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# THIRD PRESSURISED WATER REACTOR MAIN STEAM LINE BREAK BENCHMARK WORKSHOP -- SUMMARY

**GRS, Garching, Germany**
**24-25 March 1999**

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# THIRD PRESSURISED WATER REACTOR MAIN STEAM LINE BREAK BENCHMARK WORKSHOP

**Summary**

## Welcome and opening

Siegfried Langenbuch, Head of the Reactor Dynamics Department of GRS, opened the meeting. He welcomed participants to the third workshop on the joint OECD NEA NSC/CSNI PWG2 benchmark on PWR Main Steam Line Break (MSLB). Enrico Sartori welcomed participants on behalf of the OECD Nuclear Energy Agency.

S. Langenbuch recalled that the first attempt for a rod ejection transient benchmark exercise had been carried out in 1975 under the auspices of the OECD NEA Committee on Reactor Physics (CRP) and the Committee on the Safety of Nuclear Installations (CSNI). Much progress in coupled neutronics/ thermal-hydraulics has been achieved since.

The meeting was attended by 41 participants from 22 organisations from 11 countries that introduced themselves and briefly explained their experience and work. The list of participants is attached as Annex 1.

S. Langenbuch introduced the technical session and the agenda was approved. The detailed schedule and the papers distributed are listed in Annex 2.

Annex 3 lists the computer codes used in Phases I and II of the PWR MSLB benchmark study.

## Overview of the benchmark, summary and discussion of first exercise

Bryce Taylor of Pennsylvania State University (PSU) recalled the scope and objectives of the benchmark study. He gave a general overview of ongoing and planned activities and discussed in detail the benchmark distribution procedures, connected with the benchmark e-mail address, ftp site and web site. Up to now fifteen participants from ten countries have been assisted in modelling the first exercise and have subsequently submitted their point kinetics (PK) results. Some of these participants have updated their solutions since the second workshop in Madrid, using the additional information provided to participants in August 1998.

Further, Bryce Taylor presented a summary of the First Exercise of the PWR MSLB Benchmark: *Point Kinetics (PK)*, prepared by T. Beam. The summary included a description of the first exercise and the primary conservative assumptions involved. The TRAC-PF1 PK system model was then described, and the obtained results were discussed. The TRAC-PF1 solution was used as a base solution for comparison and calculation of relative differences for each of the participants results for a given parameter. Finally, a comparison of the PK participants results for 26 parameters was presented and discussed.

**Participants presentations on first phase results I**

Participants in the benchmark made a brief presentation of their revised results and approaches used for their *Point Kinetics (PK)* calculations. This session was subdivided in two parts and subsequently chaired by Siegfried Langenbuch of GRS and Adi Irani of GPUN. Some of the presentations included results from parametric studies, which demonstrated sensitivity of power response during the MSLB transient to key input parameters and were object of the participants interest. The titles of the presentations made are listed in Annex 2.

**Overall comparison and discussion**

Based on the presented comparisons it was concluded that the overall agreement of the compared parameters could be improved. The presentation, given by A. Irani, demonstrated that the participants results deviations are primarily due to the modelling differences rather than due to the different code theoretical models. It was concluded that much better comparisons would be obtained if these modelling differences (identified and addressed at the second benchmark workshop) were resolved. These differences include the conservative initial steam generator (SG) masses, modelling of the additional feed water to the broken SG, steam line break flow modelling, the flow paths to the upper head of reactor vessel and different reactor vessel mixing models (1-D vs. 3-D). The need of resolving these issues was demonstrated by the results of parametric studies, presented in the participants papers. S. Langenbuch initiated a discussion in depth about the main effects during a MSLB transient and their sensitivity to the modelling assumptions. As a result it was concluded that some modelling assumptions should be specified explicitly (such as the additional feed water to the broken SG which will be specified as feed water mass flow rate vs. time) and other assumptions should be made consistent (such as the steam generator initial mass). Due to the sensitive nature of this transient to small variations in initial parameters, the participants were urged to try to follow the specifications as closely as possible. Finally, the issue of developing a base solution for comparison and calculation of relative differences for each participants results for a given parameter was discussed again (as at the second benchmark workshop). First, it was decided that the term “reference solution” would not be used in the future. Second, a definition of acceptance criteria was discussed and the change of two-degree K in coolant temperature was proposed as acceptable deviation. A suggestion of employing a statistical methodology for evaluation of discrepancies between different code predictions was made. It was postulated that a cluster of solutions would be found, and used as the basis for deviations.

**Summary of conclusions for the first phase of the benchmark**

Based on the discussion and upon the request of participants K.N. Ivanov agreed that participants have interpreted the specification in different ways and that some further clarifications were needed before the final version was issued. The motivation behind such clarifications is to narrow down to the extent possible the modelling differences for the initial steady state conditions as well as for the transient scenario.

It was decided to change the following analysis assumptions:

1) to reduce the initial SG mass inventory to 26 000 kg;

2) to model the additional feed water between the feed water isolation valve and the broken SG as a boundary condition of extended feed water flow rate vs. time while preserving the specified mass of 16 103 kg.

It was also agreed to specify in more detail:

1) mass flow rates to the upper head of the reactor vessel;

2) reactor vessel mixing modelling;

3) steam lines and break modelling.

It was also decided that a committee comprised of A. Irani, S. Langenbuch, A. Knoll and K. Ivanov would review and comment on the Benchmark Report on First Phase prior its release.

**Overview and discussion of second and third exercises**

K. Ivanov recalled the objective of the second exercise – to test and to compare coupled three-dimensional (3-D) kinetics/core thermal-hydraulic (T-H) response predictions having provided T-H boundary conditions (BC). Another intention was to synchronise 3-D core models before performing the third exercise. Having provided the same system response and based on comparisons with results of other codes, participants have an opportunity to evaluate and verify their core models. K. Ivanov reviewed the definition of the second exercise and basic modelling assumptions involved. Emphasis was made on the additional information, provided to the participants after the second MSLB Benchmark Workshop. The discussion was further focused on clarifying specific issues which have been the object of participants questions and are still sources of modelling uncertainties or misinterpretations. These sensitivity issues include control rod modelling, reflector feedback modelling, T-H core transient BC, decay heat modelling and required output information for comparisons.

Up to now 12 participants representing six countries have been assisted in modelling the second exercise and 11 participants have submitted their results. A summary of participants results was presented based on a comparison with the PSU TRAC-PF1/NEM solution (used as a base solution) for the parameters that have the greatest effect on the initial steady state and the two versions of the transient scenario. As a result of the discussions at the second benchmark workshop in Madrid, Spain, (June 1998) five states at EOC were defined for the second exercise initialisation. Four of them are at hot zero power (HZP) conditions with fixed T-H feedback i.e. they can be considered as “clean” neutronics problems. Since the participants are provided with the cross-section libraries and the linear table interpolation procedure, it is believed that the observed discrepancies (especially in normalised power – NP predictions and scram and stuck rod worths) are still relatively large to be only due to using different methods for solving the steady state diffusion problem. The deviations probably also result from misunderstanding the specifications or miscoding the input data. A two-step procedure will be used to narrow down these HZP differences. PSU will provide one node per assembly (1 npa) and 4 npa results and as a first step the participants will compare the 2-D assembly $K_{inf}$ distributions to make sure that there is a consistency in reading and interpolating the cross-section tables. Secondly, special attention will be paid on detailed comparisons of the 2-D NP distributions. The procedures for calculation of 2-D $K_{inf}$ and NP distributions will be defined in the specifications.

The hot full power (HFP) state (the initial state for the transient) is modelled with the full T-H feedback and represents another modelling challenge. Two problems have been identified for the participants who are using parallel channels to model the core thermal-hydraulically– correct interpretation of the inlet mass flow BC (provided by TRAC-PF1/NEM calculations) and the reflector feedback modelling. It was concluded that proper compatible HFP steady state initialisation of the feedback models is important because larger discrepancies at this stage would, of course, influence the transient analysis. Two versions of the transient MSLB scenario have been analysed. Version 1 is the basic version in which the calculated 3-D neutronics models scram worth has to match the first exercise (PK simulation) tripped rod worth value. Version 2 uses a modified rodded cross-section library (the "return-to-power" scenario) which results in reduced simulated scram worth. Both versions begin from the same initial steady state, and until the reactor trip both transient simulations should be identical. Several issues contributed to the observed deviations in time history comparisons: not all participants scrammed at the specified time, different cross-section modelling (in two cases), differences in the decay heat models used and the calculated different scram worths. Different normalisation schemes were also used for calculating power distributions for the compared snapshots. The required scheme, to be used for this benchmark, will be defined in the specifications.

Further, K. Ivanov presented the coupled Penn State TRAC-PF1/NEM methodology, the thermal-hydraulic and neutronics models developed for the second exercise, and the obtained results. The performed sensitivity study demonstrated that a refinement of the 3-D neutronics model in radial plane affects mostly the accuracy of predictions of the 2-D normalised power (NP) distributions in the HZP cases. The impact of refined radial nodalisation on axial power distribution and total power transient evolution is much less pronounced. Comparative analysis of the results suggests that unlike the rod ejection calculations, MSLB simulations are less sensitive to radial neutronic nodalisation. This is especially the case when a coarser nodalisation for the T-H model is used.

**Participants presentations for the second and third and exercises**

Siegfried Langenbuch and José Maria Aragonés chaired this session. The papers presented are listed in Annex 2. The participants presented their 3-D core neutronics models, core T-H BC models, coupling schemes as well as the obtained steady state and transient results. Some participants also presented interesting results from parametric studies on different modelling issues and analysis assumptions. The sensitivity of the results to the following parameters were discussed: radial and axial neutronics nodalisation, heat structure nodalisation, density correlation and feedback, fuel rod material properties, T-H radial core nodalisation, fuel rod nodalisation, cross flow modelling and mass flow BC corrections.

**Review comments and suggestions for the second and third exercises**

It was suggested that the actual assembly flow area, to be used in the core multi-channel models, is equal to 0.0262 $m^2$, which is different from that recommended in the preliminary report on Phase I (page 50). Further, the effect of mass flow BC on results was discussed and it was suggested to use a geometrical interpolation method to process TRAC-PF1/NEM BC in order to get smoother (and more realistic) inlet and outlet conditions per assembly. The other problem addressed concerns the method to get a critical reactor at the beginning of transient. This method should be specified together with correlations for fuel properties versus temperature (heat capacity and conductivity) in order to avoid large discrepancies at the beginning of the transient. To better assess the T-H modelling effects one additional steady state needs to be defined, being the same as the second one (HFP) but with uniform BC.

At the second benchmark workshop in Madrid, Spain (June 1998), ANS-79 was defined as the standard decay heat model to be used by the participants for this benchmark problem. Based on the participants presentations it was determined that not all participants are capable of using this standard model or extending the decay heat model built in their codes to preserve compatibility with ANS-79.

In order to avoid uncertainties in the analysis, the participants decided that PSU would provide them with a file of the decay heat evolution throughout the transient for each scenario – return-to-power and no return-to-power. In addition the procedure describing the relative contribution in the steady state will be defined. The reflector feedback modelling was also simplified. PSU would provide average "fixed" feedback parameters for the radial reflector and for axial reflectors the inlet and outlet coolant parameters will be used.

The output information, to be compared, was also discussed in detail. It was decided that in the specifications the required output information should be specified for each exercise.

**Discussion of the second and third phases of the benchmark**

Based on participants experience in modelling the second exercise the following proposals were discussed and accepted at the third workshop for finalising the benchmark specifications:

1) *General*

   Each participant must provide information about the neutronics and thermal-hydraulic models used for the benchmark calculations.

2) *Modelling assumptions*

   a) PSU will provide a file with decay heat values as function of time for both scenario versions.

   b) PSU will provide a fuel average temperature value for the radial reflector cross-section modelling. The coolant average density for the radial reflector has to be taken equal to the inlet coolant density. For axial reflector regions the following assumptions are made: for bottom – the fuel temperature is equal to inlet coolant temperature (per T-H channel or cell) and coolant density is equal to the inlet coolant density (again per channel); for top – the fuel temperature is equal to the outlet coolant temperature (per channel) and the coolant density is equal to the outlet coolant density (per channel).

   c) New corrected files for transient BC per assembly will be provided by PSU for both scenario versions. No further corrections are needed.

   d) In order to obtain a critical steady state at the beginning of the transient a $K_{eff}$ adjustment procedure will be used.

   e) PSU will provide correlations for fuel properties versus temperature (heat capacity and conductivity).

   f) Two additional steady-states will be defined to better access the T-H modelling effects: (9) Same as the second one (HFP) but with uniform BC; and (10) Control rods and BC at 60 s (largest asymmetry of temperature) and total power level fixed at 20% of nominal.

3) *Comparison of results*

   a) Efforts will be made to find a base solution, which is to be used for comparison of participants results. Until that time, the different code predictions will be compared to the PSU TRAC-PF1/NEM results.

b) For the initial HZP states (0, 1, 3 and 4) the following parameters will be compared: $K_{eff}$, 2-D NP distribution and core averaged axial power distribution (in the format described in the specifications) as well as power peak factors $F_{xy}$ and $F_z$ and axial offset.

c) For the initial HFP steady states (2 and 9), the same information as for the HZP states plus the 2-D inlet coolant temperature and flow rate and 2-D outlet coolant temperature maps, and axial distributions for the stuck rod position N12 – relative power (normalised to the core power level), coolant density, mass flow rate and Doppler temperature.

d) For the snapshots states (5, 6, 7, 8 and 10) the same as for the HFP states except $K_{eff}$ the total and fission power levels will be compared.

e) Time histories (core volume averaged without the reflector region): total power, fission power, coolant density and Doppler temperature. In addition, the maximum nodal Doppler temperature vs. time will be compared.

**Criteria for comparing submitted results, publication**

It was noted that not all participants have strictly complied with the specification so far provided for the different phases of the MSLB benchmark and several participants have considerable deviations in the modelling used. This resulted in a relatively large spread of results. It was therefore agreed to issue a final version of the specification covering the three exercises, with the aim of removing problems of interpretation and sources of discrepancy. For each of the three exercises a list of calculated and used parameters will be included, which must be filled in by participants. This list must be supplemented by a description (including graphs where useful) of the models used in enough detail so that compliance with the specification can be verified. The list of deviations from the specification, if any, must be provided and the specific assumptions stated. It is up to the benchmark co-ordinators and report reviewers to decide whether the solution provided models with sufficient precision the system model provided. Solutions that deviate from the modelling in ways not compatible with the specification will not be graphically compared with those complying. These other solutions will be described in separate sections of the report, where sensitivity effects are investigated or effect of deviation from standard parameters. Participants with strongly deviating solutions will be requested to carefully review their solution and, if necessary, to withdraw it from the publication.

It was agreed that the PWR MSLB would be published in four volumes:

- *Volume I*: PWR MSLB benchmark specification (Phase I, II and III);
- *Volume II*: Summary results of Phase I (point kinetics);
- *Volume III*: Summary results of Phase II (3-D kinetics/core T-H boundary model);
- *Volume IV*: Summary results of Phase III (best estimate coupled simulation).

It is also intended to prepare a CD-ROM with the four reports and supplementary tables and graphs not published in the paper version.

The revised schedule as well as the tasks so far accomplished are shown in Annex 4.

**Conclusions of the workshop**

S. Langenbuch thanked the participants for attending and providing such valuable information for improving the understanding and providing much insight into how neutronics and thermal-hydraulics codes can be coupled to model NPP transients in detail.

E. Sartori thanked S. Langenbuch, his team and the GRS for hosting the workshop, for the high quality organisation and infrastructure they provided and for the generous hospitality they offered. He thanked in particular Kostadin Ivanov, Tara Beam, Anthony Baratta and Bryce Taylor for the great job they have accomplished in co-ordinating this activity and in analysing and reviewing the results submitted. Without the support of the US NRC it would have been difficult to achieve so much progress.

J.M. Aragonés thanked all the participants and the hosts on behalf of the NEA Nuclear Science Committee he represents. He expressed appreciation for the high quality content of the workshop. He is expecting many participants to attend the next ad-hoc benchmark group meeting that will be held with the forthcoming *International Conference on Mathematics and Computation, Reactor Physics and Environmental Analysis* (M&C’99) his university is organising on 27-30 September 1999 at the DENIM-UPM, Madrid, Spain.

## ANNEX 1

***Third Workshop on the PWR Main Steam Line Break Benchmark (MSLB3)***

*GRS Garching, Germany*
*24-25 March 1999*

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* Regrets not having been able to attend

Total: 41 participants from 22 organisations in 11 countries

# ANNEX 2

***Detailed agenda and list of papers presented or distributed***

*General chair: S. Langenbuch*
*Session chairs: A. Irani and J.M. Aragonés*
*Secretary: E. Sartori*

## Welcome, introduction of participants, approval of agenda

### *First exercise*

1. Overview of PWR MSLB benchmark: J.B. Taylor, T.M. Beam, K.N. Ivanov, A.J. Baratta

2. Summary of first exercise: T.M. Beam, J.B. Taylor

3. "Final" report on first phase of OECD PWR MSLB benchmark: T.M. Beam, K.N. Ivanov, A.J. Baratta

### *Presentation of final results for first exercise by participants*

4. FZK/SKWU final results obtained with RELAP5/Mod 3.2 using point kinetics: V. Sanchez, W. Hering, A. Knoll

5. Final results of OECD/CSNI PWR MSLB benchmark (Phase I) using ATHLET with point kinetics: S. Langenbuch, K.D. Schmidt, K. Velkov

6. Summary of Exercise 1: Code CENTS, ambitions: R. Josefsson

7. Calculation with CATHARE2: E. Raimond, S. Villalonga

8. Summary of Netcorp solution for point kinetics benchmark for PWR MSLB: R. Kern

9. RETRAN/RELAP/TRAC comparisons for point kinetics results: A. Irani (no paper)

### *Second exercise*

10. Discussion of second exercise: K.N. Ivanov, A.J. Baratta

11. Summary of participant results for second exercise: J.B. Taylor, K.N. Ivanov

12. Reference results for second exercise: K.N. Ivanov, J.B. Taylor

13. Preliminary report on second phase of the OECD PWR MSLB benchmark: J.B. Taylor, T.M. Beam, K.N. Ivanov, A.J. Baratta

14. MSLB second exercise, 3-D kinetics results with RELAP5/PANBOX: R.E. Böer, H.B. Finnemann, A. Knoll, D.G. Cacuci, V. Sanchez (Siemens, FZK)

15. Analysis of the OECD MSLB benchmark with RELAP5/PARCS and TRAC-M/PARCS: R.M. Miller, H.G. Joo, D.A. Barber, T.J. Downar, D.D. Ebert (SNE-Purdue, US NRC)

16. Results of ATHLET-QUABOX/CUBBOX for MSLB benchmark transients: S. Langenbuch, K.D. Schmidt, A. Pautz, K. Velkov

17. Preliminary results for the steady-state and guided transient (Phase II cases) using SIMTRAN code, studies on mesh and cross-flows sensitivity: V. Aragonés, J.M. Aragonés

18. Calculation of the OECD NEA PWR benchmark on MSLB with the three-dimensional core dynamics model TRAB-3D: A. Daavittila, E. Kaloinen

19. APROS results for MSLB benchmark: E.K. Puska, I. Karppinen

20. Comments on SIMULATE-3K results: R. Josefsson (*see 6*)

21. CEA preliminary results for exercise (CRONOS2/FLICA4): E. Royer, D. Caruge, D. Gallo

22. DYN3D/R calculations for the second exercise of the OECD MSLB benchmark: U. Grundmann

23. Status and summary of Netcorp solution for 3-D benchmark for PWR MSLB: R. Kern

***Third exercise – discussion***

General discussion of third exercise:

- conclusions;
- reporting to NSC and CSNI;
- schedule.

# ANNEX 3

***List of codes cited by participants***

**Phase I:**

- APROS
- ATHLET
- CATHARE
- CATHARE2/SMABRE
- CENTS
- DNP/3D
- RELAP5/MOD3.2
- RETRAN-3D
- SAS-DIF3D/K
- THYDE-NEU
- TRAC

**Phase II:**

- APROS
- ATHLET-QUABOX/CUBBOX
- CRONOS2/FLICA4
- DNP/3D
- DYN3D/R
- PANTHER/RELAP5
- RELAP5/PANBOX
- RELAP5/PARCS
- RETRAN-3D/RELAP/TRAC
- SAS-DIF3D/K
- SIMTRAN
- SIMULATE-3K
- THYC/COCCINELLE
- TRAB-3D
- TRAC-M/PARCS

## ANNEX 4

### *OECD MSLB benchmark schedule*

| | | | |
|---|---|---|---|
| 1. | 15 December 1996 | ** | Specifications |
| 2. | 14 February 1997 | ** | Distribution of first draft to potential participants from NSC and CSNI/PWG2 for comments and feedback |
| 3. | 15 March 1997 | ** | Comments and feedback from NRC, GPUN and NSC and TG-THA, OECD |
| 4. | 7 April 1997 | ** | Second revised craft of specifications (*version to be distributed by NSC to the OECD participants*) |
| 5. | 23-25 April 1997 | ** | First workshop (Washington, DC) (*objective is to finalise the second draft, taking into account the comments and feedback from NRC, GPUN, NSC and TG-THA*) |
| 6. | 9-11 June 1997 | ** | NSC meeting in Paris (*short presentation on status of the benchmark at NSC, review of comments and changes to final draft*) |
| 7. | 1 October 1997 | ** | Final draft of specifications |
| 8. | 15 January 1998 | ** | Deadline for submitting results for the first benchmark exercise (*point kinetics*) |
| 9. | June 1998 | ** | First draft of analysis (*point kinetics*) |
| 10. | 22-23 June 1998 | ** | Second benchmark workshop – Europe (Spain) *(present point kinetics results and discuss how 3-D results are coming along)* |
| 11. | 15 July 1998 | ** | Distribute specification of additional parameters for Phase I and summary of second meeting |
| 12. | 1 August 1998 | ** | Distribute agreed boundary conditions for Phase II |
| 13. | October 1998 | ** | Ad-hoc meeting in connection with the Reactor Physics Conference at Long Island, USA |
| 14. | 1 December 1998 | ** | Deadline for submitting Phase I results |
| 15. | March 1999 | ** | Issue “final” draft for Phase I results, distribute to participants for comments |
| 16. | 24-25 March 1999 | ** | Third meeting at GRS, Garching, presentation of “final” Phase I report and discussion of Phase II results |
| 17. | 20 April 1999 | | Deadline for issuing final PWR MSLB benchmark specification |
| 18. | 1 June 1999 | | Deadline for sending in Phase I results |

| | | |
|---|---|---|
| 19. | 1 July 1999 | Deadline for submitting final results for the second benchmark exercise (*3-D kinetics/core T-H boundary model*) |
| 20. | End July 1999 | Issue final draft of Phase I report for review by subgroup (*A. Irani, K. Ivanov, A. Knoll, S. Langenbuch*) |
| 21. | End August 1999 | Final check and approval of Phase I report by participants (*via mail and e-mail*) |
| 22. | 1 September 1999 | Issue final draft of Phase II report for review by subgroup (*J.M. Aragonés, H. Finnemann, K. Ivanov, S. Langenbuch*) |
| 23. | 20-22 September 1999 | Approval of final draft for Phase I by NSC members and CSNI/PWG2 on coolant system behaviour |
| 24. | 27-30 September 1999 | Ad-hoc benchmark participants meeting and presentation of progress in the PWR MSLB benchmark study during the *Mathematics and Computation '99* conference in Madrid, Spain |
| 25. | End September 1999 | Publication of Phase I report |
| 26. | 1 November 1999 | Deadline for submitting results of third benchmark exercise (*best estimate coupled simulation*) |
| 27. | 5 January 2000 | Draft of Phase III report (*best estimate coupled simulation*) |
| 28. | 27-28 January 2000 | Fourth PWR-MSLB benchmark meeting, Paris, France (*approve final Phase II report, discuss draft Phase III results and report*) |
| 29. | March 2000 | Submit final Phase II report to NSC and CSNI/PWG2 for approval |
| 30. | March 2000 | Issue final draft of Phase III report to subgroup for review |
| 31. | April 2000 | Approval by participants of Phase III report |
| 32. | May 2000 | Issue Phase II report |
| 33. | June 2000 | Submit final Phase III report to NSC and CSNI/PWG2 for approval |
| 34. | Summer 2000 | Issue Phase III report |

## ABBREVIATIONS USED

**BC** Boundary Conditions

**CSNI** Committee on the Safety of Nuclear Installations

**EOC** End of Cycle

**GPUN** General Public Utilities Nuclear

**GRS** Gesellschaft für Anlagen und Reaktorsicherheit

**HFP** Hot Full Power

**HZP** Hot Zero Power

**MSLB** Main Steam Line Break

**NP** Normalised Power

**NSC** Nuclear Science Committee

**PK** Point Kinetics

**PSU** Pennsylvania State University

**PWG2** CSNI Principal Working Group 2 on Coolant System Behaviour

**SG** Steam Generator

**TG-THA** PWG2 Task Group on Thermal-Hydraulic Analysis

**T-H** Thermal-Hydraulics

**UPM** Universidad Politécnica de Madrid