

SESSION III: APPLICATIONS TO UNCERTAINTY ASSESSMENT ON SEVERE ACCIDENT PHYSICAL PHENOMENA

SESSION CHAIRS: MESSRS CHAUMONT (IRSN) AND BOLADO LAVIN (EC)

Mr. *Journeau's* paper dealt with the uncertainty affecting data contained in databases for thermodynamic properties (NUCLEA European database containing data for 18 main elements involved in severe accident) and thermo-physical properties of corium, as for example density, viscosity, thermal conductivity, surface tension and chemical diffusion (CORPRO database developed by CEA). Main uncertainty sources are experimental errors, lack of data, modelling errors and optimisation errors. Additionally, the authors proposed a methodology to assess the influence of uncertainties on severe accident calculations based on two-level factorial designs and correlation coefficients. Main conclusions of this work are the importance of thermodynamic and thermo-physical data on severe accident results and the usefulness of sensitivity techniques to prioritise further research on specific parameters.

Mr. *Rydl*, presented the development of a simple probabilistic method for evaluation of the containment speciation and transport of iodine. In the original approach so proposed, main phenomena influencing the iodine behaviour in the containment are represented in a small event tree developed with the EVNTRE probabilistic code. The containment iodine code of ASTEC (IODE code) is directly called when quantifying the event tree. This approach has been applied as a framework to define and achieve sensitivity studies for the interpretation of PHEBUS FPT1 integral experiment. Other applications of the event tree are now expected, particularly for level 2 PSA.

Mrs. *Fleurot* presented a sensitivity study to identify most influential parameters and modeling option (within a set of eight parameters and modeling option) on the hydrogen production (total amount and flow rate), fission product release and corium composition. Computations were done with ICARE2 and ASTEC codes, for a loss of feed water accidental sequence in a French 900MWe pressurized water reactor. The results of this study indicate that, depending on the different set of parameters retained in the modelling, the mass of hydrogen produced may vary from 320 to 580 kg, whereas the flow rate can vary between 0,1 and 0,4 Kg·s⁻¹. Moreover, fission product releases increase significantly with increasing dissolved fuel. Furthermore, the uncertainty regarding the Molybdenum release (including other semi-volatile FP) induces a variation of the iodine gaseous release and of the caesium airborne from the primary circuit break. Finally, the corium composition (ratio between oxides and metal) could vary up to a factor 3.

Mr *Gauntt* gave a lecture on the use of MELCOR to perform uncertainty analysis for severe accident sequences. After an interesting introduction about the evolution of nuclear safety during the last sixty years and an overview of MELCOR capabilities to simulate relevant phenomena in severe accident problems, he stressed the importance of using order statistics and Wilk's formula in probabilistic calculations (quantile estimation and sample size determination). Two examples were shown: The first one was about hydrogen production; the second one was about the estimation of decontamination coefficients in the containment. Based on those calculations the author mentioned the benefits of using uncertainty analysis instead of the traditional bounding safety analyses, and pointed out the use of uncertainty analysis, under some circumstances, as an alternative to expert judgment, and its potential as a support tool to risk-informed regulatory decision-making. Finally he acknowledged the difficulties to determine ranges and completeness of coverage.

Mr. *Austregesilo* presented post-test calculations and an uncertainty and sensitivity analysis of test QUENCH-07 using ATHLET-CD. The first step of the work was the simulation of the test QUENCH-07 applying the modeling options recommended in the code User's Manual (reference calculation). The global results of this calculation showed a good agreement with the measured data. A sensitivity analysis was done in order to identify most influent parameters. Uncertainty analysis results indicate that the main experimental measurements lay within the uncertainty range of the corresponding

calculated values. Sensitivity analysis identified as main contributors to the uncertainty of code results the heat transfer coefficient due to forced convection to superheated steam-argon mixture, the thermal conductivity of the shroud isolation and the external heater rod resistance. Uncertainties on modeling of B4C oxidation do not affect significantly the total calculated hydrogen release rates.

Mr. Magallon described the main results of the phase 1 of the OECD SERENA (Steam Resolution for Nuclear Application) programme. In the framework of this programme, the status of the predictive capabilities of the codes have been assessed, for both premixing and explosion phenomena, first on experiment selected as the most representative of reactor situations, then considering typical in and ex vessel scenarios of reactor application. The large discrepancies on the results which are obtained illustrate the lack of understanding of the phenomena (void distribution during premixing phase recognized as a major issue) and the associated uncertainties.

Mr. Shapiro presented an overview of Advanced CANDU reactors (ACR) design. Provisions made for prevention of core damage, of core retention in fuel channels or in calandria vessel, for prevention of containment over pressurization and to minimize off site release have been particularly commented in terms of reactor design and of accident management strategies. The general objectives in terms of frequency of large early releases scenarios have been indicated. Some subjects like corium recriticality are still to be investigated.

The paper by Messrs *Oh* and *Kim* addressed the Effectiveness of External Reactor Vessel Cooling (ERVC) Strategy for APR1400 and Issues of Phenomenological Uncertainties. In Vessel core Retention (IVR) has been selected as a severe accident management strategy for APR 1400. External reactor vessel cooling design is one important element of this strategy. Critical Heat Flux (CHF) along the vessel profile appears to be a very important issue of the approach. ULPU experiments have been performed using different geometries (baffle configurations) and the reactor dominant scenarios have been investigated using the MAAP severe accident code. Results seem to show margins between CHF and heat flux but further work is expected to be done concerning the definition and assessment of all plausible melt configurations after core relocation in the lower head.

Mr. Robledo introduced to the audience the model CPPC. This is a simple computer code to predict the combustion of CO and H₂ in severe accidents, which was developed by the Polytechnic University of Madrid for the Spanish Council of Nuclear Safety. CPPC needs as inputs the masses of H₂ and CO, the initial environmental conditions in the containment and the volume of the compartments. It produces as outputs Chapman-Jouguet pressure and reflected pressure, effective pressure and combustion completeness, among others. In addition to the main hypothesis on which the model is based, the author presented validation and verification tests. The code showed a good degree of agreement with MELCOR and Breitung's model, except under some specific conditions (dry mixtures), which provide hints for improvement.

Mr. Basu's presentation focused on the Significance of the OECD-MCCI Program in Relation to Severe Accident Uncertainties Evaluation. The main objectives of the OECD MCCI (Melt Corium Concrete Interaction) programme have been remained. These objectives concern reduction of uncertainties on two main subjects: the debris coolability by the two mechanisms of water intrusion and of melt eruption (SWISS experiments) and the long-term cavity 2D erosion process (CCI experiments). Principal findings of the programme have been illustrated. Benchmark calculations by several partners' codes of the CCI2 experiment, which show sometimes rather large discrepancies (radial and axial erosions rates) compared to experiment, have been commented. The data are now available to develop or improve models and consequently reduce uncertainties on this issue.