EUROPEAN EXPERT NETWORK FOR THE REDUCTION OF UNCERTAINTIES IN SEVERE ACCIDENT SAFETY ISSUES (EURSAFE)

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SUMMARY

The EURSAFE thematic network started on December 1st, 2001, and has duration two years. The main aim of the project is to establish a large consensus on the severe accident still open issues and on the needs to resolve them. First, a PIRT (Phenomena Identification and Ranking Tables) is established for each phase of a severe accident. Second, the PIRT implications and actions are determined taking into account existing and planned European facilities, codes and programmes. Third, recommendations are made for the structure of a future Networking of Excellence. Fourth, a consolidated framework for the preservation of integral severe accident data used for the assessment of computer codes performance in nuclear reactor conditions is proposed. To date, most of the work programme has been completed satisfactorily. Project information and documentation can be found on website http://asa2.jrc.it/eursafe. This paper summarises the main outcomes.

A INTRODUCTION

Important progress towards the resolution of severe accident issues has been accomplished in the 4th and 5th framework programmes by promoting discussion and work between the experts in specific domains [1-2]. At this stage, it has been found that a network regrouping all the severe accident domains, and bringing all the actors in nuclear energy to work together, was an appropriate structure to identify those areas where large uncertainties still subsist as well as integrated programmes to reduce these uncertainties.

The objective of the EURSAFE thematic network is to establish a large consensus on the Severe Accident issues where large uncertainties still subsist, and to propose a structure to address these uncertainties by appropriate R&D programmes making the best use of the European resources. It incorporates issues related to existing plants (PWR, BWR and VVER), lifetime extension of these plants, evolutionary concepts (higher burn-up and MOX fuels), and safety and efficiency of future systems.

In order to reach the objective 20 partners representing R&D governmental institutions, regulatory bodies, nuclear industry, utilities and universities from 6 EU Member States (Finland, France, Germany, Spain, Sweden, United Kingdom) plus JRC, 3 European third countries (Czech Republic, Hungary, Switzerland), and the USA were brought to work together in a network structure, which is supposed to be the embryo of a future Severe Accident Network of Excellence.

B WORK PROGRAMME

To achieve the objectives requires obtaining among all the major European actors in Nuclear Safety sufficient convergence on issues and phenomena, and on their importance in terms of safety and knowledge, such as to arrive to a consensual approach to resolve the remaining uncertainties. Establishing Phenomena Identification and Ranking Tables (PIRT) has been proved in other areas (e.g. Loss-of-coolant accidents, LOCA) to be an efficient and unbiased way to reach such a consensus [3].

A PIRT is realised here for the first time for severe accidents as an initial step towards the objective (WP2. WP1 is management of the project). It integrates all the severe accident issues from core degradation up to release of fission products in the containment, taking into account any possible counter-measures and the evolution of fuel management.

PIRT implications are then deduced taking into account existing and planned European facilities, codes and programmes (WP3). The work package includes: i) Defining R&D needs in terms of objectives and priorities; ii) Identifying the required R&D tasks in terms of experimental programmes and codes; iii) Reviewing the European facilities and codes which could be used for these tasks, taking into account the existing and planned programmes.

The following phase is proposing a conceptual organization for a possible future European Network of Excellence for Severe Accidents (WP4). The mission of this network would be to address the remaining uncertainties on the key safety issues according to the conclusions of WP3 by optimizing the use of resources available in Europe.

Having the prospective of becoming a network of excellence, it is important that the EURSAFE network address the problem of finding a possible unified data conservation system, for both already existing experimental data and those which might be produced (WP5). This task is conducted in parallel with the other WPs.

C MAIN ACHIEVEMENTS

C.1 PIRT

For realising the PIRT, a list of severe accident phenomena, classified in five groups (Ex-vessel phenomena, In-vessel phenomena, Dynamic loading, Long term loading, Fission products), was first established. The list was then used by each partner for voting 1)- on safety importance using partner's own safety analysis criteria, including level-2 PSA, and 2)- on knowledge level. Voting and ranking were established through well-defined procedures and finalised after checking their consistency during plenary sessions at PIRT meetings.

First, three safety-oriented groups of experts scrutinized the definitive list of phenomena and ranked them according to their importance for primary circuit safety, containment safety and source term. Then, the five previously mentioned phenomena-oriented groups ranked in terms of knowledge those phenomena selected as important for safety.

Practically, numerical values were assigned to the phenomena which could be either High (H=3), Medium (M=2) or Low (L=1) for Safety Importance and Known (K=1), Partly Known (PK=2) or Unknown (UK=3) for Knowledge. According to the number of H, M and L votes assigned to a phenomenon, an Importance Ratio (IR) was deduced from :

$$IR = \frac{(3n_H + 2n_M + n_L)}{(n_H + n_M + n_L)} \qquad IR \in [1,3]$$

For IR greater than 2.32, a phenomenon was flagged as highly important for safety.

The same method, applied to the knowledge votes, allowed to define, using a similar formula, a Knowledge Ratio KR. Phenomena associated with a KR greater than 2.32 present a significant lack of knowledge.

After completion of the two ranking phases, this procedure clearly emphasized the phenomena being simultaneously highly important for safety and significantly lacking of knowledge. Such phenomena are obviously candidates for further R&D work, which will be specified in the PIRT's implications work package.

Starting with 916 identified phenomena, the list was reduced to 229 important for safety, of which 106 were found lacking sufficient knowledge. The list was in turn divided into two categories: phenomena most significantly lacking knowledge (57 phenomena) and those still lacking knowledge for some aspects (49 phenomena).

A PIRT report will be made available, which details all the phases of the work, and explains in more details the criteria used for voting, ranking and establishing the lists. Besides the consensual conclusions, the report contains also the votes and comments of all partners individually in order to keep trace of technical aspects, which justify the PIRT conclusions, and to provide a reference for future updating of the PIRT.

C.2 PIRT Implications

As a further step, the research needs to address each selected phenomena of the PIRT list were identified.

First, the objectives of research and the description of programmes and codes needed (including existing capabilities) to address each selected phenomena of the PIRT list were reviewed. A list was established assigning to each selected phenomena the relative research needs and programmes.

Next, the phenomena were regrouped into a limited number of research items according to their similarities in terms of research needs/physical processes, with the scope of being able to set up a limited number of coherent R&D programmes. A rationale for these research needs was established based on safety relevance and lack of knowledge. The outcome of this process is summarised in Table 1, which gives the 21 items of needed research and relative rationales drawn from the 106 phenomena selected in the PIRT.

C.3 Proposal for a Network of Excellence

In order to optimise the use of resources available in Europe and reinforce the credibility of severe accident analyses, the remaining issues have to be addressed within an integrated structure. A proposal has been submitted to implement such a structure as a network of excellence in FP6. This network, named SARNET (Severe Accident Research Network), is a natural continuation of the EURSAFE network, and will now bring together the European organisations around a joint programme of research activities to satisfy the needs identified in EURSAFE.

The ultimate objective is to elaborate a virtual laboratory based on national resources, know-how and expertise, and having a strong coordinating structure. This laboratory will have the mission to carry out the commonly agreed research programmes in an optimised way in order to resolve the above remaining safety issues and produce highly validated and qualified tools for Level-2 PSA studies for any kind of NPPs in Europe. It should be one the major objective of the Network to re-orientate progressively the existing national programmes and contribute to launch new ones in a coordinated way and in accordance with the research priorities identified by the Network, eliminating duplications and developing complementarities.

It will be necessary to integrate the current knowledge and all the future knowledge generated by the research activities performed within the network in a unique severe accident code. Most of the ongoing research activities will have the ultimate objective to provide this code with appropriate physical modelling. In addition, the tool will be adapted, through mostly co-operative actions, so as to be used for any reactor applications in

Europe.

Integration of the experimental research capacities will be more progressive, to account for the need to raise funding at national and extra-national levels in order to support the cost of the experimental programmes, notably in case of large ones. Nevertheless, most of the ongoing national experimental research programmes should be proposed as part of the network in view of providing the critical mass of competence needed to resolve the remaining issues as identified in EURSAFE. A clear policy in terms of access rights to experimental data produced within the network is proposed to preserve the interests of the different organizations. Progress reports on restricted experimental programmes will be widely disseminated in order to promote extension of existing collaborations within other members of the Network.

To be sure that the research is efficient and well focused, the PIRT exercise will have to be regularly updated. In parallel, actions will be taken for training students and researchers in experimental techniques, in risk evaluation and in code development, and for facilitating their mobility into the corresponding teams.

Advanced communication links and user-friendly databases will be developed to facilitate the capitalization and the diffusion of knowledge, and the joint execution of the programme of research activities together with reducing rapidly the number of meetings and amount of travel: e-learning, on-line assistance to code users, access to experimental databases and thermodynamic databases, work flow between co-developers, co-development and management of technical documentation, multi-site videoconference, etc… Actions will be taken to normalize and secure the scientific and technical information produced by the Network.

C.4 Proposal for a Data Conservation Structure

This task includes: i) Assessing current practices for the preservation and maintenance of severe accident data; ii) Identifying data access requirements by code developers and users; iii) Formulating guidelines for the preservation of and access to the data; iv) Designing a platform for the preservation of the data.

It is proposed to use advanced hardware and software computer technologies (e.g., web-based techniques) to ensure a distributed repository of the data (presently stored in variety of forms and format, e.g., paper support, tapes, CD, magnetic media), taking into account data access and retrieval requirements for code development and assessment. This allows also storage and retrieval of supporting information such as data reports, data analysis reports, test facility drawings, pictures and/or video film. A the same time it is necessary that participating organisations can establish themselves independently each other the level of access to their own information preserving possible copyright prerogatives.

In the frame of EURSAFE this activity was essentially developed for demonstration purpose and thus limited to five EURSAFE partners (CEA, FZK, IRSN, JRC, RIT,). It is envisaged to be extended to all severe accident data in the frame of the SARNET Network of Excellence. The basis is the STRESA structure developed by JRC [4]. The final product, named EURSAFE, is a network connecting five different STRESA nodes located at each partner site. Each partner manages the access level to the data stored on his node.

A preliminary version of the EURSAFE website is available at http://asa2.jrc.it/eursafe. The site is still in construction. It is composed of a number of facilities organized by thematic arguments (FCI, spreading, Vessel behaviour, etc.). At present, it contains data from selected tests of the PLINIUS, PHEBUS, DISCO, FOREVER,

MISTEE, PREMIX, QUEOS, ECO, POMECO, KJET, FARO and KROTOS programmes.

D DISSEMINATION AND EXPLOITATION OF THE RESULTS

All the major European actors in Nuclear Safety worked together in the project, whatever they are R&D organisations, utilities, regulatory bodies, industries, universities. Non-European entities like US-NRC were also participating. This large spectrum of participating organizations gives the outcome of the project an extended added value. It naturally ensures a large diffusion of the results.

The results gained in the frame of EURSAFE will mainly be also disseminated through

- International workshops;
- Communications at international conferences.

Most importantly, the results will be exploited through the SARNET network of excellence, which will be started in FP6. It will address the needs identified in EURSAFE by implementing and performing the required research programmes, which will ensure the best rationalization of work and use of resources according to the structure detailed in section C.4.

E CONCLUSIONS

EURSAFE thematic network has demonstrated that the major European actors in nuclear safety representing a large spectrum of different economic and safety interests, could reach a common agreement on severe accident issues and phenomena, on their importance in terms of safety and knowledge, on where are the remaining major uncertainties and on the necessary actions to undertake to resolve them. This of course reinforces the credibility of the conclusions on the state-of-the-art of severe accident issues.

By this diversity and close collaboration, all the pending uncertainties on severe accident issues could be identified and ranked according to commonly established and unified rules. The PIRT results represents a major outcome of the project in this respect.

EURSAFE was the starting point towards an extended harmonized effort in developing and securing the existing data for the mitigation of severe accidents. The natural continuation of this effort will be the SARNET Network of Excellence proposed in FP6 to implement and perform the required research programmes and integrated actions to resolve the remaining severe accident issues.

REFERENCES

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[3] Phenomena Identification and Ranking Tables (PIRT's) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel, NUREG/CR-6744, LA-UR-00-5079.

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Table 1: Items for still needed research in Severe Accidents as deduced from the PIRT

No	Items for needed Research	Rationale for selection
1,1	Hydrogen generation during reflood or melt relocation into water (melt water interaction)	Rapid generation of hydrogen which may not be accommodated by re-combiners and the risk of early containment failure. Improve knowledge about the magnitude of hydrogen generation.
1,3	Core coolability during reflood	Termination of the accident by re-flooding of the core while maintaining RCS integrity. Increase predictability of core cooling during re-flood.
1,4	Corium coolability in lower head and external corium catcher device	Improve predictability of the thermal loading on RPV lower head or corium catcher devices to maintain their integrity.
1,5	External vessel cooling and Integrity of RPV	Improve data base for critical heat flux and external cooling conditions to evaluate and design AM strategies of external vessel cooling for in-vessel melt retention.
1,6	Integrity of RCS	Improve predictability of heat distribution in the RCS to quantify the risk of RCS failure and possible containment bypass.
1,7	Corium release following vessel failure	Improve predictability of mode and location of RPV failure to characterise the corium release into the containment.
2,2	MCCI: molten pool configuration and concrete ablation	Improve predictability of axial versus radial ablation up to late phase MCCI to determine basemat failure time and loss of containment integrity.
2,3	Ex-Vessel corium coolability, top flooding	Increase the knowledge of cooling mechanisms by top flooding the corium pool to demonstrate termination of accident progression and maintenance of containment integrity.
2,4	Ex-Vessel corium catcher: corium ceramics interaction and properties	Demonstrate the efficiency of specific corium catcher designs by improving the predictability of the corium interaction with corium catcher materials.
2,6	Ex-Vessel corium catcher: coolability and water bottom injection	Demonstrate the efficiency of water bottom injection to cool corium pool and its impact on containment pressurisation.
3,1	Melt relocation into water and particulate formation	Determine characteristics of jet fragmentation, debris bed formation and debris coolability towards maintenance of vessel and respectively containment integrity.
3,2	FCI incl. steam explosion: melt into water, in-vessel and ex-vessel	Increase the knowledge of parameters affecting steam explosion energetics during corium relocation into water and determine the risk of vessel or containment failure.
3,2a	FCI incl. steam explosion in stratified situation	Investigate the risk of weakened vessel failure during reflooding of a molten pool in the lower head.
3,3	Containment atmosphere mixing and hydrogen combustion / detonation	Identify the risk of early containment failure due to hydrogen accumulation leading to deflagration / detonation and to identify counter-measures.
3,4	Dynamic behaviour of containment, crack formation and leakage at penetrations	Estimate the leakage of fission products to the environment.
4,1	Direct containment heating	Increase the knowledge of parameters affecting the pressure build-up due to DCH and determine the risk of containment failure.
5,1	Oxidising environment impact on source term	Quantify the source term, in particular for Ru, under oxidation conditions / air ingress for HBU and MOX.
5,2	RCS high temperature chemistry impact on source term	Improve predictability of iodine species exiting RCS to provide the best estimate of the source into the containment.
5,3	Aerosol behaviour impact on source term	Quantify the source term for aerosol retention in the secondary side of steam generator and leakage through cracks in the containment wall as well as the source into the containment due to revolatilasation in RCS.
5,4	Containment chemistry impact on source term	Improve the predictability of iodine chemistry in the containment to reduce the uncertainty in iodine source term.
5,5	Core re-flooding impact on source term	Characterise and quantify the FP release during core re-flooding.