Inside the Windscale advanced gas-cooled reactor, now being decommissioned in the United Kingdom. (Credit: UKAEA)

The European Community's research programme – next phase

Dismantling operations and waste treatment are major elements

by B. Huber

In 1979, the European Community started its first 5-year programme of research on the decommissioning of nuclear power plants. It was carried out by organizations and companies in member States under 51 research contracts, most of them cost-sharing.* In 1984, a second 5-year programme began, this one with a more general scope, the decommissioning of nuclear installations.

The second programme's general objective was set out by the Council of the European Communities during its adoption, when it considered that: "Certain parts of nuclear installations inevitably become radioactive during operations; it is therefore essential to find effective solutions which are capable of ensuring the safety and protection of both mankind and the environment against the potential hazards involved in the decommissioning of these installations".

Protection against these potential hazards means to isolate the radioactivity from man and his environment by appropriate barriers. Since strong radioactivity barriers already exist in a nuclear installation, *in-situ* storage of radioactive components is a possible way to isolate radioactivity until initially dominating shorter-lived radionuclides have died away. Eventually, however, the remaining radioactive material is to be transferred to a final radioactive waste repository, because its long-term isolation is best achieved there and it allows the release of the installation site for other uses.

This transfer, which involves breaking up existing radioactive barriers and creating new ones, is a critical phase in decommissioning. Accordingly, the programme's major part has been devoted to operations in this phase – that is, dismantling and decontamination of plant components, and treatment and packaging of arising waste materials.

The programme's main effort has been aimed at providing efficient techniques and procedures for decommissioning, considering radiation protection, restriction of radioactive waste arisings, and cost effectiveness. Though a number of conventional techniques appear to be applicable in decommissioning, there is a need to improve their performances and to optimize and characterize them with a view to special requirements owing to radioactivity – for example, control of airborne contamination and remote operation.

Another aim has been to provide basic necessary information about decommissioning, such as data on the distribution, level, and radionuclide composition of radioactivity associated with shutdown nuclear installations. A third aim has been to identify and develop plant design features facilitating decommissioning.

Integrity of buildings and systems

If one considers, for instance, that the radiation dose rate from activated stainless steel typically decreases by a factor of more than 100 000 over a period of 100 years, *in-situ* storage of nuclear power plants appears an effec-

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* See *Decommissioning of Nuclear Power Plants*, Proceedings of a European Conference held in Luxembourg, 22–24 May 1984, edited by K.H. Schaller and B. Huber, EUR 9474, Graham & Trotman Ltd. (1984).

The European Community's decommissioning research programme, 1984–88

Research and development projects
- Long-term integrity of buildings and systems
- Decontamination for decommissioning purposes
- Dismantling techniques
- Treatment of specific waste materials: steel, concrete, and graphite
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tive way to facilitate eventual dismantling and treatment of radioactive material. So far, *in-situ* storage has been the preferred procedure for commercial nuclear power plants that already have been shut down. The implications of storage over extended time periods, ranging from several decades to about 100 years, have been investigated under the Community programme.

Measures have been studied to put plants into conditions assuring safety essentially through passive means and with a minimum of continued surveillance and maintenance. Plant systems were identified that are to be maintained in operation or in operable condition (to serve in dismantling the plant).

The mode and pace of degradation of various materials as they exist in nuclear power plants have been studied. This involved inspections of plants (to identify critical areas) and examinations of samples. Measures have been proposed to prevent or control degradation.

These studies showed no problem that would make the feasibility of *in-situ* storage of shutdown nuclear power plants doubtful.

Decontamination procedures

Surface contamination represents only a minor amount of radioactivity compared with the internal activation by neutron exposure of components near the reactor core. However, it is spread over a wider range of components and is more readily accessible. Whereas activation occurs only in reactors, surface contamination also is present in other types of nuclear installations. Therefore, it is an important source of low-level radioactive waste and a concern for radiation protection in decommissioning operations.

Surface decontamination, which is the removal of the radioactive surface layer from a plant component, facilitates the component's further handling and processing. The removed radioactive substance should be concentrated into a small volume of secondary waste that is easy to condition for disposal. If the decontamination is efficient enough, it makes it possible to consider the treated component as non-radioactive material. This is then a way to reduce the overall radioactive waste volume and to recover valuable raw materials.

Decontamination for the purpose of unrestricted release is not yet a common procedure. For many nuclear components, the available information is not sufficient to decide whether decontamination is appropriate, taking into account the attendant radiation exposure, secondary waste production, and cost. Characteristics favourable for decontamination are a low level and penetration depth of the contamination and a low surface-to-volume ratio of the component. The range of components for which decontamination for unrestricted release is feasible is being enlarged by development of more efficient decontamination procedures. These can be more aggressive than those currently used since weakening of treated components is acceptable.

As a prerequisite to decontamination, investigations have been made of the distribution, the radionuclide composition, the chemical nature, and the penetration depth of surface contamination in nuclear power plants. Regarding decontamination of steel components, research has been focused on aggressive chemical and electrochemical methods. For decontamination of concrete, flame scarifying – a technique using an oxyacetylene torch to remove thin surface layers – has been developed.

Dismantling techniques

In decommissioning nuclear installations, large radioactive components and structures must be dismantled. Important examples are:
- The highly radioactive reactor internals of light-water reactors, which are made of stainless steel up to a hundred millimetres thick
- The pressure vessels of light-water reactors, which consist of stainless steel clad carbon steel, with thicknesses up to 300 millimetres in the wall and up to 600 millimetres at the vessel flange
- Biological shielding structures, consisting of reinforced concrete several metres thick.

Dismantling substantially radioactive components must be carried out remotely with adequate radiation shielding for personnel protection. Where possible, segmenting may be performed underwater.

Various conventional dismantling techniques may be employed in decommissioning. Generally speaking, thermal segmenting techniques tend to achieve high cutting rates but pose problems due to the production of fine particles. Mechanical techniques tend to be time consuming and need heavy manipulators.

Regarding segmenting of steel components, research has been focused on three thermal techniques: plasma cutting (including underwater operation); plasma-oxygen cutting; and laser cutting. Thereby, the characteristics of aerosols produced and the performances of various off-gas filtering systems have been investigated in particular.

For dismantling radioactive reinforced concrete structures, a diamond-tipped circular saw has been developed that achieves substantially higher cutting rates than previously available equipment. In a final test of the saw, a one metre cube was cut out from a reinforced concrete wall. As an alternative to sawing, explosive techniques are being investigated with a view to employing them with a high degree of control.

Treatment of waste materials

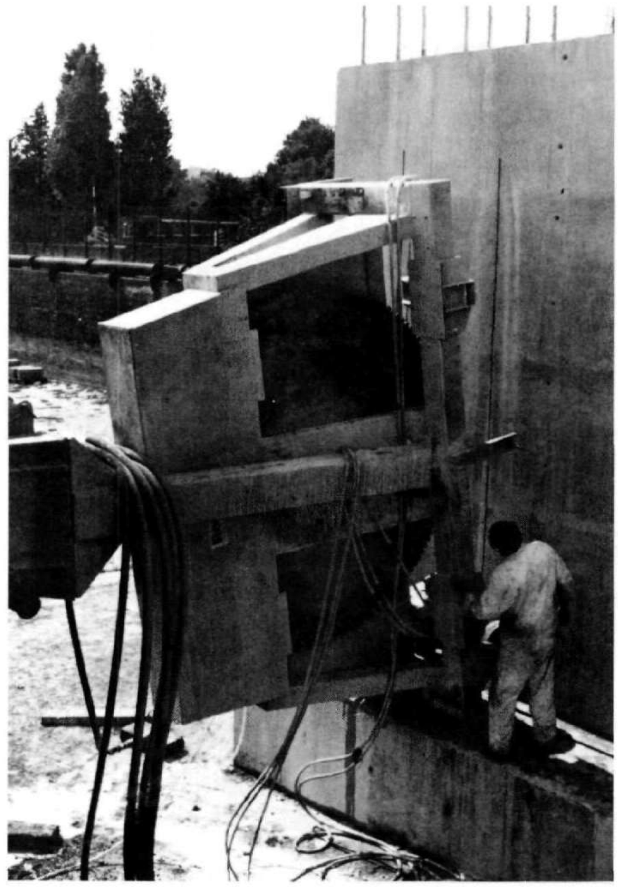
Waste from dismantling nuclear installations mainly consists of steel, concrete, and, in the case of gas-cooled reactors, graphite. Methods have been investigated for treating these materials with a view to disposal, or where possible with steel, for re-use.

Conditioning radioactive steel waste by melting offers several advantages with regard to disposal – reduction of the bulk volume; immobilization of surface contamination by incorporation into the base metal; and reduction of the surface area that might be attacked by corrosion. On the other hand, the decontamination effect of melting is important with respect to the recycling of steel. In the case of contaminated surfaces having complicated geometry or difficult access, melting enables a more accurate determination of the radioactivity.

Melt tests using low-level radioactive steel from various reactor types have been carried out. Special attention has gone to the distribution of the various radionuclides on the metal product, the slag, and the off-gas. Metal radioelements, such as cobalt and nickel, were shown to be distributed in the metal ingot, as expected. Caesium is not contained in the metal, but can be retained in the slag. Work on melting is being continued and will be extended to steel scrap that is contaminated with actinides.

Coating techniques using polymer resins are being developed to durably fix surface contamination on metal and concrete. Silicate solutions are being investigated to bind concrete dust.

For graphite waste, various management modes have been assessed: incineration, sea disposal, shallow land burial, and deep geological disposal. The research involved determination of the radionuclide inventory of reactor graphite; conceptual studies of the incinerator flow sheet and of waste packages; leach tests of irradiated graphite samples; and estimates of the radiological impact and cost. It appeared that all management modes considered in this generic study merit further investigation and that the choice of the optimum mode must be made in a specific context.



This diamond-tipped circular saw was developed and tested for dismantling thick concrete structures at nuclear plants. (Credit: CEGB)

Large waste containers

Radioactive waste from dismantling nuclear installations should be transported and disposed of in larger units than those now used for other types of radioactive waste, so that the required amount of segmenting is reduced. In an initial study, conceptual designs have been prepared of a disposable reinforced concrete container and – for the higher-level radioactive material – of re-usable, cast-iron containers. Future studies also will give consideration to disposable cast-iron containers produced by recycling of low-level radioactive steel scrap.

Estimating radioactive waste arisings

The low-level radioactive waste produced in dismantling nuclear installations ultimately will constitute a substantial part of the overall volume of radioactive waste generated by the nuclear industry. Estimates of future arisings of such waste, therefore, are needed for planning waste disposal facilities. The radioactivity associated with the waste must be known, with particular reference to long-lived radionuclides, in order to classify the various types of waste with respect to the appropriate disposal modes. The knowledge also is needed to predict the decrease of radiation levels as a function of time, which is an important factor to be considered in the timing of dismantling. This timing, in turn, will determine the point when waste disposal facilities are needed. Since this project involves the definition of reference strategies for decommissioning, it is regarded as a long-term task.

Radionuclide contents have been measured on activated steel and concrete samples from shutdown boiling-water reactor plants. In particular, the thickness of the activated inner layer of biological shields has been determined by examination of boring samples.

Trace elements whose concentrations are not defined in material specifications constitute a number of the relevant source elements for the activation of steel and concrete. Data on these concentrations, sometimes at the parts-per-million level, are needed for the calculation of activation. To explore the ranges of relevant trace element concentrations expected in reactor materials, non-radioactive samples from numerous origins were analysed.

A methodology has been prepared for evaluating the radiological consequences of various management modes for very low-activity steel and concrete from dismantlement of nuclear power plants. Such a methodology is necessary if "de minimis" radioactivity levels are to be defined.

A subject attracting more and more attention is the measurement of the radioactivity of solid material arising from dismantlement.

Design features

The design of nuclear installations has progressively evolved and many improvements that were made with a view to operations also will facilitate decommissioning. Examples are improvements of radioactivity barriers, such as fuel claddings and steam generators, which reduce the contamination of the nuclear power plant. On the other hand, more safety requirements have tended to increase the volume of components and structures to be dealt with in decommissioning.

Design features facilitating decommissioning of nuclear power plants have been reviewed. Although requirements relating to the safety and reliability of reactor operation, as well as cost-effectiveness aspects, restrict the latitude for modifying plant designs, certain specific features appeared to merit closer investigation. An example is the development of cobalt-free materials as substitutes for cobalt alloys used in reactor coolant circuits; for example, for valve seatings.

Identifying guiding principles

The identification of guiding principles in the decommissioning field is considered a long-term task, since it must be based on an appropriate body of technical information. In this regard, a number of relevant studies comprise the Community programme. Additionally, available material in CEC member States has been assembled that could serve as a basis for guiding principles.

It appears that existing systems of authorization and control, together with the radiological protection standards in force, already make it possible to decommission nuclear power plants on a case-by-case basis. However, no specific technical regulations on decommissioning exist. A basic uncertainty regarding final decommissioning – that is, release of sites for re-use – lies in the absence of specified criteria for distinguishing non-radioactive material from radioactive material.

Testing techniques in real conditions

Some decommissioning techniques being developed already have been tested under real conditions and on a significant scale during the CEC's 1979–83 programme. Examples are the decontamination of steel components and concrete surfaces in a shutdown boiling-water reactor plant, and the use of electropolishing and flame scarifying.

Currently, testing under real conditions has become an important part of the programme, involving decontamination and dismantling operations in various shutdown nuclear power stations and fuel fabrication plants.