Joint Projects and Other Co-operative Projects

NUCLEAR SAFETY

The Halden Reactor Project

The Halden Reactor Project has been in operation for 46 years and is the largest NEA project. It brings together an important international technical network in the areas of nuclear fuel reliability, integrity of reactor internals, plant control/monitoring and human factors. The programme is primarily based on experiments, product development and analyses, which are carried out at the Halden establishment in Norway, and is supported by approximately 100 organisations in 20 countries.

The 2004 programme of work in the fuel area included the realisation of the first in-pile loss-of-coolant accident (LOCA) test aimed at assessing high burn-up fuel behaviour in accident conditions. The first test was a trial with fresh fuel and was successfully completed. It will be followed up with tests using high burn-up fuel, which will be carried out in 2005. Properties of UO_2, gadolinia and MOX fuels in a variety of conditions relevant to operation and licensing were investigated. Corrosion and creep behaviour of various alloys were studied. A test on PWR crud deposition and control produced valuable results for the understanding and remedy of axial offset anomalies. Finally, tests to investigate the cracking behaviour of reactor internals material in BWRs and PWRs continued, with the aim of characterising the effect of hydrogen addition to the water coolant. The programme on human factors focused on tests and data analyses carried out in the Halden man-machine laboratory. The human factor work also encompasses new designs and evaluations of human-system interfaces and control rooms. This involves *inter alia* the use of the Halden Virtual Reality Facility.

Halden Reactor Project, Norway

Examples of large (top) and negligible (bottom) crud deposition along a PWR fuel rod after testing in the Halden test reactor.

Halden Reactor Project, Norway

Close-up (500x) of PWR internals material (from the Chooz A reactor in France) after being tested for cracking behaviour at Halden.

A number of international workshops were also organised at Halden, notably on fuel code benchmarking, online monitoring and cable ageing. The project continued its summer school programme, which is supported by the NEA Nuclear Safety Division. This is in follow-up to a recommendation of the Halden Board to actively pursue the transfer of nuclear knowledge to the younger generation.

The Halden Reactor Project operates by way of three-year renewable mandates; the current mandate runs until the end of 2005. Consultations with member country representatives have started in preparation for the 2006-2008 programme period. The Halden Project signatory organisations confirmed their intention to continue the Halden Project Agreement for the 2006-2008 period during a meeting held at NEA headquarters in December 2004.

The Cabri Water Loop Project

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 began in 2000 and will run for eight years. The experimental work is being carried out at the Institute for Radiological Protection and Nuclear Safety (IRSN) in Cadarache, France, where the Cabri reactor is located. Programme execution also involves laboratories in participating organisations for fuel preparation, post-irradiation examinations and test channel instrumentation. Organisations in 12 countries, including regulators, industry and research organisations, participate in the project.

Post-irradiation examinations of the two tests that have been carried out so far were undertaken in 2004. They involved destructive examinations and investigated in particular the effect of hydrogen on cladding properties. The planning of future tests continued, with the aim of developing a consistent set of objectives and identifying suitable fuel specimens. Considerable progress was made on the refurbishment of the Cabri test facility and the preparation of the water loop installation.

Two meetings of the Technical Advisory Group (TAG) took place in 2004, during which the programme results and the plans for future activities were reviewed. Related analyses were also presented and discussed in a Cabri seminar held in conjunction with a TAG meeting. The TAG also addressed technical issues related to the water loop design. Two meetings of the project Steering Committee were held in 2004. Among other items, recommendations were expressed in favour of the possible accession of Japan to the project.

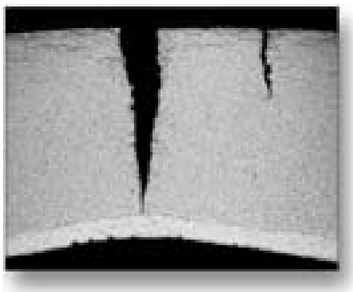
The SCIP Project

The Studsvik Cladding Integrity Project (SCIP) started in July 2004 and aims to utilise the hot cell facilities and expertise available at the Swedish Studsvik establishment in order to assess material properties and to determine conditions that can lead to fuel failures. The project has the following general objectives:

- To improve the general understanding of cladding integrity at high burn-up.
- To study both BWR and PWR/VVER fuel cladding integrity.
- To complement two large international projects (Cabri and ALPS), which focus on fuel behaviour in design basis accidents (notably RIA), where some of the mechanisms are similar to those that may occur during normal operational transients or anticipated transients.
- To achieve results of general applicability (i.e. not restricted to a particular fuel design, fabrication specification or operating condition), so that they can consequently be used in solving a wider spectrum of problems and be applied to different cases.
- To achieve experimental efficiency through the judicious use of a combination of experimental and theoretical techniques and approaches.

Although the primary concern of this project is the integrity of LWR cladding during in-reactor service, a number of closely related areas may also be addressed, of relevance to water reactors in general. In addition, some of the results will be able to be used in relation to cladding behaviour of discharged fuel during handling, transportation and storage.

Organisations from ten member countries participate in the project. As recommended by the CSNI, comprehensive industry participation was sought in the project establishment phase. The first meeting of the project steering bodies was held with NEA support in November 2004.



Cracks in BWR liner cladding material which was irradiated in the Studsvik R2 reactor to assess material properties under high burn-up conditions.

The MASCA Project

The first phase of the MASCA Project investigated the consequences of a severe accident involving core melt. It started in mid-2000 and was completed in July 2003. The second phase of the project started thereafter, upon request of the member countries and recommendation of the CSNI, and will last for three years. The programme is supported by organisations in 17 countries, and is based on experiments that are mainly carried out at the Kurchatov Institute and that make use of a variety of facilities in which corium compositions prototypical of power reactors can be tested.

The tests in the first phase of the programme were primarily associated with scaling effects and coupling between thermal-hydraulic and chemical behaviour of the melt. A workshop sponsored by the French IRSN and supported by the NEA was held in 2004. It aimed to review the results of the first phase of the programme and to provide input to the current programme.

The tests of the second phase seek to provide experimental information on the phase equilibrium for the different corium mixture compositions that can occur in water reactors. This determines the configuration of materials in the case of stratified pools, and thus the thermal loads on the vessel. In order to enhance the application of MASCA results to reactor cases, the influence of an oxidising atmosphere and the impact of non-uniform temperatures (presence of crusts or solid debris) will be addressed in addition to scaling effects. The programme is also intended to generate data on relevant physical properties of mixtures and alloys that are important for the development of qualified mechanistic models.

Two meetings of the project steering bodies, supported by the NEA, were held in 2004. During these meetings, the results obtained so far and the plans for future tests were reviewed.

The MCCI Project

The Melt Coolability and Concrete Interaction (MCCI) Project is managed by the US Nuclear Regulatory Commission (NRC), carried out at the Argonne National Laboratory (USA), and has participants from 13 countries. It was started early in 2002 and will continue for four years. It addresses ex-vessel phenomena, which occur in the hypothetical case that the molten core is not retained inside the reactor vessel and is spread in the reactor cavity where it can interact with the concrete structure.

The MCCI Project is to provide experimental data of relevance to the type of severe accident mentioned above and to resolve two important accident management issues. The first one concerns the verification that the molten debris that has spread on the base of the containment can be stabilised and cooled by water flooding from the top. The second issue concerns the two-dimensional, long-term interaction of the molten mass with the concrete structure of the containment, as the kinetics of such interaction is essential for assessing the consequences of a severe accident. To achieve these basic objectives, supporting experiments and analyses are being performed, with a view to providing an understanding of the phenomena of interest, and to producing a consistent interpretation of the results relevant to accident management.

Two Programme Review Group meetings and two Management Board meetings were held in 2004. The experiments on water ingress mechanisms were completed. They show that cooling of the melt by water is reduced at increasing concrete content, i.e. cooling by water flooding is more effective in the early phase of the melt-concrete interaction. The effect of concrete type, i.e. siliceous and limestone types (used respectively in Europe and the United States), has also been addressed. Material properties such as porosity and permeability are also derived from these tests. After a first melt-concrete interaction test, which produced unexpected results (i.e. a strong asymmetry in concrete ablation), a new test was carried out in 2004. An analytical exercise was organised among participants as a blind prediction of the test results. The test was successful and the analytical exercise very valuable in order to understand code capabilities and shortcomings. As concerns the test parameters, the second test was carried out at 30% lower power than the first test, and involved limestone concrete (siliceous concrete was used in the first test). The strength of the solid upper crust, a parameter that is of great interest for modelling and understanding MCCI at plant scale, was also determined during these experiments.

US DOE, USA

MCCI Project: cross-sections of two water-ingress test sections, obtained after test completion. The tests were run for two compositions containing 8% (left) and 25% (right) concrete respectively in the melt. One can note that the 8% case has more extensive cracking than the 25% case, indicating that the water ingress would be more effective for low concrete content in the melt.

Two meetings of the project steering bodies took place in 2004, both supported by the NEA. On these occasions the scope of a possible extension of the project was discussed.

The SETH Project

The SETH Project is supported by 14 NEA member countries. It began in 2001 and is to run for four years. It consists of thermal-hydraulic experiments in support of accident management, which are carried out at facilities identified by the CSNI as those requiring international collaboration to sponsor their continued operation. The tests carried out at Framatome's *Primär Kreislauf* (PKL) in Germany, which were completed in 2003, investigated boron dilution accidents that can arise from a small-break, loss-of-coolant accident (LOCA) during mid-loop operation (shut-down conditions) in PWRs. The final report of the PKL tests was completed in 2004.

The experiments to be carried out at the Paul Scherrer Institute (PSI) PANDA facility in Switzerland are to provide data on containment three-dimensional gas flow and distribution issues that are important for code prediction capability improvements, accident management and design of mitigating measures. After an extensive preparation phase, the experimental series started in the second half of 2004 and will continue throughout 2005.

An analytical exercise addressing code predictability took place in 2004, by means of blind computerised fluid dynamics (CFD) code predictions of the first PANDA test. To this end, a workshop supported by the NEA was organised in conjunction with a SETH Programme Review Group meeting. Two meetings of the project steering bodies took place in 2004, both supported by the NEA. Considering that, due to their complexity, there has been a delay in the PANDA experiments, the Project Board decided to extend the time frame of the programme by up to 12 months.

The PKL Project

This project started in 2004 and consists of experiments carried out in the *Primär Kreislauf* (PKL) thermal-hydraulic facility, which is operated by Framatome ANP in its establishment at Erlangen, Germany. Organisations from 14 countries participate in the project.

The PKL experiments focus on the following PWR issues that are currently receiving great attention within the international reactor safety community:

- boron dilution events after small-break, loss-of-coolant accidents (LOCAs);
- loss of residual heat removal during mid-loop operation with a closed reactor coolant system in context with boron dilution;
- loss of residual heat removal during mid-loop operation with an open reactor coolant system;
- an additional test to be defined in agreement with the project partners according to the state of open issues such as:
  - boron precipitation during large-break LOCAs, or
  - boron dilution after steam generator tube rupture.

Two tests were carried out in 2004. Their preparation and the first test outcome were extensively discussed in the two meetings of the project steering bodies that took place in 2004. These meetings were supported by the NEA.

The PSB-VVER Project

The objective of the PSB-VVER Project is to provide experimental data of relevance to the validation of safety codes in the field of VVER-1000 thermal-hydraulics. The project, in which seven countries participate, started in 2003 and will be completed at the end of 2006. It consists of five PSB-VVER experiments addressing:

- scaling effects;
- natural circulation;
- small, cold leg break LOCAs;

- primary to secondary leaks;
- 100% double-ended, cold leg break (indicative, actual size to be agreed upon).

Extensive pre- and post-test analyses are to accompany the experimental programme throughout the experimental series. The possibility of setting up sets of international standard problems – either limited to project participants or with broader attendance – will also be considered in light of the resources that this effort requires.


EREC, Russia

The PSB-VVER test facility in Russia.

Three project tests have been successfully carried out and reported upon so far. The test matrix for the remaining part of the programme was discussed and revised by members. The fourth test will investigate accidental conditions involving a primary to secondary leak (steam generator header rupture) and will be carried out in the first half of 2005. A blind test exercise where the fourth test's outcome will be predicted by calculations before its execution is being organised. Two meetings of the project's Programme Review Group were held in 2004 with NEA support.

The ICDE Project

The International Common-cause Data Exchange (ICDE) Project collects and analyses operating data related to "common-cause" failures (CCF), which have the potential to affect several systems, including safety systems. The project has been in operation since 1998, and a new agreement covering the period 2002-2005 came into force in 2002. Eleven countries participate.

The ICDE Project comprises complete, partial and incipient CCF events, called "ICDE events". The project covers the key components of the main safety systems, such as centrifugal pumps, diesel generators, motor-operated valves, power-operated relief valves, safety relief valves, check valves, batteries, reactor protection system circuit breakers, control rod drives and level measurements in the primary coolant system.

These components have been selected because probabilistic safety assessments have identified them as major risk contributors in the case of common-cause failures. Qualitative insights from the analysis of the data will help reduce the number of CCF events that are risk contributors. In the long term, the project will provide a broad basis that will enable the quantification of CCF events.

The FIRE Project

The FIRE Project started in 2002 and will run for three years, with the main purpose of encouraging multilateral co-operation in the collection and analysis of data relating to fire events in nuclear environments. The objectives are to:
- define the format for, and collect fire event experience (by international exchange) in, a quality-assured and consistent database;
- collect and analyse fire events data over the long term so as to better understand such events, their causes and their prevention;
- generate qualitative insights into the root causes of fire events that can then be used to derive approaches or mechanisms for their prevention or for mitigating their consequences;
- establish a mechanism for the efficient feedback of experience gained in connection with fire events, including the development of defences against their occurrence, such as indicators for risk-based inspections; and to record event attributes to enable quantification of fire frequencies and risk analysis.

Studying the consequences of an electrical cabinet fire (PICSEL programme, Cadarache, France).


IRSN/DPAM/SEREA, Cadarache, France

After having established the project quality guidelines and the quality-assurance procedure, data acquisition has proceeded according to plans. A meeting of the project steering body was held in 2004. Nine countries participate in the project, whose membership is expected to grow in future.

The OPDE Project

The Piping Failure Data Exchange (OPDE) Project started in 2002, currently has 12 participating countries, and will run for three years. Its goals are to:
- collect and analyse piping failure event data to promote a better understanding of underlying causes, impact on operations and safety, and prevention;
- generate qualitative insights into the root causes of piping failure events;

- establish a mechanism for efficient feedback of experience gained in connection with piping failure phenomena, including the development of defence against their occurrence;
- collect information on piping reliability attributes and factors of influence to facilitate estimation of piping failure frequencies.

The OPDE Project is envisaged to include all possible events of interest with regard to piping failures. It will cover piping components of the main safety systems (e.g. ASME Code Classes 1, 2 and 3). It will also cover non-safety piping systems that, if leaking, could lead to common-cause initiating events such as internal flooding of vital plant areas. Specific items may be added or deleted upon decision of the Project Review Group. Steam generator tubes are excluded from the OPDE project scope.

RADIOLOGICAL PROTECTION

The Information System on Occupational Exposure (ISOE)

Since its creation in 1992, the Information System on Occupational Exposure (ISOE) has been facilitating the exchange of data, lessons and experience in occupational radiological protection at nuclear power plants. Jointly sponsored by the IAEA, the ISOE programme includes 462 reactor units (403 operating and 59 in cold-shutdown or some stage of decommissioning) operated by 68 utilities in 29 countries. ISOE databases cover 92% of the total number of power reactors (441) in commercial operation throughout the world. In addition, the regulatory authorities of 25 countries participate actively in ISOE. Utilities and authorities continue to join the ISOE programme, notably the new units that have recently come on line in Korea and Japan, as well as new participants from Pakistan and the Ukraine.

The database and information exchange mechanism used initially was the floppy disk, which then evolved to the CD. With the increasing use and flexibility of the web, it was recommended in 2003 that the ISOE programme should migrate its data exchange/assessment processes, as well as its information and experience sharing to the web. As a result of a pilot study during 2004, and assessment by the ISOE Working Group on Data Assessment, it was agreed that the ISOE databases should be transferred to a web-compatible database system (such as Oracle), and that data entry and analysis should be performed online. This would also create a natural network for the online exchange of information and experience. Several approaches will be investigated during 2005. The databases will also, however, be maintained on CD for those without access to the web.

In substantive terms, the ISOE programme finalised in 2004 a report on good practice in occupational radiological protection, focusing on various practical aspects of optimisation. The areas addressed in the report include: optimisation of public protection; optimisation of worker protection; empowerment of the workforce; the use of tools in optimisation; the equality of old-plant ALARA versus new-plant ALARA; optimisation of decommissioning; and international aspects of optimisation. In addition to documenting good practice in these key areas, the report also serves as a reference point for the development of new ICRP recommendations. In order to highlight radiological protection principles that are effective in application, the optimisation processes and approaches that currently work well in nuclear power plants are put in the context of the current ICRP recommendations, as well as the newly developing context of the future recommendations.

RADIOACTIVE WASTE MANAGEMENT

The Sorption Project

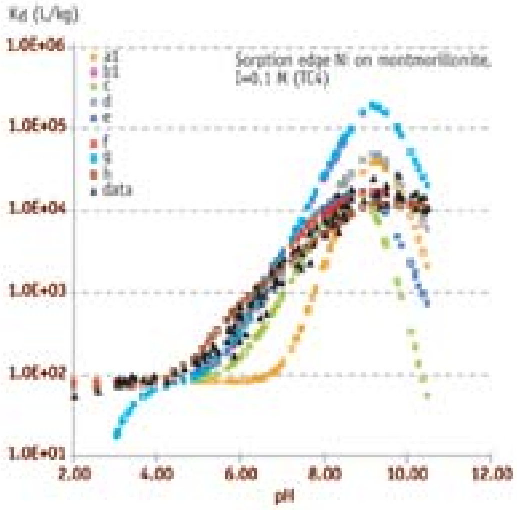
The NEA Sorption II Project was launched in October 2000 with the objective of demonstrating the applicability of different chemical thermodynamic modelling approaches to support safety assessments of geological repositories. To enable an evaluation of the respective merits and limitations of different thermodynamic sorption models, the project was implemented in the form of a comparative modelling exercise based on selected datasets for radionuclide sorption by both simple and complex materials. These were organised into seven test cases that were prepared and distributed to participating organisations. A Technical Direction Team (TDT) evaluated the existing database, developed test cases for sorption modelling, and carried out the subsequent analysis and interpretation of modelling outcomes. Eighteen funding organisations from thirteen different countries joined phase II of the Sorption Project, and in total, twenty modelling teams participated in the exercise, making it possible to base the conclusions of the project on a broad range of experience and expertise.

Using additional information gained from a workshop held in October 2002 in Spain, the TDT further interpreted and synthesised the project outcomes and delivered a draft of the final project report. In analysing the modelling outcomes, model fits as well as predictions were quantitatively compared with the respective experimental data. Particular attention was paid to elucidating the effects of certain model components and of decisions implicit in the development of preferred models on model performance.

The Sorption II Management Board agreed to publish the findings of the project as an open NEA report addressing an audience of radioactive waste management organisations and regulators, as well as modellers and experimentalists who are involved in performance assessment. The NEA report, which will be published early in 2005, summarises the main results and interpretations of test cases with examples of graphical comparisons of experimentally determined and model-derived K_d values. It reflects a view of the current capabilities of thermodynamic sorption modelling and how these could be developed in the future. The report identifies the strengths and drawbacks of various typical approaches and stresses the importance of the quality of data and specific estimates used in modelling.

As a final step for phase II of the Sorption Project, it is planned to organise an international workshop to discuss project results with a wide array of experts in the field.

Graphical comparisons of K_d values
as part of the Sorption Project



The Co-operative Programme on Decommissioning (CPD)

The Co-operative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects (CPD) is a joint research project operating under Article 5 of the NEA Statute since its inception in 1985. The concept of exchanging information, experience and possibly personnel among a number of decommissioning projects, and carrying out other forms of co-operation as appropriate, obtained strong support from all OECD countries having one or more large decommissioning projects either under way or in the planning process.


Winfrith, United Kingdom

The Winfrith fuel fabrication facility during operation, and then during demolition of the decontaminated building shell, United Kingdom.

An in-depth review of its mode of operation and its 18-year-old Agreement resulted in a consolidation of the Co-operative Agreement and the Amending Protocol regulating the financial aspects of the programme into a single document. The new Agreement came into force on 1st January 2004, again for a period of five years. It more clearly defines the scope of the information exchange actions that participants would undertake within the bounds of the Agreement. It also made changes to the way the Agreement is managed, and to the tasks and financing modus of the programme's secretary (the CPD Programme Co-ordinator).

Currently, 22 organisations from 12 countries participate in the CPD, providing experience from a total of 41 decommissioning projects, which include 26 reactors and 15 other fuel cycle facilities, along with information from some invited non-OECD projects. Altogether 47 decommissioning projects have benefited from the information exchange framework provided by the CPD since its inception in 1985.

Cross-membership of some of the programme's Management Board in the RWMC Working Party on Decommissioning and Dismantling (WPDD) ensures that insight gained at the CPD can be fed into the work of the NEA standing technical committees. CPD members also contributed to the NEA workshop on Safe, Efficient and Cost-effective Decommissioning held in Rome, Italy, in September 2004.

The new Agreement continues to include biannual meetings of the Technical Advisory Group (TAG), during which the site of one of the participating projects is visited, and good and less positive examples of decommissioning experience are openly exchanged for the benefit of all. In 2004, TAG meetings were held in Daejon, South Korea, and in Aachen, Germany. The CPD also started to prepare a brochure on the CPD, its history and work items, as well as a list with information on the participating projects, to encourage additional decommissioning projects from member countries to join the co-operative programme.

The Thermochemical Database (TDB) Project

The Thermochemical Database (TDB) Project aims to meet the specialised modelling requirements for safety assessments of radioactive waste disposal sites. Chemical thermodynamic data are collected and critically evaluated by expert review teams and the results are published in a series of books edited by the Data Bank.

Reviews of inorganic chemical thermodynamic data of selenium and nickel have been concluded and will be published in early 2005. Reviews of inorganic data of zirconium, as well as selected organic compounds and complexes of uranium, neptunium, plutonium, americium, selenium, nickel, technetium and zirconium, are currently undergoing peer review.

New reviews on inorganic data for thorium and tin have been started, together with the preparation of scientific guidelines to deal with the chemical thermodynamics of solid solutions. In view of the large amount of information available for the inorganic chemistry of iron, it has been decided to further explore the available literature with a goal to arrive at a better definition of the deliverables compatible with the project's time constraints. Accordingly, the TDB Management Board decided to lower the priority of the review of molybdenum, and to postpone a decision on its undertaking until early in 2005 when the decision on the iron review is expected to be taken.