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Nuclear Science Committee

SPECIALISTS' MEETING ON LIGHT WATER REACTOR CORE TRANSIENT BENCHMARKS

Paris, May 10-12, 1995

Summary Report of PWR Benchmark Meeting

1. Introduction

After a general introduction of the meeting by Ph. Savelli (NEA), R. Fraikin summarises the history of this second PWR benchmark, following the rod ejection benchmark co-ordinated by H. Finnemann. The "rod withdrawal from zero power" accident was chosen, adding safety related output (hot pellet max. enthalpy, cladding max. temperature,...). It was also decided to examine the effect of the Thermal & Hydraulic (T&H) correlation. The specifications have been described in [1]. This benchmark approaches now the final stage, and a first draft report [2] has been distributed among the participants. The list of participants is provided as Appendix 1. Several other experts in this field expressed interest in participating to future activities but were unable to contribute this time.

2. Review of submitted results

R. Fraikin reviews the encountered problems and the action taken from both participant and co-ordinator points of view in order to smooth the process for the next iteration. The method used to compile the results is briefly described. A flow chart describes the organisation of the work up to the final report. The handouts of the presentation are given in [3].

The "Rod Withdrawal from Zero Power" accident has been analysed for four cases. The features of each case are presented in correlation with the obtained results for two main items (core fission power and maximum pellet temperature). Case A is interesting because a first power peak was observed below the SCRAM level, followed by a slower increase of the power up to shutdown. Cases B and D exhibit a more "classical" evolution with a sharp power peak. Case C shows that the T&H heat flux transfer correlation has a very small influence on this accident.

The power peaks are spread over several seconds, depending on the participant even when using the same computer code. The time of its occurrence seems to be sensitive to the space and time discretization. However, the agreement on the global results is very satisfactory. Some discrepancies are observed for the hot pellet and envelope profiles; they are discussed under point 3.

Only one code uses 1-D model; its global results do not significantly differ from those of 3-D codes, but the hot pellet results are slightly more conservative.

3. Particular problems and sensitivity analyses

Eight papers are presented by the participants (see reference list below):

- Ph. Brohan, Nuclear Electric, GB, presents [4] a sensitivity analysis, with Panther 3-D code, on both radial and axial meshings, showing that there is more influence on the timing of the evolution than on the amplitude of the power peak;

- M. Mélice, Tractebel Energy Engineering, B, presents [5] a sensitivity analysis, with Okapi 1-D code, on the axial meshing, focusing on the "cusping effect" of the control rods, and the impact on the timing of the evolution. The sensitivity to the fraction of delayed neutrons is also analysed;

- J. Kuijper, Energieonderzoek Centrum Nederland, NL, presents [6] a sensitivity analysis, with Panther 3-D code, on the time step, showing the influence on both amplitude and timing of the power evolution;

- M. Pétiard, Framatome, F, presents [7] the results obtained with César 3-D code, explaining the possible impact of a reflector modellisation problem on the results, and noting a small discrepancy on the Doppler feedback;

- G. Alloggio, ENEL, I, presents [8] the results obtained with Quandry-En 3-D code, showing that the fast transient obtained for case B is better handled by this code than the slower case A transient. The effect of the possibly too coarse axial mesh has to be investigated;

- A. Bouamrirène, EDF, F, presents [9] the results obtained with Coccinelle 3-D code, and comments the timing of the evolution, showing that the peak is obtained later than with other codes. Some small oscillations have also been observed;

- R. Fraikin, chairman, proposes [10] some questions received from Y. Asahi, JAERI, J, who could not attend the meeting, but mentions possible sources of discrepancy: it results from the discussion that these points have been verified by the participants and are correctly handled. Y. Asahi also expresses the wish to calculate a pure mathematical benchmark to identify possible problems: the participants estimate that the PWR benchmarks are already mathematically well defined, and would prefer to go on with extended analyses;

- Kiril Velkov, GRS, D, distributes [11] results obtained with QUABOX/CUBBOX by D. Pevec, University of Zagreb, Croatia. So far, only the initial state has been calculated, but Mr. Velkov would like to participate and to send the whole set of results. The participation is accepted, and R. Fraikin agrees to handle a single iteration, provided that the final results meet the dead line.

4. Detailed report analysis and discussion

The first draft of the report is examined in detail, and any observed discrepancy is commented. The exchange of questions aims at providing hints for individual investigations.

It results that the radial peak definition differs, depending on the nodalization or the intra-nodal representation used; this explains most of the noted differences on hot pellet results:

- Coccinelle, César, Quandry-En: assembly nodal maximum, based on 4x4 mesh;
- Panther: assembly average, based on 2x2 mesh;
- Okapi: intra-assembly maximum, based on analytical nodal function;
- Panbox: intra-assembly reconstructed maximum.

Several suggestions are proposed to extend the contents of the report:

- J. Kuijper suggests to add information about the time step: minimum, maximum step, and total number of time steps;
- D. Hennig, Paul Scherrer Institut, CH, proposes to include an evaluation of the accuracy and suitability of 1-D models for this accident;
- H. Finnemann, Siemens AG/KWU, D, insists on the need to include a reference solution.

5. Lessons learned from the PWR benchmarks

There has been a great interest in the rod ejection benchmark. Many companies have used the data to validate their own codes, after the presentation of the final report in Karlsruhe, 1993.

- H. Finnemann presented an invited paper [12] on this topic at the ANS 1994 Winter meeting in Washington, which has attracted a great interest. This paper will be distributed to the participants. H. Finnemann also expresses some doubts about the published reference solution. He suggests to investigate the question, using a finer meshing. Ph. Brohan agrees to carry out the calculation, with the code PANTHER;
- Ph. Brohan presents [13] an extension of the rod ejection benchmark in hexagonal-Z geometry. The calculation was performed by Nuclear Electric, FZ-Rossendorf and Siemens/KWU. Other hexagonal benchmarks already exist, as stated by H. Raty, VTT, SF, and coordination with this group is considered as beneficial. The participants recommend that the specification is formalized as a NEA-NSC document, as an addition to the rod ejection benchmark.

The rod withdrawal benchmark leads to some conclusions, presented by R. Fraikin:

- a good agreement is obtained among most participants;
- safety related results (local peak power or temperature) are sensitive to their definition;
- the T&H heat transfer correlation has a very limited effect;

- case A, apparently less severe than cases B, C, D in terms of reactivity (single bank withdrawal) results in higher fuel heating, because the power peak is spread over about 10 seconds.

6. Decided actions – reporting – official presentation

- A last iteration is allowed to correct the problems detected during the second round;
- The dead line for submitting results is 30 SEPTEMBER 1995;
- The following participants agree to let their results be officially published: EDF, Framatome, ENEL, ECN, KWU, Nuclear Electric, and Tractebel. The other participants are invited to contact the NEA secretariat as soon as possible. In the case of disagreement, the results will not be published, but all participants will be named in the paper;
- There is a general agreement on the reference solution: it should be a nodal analysis with fine meshing, i.e. axially more than 16 nodes, radially 3x3 nodes per assembly, time step sized down to convergence. Ph. Brohan, Nuclear Electric, GB accepts to provide this reference solution;
- R. Fraikin will write the final report, that will also include the reference solution. This report will be transmitted to the participants for approval before being officially released;
- A paper summarizing the work will be written by R. Fraikin, to be presented at the PHYSOR international conference in September 1996. This report will also be submitted to the approval of the participants.

7. Further work

R. Fraikin proposes to launch a third PWR benchmark, on the "Loss of Flow" accident (LOFA). The handouts of his presentation are given in [14]. The same core data as for the former PWR benchmarks would be used, with some complements to get a more representative axial power profile, with respect to the Departure from Nucleate Boiling (DNB) problem.

M. Mélice presents some results obtained by OKAPI code for the LOFA, showing the typical evolution and pointing out the challenges it contains for computer codes' validation.

H. Finnemann insists on the need for such benchmarks for the licensing process of spatial kinetics codes. He has published a paper on the LOFA analysis at the ANS Winter meeting [15].

Since all the participants are interested in this new benchmark, and express their intention to participate, provided that the resources are available in their companies, it is decided to submit the proposal to the approval of the NSC.

H. Finnemann accepts to co-operate with R. Fraikin for the elaboration of the detailed specifications of the benchmark. The work should start at the beginning of 1996, after the conclusion of the rod withdrawal benchmark.

References

[1] R. Fraikin, "NEA-NSC 1-D/3-D PWR Core Transient Benchmark on Uncontrolled Withdrawal of Control Rods at Zero Power, final specifications", NEA-NSC (93) 9, September 1993.

[2] R. Fraikin, "Results of a NEA-NSC 1-D/3-D PWR Core Transient Benchmark on Uncontrolled Withdrawal of Control Rods at Zero Power, first draft", NEA-NSC (95) 5, February 95 (diffusion restricted to the participants).

[3] R. Fraikin, "NEA-NSC PWR Benchmarks Review", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[4] Ph. Brohan, "Panther results for the NEA-NSC 3D PWR Core Transient Benchmark", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[5] M. Mélice, R. Fraikin, Ph. Maes & Ch. Schneidesch, "NEA-NSC Core Transient Benchmark on Rod Withdrawal from Zero Power: Axial Meshing Sensitivity Study", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[6] J. Kuijper, "PANTHER solution to the NEA-NSC 3D PWR Core Transient Benchmark: Uncontrolled Withdrawal of Control Rods at Zero Power", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[7] M. Pétiard, "NEA PWR Core Transient Benchmark Uncontrolled Withdrawal of Control Rods at Zero Power, Framatome Results", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[8] G. Alloggio & E. Brega, "Results of Quandry-EN Calculations, Cases A-B", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[9] A. Boumarirène, "Coccinelle Results for PWR Rod Withdrawal Benchmark", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[10] Y. Asahi, "Comments and Proposal for Future Work", letter, March 6, 1995, distributed to participants.

[11] D. Pevec, S. Langenbuch, & K. Velkov, "Preliminary QUABOX/CUBBOX Results for Static Conditions", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[12] H. Finnemann, "NEA-NSC PWR Benchmarks", invited paper at ANS Winter Meeting, Washington, 1994.

[13] M. Knight, Ph. Brohan, U. Grundmann, U. Rohde, H. Finnemann & J. Hüsken, "Comparison of Rod Ejection Transient Calculation in Hexagonal-Z Geometry", International Conference on Mathematics and Computations, Reactor Physics, and Environmental Analyses, Portland, Oregon, April 30 - May 4, 1995, pg. 1248-1258.

[14] R. Fraikin & M. Mélice, "NEA-NSC PWR Benchmark Proposal", Specialists' Meeting on LWR Core Transient Benchmarks NEA-NSC, Paris, May 10-12, 1995.

[15] H. Finnemann & G. Drescher, "Integrated Safety Analysis Based on Spatial Kinetics", invited paper at ANS Winter Meeting, Washington, 1994.

Appendix 1

List of participants – 10 May 1995

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