break Concept in Piping Assessment and Seismic PSA
L. Pecinka, Czech (Paper submittal)

SESSION V. USE OF SEISMIC PSA/MARGIN STUDY III

Chaired by M. Elgohary and A. Bareith

V-1 Study on Importance of Systems and Components by Seismically Induced Accident Sequence Analysis in BWR
M. Sakagami and M. Hirano, Japan

V-2 Sensitivity Analyses for the Effect of Uncertainty Issues on Risk Contributors in a Seismic PSA of the BWR Model Plant at JAERI
T. Oikawa, M. Kondo, Y. Watanabe, I. Shiraishi, J. Hirose and K. Muramatsu, Japan

SESSION VI. TREATMENT OF DEPENDENCY/CORRELATION IN SEISMIC PSA

Chaired by M. K. Ravindra and W. Mizumachi

VI-1 Technical Issues in the Treatment of Dependence in Seismic Risk Analysis (Invited)
K. N. Fleming and T. J. Mikschl, USA

VI-2 Reappraisal of the Effect of Correlation of Component Failures on Core Damage Frequency in Seismic PSA Using DQFM Method
Y. Watanabe, T. Oikawa and K. Muramatsu, Japan

SESSION VII. FRAGILITY EVALUATION USING VIBRATION TESTS

Chaired by R. P. Kennedy and J. Hirose

VII-1 Generation of Fragility Curve of Components by Using Shaking Table
H. Shibata and H. Asada, Japan

VII-2 High Acceleration Level Vibration Tests for Electric Components

VII-3 Fragility Data Derived from Seismic Proving Tests
H. Abe, Y. Sasaki, N. Tanaka and M. Nishihata, Japan

VII-4 Component Fragility Evaluation for Seismic PSA on Japanese LWR
A. Shibuya, M. Nishihata, M. Izumi, and W. Mizumachi, Japan

VII-5 The Test Methodologies to Provide Data for Evaluating Seismic Margins of NPP Building and Equipment
Y. Kitada, M. Kinoshita, N. Tanaka, T. Kubo, and K. Suzuki, Japan
SESSION VIII. INSIGHTS GAINED FROM SEISMIC PSA/MARGIN STUDIES  
*Chaired by K. Fleming and S.K. Kang*

VIII-1 Lessons Learnt from Seismic Risk Research at JAERI and Issues to be Resolved in Future  
H. Shibata, T. Oikawa, J. Hirose and K. Muramatsu, Japan

VIII-2 Seismic PSAs - Issues, Resolutions and Insights  
M. K. Ravindra, USA

VIII-3 Lessons Learned from IPEEE Studies - Regulatory Application Using Risk-insights (Invited)  
N. Chokshi, A. M. Rubin, J. T. Chen, A. Murphy and R. Kenneally, USA

SESSION IX. DEVELOPMENT OF RISK-GOAL ORIENTED DESIGN PROCEDURES AND CRITERIA  
*Chaired by R. J. Budnitz and J. Kanda*

IX-1 Probabilistic Scenario Earthquakes for Seismic Design - Comparison of Two Identification Procedures  
T. Takada, T. Okumura, J. Hirose, K. Muramatsu, S. Taki and K. Ishii, Japan

IX-2 Development of Risk-Based Seismic Design Criterion  
R. P. Kennedy, USA

SUMMARY AND CLOSING SESSION  
*Chaired by N. Chokshi and K. Abe*

SUMMARY BY SUMMARY REPORTERS AND SESSION CHAIRS

SUMMARY ON METHODOLOGY AND DATA  
M.K. Ravindra, U.S.A  
Discussions

SUMMARY ON APPLICATIONS OF SEISMIC PSA/MARGIN METHODOLOGIES  
J. Sánchez-Cabañero, Spain  
Discussions

SUMMARY ON LESSONS LEARNED AND RISK-GOAL ORIENTED DESIGN PROCEDURES AND CRITERIA  
R.J. Budnitz, U.S.A.  
Discussions
### PARTICIPANTS

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GOOD MORNING DISTINGUISHED GUESTS, LADIES AND GENTLEMEN. ON BEHALF OF THE ORGANISING COMMITTEE, I AM
INDEED DELIGHTED TO EXTEND A WARMEST WELCOME TO ALL OF YOU GATHERED HERE TO PARTICIPATE IN THIS OECD-
NEA WORKSHOP ON SEISMIC RISK IN TOKYO. I AM ALSO GRATEFUL TO EVERYONE OF YOU FOR YOUR INTEREST,
DEDICATION AND EFFORTS IN HELPING US MAKING THIS WORKSHOP POSSIBLE AND ESPECIALLY FOR YOUR TAKING OUT YOUR
VALUABLE TIME TO TRAVEL ACROSS OCEANS TO JOIN US TODAY.

This three day workshop is about ways and means we obtain seismic risk insights and incorporate them
into various activities for safe design and operation of nuclear installations against earthquake.

A traditional approach for considering earthquake risk in safety design of nuclear installations is to
establish a specific set of design basis earthquake motions at the site and assure adequate engineering
margin and quality in design and operation against this set of motions. The requirements for margin and
quality assurance include those to be satisfied by safety systems which are capable of preventing and/or
mitigating the consequences of design basis events that might be initiated by earthquakes. Roughly
speaking, if we are to build a nuclear power plant at Kobe area in Japan, we would be asked by current
regulation to install in the design appropriate engineering margin against design basis earthquake motions
severe than that experienced in Kobe earthquake in 1995.

Then what is the role of seismic risk insights, that is, the results and findings that come from seismic PSAs
or equivalent analyses? Generally speaking, we have already recognised that PSAs provide critical
information for assessing risks and risk reduction values of activities in design and operations and enhance
the traditional approach by making it possible for us to more explicitly address risk and incorporate the
insights gained to optimise our resources for protection against significant risks but avoid unnecessary use
of resource for risks that are not really there or are unimportant.

The issues for seismic risk then are what are relevant risk analysis methods, how risk insights from such
analysis should be used effectively and what should be done, if necessary, to make seismic PSA or
equivalent methods a major building block for information base to support such risk-informed approaches
to decision making in safety design and operation. Based on these considerations, the organising
committee set the objectives of the workshop as follows:

- to provide a forum to review the recent advances in methodology and application of seismic
  probabilistic safety assessment and seismic margin analysis of nuclear installations,
- to discuss the effective uses of the seismic PSA/margin analysis with consideration of merits and
  limitations of probabilistic methods,
- to review the state of the art methodology to provide a guidance for conducting seismic PSA, and

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to discuss methodological issues and identify areas in which further research is needed for enhancing the usefulness of seismic PSA.

This workshop will include 24 presentations from eleven countries. If we categorise them, we have eleven papers on methodology and data, eight papers on uses of seismic PSA/Margin Analysis, three papers on insights and lessons learned, and two papers on risk goal oriented design.

We are expecting to have discussions about regulatory framework and objectives of seismic PSA/margin studies, including risk/safety goals and margin requirements. We expect a live exchange of opinion and knowledge about the lessons learned from past applications of PSA/margin results, including, but not limited to cost effective approaches, ways to deal with large uncertainties, comparison with other initiators, use of "margin" insights, difficulties and pitfalls to avoid in practices of seismic PSA, use of expert judgement in hazard analysis, plant walk-down and fragility analysis and importance of peer review.

We also expect to share information on the recent development of methodology in areas like seismic hazard methods, fragility methods, recent tests including those utilising shaking tables, operator response to seismic events, level 2 and 3 seismic PSA methods and accident management, effect of ageing on fragility/margins, systems reliability analysis methods including treatment of correlation, relay chatter etc. Seismic PSAs for low power or shutdown conditions, effects of fire, internal floods and tsunami induced by earthquakes may also be interesting topics for discussion.

We expect that the emphasis of the workshop will be placed on the exchange of ideas rather than the numerical PSA results for a specific plant such as CDF or seismic hazard. In order to stimulate effective discussions, the organising committee has asked five experts to provide a review talk on generic and/or topical issues. They are:

- Dr. Robert P. Kennedy to give us an overview of methodology including recent innovations,
- Dr. Robert L Budnitz to give us a summary of PWG5 Topical Opinion Paper on the current status of seismic PSA,
- Prof. Hiroyuki Kameda to give us an overview on the development of seismic hazard evaluation methodology in Japan,
- Dr. Karl N. Fleming to talk about technical issues in the treatment of dependence in seismic risk analysis, and
- Dr. N. Chokshi to give us a summary of lessons learned from IPEEE and a regulatory application in seismic area using risk insights.

On behalf of the organising committee, I would like to express my heartfelt appreciation to all of these gentlemen for their kind acceptance of this important role.

In the end of the third day, we will have a summary session chaired by Dr. N. Chokshi and Dr. K. Abe which will produce conclusions and recommendations based on the reports from session chairs and of course inputs from participants for that purpose. We are expecting diverse comments and viewpoints from utilities, regulators, researchers etc. at the discussion part of the session.

In conclusion, I consider this workshop to be very important to research and development of seismic risk analysis and effective application of risk insights to safety design and operation of nuclear installations, providing us an excellent opportunity to discuss and disseminate the results.

Thank you for your attention.