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NUCLEAR ENERGY AGENCY
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SUMMARY OF THE WORKSHOP ON CORE MONITORING FOR COMMERCIAL REACTORS: IMPROVEMENTS IN SYSTEMS AND METHODS (CoMoCoRe'99)

4-5 October 1999
Stockholm, Sweden

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WORKSHOP ON CORE MONITORING FOR COMMERCIAL REACTORS: IMPROVEMENTS IN SYSTEMS AND METHODS

CoMoCoRe'99

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SUMMARY

Introduction

The ninth meeting of the OECD/NEA Nuclear Science Committee (NSC), held in June 1998, was partly devoted to an in-depth discussion of core monitoring. In preparation for the discussion at the NSC meeting, a written report had been distributed to the committee members. This report (see Annex 1) gives an overview of requirements, system layouts and operational experience with regard to core monitoring for BWRs and PWRs. It also discusses improvements and further development of the present monitoring systems and methodologies that would enhance their ability to handle modern fuel under present or foreseen operational strategies. As a result of the discussion engendered by this report, the NSC concluded that a workshop would be useful follow up.

CoMoCoRe'99, organised jointly by Vattenfall AB, ABB Atom and the Swedish Nuclear Power Inspectorate, took place from 4-5 October 1999 in Stockholm. The workshop was timely, as it dealt with an issue which should be addressed in parallel to the internationally ongoing discussion among authorities, utilities and vendors on how to deal with the rapid technical development and optimisation of nuclear fuel and its utilisation under new, more aggressive fuel management strategies.

Objectives

Although having a similar scope, CoMoCoRe'99 should be considered separate from the series of specialists meetings on In-Core Instrumentation and Reactor Core Assessment, the last of which was held in 1996. The main objective of the present workshop was to discuss how instrumentation, methods and models used in core monitoring could be validated, or, if needed, improved and further developed to provide more reliable and/or detailed information on local power in the core and on other parameters indirectly affecting fuel duty as, e.g. the core decay ratio in a BWR. Another important objective was to show how the core monitoring system can be used to support reactor operation in normal and anticipated transient modes and to supply data used to derive initial key core parameters for transient and accident analysis.

Technical programme and participation

Presentations were invited dealing with applications for all types of commercial LWRs, including VVER. Twenty-three papers were accepted for presentation, structured into four technical sessions (see Annex 2):

- Session I. Requirements on Core Monitoring Systems.
- Session II. Sensors, Signal Processing and Evaluation.
- Session III. Improved Core Models in Core Monitoring.
- Session IV. Improved Core Monitoring Systems, Design and Operating Experience.
- Session V. Discussion and Conclusions.

The workshop was attended by about sixty participants from 30 organisations representing 15 countries (see the *List of Participants*), and was concluded with a discussion, the highlights of which are presented in the following.

Summary of discussion

During the meeting a good overview of present efforts to improve the capabilities of the core monitoring (CM) systems of different commercial reactor types was provided.

Some general trends may be seen:

- The introduction of more detailed physics models in on-line calculations for both BWR and PWR.
- More wide-spread discussion on possible advantages of backfitting some PWR types with fixed in-core detectors.
- Methods to combine the information from on-line measurements and on-line calculations.

There is in fact a very rapid development of more advanced fuel design and methods of operating the core. Consequently, there is a need to reconsider how the core is monitored.

Regulatory perspectives

From the regulators perspective, core monitoring should not be regarded as an isolated issue, but as part of overall fuel cycle issues. For introduction of advanced core designs, surveillance systems must be part of the strategy. It is important to treat the whole core monitoring chain, starting with detectors and signal processing. Most countries have no formal requirement to license CM systems as they are not safety critical for the reactor protection system. Discussions with regulators regarding modifications to the CM system should however be encouraged without a need of formal approaches. As for physics models, 3-D best estimate methods are accepted today by regulators if they are accompanied by thorough and well founded analysis of uncertainties, in particular as they relate to advanced fuel and core design. Obviously, old methods should not be used for advanced cores. Changes in CM systems need to be well founded, and penalties and benefits should be discussed with regulators at an early stage, as should the question of how fuel safety limits and operation margins are set.

Methods, risks – benefits, operating margins

The balance of risk (compromised fuel integrity) and benefit (fuel performance) need to be considered simultaneously in all CM upgrades. Improved core monitoring has a potential economic benefit; better in-core instrumentation and physics evaluation methods improve accuracy. The operator may benefit from this by operating the reactor core closer to thermal limits (obtaining higher performance out of the fuel) as long as the remaining thermal margins are well understood and accounted for. This can be a difficult task, which is exemplified by the fact that pellet-clad interaction (PCI) failures, even with liner fuel, are still observed. This indicates that fuel pin powers have not been adequately estimated, nor the limiting cases well identified. When more heterogeneous fuel bundles are introduced it is important to be able to carry out more precise measurements and to improve accuracy in calculations. Crude methods, such as those using one and a half energy groups and spatial resolution only on the level of a whole fuel node, now need to be replaced by the methods representing the present state of the art for a better estimation of damage risks. Commercial codes are that are currently available include full two-group energy representation and detailed pin by pin calculations. For BWRs more advanced methods for coupling of 3-D neutronics with thermal-hydraulics will soon emerge. When implementing these new models it is important that detailed, realistic experiments be used as a base for the validation.

It should be emphasised, however, that fuel reliability is today recognised as a goal in and of itself, balancing in a natural way the goal of higher fuel performance. Ensuring reliability also means that margins have to be left for the unexpected. The emerging deregulated electricity markets in Europe and the USA lead to extra economical pressure on operators and therefore also on vendors. It is important to maintain a proper balance between risk and balance under these circumstances.

New core monitoring systems should improve the view inside the reactor. Thus, a closer look should be given at the process signals from the reactor. Here, signal qualification is an important aspect that should be further addressed. Signals must be checked and validated to be useful. The role of measurements in CM is to reveal anomalies in the core for the purpose of taking action. A neural network kind of approach could be one method. How to best combine measurement and calculation is a big challenge to be tackled. Solving this challenge, though, should lead to a good industrial product.

In some countries (France, in particular) there are challenging demands on core follow operation for nuclear power plants. In PWRs this leads to an operation mode with so-called grey control rods, which affect peaking in the core. Additionally, PCI is a concern in Class II events. This means that present thermal margins are more or less used up. One way to improve operation flexibility in the future is to upgrade the present CM system using fixed in-core detectors together with full 3-D on-line simulation with short response time. However, a CM system should not be too complicated with regard to maintenance, interpretation, evaluation, etc. Confidence can be built up only under these circumstances. It is mainly the reactor operator that should run a system for continuous operation and not a group of engineers.

Some conclusions

- There is an ongoing development in physics models in the reactor physics, thermal-hydraulics and other related research communities. This will provide improved models that can be implemented in core monitoring (CM) systems.

- Signal validation is of prime importance in any CM system and could be a subject for further study in the framework of the NEA.

- More rigorous methods to combine information from measured and calculated data should also be very useful in future CM systems.

Workshop organisation

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Annex 1

On-Line Core Monitoring for BWR, PWR Overview and Comments on Operation Experience and Further Development

Presented by Tomas Lefvert at the Ninth NSC Meeting, June 1998

General requirements

Reference is made to the General Design Criteria put forward in US CFR 50 App. A, namely:

- GDC-10 Reactor Design
  The reaction core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

In order to show that these margins exist, and to take protective action if they become too small, the following criteria also apply:

- GDC-13 Instrumentation and Control
  Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, the reactor coolant pressure boundary, and the containment and its associated systems. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges.

- GDC-20 Protection System Functions
  The protection system shall be designed (1) to initiate automatically the operation of appropriate systems, including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences, and (2) to sense accident conditions and to initiate operation of systems and components important to safety.

In the following, we will only address the system for monitoring the fission process in the core. This is one of the systems referred to in GDC-13 and it is often based on neutron flux detectors. However, there is also a connection to the protection system which often takes data from the monitoring system but treats them in another way to assure redundancy, operability in adverse conditions, etc.

There are also systems for core surveillance meaning that the fission process is checked periodically rather than continuously.

The operating domain of the reactor is defined through criteria in the technical specifications and constitutes a certain 2-D region in the power-core flow (BWR) or power-axial offset (PWR) space within, but well separated from, the various protection lines. If, through core monitoring or core surveillance, we find that the operating point falls outside the operating domain, the technical specifications defines the action to be taken, e.g. lowering reactor power. Thus, there is both an administrative and an automatic protection system in place.

System layouts

BWR

The BWR typically has a heterogeneous distribution of fuel and moderator over the core, both radially and axially. This is true at zero power due to the variation in enrichment in the fuel pins, the gadolinium absorber, the fuel channel and water gaps between assemblies different from the pin-to-pin gaps in the fuel assembly. At power there is also a 3-D distribution of void due to the two-phase flow. In addition, there is the local perturbation from the control rods used to control part of the cycle excess reactivity and to shape the power distribution.

Under such conditions it is difficult to reveal unwanted local power peaks unless the neutron detector is situated in the core. All BWRs have a similar detector layout with roughly one detector string per 4*4 fuel assemblies in the core. Each string typically has four fission detectors (local power range monitors, LPRMs) in different axial positions along the active height of the fuel assemblies. The LPRM readings are frequently compared with the results of 3-D on-line core simulation using nodal diffusion codes to solve the neutron transport equation. This is normally done in the adaptive mode, where the calculated power distribution is fitted to the measured data points before evaluating the margins to the various thermal limits on the fuel pin. Alternatively, the calculated results can be used directly to find the margins and the observed deviation between measured and calculated data used to define the uncertainty to be included in the margin.

The sensitivity of the LPRMs will vary with detector burn-up. Therefore they need to be calibrated regularly, typically every 2-4 weeks. The calibration is effectuated by a system of movable fission or gamma detectors (TIPs) that can be pushed through a tube adjacent to the LPRMs. Normalisation to absolute power is done by comparison with the heat balance of the plant.

Thus, the BWR core monitoring system consists of the LPRMs, the TIPs and their associated software for treating the detector signals, etc., plus the on-line core simulator. As a result, the error in determining the local power and thermal margin is affected both by certainties in the flux measurement and calibration, by model uncertainties in the simulator and by uncertainties in input data to the models, given by the deviation between the nominal and the actual core and fuel geometry and fuel isotopics. Theoretically, and since the BWR is operated with either quarter-core or half-core symmetry, the model uncertainty could be separated from the rest if measurements were taken in symmetrical positions. However, unlike PWRs, this is normally not the case in BWRs.

The BWR protection system against high power is based on LPRM signals. Signals from a number of LPRMs spread evenly over the core are added to form an average power range monitor (APRM) signal. Typically four different sets of LPRMs form four independent APRMs, the signals of which are compared with setpoints for reactor protection.

At shutdown and low power conditions other in-core detectors are used in the source and intermediate power range, respectively. Today, many BWRs use one set of detectors for the whole range from shutdown to low power, namely wide range neutron monitors (WRNMs). They are used to monitor sub-criticality during, e.g. core shuffling and control rod scram tests, and in the measurements of shutdown margin. They also protect against inadvertent local criticality using appropriate set points for doubling time and flux level. Modern designs of WRNM are sensitive enough to allow absolute reactivity measurements down to about 1% sub-criticality. In the low power range they provide a diversified overlap with the LPRMs.

PWR

Originally the PWR core had a fairly homogeneous layout of fuel and moderator. There are no fuel channels, there are uniform pin-to-pin water gaps over the whole core and there is always one-phase flow. Originally there were no burble absorbers and control rods were not used during full power operation. However, unlike the BWR case, the layout of the core monitoring system for PWRs tends to vary between reactor vendors. The dominating designers, Westinghouse and Framatome, do not use fixed in-core detectors but rely on large volume external detectors for core monitoring and a TIP system for calibration of the external detectors and for core surveillance. The TIP can run in the centre tube of about one-third of all assemblies. Considering that one PWR assembly is roughly equivalent to four BWR assemblies, we note that more core positions are measured in a PWR than in the BWR. Some of the positions are in symmetrical core positions allowing a separate analysis of model uncertainty in calculating TIP signals.

The external detectors are also used for overpowering protection. The monitoring and protection limits are defined in terms of the axial offset evaluated directly from the ex-core detectors, which integrate the thermal flux coming from the upper and lower part of the core periphery, respectively. The limits have been set to conservatively cover an envelope of possible core perturbations where local power remains within specified fuel design limits.

The TIP data, taken about every four weeks, are evaluated off-line with a core simulator and the results compared with technical specification limits with regard to departure from nucleate boiling (DNB) and LOCA-related power peak.

PWR designs from Siemens, the former Combustion Engineering and the former B&W all have fixed in-core detectors in addition to the TIP (reference) system and ex-core detectors. The Siemens PWR has prompt responding detectors while the other designs use rhodium, which gives a delayed power response unsuitable for use in a protection system. The use of in-core detectors (PDD) and the availability of a fast reference system (Aeroball Measurement System) in Siemens PWRs also permit a PDD signal validation in perturbed conditions. Thus PDDs register all power density changes caused by power density perturbation modes or by control rod misalignments (mode detection capability). *Applying a simple calibration procedure for the PDDs under reference conditions the maximum PDD signal directly indicates the peak power density*.

PWR core monitoring with fixed in-core detectors will allow a wider operating domain. If, in addition, the in-core detectors can be used in the protection system, the operating domain may be extended further allowing even higher flexibility in operation.

Ex-core detectors are used also for monitoring and protection during shutdown and start-up.

Finally, the latest Framatome designs make use of a new system of external detectors with six axial levels instead of two and the appropriate supporting software. This allows a better reproduction of core axial power at the core periphery, which is important considering the rather demanding mode of operation that the EDF follows with both frequency control and load-follow. These grid requirements have also prompted the EDF to generally introduce an operating mode where so-called grey rods, made of steel with no extra absorber, can reside in the core during operation in order to shape the power distribution.

Comments on operational experience

BWR

There are examples where fuel pin power has exceeded design limits and failed during normal reactor operation, without the core monitoring system giving the proper indications. The main causes for this have probably been off-nominal water gap geometry and/or less than anticipated model accuracy. As already mentioned, there is no way in a BWR to separate model uncertainty from the rest of the uncertainties when comparing measured and calculated power distributions. The cross-section homogenisation models for the fuel assembly can be tested, e.g. in critical experiments with fresh fuel and in irradiation experiments, e.g. for gadolinium burn-up. Moreover, lattice code intercomparison has been made by the NEA/NSC. However, the accuracy of the older nodal diffusion codes and thermal hydraulic models in calculating power distributions in an operating BWR are not known. Also, there is no way to know the true lattice geometry in the core or the true lateral position of a LPRM or TIP detector in the narrow water gap between assemblies. We can only observe the combined uncertainty from all these sources of error.

A prudent way to deal with these uncertainties is to introduce better models, try to avoid materials and mechanical design of fuel assemblies that could lead to distortion of nominal dimensions under irradiation and to have a fuel lattice and nuclear design that provides extra thermal margins in a given mode of operation.

Thus the modern advanced nodal core simulators with two full energy groups, discontinuity factors and pin power reconstruction for the 3-D neutron transport, are now coming into use in core monitoring and will reduce the model uncertainty. Also, the thermal hydraulic models and/or the empirical correlations they use could be improved in order to cope with the increasing design complexity of modern BWR fuel. It is likely that with the new neutronic models mentioned above the T&H modelling will be limiting the total model uncertainty of the BWR core monitoring system. The 10*10 lattice is becoming a BWR industry standard, at least in Europe and the USA. It provides more margin to pellet clad interaction (PCI) and generally lowers the absolute pin powers in the core which in turn gives more margin for inadvertent variations in inter-assembly water gaps and also less fission gas release. Moreover, BWR operators keep a close check on fuel channel dimensional changes. Channel bow has in the past caused fuel failures resulting from increased water gaps which then cause corner and peripheral fuel rods to obtain better moderation and therefore higher power.

PWR

The modern PWR core is becoming less homogeneous with the introduction of burnable absorbers and low-leakage loading patterns. These patterns also cause low power assemblies to reside in the core periphery, which affects the relative contribution of high and low power assemblies to the integrated signal in the external detectors. Recently, the assumption of uniform water gaps between assemblies has also been challenged with the manifestation of the assembly bow problem in many PWRs. However, we know of no reports on fuel failures due to rod overpower within the operating domain. This is good news, indicating that there was ample margin originally. We should also keep in mind, however, that re-licensing of transients and accidents and/or power uprating using less conservative methodology, have been performed recently by many operators, allowing operation with higher load factors on individual fuel rods.

In total, it is likely that this development has decreased the available margin for unexpected and new fuel related phenomena (not detectable during operation). We also must continue to expect the unexpected in future operation and allow for appropriate margins. Again, a prudent strategy would be to try to reinstate extra margin by using a similar approach as that described for BWR, but adapted to the specific demands of the PWR design being studied, e.g. stiffer skeleton to avoid assembly bow. In the assessment of uncertainties we are better off in the PWR since analysis of measured data in symmetrical core positions allows an estimate of the model uncertainty itself. Thus, a systematic analysis of TIP comparisons along these lines would indicate where the most effective improvements could be made in order to lower the total uncertainty in the core monitoring of a given reactor.

Concerning model uncertainty, improvements could be made by introducing modern core simulation in the monitoring of PWRs, using TIP data in an adaptive or non-adaptive way in the comparison with calculated local power. Fixed in-core detector data could also be used where applicable.

Further improvement and development

Improved 3-D simulator

There are now several advanced nodal core simulators commercially available. They do a better job than the old ones, especially for the more advanced fuel and core designs. Thus the new tools are available for the utility to use, and some are presently introducing the new simulator for on-line monitoring.

Using the same models/methods and data banks for both core monitoring and surveillance as for fuel and core design will of course give better overall agreement between core design and core follow, surveillance and monitoring results. This could allow the utility to use tighter design margins when doing the reload design.

Modern 3-D core simulators handle an order of magnitude more data for the calculation than older versions Therefore, the hardware also has to be upgraded when introducing the new simulators.

Improved thermohydraulic modules

Both PWR and BWR fuel designs have evolved steadily in the areas of neutronic and mechanical designs. The current hydraulic methods, while still adequate, have not fully kept pace with this development. Longer cycles, higher peaking and non-homogeneous bundle designs will continue to challenge the adequacy of the thermohydraulic models.

Thus the T&H models need to possess flexibility to handle the new fuel designs, including part length fuel rods and other hydraulic characteristics. As always, when modelling complicated physical phenomena, it is very useful to have access to experimental data for the validation of the improved models, e.g. void data for BWR fuel.

Improved core monitoring

Incorporation of on-line DNBR calculations for PWR plants can reduce uncertainty and conservatisms currently in use. This is, however, not a simple change to the present licensing strategy and will affect many parts of the safety analysis calculations as well as core monitoring.

Most modern core simulator codes have accurate xenon transient modelling methods incorporated into their basic design. Older core monitoring codes in use at some plant sites do not have adequate transient xenon models. With the current generation of mini-computer systems, all plant core physics personnel should have access to monitoring and prediction tools utilising time and power dependent transient methods.

As concerns incorporation of boron depletion routines in core monitoring routines for PWR plants, modern utilities have maintained a much tighter control of leaks in the plant and do not have to replenish the coolant as frequently as in the past. This results in the depletion of the ^{10}B abundance in the boron concentration in the core. Since the resultant depleted boron has less neutron poisoning effect, the boron concentration needs to be increased. The inclusion and tracking of the effects of boron depletion are not included in many PWR core monitoring systems. This can result in large discrepancies (~199 ppm boron) for plants that have long operating periods between shutdowns.

As already mentioned, the results of the on-line core simulator calculations can be treated in two principally different ways: the adaptive and the best estimate method, respectively.

In the adaptive method the calculated power distribution is adapted to the local power measurements. It is then re-expanded over the whole core in order to determine the limiting thermal margin in the core, which is then compared with a given limit value. Improved adaptive models are possible. One possibility is, e.g. to take into account more than the nearest detectors when adapting the power distribution.

In the best estimate method, we use the simulator directly to determine the thermal margins without adaptation of the power distribution. The measured detector readings are used to regularly evaluate the uncertainty of the difference between measured and calculated local power in the TIP measuring positions. Based on this uncertainty a statistical confidence interval is added to the calculated thermal margin and the result compared to the given limit value.

Conclusions and recommendations

Modern BWR fuel and core designs have become rather demanding from a neutronic and thermohydraulic modelling point of view. The BWR probably presents a greater challenge than the PWR in this respect. Introducing the new, advanced nodal core simulators in core design and in on-line core monitoring could lead to smaller design margins and better known operational margins. To reach this, however, it may in some cases also be necessary to improve the T&H modelling, which now tends to limit the accuracy in BWR core simulation.

Modern PWR core designs are becoming more non-homogeneous due to requirements of longer cycle times and reduced batch sizes. The current system of depending solely on once a month in-core flux mapping coupled with continuous monitoring from large volume ex-core detectors can contribute to unnecessary uncertainty in the monitoring of the core. A more aggressive licensing position can be taken by proving the accuracy of modern core simulators with confirmation from Aeroball or moveable in-core detection systems. These licensing strategies must be co-developed with the licensing authority, the utility and the vendor.

In this overview of core monitoring we have pointed out that although the present methodology is adequate, it has some shortcomings when applied to more advanced fuel and core designs. Several possible improvements were also mentioned that would lead to smaller uncertainties in design and to better known uncertainties and margins in operation. Many of these improvements are based on having better models for fuel and core calculations. Therefore it could be fruitful to have the issue analysed further within the frame of the NSC, perhaps in the form of a workshop.

Annex 2

Technical Programme

Monday, 4 October 1999

- *Tomas Lefvert, Enrico Sartori* – Opening address

Session I: Requirements on Core Monitoring Systems (*Chairman: Oddbjörn Sandervåg*)

- *Öivind Berg* – User Interface Design and System Integration Aspects of Core Monitoring Systems
- *Tell Andersson* – Functional Requirements for PWR Core Surveillance Systems
- *Juan Casal* – Uncertainty Assessment in BWR Core Monitoring

Session II: Sensors, Signal Processing and Evaluation (*Chairmen: Etsuro Saji, Öivind Berg*)

- *Jean Mourlevat*, Daniel Janvier, Holland Warren – Industrial Tests of Rh SPDs: The Golfech 2 Experiment
- *Ferenc Adorján*, I. Pos, S. Patai Szabó – Statistical Analysis of the Ratio of Measured and Predicted Rh SPND Signals for VVER-440/213 Reactor
- *Akihiro Fukao*, Etsuro Saji – The Study on the BWR In-Core Detector Response Calculation
- *Tsunemi Kakuta*, K. Suzuki, H. Yamagishi, H. Itoh, M. Urakami – Demonstration of Optical In-Core Monitoring System for Advanced Nuclear Power Reactors
- *Koki Inagaki*, Hironobu Shinohara, Satoru Yasue, Masaru Tamuro – Development of Advanced Digital Rod Position Indication System

Session III: Improved Core Models in Core Monitoring (*Chairmen: Allen Wells, Tomas Lefvert*)

- *Hoju Moon*, Allen Wells – Impact of Advanced BWR Core Physics Method on BWR Core Monitoring
- *Alejandro Noel*, Lorn Covington, Alf Nilsson, Daniel Greiner – Core Monitoring Based on Advanced Nodal Methods: Experience and Plans for Further Improvements and Development
- *Per Claesson* – JEF-2 Cross-Section Library for Casmo-4: Impact on Core Monitoring of OKG Reactors

- *Pär Lansåker* – BWR Core Stability Prediction On-Line with the Computer Code MATSTAB
- *Makoto Tsuiki* – VNEM: Variational Nodal Expansion Method for LWR Core Analysis

Tuesday, 5 October 1999

Session IV: Improved Core Monitoring Systems, Design and Operating Experience (*Chairmen: Yoichiro Shimazu, Stig Andersson*)

- *Marek Pecka*, Jiri Svarny, Jaroslav Kment – Some Aspects of the New Core Surveillance System at NPP Dukovany and First Experience
- *Martti Antila*, J. Kuusisto – Recent Improvements in On-Line Core Supervision at Loviisa NPP
- *Ivo Endrizzi*, Michael Beczkowiak, Guido Meier – Flexibility Enhancement of Siemens Core Monitoring Based on Aeroball and PDD In-Core Measuring Systems Using On-Line Core Monitoring Software
- *Yoichiro Shimazu* – Review of the Current Status of Core Monitoring System and Future Trend in PWRs in Japan
- *Sten Lundberg*, W. van Teeffelen, Jürgen Wenisch – Core Supervision Methods and Future Improvements of the Core Master PRESTO System at KKB
- *Henning Potstada,* Michael Beczkowiak, Martin Frank, Karl Linnenfelser – The Siemens Advanced Core Monitoring System FNR-K in KKI1, KKP1 and KKK
- *Per Kelfve*, Jesper Eriksson, Carl-Åke Jonsson, Stig Andersson – Design and Validation of the New ABB Core Monitoring System
- ***Discussion and conclusions. Closure of the workshop.***

Additional papers submitted (but not presented)

Session II

- J. Runkel, D. Stegemann, J. Fiedler, P. Heidemann, R. Blaser, F. Schmid, M. Trobitz, L. Hirsch, K. Thoma – New Technologies for Acceleration and Vibration Measurements Inside of Operating Nuclear Power Reactors
- Richard J. Cacciapouti, Joseph P. Gorski – Experience with Fixed Platinum In-Core Detectors

Session IV

- Moonghu Park – Introduction of Virtual Detectors for Core Monitoring System of Korean Standard Nuclear Power Plant

LIST OF PARTICIPANTS

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