CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: 5th International Conference on Probabilistic Safety Assessment and Management (PSAM5)

DATE/PLACE: November 27–December 1, 2000 at Osaka, Japan

AUTHORS: Sitakanta Mohanty

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BACKGROUND AND PURPOSE OF TRIP:

PSAM5 was organized by the International Association for Probabilistic Safety Assessment and Management (IAPSAM) in cooperation with several educational, governmental, professional, and industrial organizations. The conference was organized in cooperation with (1) American Institute for Chemical Engineers, (2) American Nuclear Society, (3) Architectural Institute of Japan, (4) Atomic Energy Society of Japan, (5) Chemical Society of Japan, (6) European Nuclear Society, (7) European Safety and Reliability Association, (8) Japanese Association of Fire Science and Engineering, (9) Japan Institute of Energy, (10) Japan Society for Natural Disaster Science, (11) Japan Society for Safety Engineering, (12) Japan Society of Civil Engineers, (13) Japan Society of Mechanical Engineers, (14) Joint Research Center, European Commission, (15) Korean Nuclear Society, (16) Organization for Economic Co-operation and Development (OECD), (17) Nuclear Energy Agency, (18) Reliability Engineering Association of Japan, (19) Society for Industrial Plant Human Factors of Japan, (20) Society for Risk Analysis (Japan section), and (21) Society of Naval Architects of Japan.

The PSAM conference is designed to provide a forum for presentation of innovative methods and relevant applications of system-based approaches to improve design and operation of technological systems and processes. Because the role of probabilistic approaches for assessment and management of safety is expected to become increasingly more important, specialists on Probabilistic Safety Assessment and Management (PSAM) meet together every two years to review the progress and challenges during the past decades or so and to get a vision of the future. PSAM5 covered both development and application of probabilistic risk assessment methods. Areas of application discussed at PSAM5 included environmental risk assessment and management, health and medical services, nuclear industry, and transportation. Some of the example risk assessment methods discussed at the conference include risk assessment standards, insights and lessons learned from risk studies, risk-based decision making and risk management, risk perception and communication, risk characterization, operation and maintenance, information and communication, and regulations. Waste Management is also a significant component of this conference.

The purpose of this trip was to (i) to present and obtain technical comments on the latest quantitative safety assessment methods embodied in the NRC/CNWRA performance assessment (PA) methods that will be used to probe the safety case presented in the license application for the proposed repository at YM; (ii) gain insight into latest safety assessment methods developed for complex systems and, where feasible, implement them into the latest revision to the TPA and other supporting computer codes; and (iii) present the latest NRC/CNWRA total-system performance assessment approach to a wide international audience. S. Mohanty made two presentations related to NRC/CNWRA PA at the conference. NRC participants included M.A. Cunningham, J.S. Hyslop, A.J. Murphy, G.W. Parry, A.M. Rubin, N.O. Siu, and S.M. Wong.

SUMMARY OF PERTINENT POINTS:

A total of 400-450 professionals from around the world working in the field of risk and hazard assessment attended this conference. A total of 375 papers from around 30 countries were selected to be presented in seven parallel technical sessions at the conference. There were no technical exhibitions or poster sessions. Each paper presented at the conference was reviewed by several members of the Technical Program Committee. There were approximately 140 technical papers from Japan and 80 from the United States. The following are key points regarding the trip. Since proceedings of the PSAM5 Conference are available, reporting here is limited.

The conference included keynote lectures in plenary sessions and panel sessions on special topics. Dr. G. Apostolakis was one of the keynote speakers and spoke about NRC's risk-informed regulation. Dr. Apostolakis mentioned that NRC is going ahead with risk-informed regulation full speed, which is all the more reason for the risk results to be meaningful and not misleading. He believes that Probabilistic risk Assessment (PRA) for risk-informing regulation is ambitious. Numerous regulatory decisions do not need a complete PRA, while others may require additional analyses. A maturity level has not been reached yet that PRA will be the sole basis for regulatory decisions. The regulation is not yet risk-based as long as PRA is not the sole basis. Therefore, PRA results are only an input to a risk-informed decision making process. Defining what is a good PRA *a priori* is difficult because we have limited experience, the decisions are highly subjective (perhaps difficult), given varied nature of potential risk-informed decisions. Standardization of PRA is needed to facilitate review, but traditional "design-to-engineering-standard"will not apply to PRA because a lot of judgement is involved in PRA and there are no standards. He attributed NRC staff views, ASME category 3, Nuclear Energy Institute (NEI) Grade 3 as good first steps in PRA. There appears to be a consensus on what a good baseline should be. He advocated the establishment of a library/collection of examples of risk-informed decisions to provide an account of how risk information/analyses have been used. He discounted the utility of sensitivity analysis in the final analysis (reason not clear) and strongly promoted the development of model uncertainty analysis.

C. Breutel et al. of the Swiss Federal Nuclear Safety Inspectorate presented a paper on the history of risk-informed safety regulations. Breutel indicated that the Western nuclear regulatory process has evolved from the initial "engineering judgment" framework of the 1960's, the prescriptive deterministic requirements of the 1970s, the transition years of the 1980s, to the present day movement toward risk-informed approaches. The authors considered implementation of risk-informed regulation on the basis of general legal principles common to many member states of the NEA and IAEA. In the process of risk-informing regulation, principles such as equal treatment, proportionality of rules and predictability of administrative action were found to be important. The authors decided the following to be prerequisites for risk-informed regulation: (i) definitive safety criteria, which are clearly and unambiguously formulated and defined; (ii) internationally accepted, adequately detailed but not unduly prescriptive Preclosure Safety Analysis (PSA) standards which would enable maintaining plant-specific PSAs consistent with the state-of-the-art (PSAs should be of sufficient quality for regulatory applications); (iii) research needs to be ongoing as safety is not a static notion (The public demands, and is entitled to have, nuclear facilities up to par with the state of technology); (iv) for a smooth transformation in the direction of risk-informed regulation, regulatory bodies should ensure that they follow a transparent process, which adequately involves all concerned stakeholders, and it is consistent with the national legal and legislative standards, especially as they apply to regulation of industrial and technological systems (e.g., nuclear power).

During S. Mohanty's presentation of the paper titled "A Performance Assessment Review Tool for the Proposed Radioactive Waste Repository at Yucca Mountain, Nevada, USA," one of the questions from the audience was on the potential implication of DOE's use of several NRC conceptual models. S. Mohanty responded by indicating that NRC does not have any objections to DOE's use of NRC conceptual models.

However, it is DOE's responsibility to defend all models including the NRC models DOE might use in support of its license application through the use of appropriate spent fuel characteristics information, design information, site characterization data, and/or expert judgment. Discussion also took place on the NRC approach to select important parameters. The NRC use of multiple sensitivity analysis techniques and identification of important parameters through scoring system was well received by the audience.

During S. Mohanty's presentation of the paper titled "An Abstracted Model for Assessing the Effect of Seismically Induced Rockfall on the Waste Package Performance for High-level Radioactive Waste Disposal," a member of the audience asked about the validity of using a hazard curve for surface facilities for the underground repository. S. Mohanty clarified that at this time NRC is using a seismic acceleration value for the repository horizon which is half the magnitude at the surface. Based on the nature of the question asked, it appears that even if NRC agrees with DOE's attenuation value at the repository horizon, NRC needs to adequately document its corroboration of DOE's current analysis.

K. Wakasugi of Japan Nuclear Cycle Development Institute Tokai Works, Japan presented a paper titled, "A Trial of Probabilistic Simulation for Reference Case in the Second Progress Report on Research and Development for the Geological Disposal of HLW in Japan." This paper presented a trial of probabilistic simulation for performance assessment of high-level waste (HLW)disposal using the Monte Carlo method. Based on the reference case conceptual model in their H12 report, a new integrated simulation system was developed that allowed rapid evaluation of the effect of data uncertainty. The doses to a hypothetical exposure group were compared with the results of H12 that were performed by using a point-wise approach, in terms of maximum total dose. This study showed that H12 results were consistent with results of probabilistic simulation and also showed that uncertainty in host rock and backfill fluid transmissivity had a strong influence for the uncertainty of the system performance for all simulation time frames.

S. Mckenna et al. presented a related paper titled, "Threshold Assessment: Definition of Acceptable Sites as Part of Site Selection for the Japanese HLW Program." For the last ten years, the Japanese High-level Nuclear Waste (HLW) repository program has focused on assessing the feasibility of a basic repository concept, which resulted in the "H12 Report. " As a part of Japan's entry into the implementation phase, its new organization (i.e., high-level waste program) is identifying, screening, and choosing potential repository sites. Therefore, a rapid method for determining site suitability is critical. The presenter claims that the threshold approach, described in their paper, is a simple mechanism for defining the likelihood that a site is suitable, given the estimates of several critical parameters. The authors linked their results presented in the paper by Wakasugi et al., which described the probabilistic performance assessment simulation of the HLW reference case in the H12 report. They plotted two or three critical input parameters against each other and treated as spatial variables. Geostatistics were used to interpret the "spatial"correlation, which in turn was used to simulate multiple realizations of the parameter value maps. By combining an array of realizations, as represented by estimates of this combination of parameters, one can determine the probability that a given site would be a good host for a repository.

A. Dutfoy and P. Lucille of EDF, France, presented a paper titled, "Uncertainties Propagation in Radionuclide Transport for Performance Assessment Modeling of a Nuclear Waste Disposal." This paper presented a reliability-based methodology to propagate parameter uncertainties through models in performance assessments for nuclear waste disposal that have very large time scales and uncertainty in input parameters. Their reliability approach provided two quantitative results: an estimate of the probability that the outcome exceeds some specified threshold level (called failure event), and a probabilistic sensitivity measure which quantifies the relative importance of each uncertain variable with respect to the probabilistic outcome. The reliability method proposed in this paper was applied to a performance assessment model that was limited only to radionuclide transports.

D. W. Lee et al. of Korea presented a paper titled, "Parametric Uncertainty Analysis using Latin Hypercube Sampling in Risk Assessment of Deep Geological HLW Repository." The paper presented risk assessment calculations based on deterministic and probabilistic methods for the Korean High-level Waste Disposal program. The deterministic-part of the model involved radionuclide transport through the geosphere under the assumption that PWR spent-fuel rods are the only waste form disposed in the deep geological repository. The authors considered dilution to be the only process that has large uncertainty; thus, conducted uncertainty analysis of the dilution factor assuming lognormal distribution with range from 4 to 100,000. The annual individual dose was calculated with dilution factor sample using Latin Hypercube Sampling (LHS) technique. The histogram of peaks of annual individual doses showed lognormal distribution by chi-square test. Uncertainty of the dose resulted from a wide range of dilution factors that may have caused a large difference between lower and upper limit up to four orders of magnitude. Even in the condition of low dilution in geosphere, the annual individual dose was estimated to be up to 10^{-4} mSv/yr. Data from NAGRA were used because it appears that Korea does not have a database on dilution factors.

N. Siu et al. of the NRC presented a paper titled "Treating Aleatory and Epistemic Uncertainties in Analyses of Pressurized Thermal Shock." The NRC Office of Nuclear Regulatory Research is developing the technical basis for changing 10 CFR 50.61 (pertains to pressurized thermal shock). The NRC is investigating whether the screening criteria under this rule can be relaxed while maintaining adequate protection of public health and safety. The change will require a consistent treatment of uncertainties across engineering disciplines. The authors discussed the philosophy used to treat different sources of uncertainty, and provided specific examples demonstrating how this philosophy was applied to key variables and parameters. Application of a few key principles for treating these uncertainties, based on a classification of the sources of uncertainty, has led to a number of changes in the analytical methods and tools being developed.

N. Siu et al. of NRC presented a paper titled, "The U.S. Nuclear Regulatory Commission's Fire Risk Research Program: Status and Results." In 1998, the NRC initiated a fire risk research program to improve the power plant fire risk assessment (FRA) state of the art by revisiting the FRA treatment of each of the three classical elements of fire protection defense in depth (fire prevention, fire detection and suppression, fire mitigation). In addition to a discussion on these elements, the paper addressed integrated model and parameter uncertainty. They defined model uncertainty as the uncertainty in model output due to modeling approximations. The paper also addressed the impact of uncertainties in model parameters, because these are often difficult to distinguish from the model uncertainties. The specific objectives of the work were to (i) develop a unified conceptual framework and methodology for treating model and parameter uncertainties, (ii) provide guidelines for practical application, and (iii) apply to representative cases from fire risk models. A Bayesian framework was used for an integrated assessment of model and parameter uncertainties, and to demonstrate its relation to the less general and, in some cases, *ad hoc* model uncertainty analysis techniques advocated in the past. The approach allowed for the use of various types of information from models (e.g., comparisons of measurements with model predictions)as well as subjective evidence about the models themselves (e.g., expert assessments of model quality and applicability). The paper provided examples to illustrate the ability of the framework to use qualitative information concerning the degree of validity of a model developed for one situation when applied to a different situation.

T. Oehmgen of Preussen Elektra Kernkraft GmbH presented a paper titled, "Probabilistic Evaluation of Failure Events with Artificial Neural Networks." This paper presented the application of neural nets to estimating reliability parameters. The advantages of neural networks are (i) association ability (recognition and correct assignment of similar input/output models); (ii) fault tolerance (input data incomplete up to certain degree or erroneously make a correct output; (iii) learning ability (neural nets are able to learn connections between input and output data); (iv) safeguarding against failure (in the case of partial failures of fields of a neural net, it is still able to retain a majority of its abilities. Cause for this behavior is the distributed retention of information in the network structure); (v) parallel processing (great capability of the

net by high-degree parallel problem solution). However, the main problem during application of neural nets is the selection of a suitable net and the attitude of an optimal topology. This presentation was heavily debated by the audience because reliability analyses are easily done by fault-tree analyses, thus other methods such as neural nets do not generate much enthusiasm among practitioners even if these methods are more quantitative and general. The PRA community also thinks that neural nets are highly mathematical. Some argued that when data from power plants are sparse, the qualitative estimates from neural nets are useful for benchmarking purposes, which is a step toward risk-based calculation. Others argued that in addition to parameters and model uncertainties, neural nets just add more uncertainty by changing model structure (in contrast with fault tree).

I. Kozine et al. of Denmark presented a paper titled "Generalizing Markov Chains to *Imprecise Previsions*". Conventional approaches require precise probabilities and statistics. However, many real world problems for reliability and risk analyses involve substantial subjectivity in model inputs for the assessments of the likelihood of events. Methods that allow propagation of imprecision in data include fuzzy set theory and the theories of imprecise probabilities such as possibility theory, the Dempster-Shafer theory of evidence (the theory of belief functions), and the theory of coherent imprecise probabilities as a particular case of coherent *imprecise previsions*. Authors have used Markov chains as examples in the paper though the procedure of imprecise probabilities elicitation can be applied to other probabilistic subject matters. The method allows admission of a wide variety of probability judgements, allowing experts to express their beliefs in whatever form is most natural and meaningful to them. The procedure allows the experts to incorporate different number and combinations of different types of direct judgements.

CONCLUSIONS:

There was a significant level of public attention from around the world on the NRC risk-informed regulation approach. However, the conference was heavily biased toward the use of PRA approach in the nuclear power plant industry. In spite of this limitation, information presented at the meeting are generally applicable to the radioactive waste management or disposal.

Sessions on risk informed regulation, uncertainty analyses, and seismic hazards were heavily attended. Fourteen papers were presented on seismic hazards, primarily related to nuclear power plant and building facilities. Several presentations on seismic hazards were from the NRC.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

I addressed with the current and future conference organizers the issue of disproportionate representation of PRA (compared to waste management). The appointment of Dr. B. Sagar as one of the coordinators and the appointment of Dr. T. Bonano as the chair of the next conference is anticipated to increase needed emphasis on the high-level nuclear waste disposal issues.

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