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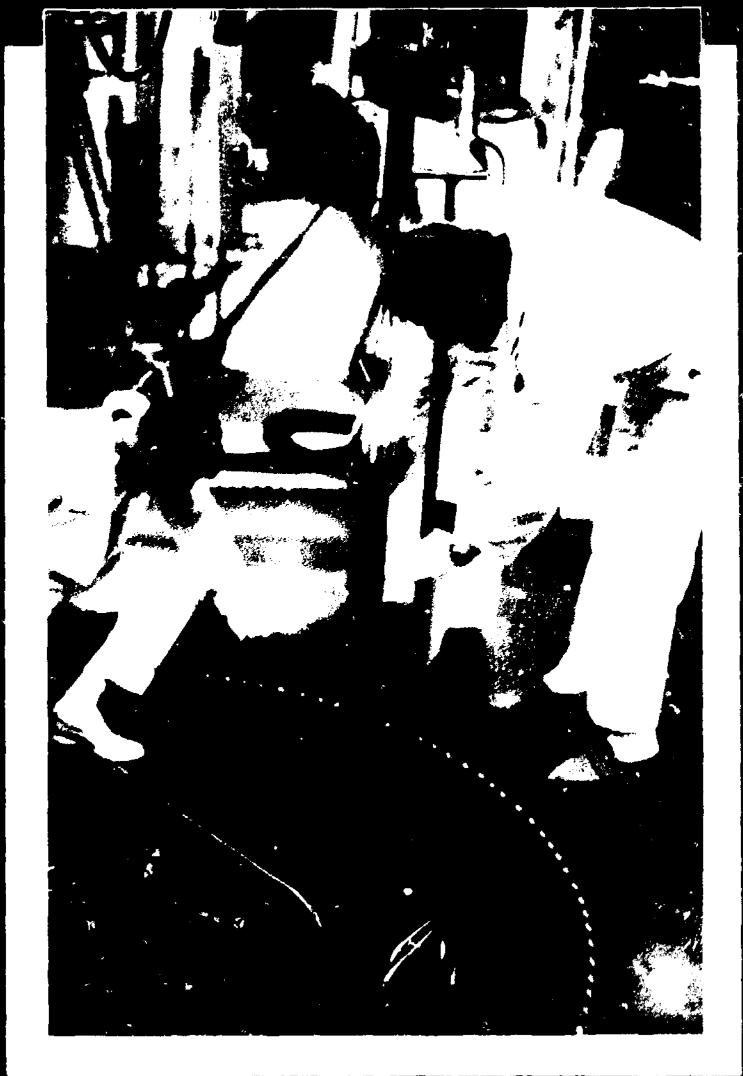
NEA INTERNATIONAL CO-OPERATIVE PROJECTS



OECD NUCLEAR ENERGY AGENCY

PARIS 1989

XN6900022A

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NEA INTERNATIONAL CO-OPERATIVE PROJECTS

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Pursuant to article 1 of the Convention signed in Paris on 14th December, 1960, and which came into force on 30th September, 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April, 1964), Finland (28th January, 1969), Australia (7th June, 1971) and New Zealand (29th May, 1973).

The Socialist Federal Republic of Yugoslavia takes part in some of the work of the OECD (agreement of 28th October, 1961).

The OECD Nuclear Energy Agency (NEA) was established in 1957 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April, 1972, when Japan became its first non-European full Member. NEA membership today consists of all European Member countries of OECD as well as Australia, Canada, Japan and the United States. The commission of the European Communities takes part in the work of the Agency.

The primary objective of NEA is to promote co-operation between the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonisation of national, regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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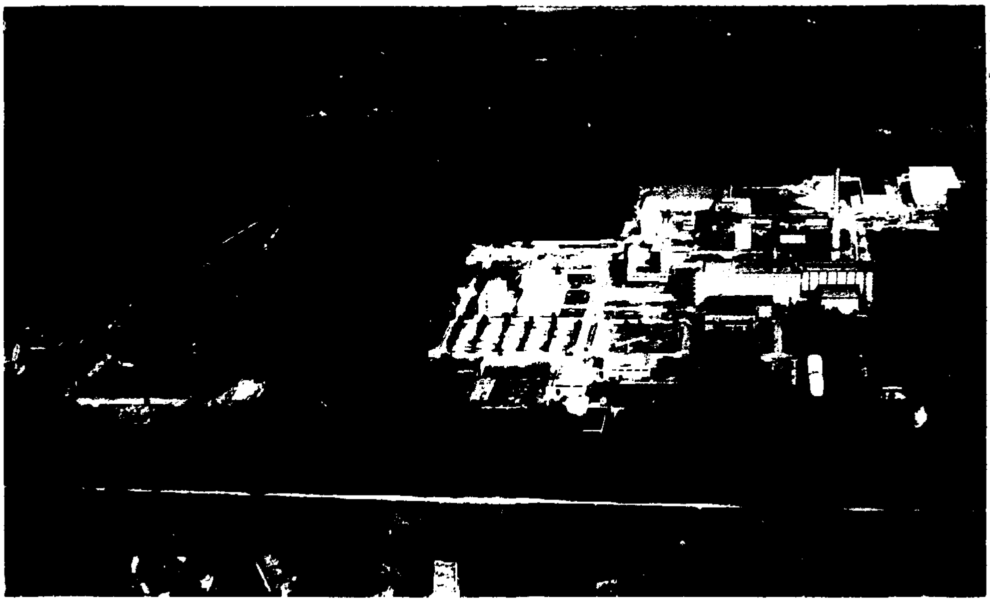
INTRODUCTION

Long before nuclear power became a viable way to produce electricity, the West European countries came to understand the large amount of development needed to launch a nuclear energy programme and the advantages of sharing the burden among them. Pooling their scientific, technical and financial resources thus became one of their major objectives in setting up, in 1958, the European Nuclear Energy Agency, the predecessor of the OECD Nuclear Energy Agency. At the time, the general trend was to spread technology through large-scale co-operative development projects. By pursuing research through an intergovernmental body, financial resources and specialised knowledge could be shared.

The common objective that united the participants in the original Agency – to promote the development of nuclear power as a safe, environmentally acceptable and economical energy source – still holds true today. To achieve this aim, the traditional role of an international agency is to serve as a forum for the exchange of information among specialists, help to harmonize national legislation and encourage consultations on the nuclear programmes of its member countries. The Agency carries out many activities in accordance with this role.

But what gave the Agency its unique value was its mission to create international undertakings or projects in which Member countries would jointly finance and construct research or industrial facilities as a stepping stone to the development of commercial nuclear power in Western Europe. Three such programmes were launched during the Agency's first three years, a remarkable example of international co-operation.

THE INTERNATIONAL CO-OPERATIVE PROJECTS OF THE OECD NUCLEAR ENERGY AGENCY



Credit Eurochemic

The Eurochemic facility in Mol, Belgium, was the first NEA Joint Undertaking and was built to develop chemical reprocessing technology for nuclear spent fuel in Europe.

The first and most ambitious of these projects was the Eurochemic Company, formed in Mol, Belgium, to develop chemical reprocessing technology in Europe. Although the plant achieved its objective, it was not designed to compete in the reprocessing market and ceased to operate in 1974. Co-operative work continued, however, to treat and store the radioactive waste produced by the plant. The second was a research programme in Halden, Norway to develop a boiling heavy water reactor. Although its emphasis has changed since its inception, it is the only original project still being pursued. The third project, to construct and operate the gas-cooled, high-temperature Dragon reactor at Winfrith, in the United Kingdom, was terminated in 1976 after 17 years of active international co-operative programming, when it was concluded that this reactor system had a rather uncertain commercial future. The practical experience gained by the Agency in conducting these early projects laid the foundation for its later role in launching and managing a wide range of international co-operative programmes, under an "à la carte" programme.

In the early 1970s, the Agency expanded to include non-European countries (Japan, Australia, Canada and the United States) and its name was changed to the OECD Nuclear Energy Agency (NEA) to reflect this broadened geographical membership. Its 23 Member countries now provide more than 80 per cent of the world's nuclear generating capacity and represent the major portion of the research and development, regulation and operation of nuclear power plants worldwide. This gives the NEA Members a significant incentive to co-operate in the development of nuclear power through a variety of Agency programmes.

Transition to Nuclear Safety and Radioactive Waste Management Projects

By the mid-1960s, industry had largely taken over the construction and operation of nuclear reactors and other fuel cycle installations as well as the development of related technology. As nuclear power advanced from the experimental stage to commercial exploitation, governments and intergovernmental organisations ceased to be regarded as the most efficient instruments for its development, and public sector participation decreased. Projects established by the Agency were gradually reduced in scale and shifted to safety issues or to fundamental research. Of particular interest in the latter category is the NEA Data Bank, established as a centre for the collection and validation of nuclear physics data and computer codes.

International co-operative projects were continued through other means, focussing more on exchanges of information concerning national programmes, on co-ordination of work at national centres and on studies by specialised international committees. In particular, co-operative activities increased considerably in reactor safety, radiation protection, and radioactive waste management, subjects which remain Agency priorities today.

For example, current safety projects are devoted to providing better understanding of nuclear fuel and plant behaviour, particularly under accident conditions; the importance of human interactions with machines in nuclear plant design, maintenance and operation; non-destructive methods for judging the physical and chemical state of plant components and improved computer codes. Projects in the radioactive waste management field include the analysis of waste disposal options, particularly for the long term, and the use of computer codes and data bases in this assessment; the suitability of crystalline rock as a burial medium; the study of radionuclide migration and the decommissioning of nuclear facilities.

Organisational Arrangements for Joint Projects

Over time, the structure of joint projects evolved from the earlier projects which were meant to be truly international bodies, or operated by international teams. Now, two types of projects are conducted under the aegis of the NEA: those which are co-ordinated by the participating countries and those which are centrally managed by the host country. The co-ordinated programmes have a common objective agreed upon by the participants and are managed on a multilateral basis but do not have a central budget. Member countries contribute scientific and technical expertise and equipment, field studies and work in national or regional research institutions and laboratories. A special committee representing all participants is entrusted with the co-ordination, supervision and execution of the programme, sometimes assisted by technical task groups. Programmes are established for a fixed term, which may be extended by common agreement.

Most of NEA's current joint projects are centrally managed, operating under the direction of a Management Board of participating countries. The host country has managerial responsibility, provides the facilities and, in most cases, is expected to contribute a substantial part of the total budget, with financial participation from the other parties. A technical committee of representatives from Member countries advises the Management Board on technical aspects of the project. The activities and budget are discussed annually and task groups may be established to assist the technical committee. These programmes also have an extendable fixed term.

Specific projects can be proposed by any Member country or by the NEA Secretariat itself. If they are of sufficient general interest to attract participation from several countries, the Secretariat initiates negotiations to define the terms of the agreement, including details such as duration, membership, financing, structure and management. Access to the know how and results of the project and the conditions for participation and withdrawal are also established. Membership in NEA joint projects is contractual and on an *ad hoc* basis but open to all Member countries. Participants may include public and private institutions as well as Governments, but they must have government approval. Financing is normally based on the OECD standard scale of contributions, itself based on the gross national product, but other financial structures can also be used.

The NEA has been particularly successful in organising these projects because, from its inception, it was designed to be a flexible vehicle for international co-operation, capable of making pragmatic adjustments to technological change. For example, some co-operative activities involve all Member countries as part of NEA's regular programme, while many of the Agency's joint projects are created by specific agreement among fewer members. Although any Member country that accepts the terms of the agreement can join, there is no obligation to participate. Countries that choose not to be involved in a specific project, however, cannot veto it. This arrangement allows the NEA to obtain the broadest possible participation while retaining the flexibility needed to meet the diverse interests of all its members.

This pragmatic and flexible approach allows for the particular nature of each project, for efficient technical management and for different legal, financial and governmental arrangements, with each project having its own constitutive acts or agreements. The NEA prepares the structure and provides technical, administrative and legal assistance wherever necessary. The Secretariat also co-ordinates the work of the joint projects with other activities and ensures that the general results are made available to all NEA Member countries.

Thus the NEA programme of Joint Undertakings and other Joint Projects has evolved over the years from a few large-scale facilities designed to develop reactor technology and the nuclear fuel cycle to about a dozen smaller projects dealing mainly with reactor safety and radioactive waste management.

These NEA international co-operative projects demonstrate the common goals of collecting and disseminating information, sharing experience and advanced technical know-how, improving confidence in the tools used for reactor safety and radioactive waste management and identifying research priorities.

NEA SAFETY-ORIENTED JOINT PROJECTS

THE OECD HALDEN REACTOR PROJECT

The Halden Reactor Project was one of the earliest joint undertakings created by the Agency and the only one still in operation, although the primary emphasis is now on safety-related activities. When the decision was made, in 1957, to build a series of prototype reactors for testing and research, the Government of Norway proposed the boiling heavy water reactor they were building in the southern coastal town of Halden as a joint project. The Norwegian Institutt for Energiteknikk is the owner of the Halden Reactor and is responsible for carrying out its programme of research and experiments. The Project is continued by an agreement which is reviewed at three-year intervals.

The 20 MW reactor began operating in 1960 with the initial goal of demonstrating the boiling water moderated reactor concept. However, it was recognised early in the life of the Project that the reactor design, particularly the spacious core, would also be particularly suitable for testing fuel. As a result, analysis of fuel performance became an important feature of the Project. In 1967, the first research programme specifically designed to investigate the performance of fuel rods was formulated, and in 1974, a new programme concerned with the safety of water reactors was added. Experiments now range from long-term testing of experimental fuel elements to computer-based systems for reactor control and supervision.

Credit R Caruso

Technicians at the OECD/Halden Reactor Project perform maintenance on reactor control rod drive mechanisms. The control rods are used to adjust reactor power and neutron flux for the reactor fuel experiments.

Fuel Performance

Recent experiments at Halden have focussed on the way nuclear fuel for commercial nuclear power plants behaves when it is overheated or otherwise subjected to unusual stress. The temperatures of different types of fuel rods are measured to determine which ones withstand the highest heat. The interaction between the fuel and the cladding surrounding it is studied to determine how the cladding corrodes or deforms during power operation. Other experiments are designed to show how the release of fission products from the fuel is related to fuel temperature and structure. Continuous improvement of instruments has made it easier to take these measurements while the fuel is in the core.

Man-machine Communications Systems

About one-half of Halden's total research programme is now devoted to developing computerised man-machine communications systems and to determining how operators and equipment interact to control nuclear power plants. The issue of man-machine interaction received significant attention following the accidents at Three-Mile Island and Chernobyl because of the important role played by human error in both instances. To help prevent similar accidents in the future, systems are being developed for early detection of faults, diagnosis of problems and guidance for operators. The focus of this research is on the changing role of the operator in increasingly computerised control rooms, the validation and assessment of new operator aids and the development of improved operator training techniques, particularly related to abnormal plant activities.

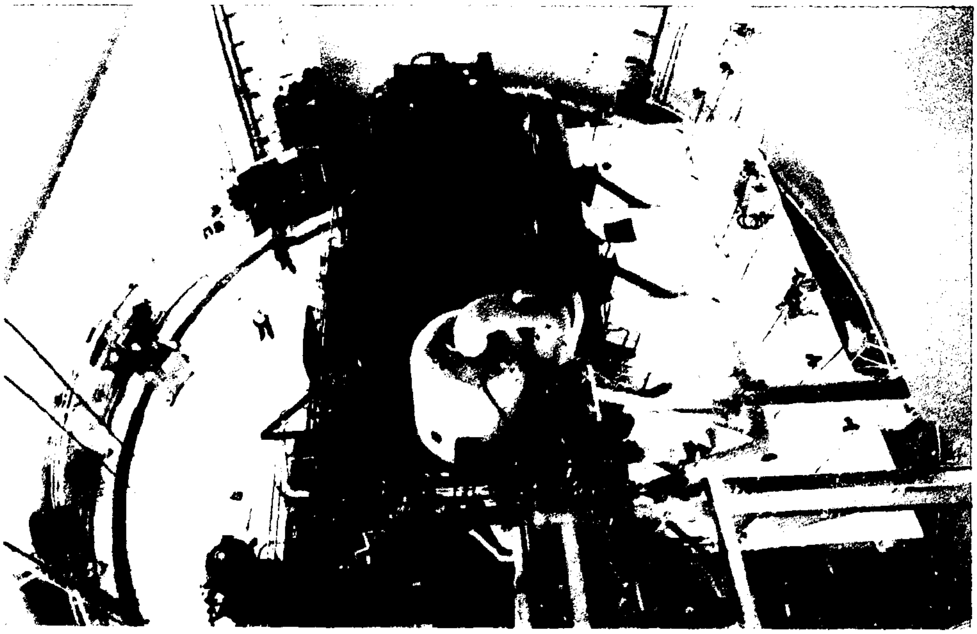
For example, the Halden Project has established a Man-Machine Systems Laboratory, in which a team of specialists, including psychologists and computer experts, develops and evaluates techniques for displaying information to help the operator make decisions under abnormal conditions. A new experimental control room facility contains operator communications equipment, an instructors' area and a full-scale training simulator. The Project has developed a number of computer systems to be used in other nuclear power facilities. This research is intended to provide a better understanding of human error and to improve systems designed to minimise them.

Thus, through a series of innovative revisions over the years, the Halden Reactor has become an extremely versatile test facility. Nearly 300 experiments have been conducted since its inception. The activities of this project are increasingly integrated with related work in NEA Member countries, particularly in co-ordinating the design of critical experiments and exchanging information among research facilities in participating countries. This will improve both the distribution of the results among the project members and their application to commercial nuclear power plants.

OECD HALDEN REACTOR PROJECT

Budget:	Central budget – $30 million
Duration:	1990
NEA Role:	Advisor
Management:	Norwegian Institutt for Energiteknikk
Members:	Denmark, Finland, Germany (Fed. Rep.), Italy, Japan, Netherlands, Norway, Sweden, United Kingdom, United States

THE OECD LOFT PROJECT



The LOFT reactor was the only thermal-hydraulic test facility in the world that used actual nuclear fuel to power its experiments.

The Loss-of-Fluid-Test (LOFT) Project, which was originally built and operated by the United States, became an NEA joint project in 1983. It was the only reactor test facility in the world to allow exact simulation of the most serious kind of nuclear accidents, those which involve a loss of coolant in the reactor. It is also the only test facility to use nuclear fuel to power its experiments. The goals of the project were to improve the ability to understand and predict abnormal behaviour of pressurised water reactor systems or components and to enhance their safety and reliability. Information obtained from these experiments is used to validate computer codes, to define safety margins and previously unanticipated phenomena and to develop techniques for accident recovery.

Although tests of fuel behaviour and damage are conducted at other facilities, such as NEA's Halden Reactor, they are based on the use of a few fuel rods, whereas the LOFT facility tested entire fuel assemblies. Its experiments permitted a typical fuel assembly to be damaged and the debris to be tracked as it moved through the reactor coolant system. The first six tests under the NEA Project studied the thermal-hydraulic response of a pressurised water reactor to abnormal or accident conditions which did not damage the nuclear fuel. The results provided data for validating the complex computer codes used to analyse full-size commercial power plants and gave reactor operators information to help identify certain phenomena that occur during an accident.

The final LOFT test, a severe accident experiment which caused significant fuel damage, was particularly valuable because of its special instrumentation systems. These instruments measured exactly what happened as the fuel was gradually allowed to heat up to nearly 3 500 °F (1 930 °C), enough to melt the fuel and cladding, dissolve the fuel and allow fission products to escape into the reactor coolant system.

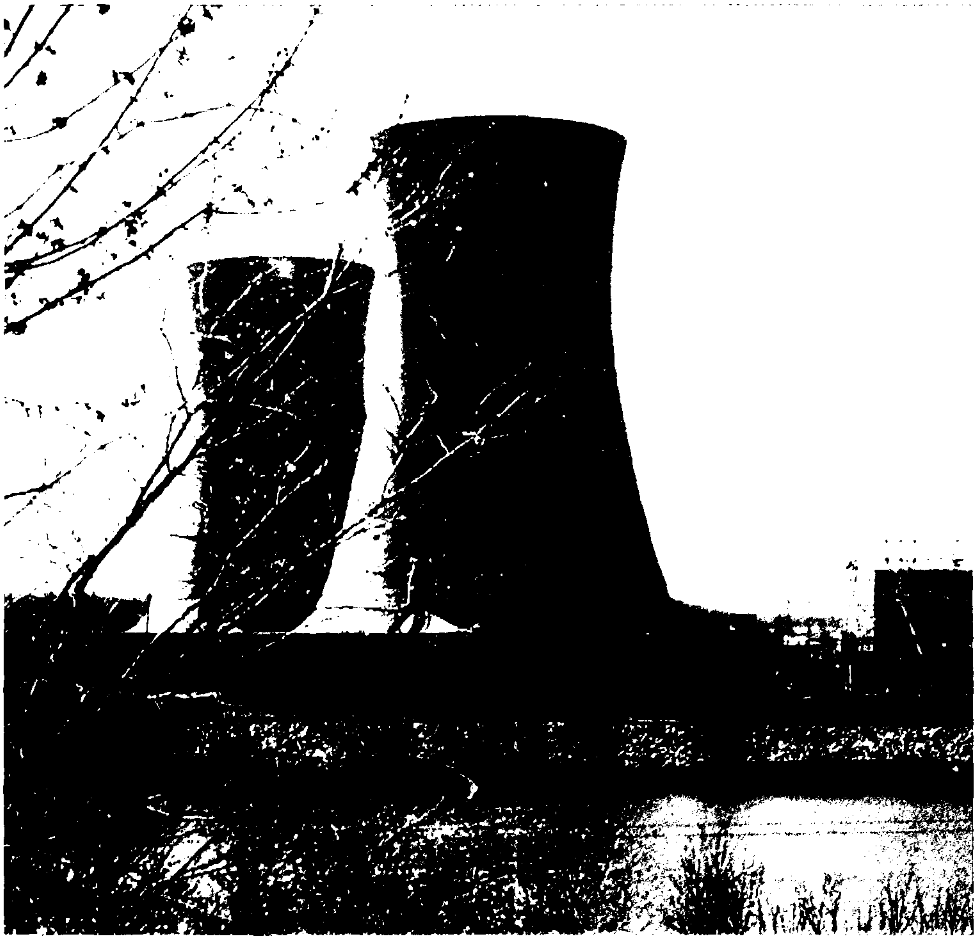
Following the successful completion of the test, the participating countries decided to prolong the project to make a detailed examination of the damaged fuel and resolve uncertainties concerning the peak fuel temperature, extent of oxidation and relocation of the melted fuel. The damaged fuel has been radiographed and sliced at several locations to expose different sections, which are being examined to determine the composition of the debris, the amount of fission products retained and other information needed to understand such incidents.

Another important subject of study is the behaviour of the reactor cooling water during the experiment, including its ability to quench the damaged fuel and its effectiveness in controlling the spread of fission products from the damaged fuel into other parts of the reactor and outside the reactor coolant system. Lessons learned during these exercises will lead to better assessment of risks, improved strategies for managing accidents and updated regulations and siting requirements for nuclear power plants.

OECD LOFT PROJECT

Budget:	Central budget —$96 million (U.S., about 50%)
Duration:	1989
NEA Role:	Advisor & secretariat services
Management:	Operated for US Department of Energy by the Idaho National Engineering Laboratory
Members:	Canada, Finland, Japan, Spain, Sweden, Switzerland, United Kingdom and United States.

CO-OPERATIVE PROGRAMMES ON THE DAMAGED THREE MILE ISLAND UNIT-2 REACTOR



Unit 2 of the Three Mile Island reactor, which was damaged in an accident in 1979, is the subject of two NEA international research projects.

Samples of damaged fuel from the Three Mile Island-2 Reactor are being studied by NEA Member countries.

THE CO-OPERATIVE PROGRAMME TO EXAMINE THE THREE MILE ISLAND-2 CORE DEBRIS

The first major accident at a commercial light water reactor occurred at Three Mile Island's Unit 2 in the United States in 1979. Although very little radioactivity was released and no one was injured, the consequences for the reactor were extremely serious. The reactor vessel was deprived of cooling water, the fuel overheated and some of it melted and ran down into the bottom of the reactor vessel, where it solidified. Efforts to clean up the reactor have been both difficult and expensive – in some cases, equipment had to be specially built to break up the fuel and remove it from the vessel.

On the other hand, the accident provided important lessons on how fuel behaves in a severe accident. Much of this information was obtained through the U.S. Department of Energy's Accident Evaluation Programme. To make maximum use of this information, several NEA countries agreed to participate in further examinations of fuel samples taken from the reactor. These samples include three types of materials: remnants of the fuel rods remaining in their original geometry, material that melted and then resolidified around undissolved fuel fragments, and rock-sized pieces of completely pr[illegible]-molten material. Other samples were taken from loose debris in the pressure vessel. These samples are analysed by the laboratories of participating countries and the results are pooled to obtain a more complete picture of the course of the acccident and the end state of the reactor.

A second task is to evaluate the computer code models of severe accidents developed by the participating countries to determine how accurately they are able to predict the behaviour of a reactor under certain severe accident conditions. These codes are programmed to simulate the progression and results of the accident at Three Mile Island and the results are compared to measurements taken during the actual accident and to the results from examining the samples.

CO-OPERATIVE PROGRAMME TO EXAMINE THREE MILE ISLAND-2 CORE DEBRIS

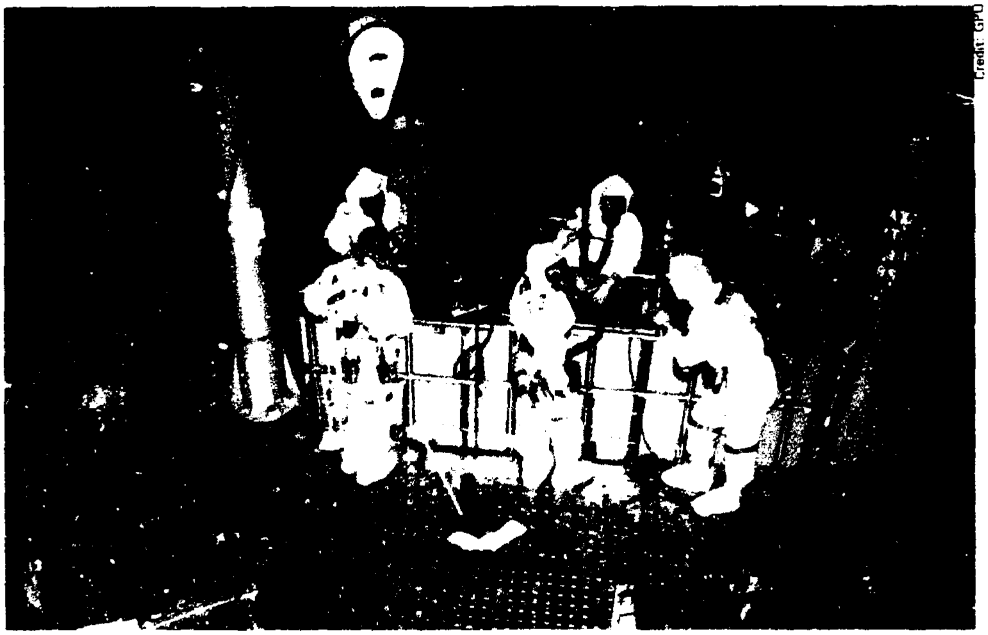
Budget:	No central budget, countries bear own costs
Duration:	1988
NEA Role:	Secretariat services
Members:	Canada, Finland, France, Germany (Fed. Rep.), Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom, United States, and the CEC.

THE OECD THREE MILE ISLAND VESSEL INVESTIGATION PROJECT

During removal of the fuel from the reactor vessel, it became clear that the accident had progressed further than originally believed, particularly in the extent to which molten material flowed inside the vessel, around the instrument guide tubes and into the lower vessel region. Although this region of the vessel experienced temperatures much higher than it was designed for, it remained sealed, retaining the operating fluid pressures and the molten contents. A programme was needed to determine the effects of this molten material on the strength and other properties of the vessel structure and its ability to contain heavily-damaged fuel.

These studies were not foreseen in the earlier DOE Accident Evaluation Programme and were therefore proposed by the U.S. Nuclear Regulatory Commission as a co-operative international project under NEA auspices. Unlike the first TMI programme, which is an informal arrangement under which countries are carrying out the experiments at their own expense and pooling their results, the Vessel Investigation Project has a central budget and programme identified in a formal Agreement.

The nature and full extent of the damage to the lower vessel structure will be explored, including an examination of samples of the steel wall and instrument penetrations to see if they have lost mechanical strength or were degraded by the thermal and chemical attack during the accident. Remote-controlled tools must be designed and manufactured to extract the samples from the inner side of the bottom wall of the vessel and from core debris nearby while care is taken to retain the leak-tightness of the vessel. Examinations will be carried out in the U.S. and in some of the other participating countries.



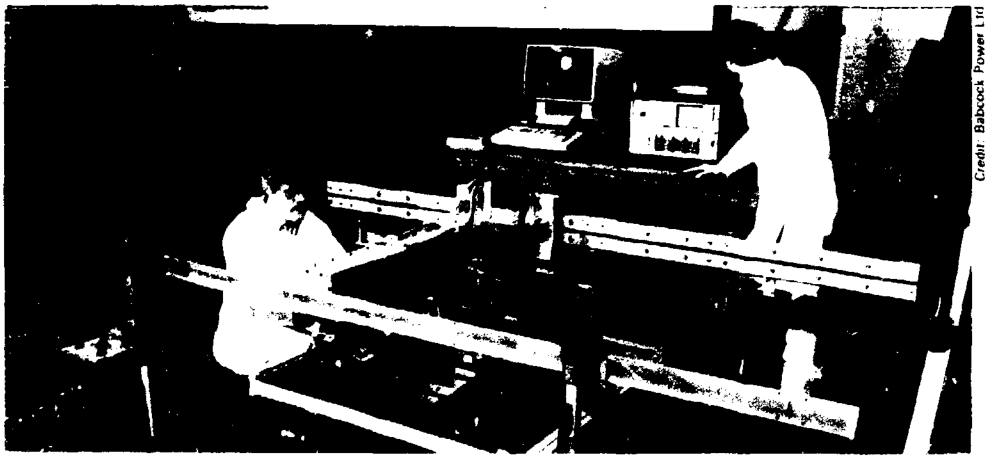
Workers on a revolving platform manipulate long-handled tools to remove core debris, guided by television cameras in the reactor vessel. Samples of the reactor vessel will also be studied by NEA.

OECD THREE MILE ISLAND VESSEL INVESTIGATION PROJECT

Budget:	Central budget –$7 million (U.S., 50%)
Duration:	1991
NEA Role:	Advisor, secretariat services
Members:	Belgium, Germany (Fed. Rep.), Finland, France, Italy, Japan, Spain, Sweden, Switzerland, United Kingdom, and United States.

The data obtained from testing these samples, together with analytical models and other information provided by the participants, will be used to determine the thermal and chemical effects on the TMI-2 vessel and the amount of structural integrity remaining after the accident. The results, when integrated with those from the U.S. Department of Energy and the international co-operative programme referred to earlier, will contribute to a better understanding of severe accidents and source term phenomena based on an actual severe accident at an operating reactor.

PROGRAMME FOR THE INSPECTION OF REACTOR STEEL COMPONENTS (PISC)



Laboratory inspections of welded steel plates are used to develop improved automated techniques for sizing internal weld defects.

The safety of nuclear power plants depends on the mechanical integrity of the materials, particularly the welds, used in their structure and on the ability to detect any degradation at an early stage or prevent it entirely. Non-destructive methods have been developed for finding surface and internal flaws that might develop and for determining their size. Techniques using sound waves of ultrasonic frequency are among the most widely applied, particularly for the important vessels and piping of the reactor plant. These components present very challenging inspection problems because of their size, complex shapes, combinations of materials and difficulties of access after construction.

Various inspection procedures using ultrasonic techniques have evolved to deal with particular circumstances but, in some cases, uncertainties have remained about their capability and reliability. Such problems were first addressed in several national programmes of round robin inspection trials. It was recognised that such trials could be more effective if they involved the much larger number of teams and additional procedures available if a number of countries participated.

Beginning in 1974, a series of major co-operative programmes known collectively as PISC was carried out. In the first of these, teams from 10 European countries inspected three thick welded steel plates provided from the U.S. national programme. The objective was to locate, size and classify as acceptable or rejectable deliberately implanted defects using the manual inspection procedures and rules of the American Society of

Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.

The nature of the test specimens and the limited data reporting requirements in PISC-I only permitted very general conclusions to be drawn about the causes and remedies of poor or variable performance on ultrasonic inspections of thick steel welds. PISC-II was set up in 1980 by the NEA and the Joint Research Centre of the Commission of the European Communities (CEC-JRC) at Ispra, Italy to undertake a more thorough study. This programme examined in more detail which techniques and procedures could provide the required level of performance in detecting, locating and sizing flaws. The parameters affecting performance were also assessed. Four new, more realistic welded test assemblies were implanted with various defects, with no prior knowledge by the participants, and were then inspected by 50 teams in 14 countries. They had no knowledge of the defect patterns and were encouraged to apply, under optimal conditions, any ultrasonic inspection procedure that was being used in, or being developed for, in-service inspections in nuclear plants.

The results confirmed that techniques and procedures exist in industrial use which are capable of locating and sizing defects with the necessary accuracy. A much clearer understanding has emerged of the parameters influencing defect detection and sizing capability and of those aspects which most need further study. As in PISC-I, however, there was considerable variability among the performances of teams using the same procedures, pointing to the importance of human reliability. The reliability of techniques and procedures in practical field conditions also needed to be further investigated.

These matters have been taken up in PISC-III, jointly launched by the NEA and the CEC-JRC in 1986. PISC-III emphasizes testing of real defects in real structures, including contaminated components. Tests will be carried out under realistic inspection conditions. In addition to ultrasonic inspection techniques, other tasks include validating mathematical models to help assess the importance of defect characteristics and assessing the significance of human performance which is not consistent during inspections and during the interpretation of inspection results.

Much of the financing and technical support for both PISC-II and III has been provided by the CEC, and the JRC has acted as the Operating Agent for both programmes. Participating countries make « in kind » contributions. The results of PISC-III will be brought to the attention of regulatory and other organisations which prepare codes and standards for in-service inspection of nuclear facilities.

PROGRAMME FOR THE INSPECTION OF REACTOR STEEL COMPONENTS (PISC) III

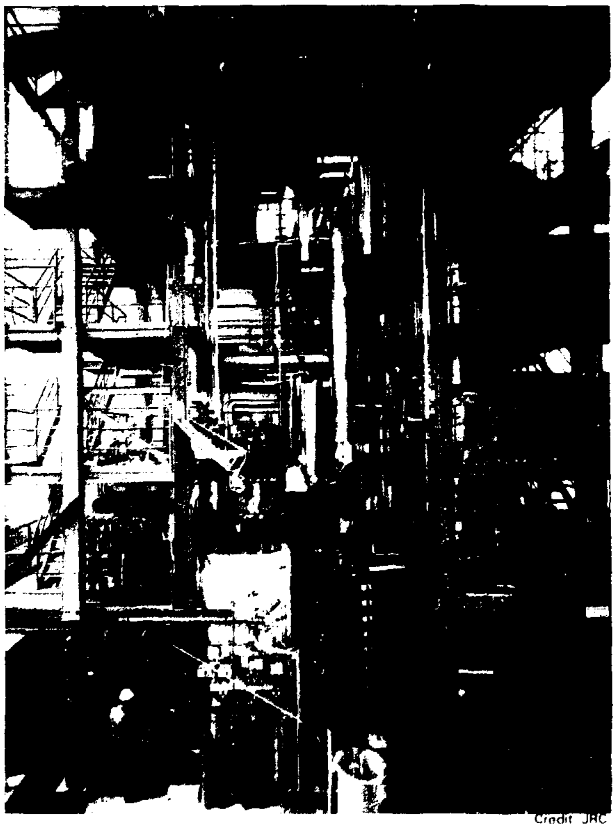
Budget:	CEC budgets half the resources, countries bear own costs and make « in kind » contributions
Duration:	1991
NEA Role:	Co-sponsor and secretariat services
Management:	CEC Joint Research Centre, Ispra, Italy
Members:	Belgium, Denmark, Italy, Finland, France, Germany (Fed. Rep.), Japan, Netherlands, Norway, Spain, Switzerland, United Kingdom, and United States.

INTERNATIONAL STANDARD PROBLEM EXERCISES

A number of highly specialised tools are used to assess the safety of nuclear facilities, including computer codes, experimental facilities and their instrumentation, special measurement techniques and methods for testing materials and components. Because they can be extremely complex and costly to produce and use, it is important to *determine their reliability* and accuracy. The NEA has developed an effective method to increase confidence in these tools through International Standard Problem Exercises, or ISPs. These exercises compare the various tools to each other or against an agreed standard.

The experimental facilities in which the ISPs are carried out are located in many OECD countries. For example, the LOBI test rig in Italy is operated by the Commission of the European Communities. It was built to simulate the primary and secondary system of a large pressurised water reactor and to investigate abnormal thermal hydraulic behaviour in a reactor when it accidentally loses cooling water. A different exercise calculated an accident involving the rupture of a steam generator tube at a Belgian power plant. Other tests have involved the interaction between molten nuclear fuel material and concrete during an accident, and the calculations used to determine how a reactor containment would perform during an accident.

A facility in the Federal Republic of Germany was designed as an actual containment for a small nuclear power plant (about 1/6 the size of a large power plant) which was completed but never operated commercially. It is now used to study the effect of pipe ruptures and other emergency situations, such as fires, on reactor containment buildings.



Credit JRC

Simulated reactor transients and accidents carried out at the LOBI thermal-hydraulic test facility at the CEC's Joint Research Centre in Ispra, Italy, are valuable for the development and improvement of computer codes that model the behaviour of operating nuclear power plants.

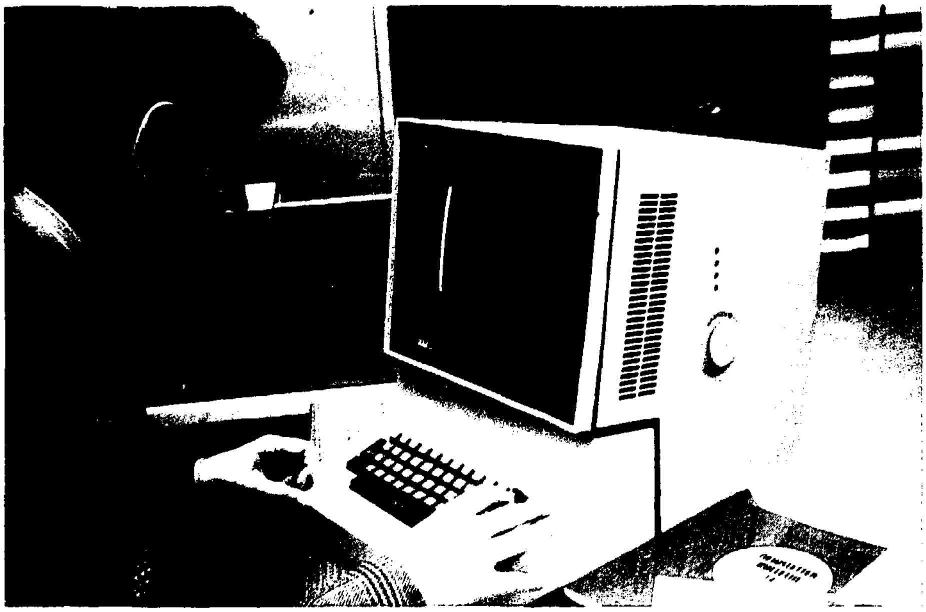
Some ISP exercises involve comparing how different computer codes predict a given physical problem. For example, most exercices involve codes to predict the results of a thermal hydraulic test which simulates abnormal conditions in a nuclear power plant. Such abnormal conditions can range from the relatively straightforward rapid reactor shutdown to the most serious full rupture of the largest pipe in the reactor system. The code results are compared with each other or with an agreed standard to determine if their predictions were accurate. They can also be compared with results obtained from specially controlled experiments conducted at research facilities such as LOFT, or through test programmes such as PISC.

Each ISP participant runs a computer simulation of the experiment, based on a complete description of the experimental facility, and care is taken to ensure that all models begin the experiment from the same point and model the same sequence of equipment operation. The predicted results are collected by a lead country and a report comparing the predictions to the actual data is prepared. This document is distributed to each participating organisation and is discussed at a subsequent workshop.

INTERNATIONAL STANDARD PROBLEM EXERCISES

Budget:	No central budget, countries bear own costs
Duration:	Varies according to the exercise
NEA Role:	Clearing house
Members:	Varies according to the exercise

THE NEA INCIDENT REPORTING SYSTEM



Reports of operating experience at reactors in NEA countries are entered into a data base at the NEA Data Bank in Saclay, France.

As with any advanced technology, unplanned events occur from time to time during the operation of a nuclear power plant, ranging from minor equipment failures such as a leaking water valve, to more significant problems such as a fault in the reactor cooling system. By reporting the event and identifying its original cause, appropriate action can be taken to prevent its recurrence or to reduce its impact, should it nevertheless recur. Thus plant safety and reliability can be improved, and hazardous or potentially hazardous conditions can be identified and eliminated. Comparing actual operating experience with the bases on which plants and equipment were designed can lead to greater confidence in present designs or indicate the need for changes in future designs.

The Incident Reporting System (IRS) was established in 1980 to collect and disseminate, as soon as practicable, detailed information on incidents of safety significance in the nuclear power plants of Member countries. All OECD Member countries with operating nuclear plants participate in the IRS. When an event occurs which is considered reportable according to predetermined criteria, the regulatory body in that country forwards a report to the NEA Secretariat in Paris. Copies of the report are sent to all participating countries and the data it contains are stored in a central data base, accessible to all participants. Follow-up reports on certain significant events are handled in a similar manner.

A rigourous quality control process ensures proper classification, storage and retrieval of data, routine maintenance and development of software and homogeneous quality and quantity of reporting. Certain reports are chosen by Member countries for deeper analysis, either because of the frequent recurrence of the problem or its significance, and the issue may receive additional attention through meetings, task forces and special studies.

The NEA and its Data Bank are also developing the use of computer software designed to link seemingly unrelated events or parts of events, thus giving members an additional tool with which to identify early signs of an impending accident or a sequence of events which could lead to serious equipment failures. Such an approach could indicate areas where generic or specific studies are needed. The Secretariat also maintains a data base on the frequency of reactor shutdowns, and exchanges reports with non-Member countries through co-operation with the International Atomic Energy Agency, which maintains a separate incident reporting system.

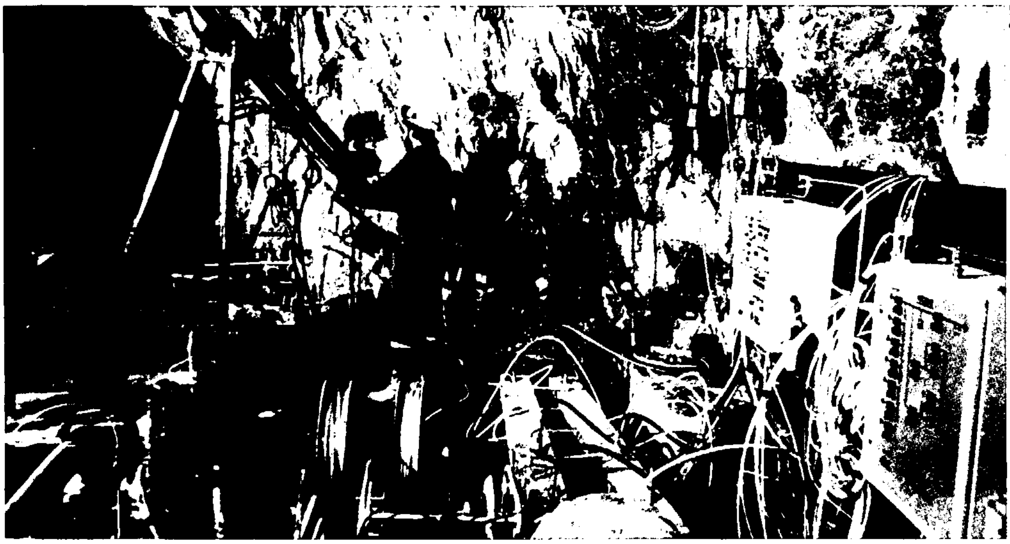
An adequate level of safety and reliability in generating nuclear electricity largely depends on mechanisms to ensure the feedback of operational experience. The IRS is an efficient system for doing this, and no incident of safety significance now escapes being reported to the NEA.

INCIDENT REPORTING SYSTEM

Budget:	NEA budget
Duration:	Indefinite
NEA Role:	Clearing house for information, information processing
Members:	Belgium, Canada, Finland, France, Germany (Fed. Rep.), Italy, Japan, Netherlands, Splain, Sweden, Switzerland, United Kingdom, United States.
	Australia, Austria, Denmark, Greece, Luxembourg, Portugal & Turkey have observer status.

JOINT PROJECTS IN RADIOACTIVE WASTE MANAGEMENT

THE INTERNATIONAL STRIPA PROJECT



Phase 3 of the Stripa Project will investigate groundwater flow characteristics of an unexplored volume of granite 350 meters below ground.

Another important element in the safe disposal of waste is to determine the geological suitability of potential disposal sites. Crystalline rock such as granite is known to provide adequate shielding against radiation and to absorb and disperse the heat produced by radioactive waste. The only probable way for radionuclides to reach man's environment would be by release from their waste packaging and subsequent migration in ground-water. Therefore extensive studies have been undertaken of the interactions between ground-water, rock and engineered barriers such as pack-aging materials.

To develop methods and techniques for such studies, the Stripa Project was organised in 1976 in an abandoned iron ore mine in central Sweden. The Stripa Mine is an *in situ* research laboratory and is not intended to be used to store radioactive material. The granitic rock adjacent to the old mine is estimated to be 1 700 million years old and is the site of all Stripa experiments. The main test area is about 800 metres from the mine access shaft, and transportation to this area is provided by a train which passes through the old mine excavations.

Successful experiments carried out at the mine from 1977-1980 by a Swedish-American group aroused international interest, and in 1980, the NEA assumed sponsorship of the project. Its principal objectives are to conduct a detailed investigation of the suitability of granite as a medium for isolating radioactive wastes and to examine specific aspects affecting the performance of an engineered repository in granite.

In the first two phases of the project, techniques were developed to study the geology, hydrology and hydrogeochemistry of potential sites, to examine how groundwater flows within fractured rock and to assess the suitability of bentonite clay as a sealing material to close a repository. The results showed that materials based on bentonite are very suitable substances to act as buffers around waste canisters and to backfill the repository when it is closed. The successful completion of these two phases led to better investigative techniques and increased practical knowledge for siting and designing repositories.

The third phase, which began in 1987, is designed to investigate how groundwater flows in an unexplored volume of granite some 350 metres below ground, based primarily on techniques developed in the first two phases of the project. Seismic, radar and hydraulic instruments are used to test the ability to predict the flow within fractured crystalline rock. This is of major importance in the selection of candidate sites for waste disposal.

Other studies will identify, select and evaluate sealing materials, such as bentonite, for long-term chemical and mechanical stability, and will demonstrate this stability for sealing fractures found in the vicinity of a repository. Possible sealing materials will be surveyed and certain ones will be selected and tested for long-term stability. A pilot field test will then be carried out to demonstrate the injection techniques appropriate for these materials and to obtain information on the effectiveness of their sealing properties.

Specific investigations are designed to establish the technical feasibility of deep disposal systems; for example, a series of *in situ* tests will be carried out to characterise the flow of groundwater in rock fractures. Although the Stripa studies have been carried out in granite, the methods used and some of the results obtained should be applicable to other media as well. The techniques developed and experience gained in the Stripa Project will thus provide the basis for OECD countries to carry out detailed investigations at a variety of potential radioactive waste disposal sites.

INTERNATIONAL STRIPA PROJECT (PHASE III)

Budget:	Central budget – $19.2 million
Duration:	1991
NEA Role:	Advisor, secretariat services
Management:	Managed by Sweden, the Host Country
Members:	Canada, Finland, Japan, Sweden, Switzerland, United Kingdom and United States.

GEOCHEMICAL DATA BASES

Credit: L. Greco

Work carried out at the NEA Data Bank helps determine the solubility of radionuclides in radioactive waste.

In a deep geologic disposal system, the migration of radionuclides into man's environment is prevented by a series of barriers such as the form of the waste and its packaging, the engineered repository and the geologic environment surrounding it. Of these barriers, the geologic environment generally contributes most to the long-term isolation of the waste.

Any credible scenario for the release of radioactivity from a repository is based on the mobilisation and transport of radionuclides by water. In some geologic media, such as massive salts or clays, water is not expected to be present. In others, water could eventually breach the waste package and dissolve radioelements. In such scenarios, chemical processes in the geologic barrier will, to some extent, retard or actually stop this migration in flowing groundwater. Understanding these processes and being able to predict their effect by the use of mathematical models are therefore essential for assessing the performance of the geologic barrier.

The Sorption Data Base (SDB) is a system for storing and handling information related to the transfer of radionuclides from groundwater solutions into or onto geologic materials, expressed in terms of a distribution coefficient, called Kd.

The system was initially created in 1981 as the International Sorption Information Retrieval System (ISIRS) for an experimental two-year period while the computer software was being developed in the United States. In 1983, the data base and software were transferred to the NEA Data Bank for a two-year evaluation period, after which the system was in routine operation. The information contained in the system provides a large number of parameters describing the experimental conditions designed to obtain the coefficients. In 1987, ISIRS was merged into the newly created and expanded SDB which now operates from a personal computer using commercially available software.

Another powerful tool used in geochemical modelling is chemical thermodynamics, which predicts the concentration of radionuclides under various conditions. The NEA Thermochemical Data Base (TDB) was established in 1983 to provide a reliable source of geochemical data to Member countries. The objective of the TDB is to compile, critically review and publish the best chemical data for key elements involved in the disposal of nuclear waste, such as uranium and plutonium. The reviews are performed by a group of independent experts knowledgeable in the chemical thermodynamics of each element. This data can be used in particular by geochemists to model the migration of radionuclides in the geosphere and thereby assess the safety of waste disposal systems. The TDB project is still under development.

A Geochemical Modelling and Data Group was established in 1987 to co-ordinate and advise on the activities of SDB, TDB and related topics. By promoting the development of complementary international data bases, the NEA tries to provide the primary geochemical modelling data needed to assess the performance of radioactive waste disposal systems.

THE NEA SORPTION DATA BASE (SDB) AND THE NEA THERMOCHEMICAL DATA BASE (TDB)

The SDB and the TDB are projects run by the NEA Secretariat in co-operation with the NEA Data Bank for the benefit of all NEA Member countries. They are financed through the normal NEA budget and include *ad hoc* contributions from Member countries.

THE ALLIGATOR RIVERS ANALOGUE PROJECT

Studies at the Alligator Rivers site will determine the long-term physical and chemical processes likely to influence the transport of radionuclides through rock masses.

Effective disposal of high-level radioactive waste requires the ability to predict how radionuclides might move through the rock masses in which they are to be buried. By studying uranium ore deposits which contain naturally occurring radionuclides, insight can be gained into the long-term physical and chemical processes likely to influence this movement. These processes may resemble those which would act upon a high-level waste disposal facility; hence the term "natural analogues" to describe such studies. These studies can thus be used to increase the confidence placed in predictions of the safety of potential radioactive waste disposal sites.

The Koongarra uranium ore deposit in the Alligator Rivers region of the Northern Territory of Australia has been chosen for an international research project under the auspices of the NEA. The project, which is managed by the Australian

Nuclear Science and Technology Organisation (ANSTO), was approved in 1987 for an initial three-year period. It builds on research carried out at the site since 1981 and will include six technical sub-projects. Extensive mineralogical, geochemical and hydrological information was made available by Denison Australia Pty. Ltd., which carried out the initial exploratory work at the Koongarra deposit.

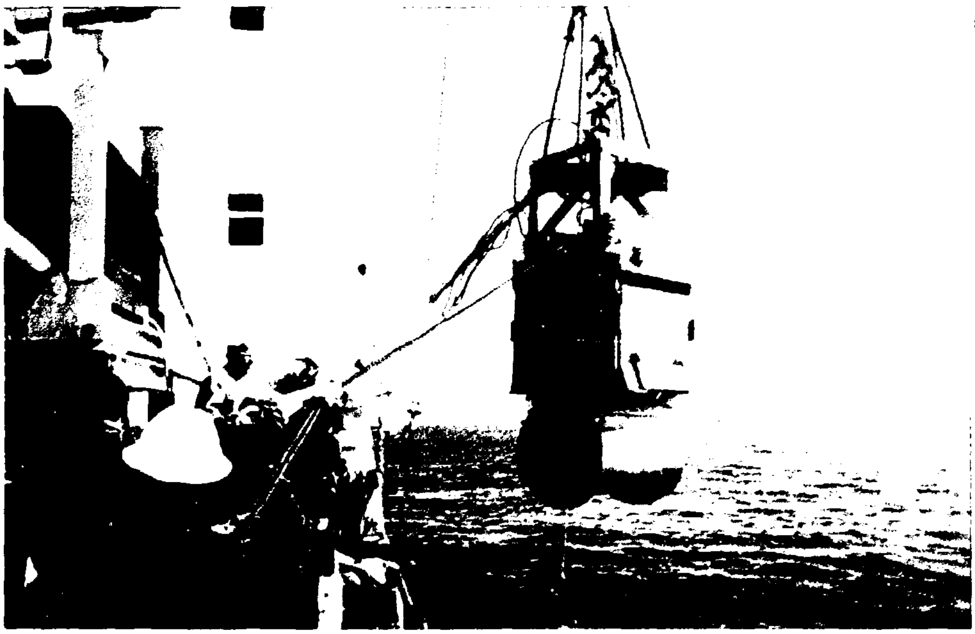
The Koongarra deposit lies near a fault between sandstone and quartz chlorite schist, and a strong groundwater flow crosses it. This makes it a suitable site to study the concentrations of uranium in the various kinds of rock and the effect of the groundwater movement. Field observations and laboratory measurements will be made at Koongarra and compared with large-scale hydrogeological models and detailed geochemical models to determine if they accurately predict the behaviour of radionuclides.

Existing experimental data have been reviewed, areas have been identified where new data are required, and basic data have been assembled for a test to validate the migration model. On-going field work is contributing significant new data on hydrology, geochemistry, radioisotope disequilibria and fission product and plutonium distributions.

ALLIGATOR RIVERS ANALOGUE PROJECT

Budget:	Central budget – $1.85 million
Duration:	1990
NEA Role:	Advisor
Management:	Australian Nuclear Science & Technology Organization
Members:	ANSTO, Japanese Atomic Energy Research Institute, Swedish Nuclear Power Inspectorate, Her Majesty's Inspectorate of Pollution (U.K.), the U.K. Department of the Environment, the U.S. Nuclear Regulatory Commission, and, as an associate participant, the Power Reactor and Nuclear Fuel Development Corporation of Japan.

SEABED DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE



Credit CEA

This instrument was used to take samples of sediment in an effort to determine if high-level waste could be disposed of deep beneath the ocean floor.

Although burial in deep geologic formations on land is the preferred option for high-level waste, a second option has been studied in depth—disposal in geological layers underlying the ocean floor. Both options have the same *objective*: to isolate the radionuclides in a multi-barrier system in which the geological environment provides the main containment barrier.

The Co-ordinated Programme on Seabed Disposal of High-level Radioactive Waste was formally created within the NEA in 1977 to study this concept. After more than eleven years of research conducted by the NEA Seabed Working Group, an *eight-volume report* was published in 1988 which evaluated the technical feasibility and radiological safety of this disposal concept. Three key questions were the focus for the report:

1) Are there locations under the oceans which have the geological stability and barrier properties suitable for disposal?

2) Is it possible to implant waste-filled canisters in the seabed sediments and what effect does this emplacement have on the barrier properties of the containment system?

3) What are the radiological consequences of seabed burial?

Volume I provides an overview of the research and a summary of the results. The other volumes contain a more detailed description of radiological assessment, geoscience characterisation, engineering studies and the scientific basis upon which the radiological assessment is built. Two sites in the North Atlantic were used as reference sites for the assessment, while eight other North Atlantic and two North Pacific sites were also evaluated, less extensively. The ideal site, in principle, would be located 4,000 to 6,000 meters below sea level, away from the edges of tectonic plates where seismic or volcanic movements could disrupt the repository and expose the waste canisters. The sites would be chosen for their ability to contain radionuclides if the canister fails through corrosion.

To help determine which sediments would best contain the radionuclides, one of the world's largest international research cruises was organised in 1985 to bore holes in two areas in the Eastern and Western Atlantic, at sites identified during previous cruises. Samples were taken at both sites and extensively analysed on board, using the most advanced equipment available. Other studies carried out during the cruise focussed on methods of placing the waste into the seabed.

Waste canisters can be implanted at a depth of 50 to 70 meters into the sediments by using a penetration technique. Canisters weighing several tons would be loaded into a torpedo-shaped device which is dropped from a ship above the disposal area and allowed to fall through the water column, gaining enough momentum to imbed itself deep into the sediments. The holes would immediately close and seal dynamically. Alternatively, holes 800 meters deep could be drilled in the sediment to hold stacks of canisters, the uppermost at about 100 to 200 meters below the ocean floor. The holes would then be backfilled. Deep-hole drilling beneath the ocean floor is a method that has been demonstrated in non-nuclear programmes over the past 20 years, and thus much of the technology has already been developed. The properties of the sediments seem to be unaffected by either method.

The studies carried out by the Working Group point out that seabed burial appears to be a potentially safe and practically feasible method to dispose of high-level radioactive wastes or spent

CO-OPERATIVE PROGRAMME ON SEABED DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE

Budget:	No central budget, countries bear own costs
Duration:	Project completed
NEA Role:	Secretariat Services
Members:	Belgium, Canada, France, Germany (Fed. Rep.), Italy, Japan, Netherlands, Switzerland, United Kingdom and United States. Observer: Sweden.

fuel. Among the specific conclusions reached by the group were that these wastes could be emplaced in sediment formations using currently available technology and that seabed disposal would be economically acceptable.

Results of the study indicated that the primary sediment barrier would contain most of the radionuclides for thousands of years and that any possible subsequent release of radionuclides in the environment would result in radiological risks many orders of magnitude below present standards for human health protection, even in the long term. Further research is needed, however, to reduce uncertainties on a number of specific issues related to engineering aspects and to the migration of radionuclides in the sediments. The NEA report will help determine whether research on this subject will be continued at an international level.

DECOMMISSIONING NUCLEAR FACILITIES

One of the important sources of radioactive waste in the future will result from the decommissioning of nuclear reactors once they have ceased generating power and their fuel has been removed. The time between actual shutdown and the beginning of decommissioning may range from a few years to a few decades and several large reactors in the OECD area have already undergone defuelling.

In 1985, the NEA established the Co-operative Programme on the Exchange of Scientific and Technical Information Concerning Decommissioning of Nuclear Installations to provide a forum for the exchange of experience and to develop the data base needed for decommissioning large nuclear power plants.

The programme currently includes 13 national decommissioning projects which are of comparable magnitude or degree of technical interest. Each participating country bears the cost of its national Project and is represented on the Liaison Committee, which develops arrangements and procedures for the programme. Participating countries without a project may attend meetings in an observer capacity.

Credit JAERI

A number of NEA countries exchange information on the tools and techniques used to dismantle nuclear reactors. Here, the JPDR reactor in Japan.

In addition to this broad exchange of information, participants have also entered into special arrangements to pursue subjects of mutual interest. A Technical Advisory Group, consisting of senior specialists for each national Project, is responsible for the actual management and organisation of the technical exchanges. This Group makes technical visits to the participating countries to observe work in progress on decommissioning Projects and other technical installations.

Decommissioning is not a single operation, but rather a complex series of inter-related steps, ranging from the removal of reactor fuel and the disconnection of operating systems to the complete dismantlement of the plant and return of the site to its original state. These stages can be carried out by rapidly progressing from one stage to the next or by prolonging the decommissioning period for as long as 100 years or more.

Decommissioning has already been carried out on small test, training and power demonstration reactors and supporting fuel cycle facilities. Thus, some experience has been gained in decommissioning the major reactor types. Although present technology is believed to be adequate because techniques used to decommission small plants can be applied to commercial-size facilities, further development is desirable in some areas to reduce worker exposure, costs and waste volumes. Such areas include the development of better equipment and methods for remote dismantlement to reduce worker exposures, better methods for rapidly determining the radioactivity levels in waste and improved techniques for minimizing the generation of waste by treating it and reducing its volume. The NEA Co-operative Programme will reduce the resources needed for research and development by making information on these new developments readily available to all participating countries.

DECOMMISSIONING NUCLEAR FACILITIES

Budget:	No central budget, countries bear own costs
Duration:	*5 years, renewable*
NEA Role:	Secretariat of the Liaison Committee, advisor and co-ordinator
Members:	Belgium, Canada, France, Germany (Fed. Rep.), Italy, Japan, Spain, Sweden, United Kingdom and the United States.