SESSION II: METHODS FOR UNCERTAINTY ASSESSMENT

SESSION CHAIRS: MESSRS D'AURIA (University of Pisa) AND DEVICTOR (CEA)

Mr. *D'Auria* presented an overview of the programme on Best-Estimate Methods Uncertainty and Sensitivity Evaluation, which is carried out in the context of the CSNI Working Group on the Analysis and Management of Accidents (GAMA). The paper concentrates on the re-analysis of a loss of coolant test carried out in the LOFT facility, using different codes. The outcome was that almost all codes produced results that were within the prediction acceptance criteria and that the dispersion band of calculations is smaller than the experimental data scatter.

In his presentation, Mr. *Chojnacki* recalled that the CSNI has sponsored few years ago (1998) the Uncertainty Methods Study (UMS) program on uncertainty methodologies used for a SBLOCA transient and is now supporting the BEMUSE program for a LBLOCA transient. The main aim of this paper is to remind advantages and assumptions of probabilistic modelling and more specifically of order statistics (Wilks' formula) in uncertainty methodologies. It is important to keep in mind that probabilistic methods such as Monte Carlo methods are data-intensive. A main motivation for the use of order statistics results is to allow to take into account an unlimited number of uncertain parameters and, from a restricted number of code calculations to provide statistical tolerance limits for any code results.

Mr. *Ahn* presented a paper on formal handling of the Level 2 uncertainty sources and their combination with the Level 1 PSA uncertainties. As an essential part of the Level 2 PSA, a probabilistic treatment of complex phenomenological accident pathways inevitably leads to two sources of uncertainty: (a) an incomplete modeling of these accident pathways and their subsequent impacts on the Level 2 risk, and (b) an expert-to-expert variation in the their probabilistic estimates. While the former type of uncertainty is epistemic in nature from the viewpoint that we deal with an uncertainty addressed in the deterministic events, the latter type is a random/aleatory uncertainty. The impacts of the preceding sources of uncertainty on the Level 2 risk measures are different for each other, thus leading to a different conclusion in the decision-making process. A primary objective of this paper was to explore the sources of the Level 2 uncertainty and provide the corresponding approaches for handling them formally. An additional purpose is to provide an approach for combining consistently aleatory uncertainties addressed in the Level 1 PSA with the Level 2 epistemic uncertainties, so that the Level 1 and 2 uncertainties are finally represented as an integrated measure.

Mr. *Kodeli* discussed the issue of sensitivity analysis and uncertainty propagation from basic nuclear data to reactor physics and safety relevant parameters. Reliable knowledge of the uncertainties in important reactor parameters, like criticality, radiation load on the reactor components, neutron/gamma ray flux, nuclear heating and dose are crucial for nuclear safety concerns. Uncertainties are introduced either through the calculation algorithms or through the data uncertainties. The paper addresses the uncertainties in the reactor parameters linked to the basic nuclear data uncertainties. The method used is based on linear perturbation theory to calculate the sensitivity coefficients, and propagates these sensitivities using the basic data covariance matrices to the target reactor quantities. The NEA Data Bank activities related to the sensitivity and uncertainty analysis were also presented.

Messrs. *Devictor* and *Lavin* presented a paper on uncertainty and sensitivity methods in support of Level2 PSA. Dealing with uncertainties in PSA level 2 requires using a set of statistical techniques to assess input uncertainty, to propagate uncertainties in an efficient way, to characterize appropriately output uncertainty and to get information from computer code runs through an intelligent use of sensitivity analysis techniques. The purpose of the paper was to give an overview of statistical and probabilistic methods and tools to answer to these topics, and to provide some guidance about their suitability and limitations to be used in a PSA level 2.

Mr *Chojnacki* stated that the Monte-Carlo methods provide extremely flexible and powerful techniques for solving many of the uncertainty propagation problems encountered in safety analysis,. However, these methods have the drawbacks that they need a considerable amount of information and that knowledge about all the possible dependencies between the uncertain parameters should be available. In practice, such information is rarely fully available in several domains pertinent to reactor safety.

To overcome these limitations, the French Institute for Radiological Protection and Nuclear Safety (IRSN) intends to experiment recent advances in Dempster Shafer theory. The purpose of the paper was to introduce the IRSN developments of this theory through the example of the transport of radio-nuclides in the environment. In particular, it is shown that fuzzy numbers in uncertainty analysis allow to avoid the subjectivity which may exist in the choice of a single probability distribution. The Dempster-Shafer theory provides an unified theoretical framework allowing both the use of probability functions for stochastic uncertainties modelling and fuzzy numbers for epistemic uncertainties modelling. This type of uncertainty methodology seems in IRSN view to be the only possibility to warrant the robustness of Monte-Carlo simulation in cases where knowledge is incomplete.

The topics discussed in the session can be grouped as follows:

- Mathematical methods (order statistics) and applications.
- Propagation of uncertainty from level 1 to level 2 PSA (very important topic).
- Results from the ongoing BEMUSE benchmark activity (OECD/CSNI framework).
- Dempster-Shafer theory: not yet a methodology for industrial applications, but an idea to be considered in the short term.
- Uncertainty and sensitivity analysis on nuclear data (the influence of nuclear database on the code response was shown and the difficulty was emphasized to obtain confident and reliable results).
- Application of uncertainty methods to the evaluation of error in predicting radiation release to the environment.

The presented papers show that the uncertainty and sensitivity analysis constitute a current and active R & D topic in L2 PSA and Severe Accident areas.

During the discussion, the following suggestions were made:

- The writing of guidelines on best practice documents for uncertainty and sensitivity analysis should be encouraged. Contribution to these documents should come from different parts including industry, regulators and research institutions. The actual use of the methods will be very much affected by the consensus reached and by the amount of support coming from the various parts.

- The use of uncertainty and sensitivity analysis in licensing and in decision making processes should be supported.
- On-going research should be carried out to obtain in the mid term (3-5 years) a consistent method for PSA level 2 combining epistemic and aleatory uncertainties.
- The experience gathered in the area of characterization of the uncertainty for system thermal-hydraulic codes (with main reference to the area of DBA) should be considered. Namely, the OECD/CSNI Projects UMS (completed at the end of 90's), BEMUSE (now in progress, but significant results already available) and the IAEA Tecdoc (to be issued in the forthcoming months) should be considered.