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Conclusions on severe accident research priorities

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ABSTRACT

The objectives of the SARNET network of excellence are to define and work on common research programs in the field of severe accidents in Gen. II–III nuclear power plants and to further develop common tools and methodologies for safety assessment in this area. In order to ensure that the research conducted on severe accidents is efficient and well-focused, it is necessary to periodically evaluate and rank the priorities of research. This was done at the end of 2008 by the Severe Accident Research Priority (SARP) group at the end of the SARNET project of the 6th Framework Programme of European Commission (FP6). This group has updated this work in the FP7 SARNET2 project by accounting for the recent experimental results, the remaining safety issues as e.g. highlighted by Level 2 PSA national studies and the results of the recent ASAMPSA2 FP7 project. These evaluation activities were conducted in close relation with the work performed under the auspices of international organizations like OECD or IAEA. The Fukushima-Daiichi severe accidents, which occurred while SARNET2 was running, had some effects on the prioritization and definition of new research topics. Although significant progress has been gained and simulation models (e.g. the ASTEC integral code, jointly developed by IRSN and GRS) were improved, leading to an increased confidence in the predictive capabilities for assessing the success potential of countermeasures and/or mitigation measures, most of the selected research topics in 2008 are still of high priority. But the Fukushima-Daiichi accidents underlined that research efforts had to focus still more to improve severe accident management efficiency.

1. Introduction

Severe accidents can cause significant damage to reactor fuel resulting in more or less complete core meltdown. Although such accidents are highly unlikely in the light of the preventive measures implemented by operators they are indeed possible as recently happened at Fukushima-Daiichi I plant in Japan. Therefore, they are continuously in the focus of considerable research because of their serious consequences due to possible releases of radioactive products into the environment. This research also reflects a commitment to the defence-in-depth approach.

To be sure that the research conducted on severe accidents is efficient and focusing on relevant topics, the Severe Accident

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Research Priority (SARP) work that started already in the first SARNET FP6 project (Schwinges et al., 2008a) is being updated, evaluating the most recent experimental results and taking into account the remaining safety issues, as those highlighted by Level 2 PSA studies as being of high priority for reducing uncertainties (link between SARNET2 FP7 and the ASAMPSA2 FP7 project that ended in early 2013 (Raimond et al., 2013). These evaluation activities are being conducted in close relation with the work performed both in existing international organizations – mainly the OECD/NEA/CSNI Group on Analysis and Management of Accidents (GAMA) and the International Science and Technology Centre (ISTC) Projects – and in the Sustainable Nuclear Energy Technology Platform (SNETP), including the new NUGENIA association (see www.nugenia.org), dedicated to the research and development of Generation II–III nuclear fission technologies. NUGENIA gathers stakeholders from industry, research, safety organizations and academia, committed to develop joint R&D projects in the field.

The SARP work, led by GRS, was performed in close collaboration with 14 partners representing Technical Safety Organizations (TSO), R&D centers, universities, industry and utilities (IRSN, CEA, EDF, KIT, GRS, AREVA NP GmbH, KTH, TUS, VTT, JSI, PSI, CIEMAT, JRC and RUB). It should be further noted that the collaboration among those who perform the research and those who use its results is essential to correctly address the problem which may lead to the closure.

The work of the SARP group is originally based on the results of the EURSAFE FP5 project (Magallon et al., 2005). The objectives of the EURSAFE thematic network were 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 programs making the best use of the European and national resources. It incorporated issues related to existing European 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 EURSAFE the first Priority Identification and Ranking Table (PIRT) was realized for severe accidents as an initial step towards the objectives. It integrated all the severe accident issues from core degradation up to release of fission products (FP) from the containment, taking into account any possible counter-measures and the evolution of fuel management. Two evaluation parameters, the safety importance ratio and the knowledge ratio, were established. Starting with 1016 identified phenomena, the list was reduced to 239 items, important for safety, of which 106 were found with a significant lack of knowledge. These items have been regrouped and summarized in 21 items, the so-called EURSAFE Research Issues (ERI).

As a result of the SARP Group in SARNET FP6, thus at the end of 2008, six of these 21 issues were still considered as "high priority" ones, four issues were re-assessed with medium and five with low priority. Three issues were marked as "issue could be closed". New issues (in total seven topics have been discussed), such as combustion of hydrogen jets in the containment with pre-existing hydrogen atmosphere in conjunction with Direct Containment Heating (DCH) were identified, and the final SARP/FP6 report (Schwinges et al., 2008b) have been the basis of the follow-up SARNET2 FP7 project.

The understanding of severe accident phenomena is today quite important. This was underlined again regarding the consequence of the severe accidents in Japan. Although a considerable progress has been gained in the recent decades, it is still necessary to reduce further the uncertainties of simulation results, to investigate new phenomena not regarded in detail before and to improve further severe accident management (SAM) measures under extreme boundary conditions.

In addition, the improvement of computer codes, in particular integral codes like ASTEC, is not explicitly included in all these issues but obviously it remains a continuous and essential line of R&D.

This paper summarizes the concluding results of the work in the SARP group at the end of the SARNET2 FP7 activity.

2. Ranking of research priorities

The resulting decisions and reassessments performed in the SARP group are an attempt to reach, in a reasonable time an agreed decision considering all aspects of innovation and economic efficiency.

The ERI issues used in the previous SARP FP6 report were a collection of different severe accident phenomena. It has to be pointed out that the details and content these different issues have been changed partly and/or the safety requirements and assumed boundary conditions may have been changed. Therefore, a new numbering was set-up and issues have been sorted in a more logical order as a result of the SARP work in SARNET2.

Comparing the priority level with the original levels decided in SARNET FP6, most of the levels have not been changed or even received again higher priorities (Table 1). This could lead to the misleading impression that, during the last period, the progress in severe accident research was quite low. On the contrary, the progress on severe accident phenomenology understanding was important but during SARNET2 FP7 it was noticed that more efforts are needed to increase the knowledge necessary for a better appreciation of existing – or for the development of new – mitigation means: in- and ex-vessel corium and debris cooling, steam and hydrogen explosions mitigation, reduction of FPs releases (scrubbing, filtered containment venting systems or FCVS). The same need applied to the source term towards the external environment for all accident scenarios. Especially the new issues related to FCVS and pool scrubbing phenomena under boiling conditions underline that an improved assessment of SAM measures gets a higher relevance.

The SARP final report has formed the basis of the R&D roadmap established in 2013 in NUGENIA that will be used as a guideline for the definition of future European R&D projects.

The definition of ranking (see Table 1) includes the level of safety importance and the knowledge level, based on the consensus found in the SARP group. In addition the old ERI numbering of issues is provided in the third column of this table.

2.1. Phenomena during in-vessel accident progression

The **1,1 issue** concerns the in-vessel H_2 generation (by oxidation of metal-rich melt mixtures) during the core re-flooding accident phase in a slightly degraded core. During this phase, the hydrogen is generated rapidly and may not be totally recombined by passive autocatalytic recombiners in the containment in this short time frame. This may increase the risk of hydrogen combustion and the potential consequences of an early containment failure. This issue is of **low priority** as several validated models exist to properly evaluate the phenomenon.

In a later accident phase with highly degraded core or in case of melt relocation into water in the RPV lower head (**1,2 issue**) the prediction of hydrogen generation during in-vessel re-flooding is much more uncertain. Therefore this issue is still of **medium priority**. It has to be pointed out that the risk significance of both situations depends strongly on the considered sequence and the degraded core geometry.

The **1,3 issue** concerns the core and debris coolability (rod failure, molten pool formation, molten pool and debris cooling, crust failure) and thermal-hydraulics within particulate debris during re-flooding. This research item addresses the re-flooding of a core