
EURSAFE PROJECT

The Status of The European Severe Accident PIRTs

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Abstract:

This paper intends to provide an overview of the EURSAFE PIRT's Status. In the frame of the 5th European Framework programme, EURSAFE is a two-year long concerted action started in January 2002 devoted to reactor severe accident studies. The objective of the EURSAFE project is to establish a large consensus on the severe accident issues where large uncertainties still subsist and to propose a possible Severe Accident Network of Excellence structure to address these issues through concerted and optimised research programmes. First, a PIRTs (Phenomena Identification and Ranking Tables) is established for each phase of a severe accident, from core degradation up to the release of fission products into the containment and to the environment, taking into account possible counter-measures and the evolution of fuel management. Secondly, the PIRT'S implications and actions are determined taking into account existing and planned European facilities, codes and programmes. Thirdly, recommendations are made for a joint programme to be performed by a future Network of Excellence. Fourthly, 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.

1. INTRODUCTION

A few years ago, a number of people, including IRSN staff were involved in Phenomena Identification and Ranking Tables (PIRTs) procedures organised by USNRC, see e.g. [1]. They have appreciated the interest of such a method as an efficient way both for identifying the important pending issues in the field of reactor safety and for selecting the future research programmes on a reliable basis. This is especially important for an optimal use of the resources when the overall severe accident research budget is declining. According to such an experience, IRSN established contacts in Europe and overseas, with a view to prepare a methodology similar to that of a PIRT's procedure on topics related to severe accidents, especially regarding In-vessel degradation, fission product release, transport processes and behaviour in the containment. At the same time, CEA was looking for an extension of the European group EUROCORE activities [2], devoted to core corium recovery after vessel failure of which the methods were rather comparable to the PIRT's ones.

Besides, both via national initiatives and CEE programmes [2], Europe is today a central platform for ongoing severe accident research and expertise in terms of code developments, separate effects and integral experimental programmes.

Given this common interest for severe accident issues, the existence of comparable methodologies in complementary fields of expertise and the European context, IRSN and CEA jointly decided to submit a concerted action project for the 5th European Frame-Work Programme (FP5). A preliminary version of the proposal was circulated among several organisations - utilities, research centres, safety authority supports and the EC Joint Research Centres in order to collect suggestions and to build a finalised project. This one involves nineteen organisations from ten countries, several utilities from Europe (EDF, TVO, VEIKEI), vendor (Framatome ANP), regulatory bodies and their supports (IRSN, HSE, GRS, US-NRC, CSN,) and research centres (CEA, FZK, RIT, JRC, PSI, IKE, CIEMAT, UPM, AEAT). The project was approved and funded by the 5th FP as a two-year long concerted action under the name EURSAFE.

The EURSAFE project is organised in five work packages (WP). The first one, WP1, is the coordination activities which are performed jointly by IRSN and CEA. The second package WP2 is the PIRTs itself. We will consider this point in details later on in this paper. WP3 is called -PIRT's implications. It will take place after completion of the PIRT's procedure. Its objective is to identify the needs in terms of future severe accident R&D programmes in the fields of code developments, separate effect experiments and integral tests, using as inputs the PIRT's conclusions regarding important pending issues. The fourth work package WP4 should be a proposal of an optimised arrangement of European laboratories -a network of excellence- to perform these R&D programmes taking advantage of complementary competencies in both experimental and analytical areas, including operational experimental facilities, analytical tool and manpower. Finally, the fifth work package addresses the problem of finding a possible unified data conservation system for both existing and future severe accident experimental data which would ease the exchange of information and contributes to optimise the use of the resources.

EURSAFE PIRT's work includes three different activities. The first one is to identify severe accident phenomena. The second and third ones are the Safety oriented and Phenomena oriented ranking procedures. First, experts are requested to select from the list of phenomena those they consider as important from a reactor safety point of view. Then, for each of the selected items, they have to provide an estimate of the level of available knowledge. At the end, the phenomena having both a large impact on reactor safety and a rather low level of understanding are highlighted and will be potential candidates for additional R&D efforts. These three aspects are developed below.

2 THE PHENOMENA IDENTIFICATION PROCESSES

In a kick-off meeting held in January 2002, the PIRT's coordination group decided, according to the complexity of the severe accident phenomenology, to divide the Phenomena Identification work within five domains, each of them including a specific aspect of the reactor behaviour during the reactor accident sequences. The corresponding partial lists were prepared by five independent groups of reactor physics experts.

These five phenomena-oriented groups are :

The "**In Vessel**" group which tackle with the core degradation, the core reflooding, the corium behaviour in the vessel lower head and the integrity of the primary and secondary circuits.

The "**Ex Vessel**" group is mainly devoted to the corium behaviour. It includes the phenomena related to vessel failure and the subsequent corium release, the interactions between the core molten material and the base mat concrete. In addition, the core catchers and corium ceramic interaction phenomena are also considered in this second group.

"Dynamic Loading" is the third one. It is in charge of all the physical processes which can induce a dynamic loading of the reactor pressure vessel and of the reactor building. The main processes are the steam explosion, the steam spikes production from melt material quenching and the hydrogen combustion and detonation. The dynamic behaviour of the pressure vessel, the primary circuit and the containment itself is also considered in this group.

"Long Term Loading" is a fourth group of phenomena which includes the reactor building thermo-hydraulics, the mechanical behaviour of the containment and the base-mat. The process itself of melt ejection from the vessel and its consequences in terms of containment heating, the so-called Direct Containment Heating, are also included in this group .

Finally, the fifth group is the **"Fission Product Group"** which investigates any phenomena related with fission products (FPs), actinides and structural material releases from the core. The group tackles also with the transport in the Reactor Coolant Circuit (RCS), in the containment and in the containment bypass flow paths including deposition and resuspension, retention within the equipments and complex structures. Also included in this fifth group are the ex-vessel release, for example from molten core concrete interaction (MCCI) and the aerosol behaviour in the reactor building. Finally the chemistry of iodine and other FP's is an important part of the reactor phenomenology considered by the **"Fission Product Group"** .

Each of the previous groups is managed by a board of two chair persons from different organisations, when possible, one being a specialist of reactor safety, the second one being a relevant expert of the phenomenology considered in the group. First, they were asked to prepare a preliminary list of phenomena for their group and to circulate it within the participating organisations in order to collect comments and additions. Inside each organisation, one PIRT's correspondent was in charge to gather the comments and suggestions before transferring them to the group board. Then, from collected information, chairpersons prepared the list of phenomena for their group. Finally, during a first plenary meeting of the PIRTs held in Aix-en-Provence on February 25-26th 2002, detailed discussions took place in order to reach an agreement of the participating organisations on the content of the lists, the definition of the phenomena and some specific comments. Afterwards, the group lists were finalised and declared as definitive lists to be used as input for the next steps of the PIRTs devoted to ranking. At this stage, no new phenomena can be added to the lists.

The expert selection includes 983 chemical or physical processes which are organized within the lists as follows. Each of the five group lists contains sub-lists about general items, each of them resulting in phenomena classification as a function of physical situations and issues. As an example, In-vessel phenomena are divided into four items, namely Core Degradation, Reflooding, Corium Behaviour in Lower Head and Integrity of Primary and Secondary Circuits, giving four sub-lists in which the phenomena are classified according to generic physical situations and issues. A brief description of the phenomena and possible other specific features are included in the lists (see an example in the table below) to avoid misunderstandings and ambiguity which may result from the synthetic names given to the phenomena.

LIST OF PHENOMENA FOR THE SUB GROUP 1 / IN-VESSEL SITUATION 1.1 : CORE DEGRADATION					
PHYSICAL SITUATION	ISSUE	Ref Number	PHENOMENON	PHENOMENA DESCRIPTION	SPECIFIC FEATURES
Oxidation and hydrogen production in a damaged core	Material oxidation by steam	1.1.101	Steel oxidation	Stainless steel oxidation by steam is less exothermic than Zr oxidation , and the surface area is generally much smaller than that of the cladding	The amount of steel is larger in VVER than in western PWR

The lists included also empty columns for voting on safety importance for Containment, Primary Circuit and Source Term, which are not presented in the example above.

3 RANKING PROCEDURES

Ranking is a two-phase procedure. First, three safety-oriented groups of experts scrutinize the definitive lists of phenomena being in charge to rank each of them against their importance for primary circuit safety, containment safety and source term. Then, the five previously mentioned phenomena-oriented groups will rank in terms of knowledge those phenomena selected for their safety importance.

Practically, numerical values are assigned to the phenomena which can 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) is deduced from :

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

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

The same method, applied to the knowledge votes, allows 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.

Therefore, after completion of the two ranking phases, this procedure will clearly emphasize the phenomena being simultaneously highly important for safety and significantly lacking of knowledge. Such phenomena will be obviously candidates for further R&D work which will be defined in the PIRT's implications in WP3 and WP4.

The grid to be used for safety oriented votes has been finalized during the February plenary meeting. The safety vote associated to each phenomenon is a function of two parameters : the consequences for safety and the probability of occurrence of a phenomenon. The various vote levels are provided by the following matrix.

Phenomena Probability				
HIGH	1	3	3	
MEDIUM	1	2	3	
LOW	1	2	3L	
	LOW	MEDIUM	HIGH	Phenomena Consequence

High importance for safety (vote level=3) means a phenomenon which has very important consequences for safety and has a high or medium probability of occurrence. Note that the grid includes a ranking 3L when the probability of occurrence is low. This difference can be useful for a detailed analysis of the safety-oriented votes. Nevertheless, votes 3 and 3L were considered as equivalent for selecting the phenomena according to the obligation of precautionary measures.

Medium importance for safety (vote level=2) means a phenomenon with medium safety consequence and a low or medium probability.

Low importance for safety (vote level=1) is corresponding to a phenomenon with low safety consequence whatever its probability.

Regarding the criteria for the knowledge level votes the rationale is the following.

Unknown (vote level=3) has to be applied to a phenomenon which is only partly understood. So to

say, the available models are rudimentary, their verification is insufficient due to a significant lack of experimental data. There are needs for important R&D efforts.

Partly Known (vote level=2): the phenomenon is on the whole understood. Uncertainties remain for unexplored parameter ranges or extrapolation to reactor scale. The main processes are described by adequate models but the verification is not complete due to limited number of data. There are needs for limited model development and for more verification (limited R&D efforts).

Known (vote level=1): the phenomenon is well understood. The processes are adequately modelled and well verified in general on an extended experimental basis. The phenomenon needs little or no R&D efforts.

4 THE SAFETY ORIENTED VOTES

Based on the definitive lists and the previous voting criteria, Safety oriented ranking procedure took place in two steps. First, each organisation having only one set of votes for In-vessel safety, containment safety and source term, the phenomena lists were scrutinized internally in order to reach a consensus on the three votes. The way to proceed inside each company was totally open.

Then, the ranked lists were returned to the safety oriented group boards which gathered the votes in unified lists and sent them to all the participating organisations. By this way the experts were provided with the votes in view of the Safety oriented plenary meeting in Garching on June 26-28th, 2002.

The meeting was organised into three one day sessions, each dedicated to one specific safety oriented aspect, i.e., Primary Circuit, Containment and Source Term, respectively. In order to give a sound basis to the results of the votes, it was decided to disregard any phenomena for which the number of votes was less than five whatever was the average value of the votes. It was also decided to re-examine in more details during the sessions those phenomena having a tendency to bi-modal distribution of "Low importance" and "High importance" votes. The objective was to check whether such a discrepancy between the expert statements could be reduced to a unique position through expert debates or, after technical discussions, had to be maintained, the experts standing on their positions. In this case, the bimodal ranking has to be underlined and corresponds to two quite different safety opinions which cannot be reduced without additional new pieces of information or experimental evidences which are not presently available.

Then, starting from the 983 phenomena of the definitive lists the selected items regarded as highly important for reactor safety are :

- 46 for In-Vessel Phenomena (+1 non resolved bi-modal),
- 47 for Ex-vessel Phenomena ,
- 61 for Dynamic Loading (+10 non resolved bi-modal).
- 36 for Long Term Loading,
- 28 for Fission Products (+2 non resolved bi-modal),

As the PIRTs is not completed and the phenomena oriented votes being not yet available, it is not possible, in the context of this paper, to provide now a technical analysis of the PIRT's results.

5 EURSAFE PROJECT CONTINUATION

The major next step for the PIRT's procedure is the Phenomena Oriented votes. The objective is to appreciate the level of knowledge of the phenomena ranked as highly important for safety. A method comparable to the one applied for Safety votes will be used. First, internal debates will take place inside the participating organisations to make their votes. Then, chairperson boards will release the unified lists of votes and a plenary meeting in Aix-en-Provence on November 7-8th 2002 will allow to exchange views and vote rationales, and correct the misunderstandings which could induce erroneous votes.

Then, by the beginning of 2003, the PIRT's chairman and the board members will prepare the definitive list of the phenomena having both a large impact on reactor safety and a rather low level of understanding and the associated rationales. This PIRT's document will be the input for the next EURSAFE phases.

The first of them is the *PIRT's implications (WP3) work package*. It 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 will be the *Network of Excellence structure (WP4) work package*. The objective is to propose a joint research programme for a possible future European Network of Excellence on Severe Accidents. 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.

Finally, having the prospective of becoming a network of excellence, it is found important that the EURSAFE network addresses the problem of finding a possible unified data conservation system, for both already existing experimental data and those which might be produced. The *Severe Accident Data Base structure (WP5) work package* which is prepared in parallel with the other WPs' addresses this issue. It 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.

REFERENCES

[1] 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.

[2] FISA 2001, EU research in reactor safety, Luxembourg, 12-15 November 2001, EURATOM EUR 20281.