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SUMMARY AND CONCLUSIONS

SPECIALIST MEETING ON SEVERE ACCIDENT MANAGEMENT IMPLEMENTATION

Organised by

OECD NUCLEAR ENERGY AGENCY

in collaboration with

NORTHEAST UTILITIES

Niantic, Connecticut, USA
12-14 June 1995

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OECD

The Convention establishing the Organisation for Economic Co-operation and Development (OECD) was signed on 14th December 1960.

Pursuant to Article 1 of the Convention, the 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 current Signatories of the Convention are Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NEA

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, Republic of Korea, Mexico and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

NEA works in close collaboration with the International Atomic Energy Agency (IAEA), with which it has concluded 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 coordinate the activities of the OECD Nuclear Energy Agency 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, and develop improvements and reach consensus on technical issues;
- to promote coordination of work, including the establishment of joint undertakings.

FOREWORD

The CSNI Specialist Meeting on Severe Accident Management Implementation held in Niantic, Connecticut, USA In June 1995 was organised by the Senior Group of Experts on Severe Accident Management (SESAM) in collaboration with Northeast Utilities.

The Summary and Conclusions of the Specialist Meeting are attached. The Session Summaries were prepared by the Session Chairmen, the Conclusions by the Programme Committee of the Specialist Meeting (a list of members is given in an Appendix). Subsequently they were discussed and endorsed by SESAM. Comments sent by the participants in the meeting have also been incorporated.

SUMMARY AND CONCLUSIONS

OECD SPECIALIST MEETING ON SEVERE ACCIDENT MANAGEMENT IMPLEMENTATION

The OECD Specialist Meeting on Severe Accident Management (SAM) Implementation was held in Niantic, Connecticut, U.S.A., June 12 - 14, 1995. It was hosted by Northeast Utilities at the Training Simulator Building located at the Millstone Nuclear Station. About sixty experts from fourteen OECD Member countries attended the meeting, as well as experts from Lithuania, Russia and Slovenia. Thirty-three papers were presented in three sessions.

The purpose of this meeting was to bring together experts involved in the implementation of severe accident management. These experts came from research organisations, regulatory authorities, vendors and utilities. It is worthwhile to note that about one-half of the participants represented utilities. The meeting had, therefore, a very practical and concrete tone. Information was shared and discussed on the knowledge needed and the problems encountered during the implementation phase of all the provisions necessary to successfully manage severe accidents: guidelines, hardware modifications, training and organisational aspects.

The meeting enabled the Senior Group of Experts on Severe Accident Management (SESAM) of OECD's Nuclear Energy Agency to gather information needed to complete a report for the Committee on the Safety of Nuclear Installations (CSNI) documenting severe accident management implementation in OECD countries.

This is the second and final report on SAM programmes in OECD countries that SESAM prepares for CSNI. The first was published in 1992, and focused on the development of SAM programmes in OECD countries. A Specialist Meeting on SAM Programme Development was held in Rome, Italy in September of 1991 to help gather information SESAM needed to write the first report. Since significant progress towards SAM programme implementation had been noted in all OECD Member countries since 1991, CSNI requested SESAM to produce a second and final report documenting SAM programme implementation in Member countries.

The Niantic Specialist Meeting was structured around three main themes, one for each session of the meeting.

During the first session, papers from regulators, research groups, designers/owners' groups and some utilities discussed the critical decisions in SAM, how these decisions were addressed and implemented in generic SAM guidelines, what equipment and instrumentation was used, what are the differences in national approaches, etc.

During the second session, papers were presented by utility specialists that described approaches chosen for specific implementation of the generic guidelines, the difficulties encountered in the implementation process and the perceived likelihood of success of their SAM programme in dealing with severe accidents.

The third and final session was dedicated to discussing what are the remaining uncertainties and open questions in SAM. Experts from several OECD countries presented significant perspectives on remaining open issues.

SAM GUIDELINES IMPLEMENTATION AND MAINTENANCE

There was general consensus that major progress toward SAM guidelines implementation has been made. Extensive efforts have gone into developing comprehensive and robust guidelines that have been, or are being used, for the development of plant specific SAM guidelines or procedures. These are valuable tools that the utilities should implement as soon as practical.

There was general recognition that although sufficient information is available to allow SAM implementation to proceed, all issues are not closed yet, and new information will become available that may affect the content of the current guidelines. Utilities should be encouraged to maintain and enhance the effectiveness of their SAM programme by performing periodic reviews and updates to incorporate significant new information. These periodic updates should not require extensive effort, because all new information can be screened to assess if it has an impact on existing guidelines. It was suggested by some participants that the industry should explore means of performing such screening at the Owners' Group or research facility level for all plants.

A concluding perspective presented at the Specialist Meeting was the need of feedback from implementation to research. This is because translation of phenomena insights into SAM guidelines has been a complex process, and it is not always clear that all strategies can be implemented, or that implemented strategies can be effective.

REMAINING UNCERTAINTIES IN SAM

In summary, there was general agreement that much progress has been made, but some uncertainties still remain and some additional work needs to be done.

There was no general agreement on the extent of uncertainties still remaining to be addressed. Expert opinions ranged from a perspective that the only remaining uncertainties which may impact SAM measures had to do with in-vessel and ex-vessel debris coolability, to other perspectives that included, among remaining significant uncertainties, other issues or phenomena, such as long-term containment pressurization, possible re-criticality of corium debris, coolability of pressure vessel, corium-steel mixing and its impact on reactor pressure vessel integrity.

In part, this variation of opinions is due to the varying degree of knowledge that individual SAM programmes require to support SAM actions. Since SAM dedicated equipment and actions vary from plant to plant and among national programmes, a varying degree of knowledge of possible phenomena is required to support SAM decisions; thus, varying perspectives exist on remaining uncertainties.

There was a general recognition of four significant issues regarding uncertainties:

1) Disagreement regarding remaining uncertainties is probably much less than it appears on the surface, if the stated uncertainty is complemented by answering the question: "Will further knowledge to reduce this uncertainty change the currently recommended operator action?" For example, all participants agreed that "water is good": in absence of further information, water should be fed in all cases to a molten core. There is also general agreement that there are uncertainties regarding the effectiveness and possible downsides of such action in some situations. Some experts believe that some degree of uncertainty will always remain, such that further work to reduce this uncertainty will not change the recommended operator action to add water: therefore, they consider this issue significantly closed. Others believe that additional work can and should be done, that could refine or modify the recommended operator action to add water in some situations.

2) Some uncertainties, even large, will always exist in SAM. Regarding further work to be done to reduce such uncertainties, the question must be asked: "will it change the currently recommended operator action?" This operator action should be one of the focuses of such research.

3) Meanwhile, operators should be provided SAM guidelines that are direct and support the action that they need to take, even if there are possible negative outcomes of that action. SAM training should recognize the downsides of the action, so that the operators are aware of the potential negative consequences, but guidelines should reinforce the action to be taken.

4) One of the focuses of continuing severe accident R&D relates to the information required to optimize proposed ALWR design features, rather than being essential for SAM decision making.

DIFFERENCES IN SAM PHILOSOPHY OF NATIONAL APPROACHES

At the national level, due to differences in approaches to economic issues and societal risks, practical implementation has been made in a wide variety of regulatory contexts and technical options. From a regulatory standpoint, situations range from voluntary actions made on the basis of agreements between the utilities and the regulatory bodies, to the imposition of requirements that severe accidents safety goals be met together with release limits. This varied range of situations has resulted in significant differences in the amount of hardware modifications included into the SAM programmes in different countries. These differences in hardware dedicated to the management of severe accidents also influence the perceived need for further work to address uncertainties in areas where additional information is needed to operate such equipment.

However, it was recognized that when design and operation of existing plants provide adequate protection of public health and safety, enhancements to address SAM must be balanced with costs and the need to maintain the economic viability of the nuclear option.

ORGANISATIONAL ISSUES

The issue of organisational efficiency in case of complex malfunctions or severe accidents was also dealt with and there was consensus on the following:

- Responsibilities and the chain of command must be clearly defined and known to all staff.
- The added complexity resulting from AM guidelines will require training, periodic exercises and monitoring to assure effectiveness of the Emergency Plan.
- Possible drawbacks or deficiencies which could appear during such exercises need to be analyzed and corrected accordingly.

Differences were observed among national programmes, generic guidelines and specific utilities in the assignment of responsibilities for SAM guidelines implementation during SAM. The differences relate to the respective roles and responsibilities of control room and technical support staff in their shared effort to manage Severe Accidents. However, in general, the responsibility for all actions taken at the plant remains with plant personnel.

CONCLUSIONS

1) The meeting was very successful and achieved its intended purposes. Major progress toward SAM guidelines implementation has been made in recent years. The SESAM group gathered valuable information for its report to CSNI. A clear picture of the state of implementation was obtained, and the reasons behind the differences were made clear.

2) Open issues and remaining uncertainties were identified. However, they are not of such importance as to impede implementation. In addressing these remaining issues, their impact on the SAM guidelines has to be taken into account.

3) The translation of phenomena insights into SAM guidelines has been a complex process. It is not clear that all strategies can be implemented, nor that implemented strategies can be always effective. New questions might arise during the implementation process. Therefore, there should be a feedback process from implementation to research.

4) Low power and shutdown states were not covered in detail during the meeting. Severe accidents during these states have specific characteristics and pose specific challenges. Clear picture of how this could impact SAM strategies was not provided in the meeting. Further work on this topic is recommended.

SESSION I

APPROACHES TO SEVERE ACCIDENT MANAGEMENT PROGRAMME DEVELOPMENT

The session consisted of thirteen papers from seven countries and concentrated on the development of severe accident management (SAM) strategies and resulting generic guidelines and their bases.

A definition of SAM was provided early in the session and repeatedly referred to during the meeting, showing a general consensus of all participants with this definition:

> "SAM consists of those actions that are taken by the plant staff during the course of an accident to:
>
> - o Prevent core damage
> - o Terminate progress of core damage and retain the core within the vessel
> - o Maintain containment integrity
> - o Minimize offsite releases
>
> SAM also involves pre-planning and preparatory measures for:
>
> - o SAM guidance and procedures
> - o Equipment modifications to facilitate procedure implementation
> - o Severe accident training
>
> The overall objective is to further reduce the risks of large releases. It is the responsibility of the licensees to develop and implement a SAM programme."

This definition includes the concept that there is some overlap between what is referred to as Accident Management (AM) and Severe Accident Management (SAM).

From the presentations provided during this session, it is apparent that the development of SAM programmes in different countries is highly influenced by the general expectations set at the national level for such programmes.

In some countries, risk reduction through SAM programmes is pursued by simply applying existing equipment and instrumentation when developing SAM guidelines and procedures. Minor equipment modifications for SAM are made whenever they are cost-effective in facilitating the plant staff to apply procedures. Major plant modifications have been implemented over the past several years but were generally focused on prevention of core damage, rather than management of a damaged core in vessel or in containment. In other countries instead, SAM is considered a basis of design by requiring that certain severe accident safety goals and release limits have to be met. This approach can lead to major plant modifications that are needed for ensuring a SAM safety goal.

Some other countries have chosen to combine features of both of these approaches.

Development of SAM guidelines and procedures differ from country to country depending on the number and diversity of Nuclear Power Plants and on the number of utilities.

In the U.S.A., the technical basis for SAM guidelines and procedures was developed by EPRI. The Owners' Groups used the EPRI work to develop generic SAM guidelines for different plant types. The Severe Accident Issue Closure Guidelines issued by NEI provides an approach to bring closure to SAM issues with an industry initiative. As a final step , the utilities have started to prepare the plant-specific procedures and guidance based on these documents. The approach taken in implementing SAM procedures and guidance will be licensee-specific according to different plant design features, technical support and operational capabilities of the utilities.

In Japan, MITI, in July 1992, strongly encouraged the utilities to develop SAM strategies based on the Japan Nuclear Safety Commission's statement. Utilities submitted their action plan in March, 1994 for review.

In France, EdF has developed its SAM approach in close cooperation with safety authorities and Framatome by optimum use of existing systems, implementing a number of modifications on plant and implementing specific procedures.

In Canada, Ontario Hydro is in the early stages of developing SAM guidelines for its CANDU plants.

In Germany, the licensees have agreed to implement SAM measures on a voluntary basis after recommendation of RSK in 1986. The SAM procedures and guidance cope mainly with the beyond design basis range, and are an extension of safety-function-oriented procedures.

In Sweden, the SAM implementation was completed in 1988 for all plants. Since that time, the efforts of the Swedish Industry have concentrated on maintaining and upgrading their SAM capability.

In Korea, KAERI has started to develop a research programme to resolve plant-specific SAM issues.

In the Netherlands, the licensees have been requested to re-baseline and backfit their plants to modern safety standards. As part of this process, also SAM hardware will be added; SAM procedures will then be developed and integrated with the symptom based procedures already in place.

SESSION II

SEVERE ACCIDENT MANAGEMENT IMPLEMENTATION

The session consisted of fifteen papers from nine countries and clearly illustrated that great progress has been made since the Rome meeting (1991). There were many common elements in the strategies, and, in general, the overall objective was the same: to build upon the strengths of existing emergency arrangements. There were also differences in the strategies adopted and in the way they were implemented, which were largely the result of plant design differences and differences in national regulatory or operational arrangements.

The presentations came from countries at different stages of implementation ranging from Sweden, who had achieved full implementation in 1988, to the U.S.A. and Japan, who have developed generic guidance and are programmed to complete implementation towards the end of the 1990;s. The papers, therefore, provided feedback or experience from each phase of implementation. The common themes of the papers are summarized below:

(i) Development of Guidance and Procedures

In the development of their accident management guidance and procedures, most utilities are making use of the insights gained from PSAs/IPEs to focus efforts. Though useful, this is not an essential element of a programme; for instance, Sweden and France started developing their original procedures before the availability of a plant specific PSA. The development of severe accident management has been a voluntary effort by the utilities in most countries, with the support and encouragement of their regulatory authorities. In the Scandinavian countries, quantitative regulatory targets have been specified.

In most cases, accident management has been applied to already operating plants and so must build on and be consistent with existing operating procedures. Examples were presented of cases where accident management was considered in the design conception phase (VVER 91), in the detailed design stage (Sizewell B), and during construction (GKN II).

There was general agreement that severe accident management procedures should avoid the need for changes to existing procedures. They should try to avoid contradictions with such procedures since this could introduce confusion into the decision making process. If it is necessary to take actions which are inconsistent with normal practices, the instructions need to be clear and simple. Over-sophisticated procedures should be avoided.

The papers indicated a widespread use of Critical Safety Functions, symptom-based approaches in guidance and procedures.

(ii) Severe Accident Management Measures

There were differences in emphasis in the approaches adopted to the provision of measures aimed at severe accident mitigation. Everyone seems to make full use of existing equipment but some utilities have also implemented hardware changes. On existing plants, many backfits and improvements have been made to enhance preventive measures. On new plants, such measures form part of the base design. For additional accident management provisions, the need for cost effectiveness was emphasized.

The measures implemented for which there was a measure of agreement in terms of basic objectives are:

- the addition of water for core/debris cooling.
- cooling the containment.
- provision of back-up power supplies.

There was more diversity in terms of the means to achieve the objectives. For instance, water injection can be achieved by the use of ECCS, fire water systems or mobile equipment. The containment can be cooled by sprays, containment coolers, external sprays (for steel containments) or even by venting. Containment coolers can be cooled by any source of water or ultimate heat sinks. Backup power supplies can be provided by additional diesels (fixed or mobile) or by connection to other offsite power sources. To make maximum use of existing equipment, the means to override interlocks has been provided in some cases.

Areas where there are still differences in approach include hydrogen control (for large dry containments) and the use of filtered venting.

(iii) Organisational Implementation and Training

Severe accident management measures must be implemented in the framework of the existing emergency organisation and build on this foundation. The need to involve and make use of additional technical support staff is recognized but there were apparent differences in the roles and responsibilities with respect to Severe Accident Management Guidance in different utilities. The plant knowledge and experience of the Control Room Operators was generally recognized but many utilities favor transferring to, or sharing with the TSC or crisis team, responsibility for decision making for SAMGs, so as not to overburden the operator. Although specific SAMG documentation is provided to TSC and Crisis Team staff, control remains within the plant. In general, the emergency organisation works as part of a team with ultimate responsibility resting with the utility emergency organisation. In Canada, the decision to vent rests with the Provincial Authorities. In papers from countries such as France who have experience of exercises using their accident management procedures, the role of good teamwork and communications between the teams involved was emphasized. Some changes to the structure of the emergency organisation had taken place as a result of this to better integrate the safety engineer with the operational team and to avoid the crisis teams taking over on-site responsibilities.

Many of the apparent differences appeared to be associated with differences of approach as far as external emergency arrangements and regulations were concerned.

The need to train people at all levels in SAMG, including basic knowledge of physical phenomena, was recognized though concern about the burden this may place on operators was expressed. In general, it was felt that all those involved should understand why actions were being taken.

The use of drills and exercises had proved valuable for those utilities that had already implemented their SAMGs and those in the process of implementation instead to use these as an integral part of the update/refinement process as well as for training purposes. The need to make the SAMGs "living documents" and to update them was generally agreed.

SESSION III

UNCERTAINTIES AND OPEN ISSUES

In this session, six presentations were given, concentrating on remaining uncertainties in severe accident phenomenology and trying to give a picture of the resolution status with respect to accident management decision making. Furthermore, unresolved issues, particularly in the area of the phenomenological behavior that can introduce uncertainties into some of the decisions, were discussed to better understand potential side effects of implementing some of the accident management strategies.

For the Swedish and Finnish approaches, the consistency and completeness of accident management measures together with important issues remaining were presented and discussed. One specific paper dealt with investigations on how to design adequate computerized tools and information systems for assistance in accident management.

There was a general understanding that uncertainties in severe accident phenomenology will always remain, but that the knowledge base exists and has been used to develop plant specific solutions. It is important to note that the sources of uncertainties can be identified and have to be taken into account when developing specific severe accident measures. In cases where these uncertainties remain unacceptably high, so that the effectiveness of a specific measure becomes questionable or the measure could lead to serious adverse effects, an alternate strategy should be considered when possible and decisions made accordingly.

The basic approach to develop a plant specific SAM concept requires deterministic investigation. Sources of uncertainties could be the:

- experimental data base for specific severe accident phenomena
- application of experimental results for real plant conditions
- physical and mathematical modeling techniques in computer codes
- limited experience of the code user in modeling technical systems
- measured parameters that could be affected by accident conditions

But also the use of PSA - work to support the development of a SAM concept contains sources of uncertainties. All such potential sources of uncertainties have to be carefully investigated, to see clearly the influence on the accident management concept being developed.

One main point of discussion concentrated on strategies to keep molten core material inside the reactor pressure vessel by late phase water injection or early cavity flooding for cooling the vessel outside. Additional research work seems to be necessary to understand and realize the different heat transfer modes involved and the mechanism creating a gap between reactor pressure vessel bottom head and lower crust of the molten pool, providing the space for water ingression. If such strategies to prevent vessel breach could be demonstrated to be effective for different reactor designs, there was a general consensus that this will drastically reduce the importance of several uncertainties, especially for those phenomena dominating the ex-vessel melt behavior. As an example, flooding the PWR reactor cavity to cool molten materials on the containment floor is the only available strategy capable of preventing basemat meltthrough, but large uncertainties still exist on how successful this strategy may be.

Specific SAM guidelines also have to deal with the possibility of unreliable instrumentation under severe accident conditions. Also, the influence of aging effects has to be taken into consideration, e.g. catalytic recombiners where periodical testing of the effectiveness is required.

Current SAM procedures include a number of critical decisions, including depressurization of secondary and primary side, addition of water to dry steam generators or to a degraded core, venting of containment, flooding the cavity and burning hydrogen. The SAM guidelines recognize that these decisions may also have detrimental effects. Both the positive and negative consequences of these SAM actions are weighed to determine whether an action, on the whole, will be beneficial to the plant. These critical decisions are implemented into procedures in such a way that no unnecessary confusion is caused among the plant staff taking SAM actions during an accident. The task of the Severe Accident research programmes carried out by research organisations, regulatory support organisations, vendors, and utilities is to reduce the uncertainties associated with these critical decisions.

What are the remaining issues? For some planned actions or strategies, additional research seems to be needed to further decrease existing uncertainties and to get the required knowledge base to develop more natural and optimized strategies.

Examples are:

- extent of hydrogen generation during reflood of a partly damaged core
- conditions for recriticality of a partly control rod free core during reflood
- heat transfer mechanism to cool molten core materials in the reactor pressure vessel

The different presentations pointed out some open issues which are still in the phase of study in different OECD Member countries, including:

- distribution and effectiveness of local boron injection under natural convection conditions inside the primary system
- implementation of hydrogen mitigation measures in large dry containment (OECD-Specialist Meeting on this topic, planned for May, 1996)
- coolability of molten core materials in the reactor pressure vessel and the cavity
- water level detection in the RPV
- vessel failure criteria and detection
- saving of ECCS equipment and water inventory
- long term SAM planning

It was also pointed out during the conference that, up to now, mainly accidents starting from full power operation have been addressed in the development of SAM procedures. Several attendees expressed the belief that future work should include shut-down conditions.

In summary, there was a general consensus among the participants that uncertainties remain and always will, but that additional research efforts should focus on reducing areas of large uncertainties affecting specific SAM decisions.

ANNEX

MEMBERS OF THE PROGRAMME COMMITTEE AND/OR SESSION CHAIRMEN

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