INTRODUCTION TO SEVERE ACCIDENTS AND THEIR MANAGEMENT
THE ROLE OF SEVERE ACCIDENT RESEARCH

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DEFINITIONS (1/3)

Design Basis Accident (DBA): **Essentially a design tool to help make engineering judgment on safety margins for component parts and systems of a nuclear plant; the design basis (DB) includes specifications of challenging events, important assumptions, and in some cases particular methods of analysis.**

Severe Accident (SA): **Exceeds the DB sufficiently to cause failure of structures, materials, systems, etc. without which core cooling cannot be properly assured by normal means.**

DEFINITIONS (2/3)

Accident Prevention: **All measures taken to prevent severe core damage.**

Mitigation: **All measures taken to limit radiological consequences of an accident.**

Accident Management (AM): **Totality of measures (short- and long-term) taken by plant staff to prevent accidents, control the course of an accident in progress, and mitigate consequences.**

DEFINITIONS (3/3)

Severe Accident Management (SAM): **Actions taken by plant staff during the course of an accident to prevent core damage, terminate progress of core damage and retain the core within the vessel, maintain containment integrity, and minimize off-site releases. Also involves pre-planning and preparatory measures for SAM guidance and procedures, equipment modifications to facilitate procedure implementation, and SA training.**

This definition implies overlap between AM and SAM. There is significant variation among countries as to what should be classified as SAM.

ORIGIN OF CURRENT POSITIONS ON SEVERE ACCIDENTS (1/2)

Before TMI-2: Class 9 Accidents

- **WASH-1270 document (August 1976)**
- **8 classes of accidents within design basis; beyond DB: Class 9 accidents**
- **Recognition that SA sequences are part of residual risk (residuum of conceivable very low probability accident sequences that could lead to radiological consequences in excess of 10 CFR Part 100 guidelines), and that it is not necessary, nor even possible, to design NPPs for all conceivable eventualities that are physically possible**

ORIGIN OF CURRENT POSITIONS ON SEVERE ACCIDENTS (2/2)

After TMI-2 (28 March 1979): Severe Accidents

- **Strong impetus to severe accident studies**
- **Danger of developing divergent approaches; in 1980, creation of restricted Senior Group of Experts on Severe Accidents (SGESA), under OECD/NEA**
- **SGESA replaced in 1989 by restricted Senior Group of Experts on Severe Accident Management (SESAM); SESAM included representatives from American, European and Japanese utilities.**

SGESA and SESAM played major role in shaping international consensus on the approach to dealing with SA, in cooperation with EC and IAEA - EC played increasingly important role in SA research

DEALING WITH SEVERE ACCIDENTS IN EXISTING PLANTS (1/3)

Ultimate objective of SAM: bring installation back to controlled, safe and stable state that can be maintained in the long term

Prevention is top priority; should it fail, make best use of capabilities and resilience of the plant as designed

Consensus that

- **designs of existing water-cooled reactors are very capable of coping with SA (ample margins, defence in depth)**
- **AM of highest importance, at all stages of accident development, from initiation to long-term control**

DEALING WITH SEVERE ACCIDENTS IN EXISTING PLANTS (2/3)

Highest priority to be given to improving ability of plant personnel to monitor, diagnose and influence from earliest stages the course of a SA

Operator training programmes must take into account diagnosis and management beyond normal operating transients and incidents, from earliest precursors to long-term considerations

DEALING WITH SEVERE ACCIDENTS IN EXISTING PLANTS (3/3)

Establish pervasive safety culture at all levels – large task !

Routine and complacency are formidable obstacles – SA will strike with deceit, through improbable combinations of hardware or maintenance failures, human misinterpretations and errors

Staff must be vigilant and on constant alert to identify SA at early stage

INTERNATIONAL SIMILARITIES AND DIFFERENCES IN SAM (1/4)

Most countries advocate use of available means at the plant to control SA; approaches are, on the whole, of similar nature, in spite of plant-specific features and differing national practices

Present understanding considered adequate for defining corrective action guidelines based on evolution of physical parameters

Two approaches: state-by-state and symptom-based; do not require operator to diagnose accident initiator but depend on continued availability of means of assessment and measurement

INTERNATIONAL SIMILARITIES AND DIFFERENCES IN SAM (2/4)

Should initial measures fail, further measures might differ considerably from one country to another (e.g., depending on whether or not a filtered containment venting system is adopted)

However, priority is always given to preserving containment integrity

Several alternatives exist for integrating AM activities into existing emergency response actions, e.g. incorporating AM into existing procedures, or providing general guidance rather than specific procedures

INTERNATIONAL SIMILARITIES AND DIFFERENCES IN SAM (3/4)

Devising procedures for AM actions means that the directions the operating staff receives are very specific and in familiar format; *drawback*: such an approach could lead to inappropriate actions if a situation occurred which was not foreseen during procedure development

Development of a guidance document might identify equipment, water supplies, and power sources needed to restore safety functions, allowing consideration of pros and cons of an action; *drawback*: this approach leads to slower response and requires availability of more independent technical expertise

INTERNATIONAL SIMILARITIES AND DIFFERENCES IN SAM (4/4)

No single method of integration likely to be best for every nuclear plant operating organisation; a combination of approaches may prove to be most effective

Essential point in any case: an overall structure which clearly delineates responsibilities and any transfer of responsibilities during the development of an accident - organisational lines of authority must have been previously established

THE ROLE OF SEVERE ACCIDENT RESEARCH (1/9)

Extraordinary progress in the understanding of SA phenomena and their management over the last 25 years

In-vessel melt progression now fairly well understood

THE ROLE OF SEVERE ACCIDENT RESEARCH (2/9)

It is likely that SA research is now progressively reaching a point where regulatory and safety decisions may not be impacted significantly by any new research results, at least for LWRs

Utilities and safety authorities have learned to deal with SA and their management on the basis of information available at a given point in time; utilities are implementing SAM strategies since several years

THE ROLE OF SEVERE ACCIDENT RESEARCH (3/9)

However, still significant uncertainties in predicting whether or not molten core material will remain in-vessel, consequences of molten core material getting out of the reactor vessel, source term generation, as well as most effective AM strategies for preserving RPV and containment integrity and reducing amount of radioactive material available for release to atmosphere

SARNET work has developed European consensus on high-priority SA issues (and on medium- and low priority issues) – See ERMSAR-2008 paper 5.1

THE ROLE OF SEVERE ACCIDENT RESEARCH (4/9)

Generally speaking, research on SA phenomenology, progression and management remains important for the following reasons:

- **to obtain understanding of phenomena occurring in accident progression that is adequate – according to current requirements – for safety assessment purposes**
- **to reduce most important uncertainties (improvements to be expected are listed on the next slide)**
- **to provide high-quality data for model development and analytical studies**

THE ROLE OF SEVERE ACCIDENT RESEARCH (5/9)

Reducing most important uncertainties will improve:

1. **development of common technical and regulatory positions and approaches to SA**
2. **prevention of SA, and their mitigation should they happen**
3. **confidence in the robustness of existing SAM strategies, or the development of more robust strategies**
4. **more generally, confidence in appropriateness and effectiveness of SAM actions**
5. **SAM training**
6. **focusing of research efforts and resources on priority issues**
7. **possibility to reduce need for unnecessarily large safety margins and thereby, possibility to concentrate on most significant safety issues while eliminating superfluous hardware and procedures and improving plant overall safety and economics**

THE ROLE OF SEVERE ACCIDENT RESEARCH (6/9)

There are differences among countries with respect to necessity, goals, scope, type and level of SA research they wish to carry out, for multiple reasons

What matters is not that all countries perform identical research programmes, but to demonstrate that similar levels of safety have been achieved

Most important: safety authorities and experts should use similar language and approaches, or otherwise justify and explain differences – international technical consensus on the main safety issues is an absolute necessity

THE ROLE OF SEVERE ACCIDENT RESEARCH (7/9)

Cost of safety research programmes also matters (wide spectrum: from a few 100 000 euros to several 10 000 000 euros) but cost is a relative factor, very small compared to

- **size of public and private investment in the nuclear industry**
- **size of economic penalty entailed by a major nuclear accident**
- **size of mass spending in day-to-day life**

One way to overcome constraints is to share the burden internationally

THE ROLE OF SEVERE ACCIDENT RESEARCH (8/9)

Whatever cost and immediate need for further research, it is necessary to maintain appropriate levels of safety research for four reasons:

- **to maintain a living safety case while contributing to establishing independence of the regulator**
- **to maintain sufficient and flexible competence and capabilities (future Generation II, III and IV issues)**
- **for the countries designing and exporting nuclear plants, to demonstrate and maintain competence and innovation, and adequate after sale service**
- **to keep attracting brilliant students and experts through challenging work**

THE ROLE OF SEVERE ACCIDENT RESEARCH (9/9)

It takes a long time to develop, or redevelop, competence in nuclear engineering and safety once it is lost or where it is non-existent: a few months to a few years to train industrial specialists, 10 to 15 years to build nuclear departments at universities and establish adequate education and research infrastructure

Networks of excellence, like SARNET, strongly supported by the EC, help to maintain and develop national and international expertise, establish international consensus and train newcomers in the field

THANK YOU FOR YOUR ATTENTION

Bibliographic references are given at the end of the written version of the paper

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