

**Unclassified**

**NEA/CSNI/R(2002)11**

Organisation de Coopération et de Développement Economiques  
Organisation for Economic Co-operation and Development

**09-Jul-2002**

**English - Or. English**

**NUCLEAR ENERGY AGENCY  
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS**

**NEA/CSNI/R(2002)11  
Unclassified**

**SEVERE ACCIDENT MANAGEMENT (SAM)  
OPERATOR TRAINING AND INSTRUMENTATION CAPABILITIES**

**SUMMARY AND CONCLUSIONS  
of a Workshop organised in Lyon, France  
in collaboration with EDF/SEPTEN**

**12-14 March 2001**

*This document has already been distributed as part of document NEA/CSNI/R(2001)7, Proceedings of the Workshop on Operator Training for Severe Accident Management and instrumentation Capabilities during Severe Accidents, Lyon (France), 12-14 March 2001.*

**JT00129398**

Document complet disponible sur OLIS dans son format d'origine  
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## **ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT**

Pursuant to Article 1 of the Convention signed in Paris on 14<sup>th</sup> December 1960, and which came into force on 30<sup>th</sup> September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), the Republic of Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

## **NUCLEAR ENERGY AGENCY**

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. NEA membership today consists of all European Member countries of OECD as well as Australia, Canada, Japan, the Republic of Korea, Mexico and the United States. The Commission of the European Communities takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency (IAEA), with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

## **CSNI**

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of senior scientists and engineers, with broad responsibilities for safety technology and research programmes, and representatives from regulatory authorities. It was set up in 1973 to develop and co-ordinate the activities of the NEA concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries. CSNI's main tasks are to exchange technical information and to promote collaboration between research, development, engineering and regulation organisations; to review the state of knowledge on selected topics of nuclear safety technology and safety assessments, including operating experience; to initiate and conduct programmes to overcome discrepancies, develop improvements and reach consensus on technical issues; to promote co-ordination of work, including the establishment of joint projects.

### **WORKING GROUP ON THE ANALYSIS AND MANAGEMENT OF ACCIDENTS (GAMA)**

The Working Group on the Analysis and Management of Accidents is mainly composed of technical specialists in the areas of coolant system thermal-hydraulics, in-vessel protection, containment protection, and fission product retention. Its general functions include the exchange of information on national and international activities in these areas, the exchange of detailed technical information, and the discussion of progress achieved in respect of specific technical issues. Severe accident management is one of the important tasks of the group.



**WORKSHOP ON OPERATOR TRAINING  
FOR SEVERE ACCIDENT MANAGEMENT  
AND INSTRUMENTATION CAPABILITIES  
DURING SEVERE ACCIDENTS**

**organised in collaboration with  
ELECTRICITE DE FRANCE/SEPTEN**

Lyon (France), 12-14 March 2001

## **SUMMARY AND CONCLUSIONS**

### **INTRODUCTION**

The Workshop on Operator Training for Severe Accident Management (SAM) and Instrumentation Capabilities During Severe Accidents was organised in Lyon, France from 12 to 14 March 2001, in collaboration with Electricité de France (Service Etudes et Projets Thermiques et Nucléaires). There were 34 participants, representing thirteen OECD Member countries, the Russian Federation and the OECD/NEA. Almost half the participants represented utilities. The second largest group was regulatory authorities and their technical support organisations.

Basically, the Workshop was a follow-up to the 1997 Second Specialist Meeting on Operator Aids for Severe Accident Management (SAMOA-2) [Reports NEA/CSNI/R(97)10 and 27] and to the 1992 Specialist Meeting on Instrumentation to Manage Severe Accidents [Reports NEA/CSNI/R(92)11 and (93)3].

It was aimed at sharing and comparing progress made and experience gained from these two meetings, emphasising practical lessons learnt during training or incidents as well as feedback from instrumentation capability assessment.

The objectives of the Workshop were therefore:

- to exchange information on recent and current activities in the area of operator training for SAM, and lessons learnt during the management of real incidents (« operator » is defined here as *all personnel involved in SAM*);
- to compare capabilities and use of instrumentation available during severe accidents;
- to monitor progress made;
- to identify and discuss differences between approaches relevant to reactor safety;
- and to make recommendations to the Working Group on the Analysis and Management of Accidents and the CSNI (GAMA).

## CONCLUSIONS

The meeting confirmed that only limited information is needed for making required decisions for SAM. In most cases existing instrumentation should be able to provide usable information. Additional instrumentation requirements may arise from particular accident management measures implemented in some plants. In any case, depending on the time frame where the instrumentation should be relied upon, it should be assessed whether it is likely to survive the harsh environmental conditions it will be exposed to.

Though uncertainties still remain in the understanding of some severe accident phenomena, this should not be considered as a de-facto impediment against using simplified models both as operator aids in the course of an accident and as an option of a simulator severe accident mathematical model. These tools, however, should be based on state-of-the-art physics and calibrated using more sophisticated codes. Having the capability for periodic assessment of trends and predictions against real plant parameter evolution, and subsequent correction, is also advised for such tools.

Being prepared for the unexpected is the major objective pursued in training, especially when capabilities extend into severe accident situations. When training for severe accidents is contemplated, skill-oriented sessions should be emphasized as they allow evaluating operator reactions in highly perturbed situations. However, it is also advised to increase operator awareness in case of severe accident situations through tailored sessions stressing knowledge of basic phenomena involved in degraded situations. Though computer-based training could well prevail in the long run, table-top exercises as currently implemented by many utilities also bring extremely valuable results.

There was consensus among the participants that the Workshop had been most useful, and that similar meetings should be organised at regular intervals to allow fruitful exchange of information, experience and viewpoints among utilities, regulatory authorities, technical support organisations, reactor designers and vendors, architect-engineers and research organisations.

## **SESSION SUMMARIES**

The Workshop was organised into five sessions:

- Session 1: Introduction
- Session 2: Tools and Methods
- Session 3: Training Programmes and Experience
- Session 4: SAM Organisation Efficiency
- Session 5: Instrumentation Capabilities

It was concluded by a Panel and General Discussion.





*Session 1***INTRODUCTION**

**Chair: Michel Vidard (EDF-SEPTEN)**  
**Co-Chair: Ahcène Sekri (EDF-SEPTEN)**

Two invited papers were presented as an introduction to the workshop. The first one put into perspective instrumentation capabilities for severe accidents, which kind of information is needed for severe accident management, and how these issues relate to operator training, while the second one dealt with the structure of accident management procedures and shift tasks and responsibilities in the German approach.

The main conclusions of the discussion following these presentations were:

- Information needed for making decisions for SAM is limited.
- In general, decisions have to be made early into the accident: instrumentation qualified for Design Basis Accidents seems robust enough to survive in this period.
- Valuable information can be gathered through more creative use of existing instrumentation. For instance, rapid increase of the containment pressure or of containment activity were deemed good indicators for detecting vessel failure. Parameter trends and sensor failures could also provide information on accident progression
- Some information needs to be interpreted with care. This is the case when large variations of the measured parameter are likely to exist depending on sensor location. A typical case is hydrogen concentration inside containment. When decisions are made using such measurements, it is recommended to have thresholds included in operator guidance. The need for hydrogen concentration measurements was also discussed, and some participants were of the opinion that they were not actually needed for Accident Management purposes when passive devices are used for hydrogen removal, but were recommended despite the above mentioned limitations if active devices need to be actuated.
- There was also general agreement that strategies should rely on measurable information to facilitate work for operators and crisis teams.
- Beyond what is needed from a technical standpoint, additional information could be necessary for compliance with local safety authority requirements, for plant specifics, or communication with the authorities and the public.

Concerning accident management and operator training, it appears that all countries or utilities represented in the meeting train their operators or technical support teams for beyond design basis accident management, at least for implementation of preventive measures. Skill-oriented training, which emphasizes assessment and improvement of operator behavior in case of accident seems to be favored by those countries training their operators for severe accident situations.

It was also recognized that unanticipated situations could happen, but there could be a need for concern if operator knowledge and responsiveness are not adequate. Knowledge-based training, stressing proper understanding of Severe Accident physical phenomena, could be contemplated for such improvement.

Though there was a general feeling that training or drills were extremely valuable even when dedicated severe accident capabilities were not built in simulators, it was stressed that such capabilities are a plus as they make operators aware of the time needed to perform some actions, which is not the case when table-top exercises are contemplated.

At last, though situations could differ from country to country, the need for clear definition of responsibilities during accident situations was stressed, in particular when such responsibilities change during the course of an accident.

*Session 2***TOOLS AND METHODS****Chair: Petra Lundström (Fortum Engineering Ltd)****Co-chair: Salih Güntay (PSI)**

Six papers were presented in Session 2 on tools and methods. The scope of the session was to present different tools (e.g. computer models, simulators) to be used for operator training purposes or operator support during the accident.

The first presentation described applications of the ADAM system to SAM and training. The paper was presented by Dr. Khatib-Rahbar. ADAM can be used in an on-line diagnosis mode or in an accident management and simulation mode. The goal is to have much faster than real-time simulation, using simplified models and a coarse nodalization. The presentation also included a demonstration of ADAM.

New developments aiming for determination of the break size for VVER-440 reactors in the beginning of an accident were presented by Mr Horváth from the Hungarian Atomic Energy Authority. The method was based on the rate of change of pressurizer level. In order to develop the correlation between break size and pressurizer water level, accident simulations were carried out on the full scope simulator of Paks, MELCOR, and ADAM.

A universal model for RBMK reactors for safety analysis and SAM purposes was presented by Dr. Zenkov. The name of the model is STEPAN/KOBRA. It is the basic code of the Total Training System full-scope and analytical simulators installed and operating at the Leningrad NPP Training Center for operator training for normal operation, emergencies, and design basis accident conditions. Power unit behavior reproduction under severe beyond design basis accident conditions has also been verified. Inclusion of this type of accidents in the operator training procedure is the next task.

ALIBABA is an expert system, developed by IPSN France, to provide complementary information on the state of the containment barrier, specifically, detection and localisation of the leak paths. The system is designed to help specialists to judge and make decisions. The inputs to the expert system are:

- a) containment isolation reports (isolation valve positions);
- b) level of activities in connecting buildings and
- c) global activity readings in ventilation ducts and the stack.

The expert system, based on the hard-wired data bases on the whole installation and method of assessment constitutes a 'knowledge base' structure and through a user interface, helps the user to raise questions. Assessment of availability of equipment, identification of potential leakage paths, sorting of leakage paths based on their probability of occurrence, and determination of possible restoring actions are the key elements of the method of assessment. It provides assistance to IPSN Technical Emergency Center in charge of containment of fission product release quantification, and is used for emergency drills.

APROS is a multifunctional simulator environment developed by VTT and Fortum Engineering Ltd. in Finland. It has been applied to analysis of all operational and accident conditions of the Loviisa NPP. APROS SA is an extension of the APROS system to cover the severe accident regime. The main motivation for developing APROS SA is to utilize the degree of freedom of the APROS system for carrying out modifications and the flexibility to add new models. APROS SA is tailored to follow the Loviisa SAM strategy and will facilitate assessment and management of severe accidents and will be employed for a wide range of operator training.

The last paper of the session dealt with insights concerning operator actions derived in the study on in-vessel retention for BWR plants in Japan. Physical phenomena and operator interventions in triggering and enhancing these phenomena may greatly reduce the likelihood of reactor pressure vessel breach. Separate effect experiments were conducted to characterise the molten debris break-up and coolability in BWR lower plenum geometries together with modelling efforts. The operator actions, prescribed in the severe accident management guidelines, have been re-prioritised to increase the likelihood of successful in-vessel retention.

### **Summary of discussion (Session 2)**

The session presented examples of:

- diagnostic support and on-line SAM support in ADAM
- an expert system on containment status in ALIBABA
- pure training simulators like STEPAN/KOBRA and APROS SA.

The audience was asked to comment on these different approaches from a plant or end-user perspective.

Many participants thought that a clear distinction should be made between using tools for training and for support during an accident.

The view was expressed that using tools like codes or simulators for deriving SAM strategies during an accident may be misleading. In any case it would be necessary to introduce feedback e.g. from real plant measurement data. Computational aids could however be used when they are likely to relieve unnecessary operator burden.

There were many words of caution against using very simplified models for which uncertainties may be large. Such tools should perhaps only be used for certain special purposes, for which the implications of the uncertainties involved can be explained.

Some utilities, having already implemented SAM measures, expressed a need for extending their simulation capability into the severe accident regime for training purposes. Also specific tools, e.g. for determining containment status or radiation levels during the accident, were considered to be quite useful, since they provide relief to the operators in the emergency situation.

*Session 3***TRAINING PROGRAMME AND EXPERIENCE****Chair: Jürgen Rohde (GRS)****Co-chair: Claude Manuel (IPSN)**

This session included 6 papers dealing with training programmes in The Netherlands, Germany, United States, Belgium, Russia and France. From these papers, it was observed that SAMGs are now implemented in most participating countries. Therefore, SAMG training programmes are in place or are being implemented in these countries. Such programmes involve generally both classroom training and performance training.

Presentations showed that there was no universal approach to training. Some utilities essentially rely on knowledge-based training while others emphasize skill-oriented training in order to improve organisation effectiveness.

Training exercises are based either on event sheets or assisted by simulators. Some utilities having already implemented SAM measures expressed a need for extending their simulators capability into the severe accident regime for training purposes.

For some participants, being prepared to deal with unexpected situations can be addressed through implementation of knowledge-based training for operators. They stressed that mini-drills completing more extended training sessions could also be of interest for improving operator awareness.

Also, many participants stressed the interest of using simulators for SAM operator training, but only few utilities have already made such a move.

For all plants, training is primarily focused on core melt prevention. Currently, most simulators do not incorporate severe accident capabilities, but there are developments underway for this purpose in some utilities.

Training experience should be backfitted in SAMGs, after adequate consideration of bias resulting from time-compressed sessions.



*Session 4***SAM ORGANISATION EFFICIENCY**

**Chair: Benoît De Boeck (AVN)**  
**Co-chair: Michel Roy (EDF-SEPTEN)**

Four papers were presented in this session, dealing with the organisational aspects of SAM and the related training programme.

The first paper, by Dr. Fil of OKB Hidropress, dealt with the Russian organisation for emergency situations, the structure and functions of the VVER TSC within that organisation, and the training of the TSC experts and NPP personnel.

The second paper, by Mrs. Lundström of Fortum Engineering, dealt with the development and user experience of the computerised SaTu tool, to be used as a support system for radiation experts during severe accidents at the Loviisa NPP.

The third presentation, covering two papers, by Mr. Vidard of EDF, dealt with the French emergency organisation, the methods and guidelines used by the emergency teams, and the training and drills. The experience gained from two real incidents was then presented.

The presentations made clear that an efficient organisation has to be put in place in order to be able to manage crisis situations in an effective way. Operators and experts in various teams of the emergency organisation must have sufficient knowledge and skills, and this must be supported by an adequate training and drills programme. The teams should be knowledgeable not only about the plant itself and its accident management procedures, but also about the geographical characteristics and municipal infrastructure of the vicinity (e.g. to be aware of access difficulties).

It is not expected that full detailed knowledge and information is available in each and every specialised team, but an efficient communication system is essential to allow the teams to interact, share information on and understanding of the situation, in order to find the best way to manage the situation. Experts may have difficulty ranking priorities and logic of the systems and formulating a response, or they may be unaware of specific details of the systems. It is therefore important that they are able to communicate efficiently with those who have that knowledge. The situation is more complex in countries with different types of reactors, because there is more plant specific knowledge to be mastered within the emergency organisation. The solution in Russia is to have different TSCs for the different designs and scientific organisations. In an emergency, only the relevant TSCs are activated under the central crisis centre.

In France, the utility has put in place an emergency organisation with two levels: local and national, and with two objectives: (1) give the best possible advice to the site manager, responsible for the decisions, and (2) match the needs of the local and national authorities in terms of information required to take the off-site protection measures. The EDF national emergency team includes

specialists with expertise in components, instrumentation, transient analysis, emergency procedures, containment, and radioactive releases evaluations.

The training programme of the plant operating team, of the TSC experts and of the national crisis centre experts, has to match the role of the various teams in the emergency organisation. The presentations of this session gave examples of how this can be achieved. The depth and duration of training, as well as the frequency of the drills, were briefly discussed. It is important that the teams are not trained exclusively on stylised or predetermined scenarios, but that they be prepared for the unexpected.

Drills are an indispensable component of any emergency readiness programme and lessons learned from drills must be used to improve the organisation and increase the confidence in its ability to manage crisis situations. Nevertheless, important lessons can be drawn from real situation as was shown from the French examples. One example was the difficulty to reach the site in very adverse weather conditions. It was noted that preoccupation with plant sequences during drills can miss conventional problems of communication, transportation and civil systems in real emergencies. Also communication with the media cannot be overlooked. Trying to reassure the surrounding populations is not enough: there is a need for factual information. EDF concluded that communication in case of emergency should be handled by professionals both at the local and national levels.

Finally, it was noted that the operating team can be overloaded with information coming from the process, not necessarily relevant to the situation. The teams must be trained to look for the information they need. Tools can also be prepared to help them make sense of potentially confusing information, as was shown from the Finnish presentation. Training in the use of such tools must of course be provided.



*Session 5***INSTRUMENTATION CAPABILITIES****Chair: Grant Koroll (AECL)****Co-chair: Rafael Martinez-Fanegas (TECNATOM)**

Session 5 comprised two papers. An invited paper on “Instrumentation Needs and Capabilities for SAM” by B. De Boeck provided a technical and historical overview of instrumentation needs and capabilities from the perspective of CSNI activities over the last ten years. The main conclusion of past CSNI workshops were reviewed and the current controversies were elucidated. The second paper, “instrumentation for SAM in Olkiluoto 1 and 2” presented by H. Sjövall (TVO), showed the application of new instrumentation for SAM in a Finnish BWR plant with long operation history inside the Olkiluoto modernization project.

There was general agreement that instrumentation for SAM should be as simple and straightforward as possible, due to limitations on power availability under severe accident conditions and ability of operators to assimilate and use information. Some SAMGs rely on adaptation of existing Design Basis instrumentation to meet SAM needs. Other SAMGs introduce new instrumentation for SAM needs for particular plants. There is a conflicting view in the industry that certain aspects of the plant condition should be monitored, irrespective of whether the information is used in SAM.

There is an Equipment Qualification issue in the use of design Basis Accident instrumentation for SAM: operating margins must be carefully considered and may require additional Equipment Qualification tests to verify needed operating range, particularly for temperature and mission time.

It was noted that some measured quantities became invalid under Severe Accident conditions due to changes in the physics of the situation (i.e. oxygen limitation for air-breathing hydrogen detection systems). These points were revisited in the panel discussion. The U.S. utility view was that instrumentation is very expensive and of limited value in SAM. The German opinion was that certain information (such as containment pressure) is essential for SAM. The Finnish utility view was that it is necessary to monitor the plant condition.

The question was raised about the value of new techniques such as neural networks or fuzzy logic as operator aids for SAM. The prevailing view was that such systems are not mature nor sufficiently simple at this time and are topics for research. Discussions of the second paper were related to clarification of features of the implemented systems and additional details. In particular, there was interest whether the monitoring system implemented at Olkiluoto could have application in new plants. Also, the lower drywell effectiveness was noted with respect to fragmentation of molten core. Recriticality was discussed in context of adequacy of instrumentation to detect it.



## **ORGANISING COMMITTEE**

<b>Michel Vidard</b>	(EDF/SEPTEN, France) - Chairman
<b>Benoît De Boeck</b>	(AVN, Belgium)
<b>Salih Gütay</b>	(PSI, Switzerland)
<b>Grant W. Koroll</b>	(AECL, Canada)
<b>Petra Lundström</b>	(Fortum Engineering, Finland)
<b>Claude Manuel</b>	(IPSN, France)
<b>Rafael Martinez Fanegas</b>	(TECNATOM, Spain)
<b>Jürgen Rohde</b>	(GRS, Germany)
<b>Jacques Royen</b>	(OECD/NEA) - Secretary