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Nuclear safety research at the NEA

The nuclear community has for some time been facing changing conditions in the industry as well as in governmental organisations. These changes have had, and will continue to have, profound impacts on the access to R&D funding and on the way research is organised and financed in most NEA Member countries.

On the industry side, utilities are faced with intense competition, and in order to compete efficiently they are looking for means to improve operational economics and flexibility and to reduce costs whenever feasible. The focus of utility-sponsored research is thus narrowing towards programmes devised to demonstrate more efficient means of running the plants, i.e. programmes that can provide a tangible economic return as convincingly and as quickly as possible.

At the same time, government funding has also been decreasing in most Member countries, affecting the grants made available for experimental work in facilities and R&D centres as well as the budgets of safety research programmes that are traditionally carried out by safety organisations.

This article provides an overview of the activities being carried out under the aegis of the NEA with a view to preventing irreversible losses of infrastructure and technical competence in critical safety research. It is apparent, however, that the reduction of both industry and government funds has put great pressure on all nuclear research centres, which as a result have been experiencing reductions in personnel and scope of work throughout the last decade. While significant differences exist from one country to the next, the overall trend has been in the direction of smaller and fewer safety-related programmes, a decrease in nuclear R&D expertise, and the closure or threat of closure of many facilities.

There are indications suggesting that this trend is likely to continue in the immediate future and possibly extend to countries that have so far been relatively immune to this process. Consequently, concerns have been raised as to the ability of individual NEA Member countries to maintain critical competence and focus on important safety areas, unless practical countermeasures are put in place. International co-operation can help provide a solution and makes economic sense.

The SESAR-FAP Initiative

For the past several years, the NEA Committee on the Safety of Nuclear Installations (CSNI) has commissioned studies by senior experts in safety research (SESAR), the last of which addressed technical priorities for facilities and programmes (FAP). The outcome of this study will be presented in a report focusing on research needs and priorities in the areas of: thermal hydraulics; fuel and reactor physics; severe accidents; human factors; plant control and monitoring; integrity of components and structures; and seismic behaviour of structures.

It emerges that in some areas specific follow-up is not needed at this time, either because sufficient infrastructure and programmes already exist or because the priority is low. The areas of

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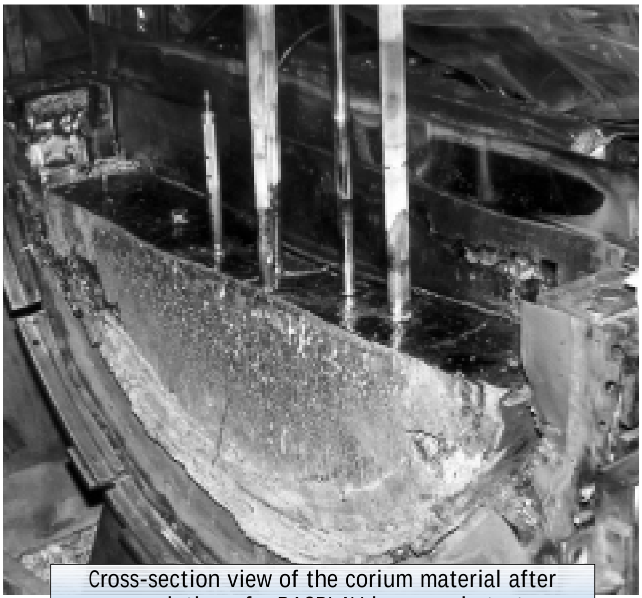
thermal hydraulics and severe accidents, however, were identified as requiring immediate attention. The CSNI is thus focusing its efforts on both of them, keeping in mind that certain other areas such as seismic behaviour may also need attention in the future.

The next steps must concentrate on the implementation of a convincing experimental programme for specific facilities. The intention is not to arrest a general process of downsizing, which largely depends on framework conditions that cannot feasibly be changed, but to provide a method and the means for preserving a meaningful technical infrastructure on nuclear safety research.

As a first step in this direction, the facilities identified in the SESAR-FAP report, operating in the thermal-hydraulic area, were requested to define a three-year programme of work consistent with the priorities indicated in the report. The facilities in question are PANDA in Switzerland, PKL in Germany, and SPES in Italy.

The PANDA tests address important containment 3-D flow distribution issues in a multi-compartment, two-phase configuration. The well-defined geometry of the facility makes the proposed tests particularly suitable for validating fluid dynamics codes and improving their accuracy. The tests intended for the PKL facility are to investigate two potential accident scenarios pertinent to existing PWRs. The first is the potential for reactivity insertion in the core due to ingress of low-borated water; the second addresses fuel uncoverage (an accidental condition that can occur in situations of plant shutdown). The SPES tests are to investigate phenomena related to station black-out and anticipated transients without scram, and can be used with modification to address the location of failures in PWR primary and secondary coolant systems.

Similar to what has been done in the thermal-hydraulic area, two research centres have put forward proposals for possible NEA research programmes in the severe accidents area. The two centres are the Kurtchatov Institute in Russia and the Argonne National Laboratory in the USA. Both proposals deal with phenomena occurring during a severe accident progression. The objective of the programme proposed by the Kurtchatov Institute (MASCA project) is to investigate in-vessel phenomena. In particular, it will address the influence of the chemical composition of the molten corium on the heat transfer to the pressure vessel environment. The tests will also investigate stratification phenomena of the molten pool and the partitioning of fission products within the different layers of the melt. The Argonne proposal focuses on ex-vessel phenomena and, in particular, on the molten core/concrete interaction, both in the case of a dry containment cavity and of the presence of an overlying water layer. Molten core coolability will also be investigated. The tests are to be carried out in the Argonne MACE facility.


Cross-section view of the corium material after completion of a RASPLAV large-scale test.

Kurtchatov Institute, Moscow

The next step will be to form sufficient consensus around the FAP proposals such that formal agreements can be established with adequate financial support from Member countries, both in the thermal-hydraulics and severe accident areas. Efforts will be made to phase the programmes such that yearly costs to participants will be as low as reasonably possible.

Other ongoing safety projects

Considerable experience exists at the NEA in the implementation and execution of a variety of projects dealing with nuclear reactor safety and reliability issues. In general, results from these projects have been very good, and the NEA will build upon this experience when establishing the new FAP projects. An overview of NEA projects currently being carried out in the area of reactor safety is given below.

The Lower Head Failure Project is a three-year project dedicated to understanding key phenomena of vessel deformation and failure following an accident with core melt. The programme background resides in the inability of current models to predict adequately the failure of the vessel lower head. The programme of work contemplates a total of eight experiments carried out with prototypic materials at representative pressure conditions. The reactor pressure vessel mock-up will be heated from the inside to simulate the temperature conditions that might occur on the lower head. The experimental programme will be carried out at the Sandia National Laboratory in the USA and is planned for completion in mid-2001. It will be complemented by analyses, including a round-robin exercise to assess and harmonise modelling approaches in participating organisations. Organisations from eight countries participate.

The RASPLAV Phase-2 Project investigates the progression of a severe accident, and in particular the thermal loading imposed by a convective corium pool on the lower head of a LWR pressure vessel. It follows an earlier Phase-1 project dedicated mainly to building up experimental and analytical infrastructure. The project is carried out at the Kurtchatov Institute in Russia. Its objectives are to obtain relevant data on the physical and thermal behaviour of the corium in large-scale tests, to derive thermo-physical property data for various molten core materials, and to investigate the effects of stratification of molten materials. The programme of work uses facilities of different sizes available at the Kurtchatov Institute, is supported and co-financed by organisations in 16 countries, and is due to be completed by mid-2000. A proposal for a follow-on project (the MASCA project mentioned earlier) has been submitted to potential participants.

The CABRI Water Loop Project is investigating the ability of high burn-up fuel to withstand the sharp power peaks that can occur in power reactors due to rapid reactivity insertion in the core (RIA accidents). It involves substantial facility modifications and upgrades and consists of 12 experiments to be performed with fuel retrieved from power reactors and refabricated to suitable length. The project has just begun and will run for eight years. While the main lines of the programme of work and schedule have been defined, details of the scope and of the experimental conditions are still being discussed by participants. The experimental work will be carried out at the *Institut de protection et de sûreté nucléaire* (IPSN) in Cadarache, France, where the CABRI reactor is located. Programme execution can, however, involve laboratories in participating organisations (for instance, in relation to fuel characterisation or post-irradiation examinations). At present, organisations in ten countries have confirmed their intention to participate. Wider participation is expected as the project scope becomes more defined.

The Halden Reactor Project is the largest NEA project and constitutes a very important international technical network in the areas of nuclear fuel reliability, integrity of reactor internals, plant control/monitoring and human factors. The project has been operating by way of three-year renewable mandates over the past 40 years. The present mandate started at the beginning of 2000. The programme of work in the fuel and materials area includes fuel assessments in the high/very high burn-up range (both at normal operating conditions) and in transients, as well as embrittlement and cracking behaviour of reactor internals materials. These investigations are carried out experimentally at representative reactor conditions and with the utilisation of advanced instrumentation. The proposed programme on plant control and monitoring is intended to assess systems having the potential for improving plant performance and operational safety. The activities on human factors aim to extend the knowledge of human performance in a control room environment and to demonstrate how this knowledge can be incorporated in control room engineering solutions. The Halden Project is executed at the Halden establishment in Norway and is supported by approximately 100 organisations in 20 countries.

The PLASMA Project can be considered as a spin-off of the Halden Project in that it represents a practical utilisation and extension of the technology developed at Halden on plant monitoring. As in the case of a previous project (denominated SCORPIO VVER), it also represents a way to enhance interaction among Halden participants on practical plant applications. The PLASMA project is a collaborative effort among JAERI, Japan, the KFKI institute in Budapest, the Hungarian Paks power plant and Halden. The objective is to implement a system to monitor plant safety parameters in VVER power plants as part of VVER control system upgradings. Paks is the reference plant in which the system is first being implemented and demonstrated. The project has a duration of two years and is due to be completed during the course of 2000.