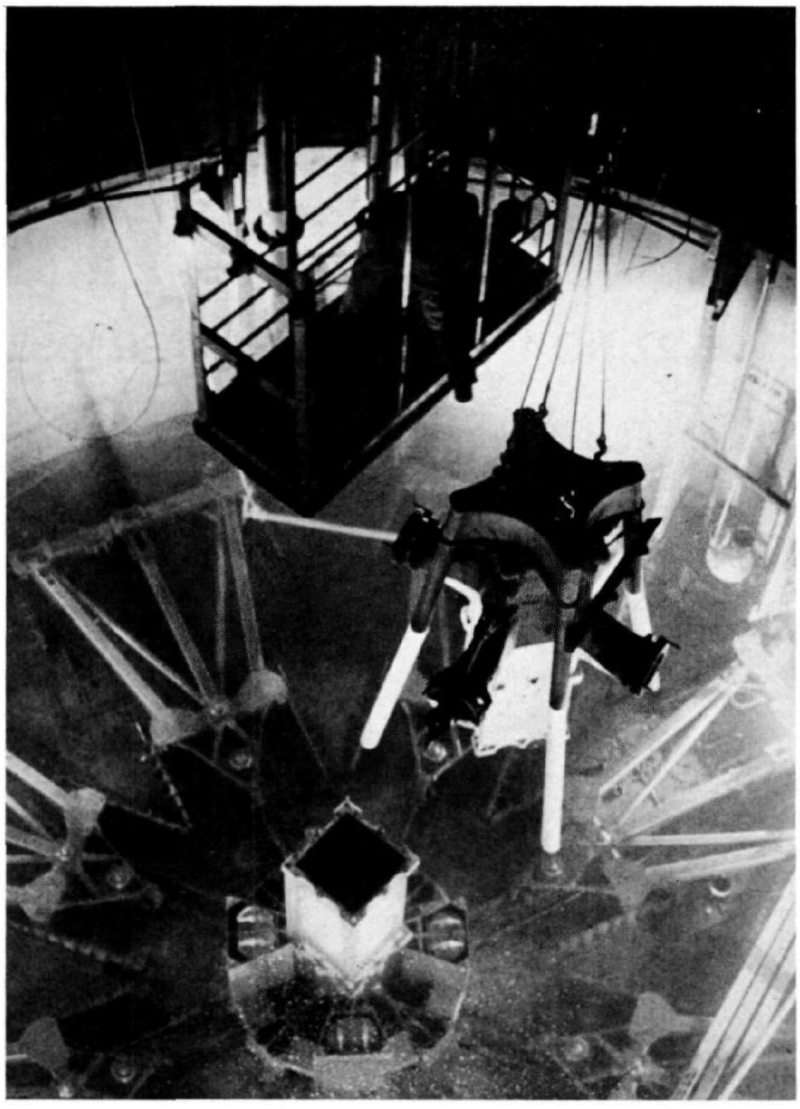
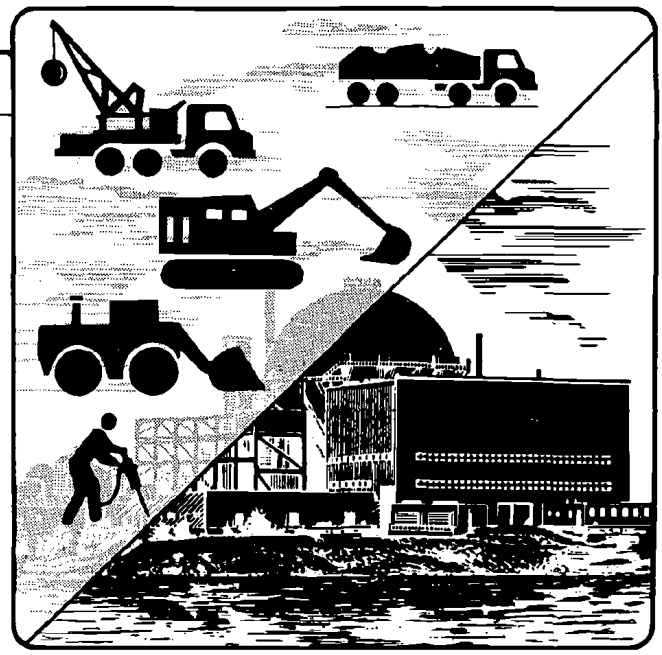


Dismantling operations inside the core of the Pégase research reactor in France. The reactor was decommissioned to Stage-3 in 1978. (Credit: CEA)

Below: At the Elk River facility in the USA, a worker uses a conventional flame torch to remove control rod nozzles before the lower head of the reactor pressure vessel was lifed. The facility was dismantled from 1971 to 1974. (Credit: US DOE)



Building on experience: An international perspective

An overview of decommissioning and the IAEA's role in worldwide co-operation

by M.A. Feraday

Taking a plant out of service for good – a process generally called decommissioning – is a common industrial activity often portrayed as an operation for a giant wrecking ball and crane. Plants and buildings can wear out, become obsolete, or become too costly to keep maintaining. Many simply are demolished or disassembled. But others are cleaned up, overhauled, and adapted for other uses, not necessarily industrial uses. Options exist.

In the nuclear industry in years ahead, decommissioning activities will take on added importance. After decades of service, many facilities are due for permanent retirement, and decisions will be taken about their fate. For some installations, choices already have been made and work is in progress.

In the planning and work ahead, past experience in decommissioning nuclear and other industrial facilities will be of major benefit in closing down nuclear reactors safely and efficiently. So, too, will be new techniques, equipment, and procedures that are now being studied, tested, or demonstrated in specific applications at nuclear sites. Yet work remains to be done in various areas.

The following series of articles offers an overview of the field by highlighting some activities around the world.

With a large number of potential candidates on the horizon, the decontamination and decommissioning of nuclear facilities is of great interest internationally. More than 100 of 270 research and test reactors worldwide, for example, have been in operation for more than 20 years. Some will soon be past their useful lives. Also, older nuclear power plants, such as Gundremmingen-A in the Federal Republic of Germany, Windscale (WAGR) in the United Kingdom, and Shippingport in the United States, are currently being decommissioned.

By the year 2010, it is estimated that reactors equivalent to over 50 gigawatts-electric (GWe) could be ready for decommissioning in countries of the Organisation for Economic Co-operation and Development (OECD). By 2030, another 330 GWe could be ready.

In addition, a wide variety of other nuclear fuel cycle and non-nuclear fuel cycle facilities currently need remedial action or decommissioning. In the USA alone, over 50 formerly used sites for processing or mine tailing, and 500 other active surplus facilities, require decommissioning. The nuclear fuel cycle facilities include fuel fabrication, conversion and reprocessing plants, hot cells, laboratories, and storage buildings. Non-nuclear fuel cycle facilities include facilities such as hospitals, research laboratories, and radiopharmaceutical manufacturers which handle radioisotopes.

No serious technical problems

During the last 35 years, considerable experience and technology have been accumulated on the decommissioning and rehabilitation of many types of nuclear facilities. Although no large power reactors have been completely dismantled yet, there is a general consensus

Mr Feraday is a staff member in the Agency's Division of Nuclear Fuel Cycle.

Designs: W. Kalabis

Technical reading

Technical information about various aspects of decontamination and decommissioning nuclear facilities appears in a number of reports based on the co-operative work of IAEA's Member States in various forums. Prepared and published by the Agency, these include:*

- *Decommissioning of Nuclear Facilities,* IAEA-TECDOC-179 (1975)
- *Decommissioning of Nuclear Facilities,* IAEA-TECDOC-205 (1977)
- *Safety in Nuclear Power Plant Operation Including Commissioning and Decommissioning: A Code of Practice,* IAEA Safety Series No.50-C-O (1978)
- *Decommissioning of Nuclear Facilities,* Proceedings of an international symposium jointly sponsored by the OECD/NEA and IAEA (1979)
- *Manual on Decontamination of Surfaces,* IAEA Safety Series No.48 (1979)
- *Factors Related to the Decommissioning of Land-Based Nuclear Reactor Plants,* IAEA Safety Series No.52 (1980)
- *Decommissioning of Operational Nuclear Power Plants,* IAEA-TECDOC-248 (1981)
- *Decommissioning of Nuclear Facilities: Decontamination, Disassembly, and Waste Management,* IAEA Technical Reports Series No.230 (1983)
- *Decontamination of Nuclear Facilities to Permit Operation, Inspection, Maintenance, Modification, or Plant Decommissioning,* IAEA Technical Reports Series No.249 (1985)
- *The Methodology and Technology of Decommissioning of Nuclear Facilities,* IAEA Technical Reports Series (in press)
- *Safety in Decommissioning of Research Reactors,* IAEA Safety Series (in press).

* See *Keep Abreast* section for ordering information. TECDOCS generally are available only on microfiche.

amongst experts that, regardless of the sequence of stages, there are no serious technical problems which will prevent the safe decommissioning of any nuclear facility using current technology. Conceptual studies and projects support this viewpoint.

There is also a general consensus that the cost of decommissioning nuclear facilities and disposing of the wastes will only represent a small fraction of the electricity bill to the customer.

Although progress has been made in the development of the technology and methodology of decommissioning, further work is required to improve equipment and techniques, reduce costs, and reduce exposures to as low as reasonably achievable taking into account economic and social conditions. These developments must ensure that the technology required to perform the major steps in a decommissioning programme is available.

A multi-step process

Decommissioning a major nuclear facility such as a large power reactor is a fairly complex multi-step process requiring good planning, the right equipment, storage or disposal facilities, and well-trained crews.

Once a decision has been made to decommission a facility and the preliminary socio-political and regulatory steps have been completed, the major decommissioning steps in simplistic terms are:

- Calculate residual radioactive inventory in the facility
- Draw up detailed decommissioning, financial, safety, and management plans
- Get final regulatory approval
- Decontaminate the facility
- Dismantle the facility
- Characterize the wastes, segregating for re-use or disposal to a repository site or landfill
- Condition, immobilize, and package the waste
- Transport wastes to a disposal repository
- Clean site for unrestricted use
- Dispose of the wastes in sites suitable for their level of activity
- Provide feedback to designers of new facilities.

Importance of national strategy

To ensure that nuclear facilities can be decommissioned in a safe, efficient, and cost-effective manner, each country should have a national strategy to ensure that the important facets of a decommissioning programme are developed on a co-ordinated timescale and in a manner to meet national requirements. Such a strategy will ensure that the technology and methodology to complete each technical step are available. For example, suitable disposal or storage facilities must be available or decommissioning cannot proceed past the third step listed above.

Although the types of nuclear facilities and wastes arising from facilities are quite diverse, the planning, as well as many techniques used for the above technical steps, are similar and adaptable to different types of facilities.

For countries not having well-developed decommissioning programmes and equipment, assistance is available from international organizations such as the IAEA or from other countries having well-developed programmes.

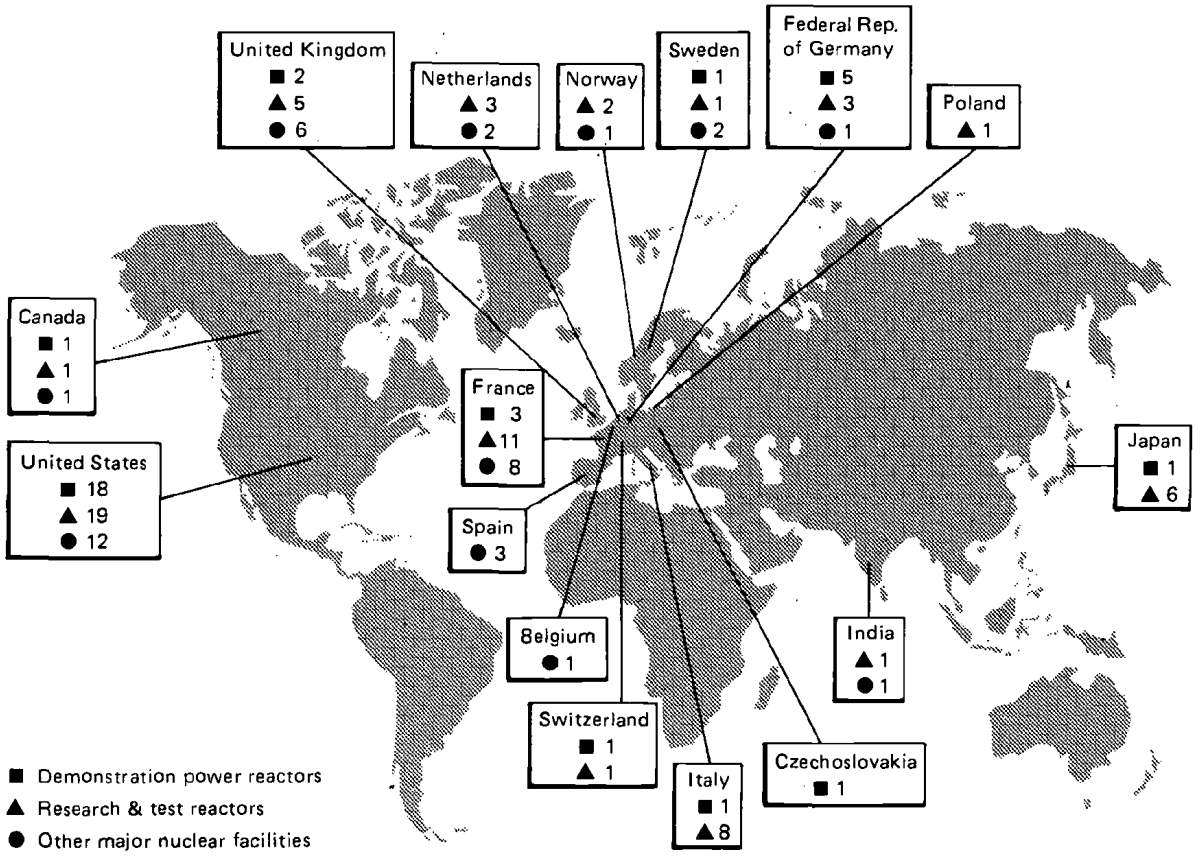
IAEA's decommissioning programme

Since the IAEA first included the subject of decommissioning in its programmes in 1973, various Agency documents reflecting the needs of Member States on this topic have been written (see accompanying box for a listing). These reports summarize the work done by various technical committees, advisory groups, and international symposia on various decommissioning and decontamination topics. The documents produced by the Agency on this topic in the past have been well received by the technical community and provide a valuable resource to Member States, particularly to those developing countries which are initiating decommissioning activities.

In response to increased international interest in decommissioning and to the needs of Member States,

Decommissioning projects worldwide

Over the past 35 years, considerable experience has been gained in decommissioning and rehabilitating many types of nuclear facilities. Others are now in various stages of decommissioning or soon are expected to be. In all, some 134 nuclear facilities in 16 countries are listed in IAEA's inventory of decommissioning projects either completed, planned, or in progress. Comprehensive tables of nuclear facilities by type, location, and decommissioning stages appear in the IAEA Technical Report *The Methodology and Technology of Decommissioning of Nuclear Facilities* (in press).



the IAEA's activities in this area have increased during the past few years. It has been decided that these activities will be enhanced considerably in the future. As a result of an intensive review of the programme and the needs of Member States, a long-range programme using an integrated systems approach covering all the technical and regulatory steps associated with the decommissioning of nuclear facilities is being developed. The data base resulting from this work is required so that Member States can decommission their nuclear facilities in a safe, timely, and cost-effective manner and the Agency can effectively respond to requests for assistance.

The objective of the Agency's decommissioning programme is to assist Member States to develop the expertise required to decommission their nuclear facilities. This is done in particular by collecting, assessing, and disseminating data on the latest technical, regulatory, and economic aspects of decommissioning; giving technical assistance and guidance to Member States to help in the establishment of suitable programmes and in the planning and implementation of their decommissioning activities; and co-operating in the development of guidelines, safety codes, and guides on this topic.

Data base on decommissioning

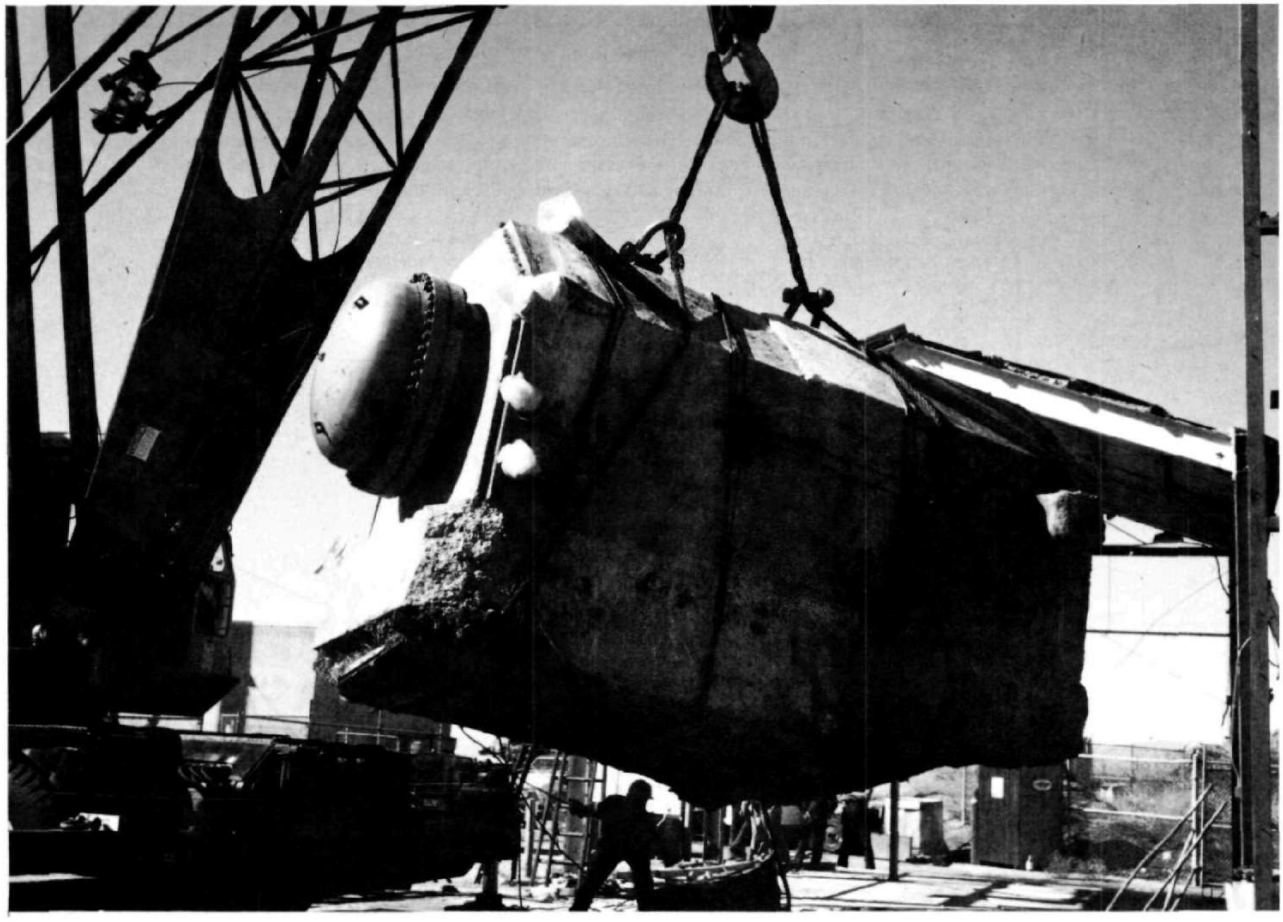
The integrated data base being developed will cover all the technical and regulatory aspects of decontamination and decommissioning.

In an earlier report, an outline of the general principles and factors to be considered in the decommissioning of land-based nuclear reactors in a safe and orderly manner was provided.* That report contains discussions on the planning, management, quality assurance, and release criteria to carry out a decommissioning project successfully. A later report provides information on the technical considerations important to decommissioning, as well as briefly looking at methods available for decontamination and disassembly of a nuclear facility and outlining areas of decommissioning methodology where improvements can be made.**

In general, the wastes arising from the decommissioning of nuclear facilities are not significantly different

* *Factors Related to the Decommissioning of Land-Based Nuclear Reactor Plants*, IAEA Safety Series No.52 (1980).

** *Decommissioning of Nuclear Facilities: Decontamination, Disassembly, and Waste Management*, IAEA Technical Reports Series No.230 (1983).



A reactor vessel with its concrete shielding being removed before shipment for burial. (Credit: Rockwell International)

Decommissioning — goals and stages

In the nuclear industry, "decommissioning" means the actions taken at the end of a facility's useful life to retire it from service in a manner that provides adequate protection for the health and safety of the decommissioning workers, the public, and the environment. These actions can range from just closing down the facility (with minimum removal of radioactive material and with continued surveillance and maintenance) to complete removal of all residual activity above levels that would not permit unrestricted use of the site or facility. The ultimate goal of all decommissioning actions is the cleanup of facilities and sites so that they can be released eventually for unrestricted use.

Decommissioning stages

The term "stage", as used here, implies a set of conditions at the facility being decommissioned. It does not imply a continuous step-by-step procedure or require the adoption of all three stages described below. For example, Stage-3 could follow Stage-2 immediately or in a hundred years depending on the strategy, or the operator could proceed immediately to Stage-3 without going through the other stages.

The three stages of decommissioning commonly used are:

- *Stage-1.* The first containment barrier is kept as it was during operation but mechanical openings are permanently sealed. The containment building and atmosphere are kept in a state appropriate to the hazard in the building. Surveillance, monitoring, and inspections are carried out to ensure the plant remains in good condition.
- *Stage-2.* The first contamination barrier is reduced to minimum size by removing easily dismantled parts. Sealing of the barrier is reinforced by physical means and the biological shield is extended, if necessary, to completely surround the barrier. After decontamination, the containment building may be modified or removed if it is no longer required for radiological safety. Access to the building can be permitted. The non-radioactive buildings on site can be used for other purposes. Surveillance and inspection can be relaxed but spot checks should be continued.
- *Stage-3.* All materials, equipment, and parts of the plant still containing significant radioactivity are removed. The plant and site are released for unrestricted use. No further inspection or monitoring is required.

Factors to consider

A large number of important regulatory, technical, safety, environmental, and social factors must be considered in selecting the appropriate decommissioning stages. These include: national strategy; availability of adequate funds; storage or disposal areas; suitable decontamination methods and disassembly equipment; and well-trained crews. Other factors are the condition of the buildings; the owner's planned use of the site; availability of other suitable nuclear sites; environmental and social issues; and potential hazards to the workers and public.

from other radioactive wastes. Since the methods for treating, conditioning, storing, transporting, and disposing of radioactive wastes are well covered in other IAEA reports, no new documents on decommissioning wastes are planned in the immediate future.

Two other reports deal in greater depth with the technical aspects of decommissioning. One reviews the techniques used or being developed for the decontamination of nuclear facilities not only for decommissioning but also to facilitate operation, inspection, maintenance, and modifications to operating plants.*

The second report gives a state-of-the-art review of the methods and technology used for the decommissioning of nuclear facilities.** Its purpose is to complement and reinforce data published previously and, in particular, to provide in-depth technical data for those areas of decommissioning technology not covered elsewhere, including costs and financing of decommissioning operations.

Three detailed annexes are included in the report. The first gives details on the reactors and other nuclear facilities which have been or will be decommissioned shortly. The second annex reviews the special and conventional tooling used for the demolition and disassembly of reactor vessels, concrete, piping and other components. Some techniques described include: plasma arc torch, explosive cutting, wrecking ball, thermite reaction lance, hacksaws, large concrete sawing devices, industrial robots, automated guided vehicle systems, and the use of, and performance criteria for, equipment in the nuclear industry. Many Member States are developing sophisticated remote manipulator systems, robotic remote handling systems, and other such advanced technologies for future decommissioning tasks.

As follow-up to these reports, the IAEA is preparing or planning technical reports on decommissioning topics such as: methods of reducing occupational exposures; technology, safety, and economics of recycling materials; decontamination and demolition of concrete and steel structures; monitoring for compliance with unrestricted use criteria; the status of the development and use of remote system technology in decommissioning; and the development of regulatory procedures.

Decommissioning standards

During decommissioning, as in all other nuclear activities, standards must be available to ensure that the decommissioning worker, the public, and the environment are protected from unacceptable nuclear hazards arising from the work. The types of procedures, standards, and equipment chosen to guarantee safety during decommissioning are dictated by many factors. These include the type of facility; the magnitude and characteristics of the radioactive inventory in the facility; the equipment available; the site; and the location of the facility.

Standards used during the normal operation of nuclear facilities – for example, those for radiation protection, waste disposal, transport, air and water effluent quality – are also applicable during decommissioning. In addition, the development of standards for the unrestricted re-use or disposal of materials, equipment, facilities, and sites is required for decommissioning, as well as for regular waste management purposes.

Once these standards have been developed by national or international bodies, they would have to be adopted by national authorities before they would become law in individual Member States.

In the past, *ad hoc* standards have been used on a case-by-case basis for the unrestricted release or recycle of various items. Some examples:

- In the Federal Republic of Germany (FRG), the nuclear ship *Otto Hahn* was fully decommissioned by removing all the nuclear parts and cleaning up any residual activity. The ship can now be used as a normal ship.
- About 900 million grams of metal scrap from the Würgassen nuclear power station in the FRG were decontaminated and re-used as normal scrap metal.
- The cleanup of nuclear sites and facilities for unrestricted use has been permitted in the USA using cleanup guidelines of the Nuclear Regulatory Commission.

This practice of using criteria developed on a case-by-case basis for a specific set of circumstances has worked reasonably well. However, the development of a general set of principles for unrestricted release is desirable from an operational viewpoint for application. This is so that:

- The large volume of very low-level wastes from decommissioning and elsewhere can be safely disposed of as landfill, which is usually much cheaper than even the least expensive form of shallow land burial in a radioactive repository.
- Valuable metals from facilities being decommissioned can be recycled and expensive equipment and sites can be re-used.

International radiological principles

In the past the IAEA has had an interest in the development of international principles for dealing with the disposal of those radioactive materials that represent a trivial hazard to health. Previous IAEA working groups have looked at considerations required to define quantities and types of waste that could be disposed of in the sea without special permit, and for disposal in the terrestrial environment without the need for regulatory control.

Current work on the subject of exemption is aimed at developing a set of radiological principles or rules that can be generally applied to circumstances where it is felt that exemption from requirements or regulations may be justified. It seems likely that these exemption principles will require that each situation in which

* *Decontamination of Nuclear Facilities to Permit Operation, Inspection, Maintenance, Modification, or Plant Decommissioning*, IAEA Technical Reports Series No.249 (1985).

** *The Methodology and Technology of Decommissioning Nuclear Facilities*, IAEA Technical Reports Series (in press).

exemption is considered has to be analysed separately to determine compliance with the radiological rules. The main purpose of this requirement is to prevent the possible abuse of exemption procedures and to avoid the generation of widespread low-levels of radioactive pollution. However, the possibility still exists for more generalized exemptions for disposal of certain well-defined types of waste by defined disposal routes.

The philosophical basis for exemption rules is being developed jointly by the IAEA in co-operation with the OECD's Nuclear Energy Agency, the World Health Organization, and the International Labour Organization. In addition, a report is being prepared outlining the methods to be used in applying the exemption principles for the determination of practical exempt quantities for disposal at municipal landfill sites or by incineration.

A further study is being initiated to apply the exemption rules and to develop modelling methods for evaluating practical exempt quantities for application to disposal of wastes from decommissioning and for possible recycling of equipment and materials.

During the decommissioning of a nuclear facility, standards and means of verification should be available to segregate active waste from low-level wastes that come into the exempt category. In general, there are three categories of exempt material:

- Real waste that would be sent for disposal in landfill sites
- Valuable metals that could be remelted and recycled
- Valuable equipment that could be re-used.

Of these three categories, it is probably most important that suitable criteria and instrumentation be available to classify the first category of waste for release to disposal. This is because it represents the largest volume of waste and the difference in cost between disposal as landfill and in a nuclear waste repository is usually quite high.

Sharing expertise

In addition to activities described here, the IAEA actively interacts and co-operates with many other international and national organizations in the fields of decommissioning and decontamination of nuclear facilities. The aim is to minimize the amount of overlap and duplication of effort and to share expertise as much as possible.

A wrecking ball and crane in action during reactor dismantling. (Credit: US DOE)