Engineering: A vital role

In France, the role of engineering in decommissioning operations is apparent right from the start of nuclear facility design — exactly when engineers are in charge of planning and construction. Recommendations based on experience with decommissioning must be taken into account to the fullest possible extent.

Generally, there is no justification at the construction stage for making provision for additional investment costs related to all arrangements that would be advantageous for later dismantling. However, there are many constructive steps that can easily be taken — and are being taken more and more — to facilitate these later operations. For example, a suitable means of access can be set aside to hot cells; hooks or maintenance rails can be installed; floor loads can be forecasted to allow for subsequent installation of mobile shields. All these provisions will, of course, also be of use for emergency or maintenance operations, not only dismantling.

Engineering also has a role in the use, on an industrial scale, of special remote-control and remote-handling devices adapted to dismantling requirements. In this area, engineers must apply great rigour in preparing specifications and in ensuring compliance with them, seeing to it that the devices are precisely suited to their task and that they meet expected performance standards — despite initial difficulties associated with the multi-disciplinary nature of the work and particular constraints involved in work with nuclear energy.

Also in the province of engineering is the reinforcement of facilities for effluent treatment and waste processing made necessary by decontamination and dismantling operations. This job requires employment of the entire arsenal of existing techniques, depending on specific constraints at each site and within the context of national waste policy. Of fundamental importance in the selection of the best decontamination and dismantling tactics is the integration of costs associated with waste processing and storage.

Overall, the involvement of engineering in large-scale decommissioning operations is a natural consequence of the range of studies that have to be carried out, of the scope of organizational and co-ordinating tasks, and of the vital importance of proper preparation and compliance with planning. All this is to ensure that work remains within a given financial framework and is carried out under the most satisfactory safety conditions.

Taking Canada's Gentilly-1 to a "static state"

by Balarko Gupta

In 1971, Canada's 250-megawatt Gentilly-1 went into service in the province of Quebec and produced power intermittently until 1979. Today, the station is the focus of a two-year decommissioning project that will take it to a "static state" by March 1986: Some radioactive materials and components will be removed, parts of the plant will be decontaminated and released for alternate uses, and the reactor building will be sealed off. Final dismantlement is expected in about 50 years, which allows time for radioactivity levels to fall significantly.

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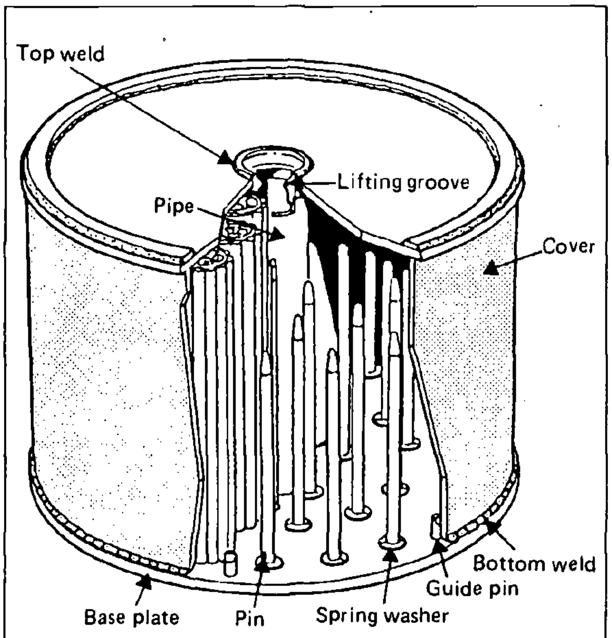
The decision to take this route was based on several factors. After the plant was shut down for repair work in 1979, the Canadian regulatory authority demanded extensive modifications before re-start to bring the plant in line with existing safety requirements. The station was mothballed for three years, and in 1983 it was decided to retire it because rehabilitation would not be economically worthwhile. Subsequent engineering and economic studies were the basis for the decommissioning project.

Project objectives and scope

The project's four major objectives are to significantly reduce the station's operating and maintenance costs; to confine radioactivity into clearly identified sealed areas (for example, the reactor building); to release parts of the station for alternate use; and to



Schematic of fuel basket used during spent-fuel storage operations at Gentilly-1. (Credit: AECL)

gain "hands-on" experience in decommissioning a nuclear station on a commercial scale. (A prototype, Gentilly-1 is a CANDU boiling light-water reactor that is fuelled with natural uranium, moderated with heavy water, and cooled with light water.)

The project's scope identifies specific tasks:

- Retrieving all spent fuel from the spent-fuel bay in the service building and placing it in dry storage in specially designed concrete canisters. This will eliminate most of the maintenance cost and release the service building for other purposes.
- Putting the reactor building into a static state condition.
- Removing all components (equipment, piping, cabling, control panels, etc.) from the service building and parts of the turbine building so that these areas can be transferred to Hydro Quebec, which owns and operates the adjacent Gentilly-2 nuclear station.* Administration areas will be transferred in "as-is" condition.
- Decontaminating the spent-fuel bay, fuel trays, and various other contaminated components.
- Developing and implementing radiological, and health and safety, policies and procedures that are consistent with the ALARA principle (as low as reasonably achievable, economic and social factors being taken into account) of radiation protection.

* Before transfer, the areas must meet Zone-1 criteria, which include no loose contamination, no beta fields above 10 micro-sieverts per hour, and no gamma fields above 2.5 micro-sieverts per hour at one centimeter.

Dry storage of spent fuel

Some 3213 bundles of irradiated fuel and fuel hardware have been stored in eleven cylindrical concrete canisters that were specially designed for the purpose. Each canister (6 metres high with an outside diameter of 2.6 metres) has a steel liner that serves as the storage cavity for eight specially designed stainless steel baskets. Each basket contains 38 fuel bundles, each of which is placed over one basket pin. (The bundles had been stored in the spent-fuel bay for a minimum of 7 years and the decay heat emitted averages approximately 1.4 watts per bundle.) Irradiated fuel is contained in 85 baskets, while two baskets contain flux suppressors and keys that are parts of the fuel string.

Typical storage operation

A typical storage operation starts by unstringing the bundles and removing the central structural tubes (CST) that contain cobalt-60. Each bundle number is then identified and individually loaded into a numbered basket. Both the basket and bundle numbers are permanently recorded in keeping with IAEA safeguards requirements. Once a basket is filled, a cover is put on and the basket assembly is raised into a shielded station by a grapple that engages inside a central opening. All these operations are done underwater for shielding purposes.

Inside the shielded station, the basket cover is removed, the fuel assembly is dried, and the basket assembly is seal-welded at top and bottom by remote semi-automatic welding. The basket is then moved laterally inside the shielded station to a position directly below the shipping flask. Flask doors are then opened, a grapple inside the flask is lowered to raise the basket from the shielded station into the flask, and the flask doors are closed. The flask is now ready for transfer to the canister area.

Inside the shielded station, radiation of up to 3500 rem has been measured.* However, outside the station (and the flask) radiation always has been less than one millirem on contact.

To transport the flask to the canister site, a specially designed trailer is used. The flask is raised to the top of a canister by a 15-ton crane. The grapple assembly and a 3-ton crane lower the basket from the flask into the canister. The top plug is then welded to the canister, and an IAEA safeguards seal is installed by Agency inspectors.

From start to finish, this operation took a crew of six an average of three hours. Since the process must be repeated for all 11 canisters and the eight baskets each contains, the entire fuel-storage operation took six weeks, not including five weeks for construction of the canisters themselves.

The radiation level outside a loaded canister is about 0.6 millirem on contact.

* In international usage, the rem has been replaced by the sievert, which is equal to 100 rem.

The reactor building

Most common pipes, cables, ducts, etc., between the reactor, turbine, and service buildings have been cut and sealed to prevent the spread of radioactivity. All components in the reactor building have been drained and dried, including oil and other inflammable agents that have been removed. Systems inside the reactor building have been isolated and tagged.

Access to the building has been permanently shut off, except for one airlock that can be made operable for periodic inspection. This static state will be maintained for the reactor building for at least the next 40 or 50 years, with periodic inspection to ensure structural integrity. The delay will mean a significant reduction of radioactivity of benefit to final dismantling.

Other uses for buildings

In the service and turbine buildings, Hydro Quebec, the local utility, will install a full-scope training simulator for the adjacent 600-megawatt-electric Gentilly-2 reactor; a training centre; and some offices. Currently under way are removal of components, radiological surveys, and decontamination around areas to be transferred to Hydro Quebec, including the spent-fuel bay inside the service building. Once the bay is decontaminated, a new concrete slab will be built on top of it and the area will be a part of the simulator's headquarters complex.

Decontamination work

Engineering and economic studies, and initial site experience, have shown that large-scale system decontamination to release components for unrestricted use is neither time nor cost effective. Nonetheless, a significant decontamination programme has been set up at the site to meet the criteria (Zone-1) to transfer areas for other uses, and to gain "hands-on" experience for determining future methods and estimating manpower and cost requirements.

Major experience has been gained through decontamination of the feedwater and hydrazine dosing system, feedwater sampling system, various sizes of piping, fuel trays, new fuel inside the spent-fuel bay, and several ventilating ducts and fans.*

* A Butterworth hydrolaser model 110-ET has been used extensively in this programme at a pressure of up to 2000 pounds per square inch (psi), or 40 mega-Pascals (MPa), although it can operate at up to 10 000 psi, or 68 MPa. Regarding loose surface contamination, 170 bundles of new fuel had up to 1.7 megabecquerels per square metre (MBq/m^2), whereas the fuel trays had up to 2.2 MBq/m^2 loose contamination. Frequently, mixing the water jet with a foam cleaner was found adequate for cleaning in most cases. A stainless steel cabinet has been designed to work with the hydrolaser to hold small pieces to be cleaned and to contain the water spray. This combination has been very effective, and it has eliminated the need for protective clothing. Fixed contaminations up to 500 kBq/m^2 on concrete floors have been reduced to Zone-1 level by using a scarifier coupled with a vacuum take-off.

Radiation protection

All aspects of the Gentilly-1 decommissioning are regulated by a license from the AECB, which has insisted on the maximum health and safety protection for workers and the public. To satisfy these requirements, and the ALARA principle, documents have been developed, specifically health guidelines and radiation protection standards; a health and safety manual; and radiation protection procedures.

The health and safety group produces and distributes a computerized report that shows biweekly dose exposure of everyone working on the project. So far, the individual dose has been much lower than allowable (5 rem per year, 3 rem per quarter), and it is very unlikely that anyone will even approach the limit on this project. The maximum recorded dose for a 12-month period for an individual has been 225 millirem. However, the individual dose for most workers has been less than 110 millirem.

Project management, cost

Currently, the site organization consists of about 40 professionals/technicians and 50 craftsmen from AECL. Additionally, 15 to 25 workers are available from outside contractors.

Site organization is headed by a station and project manager, and there are seven managers/supervisors responsible for resident engineering, decontamination, radiological protection, fuel handling, operations, plant services, and security. To preserve their independence, the heads of health and safety and of quality assurance do not report to the station/project manager.

During the study stage, the cost estimates for various decommissioning scenarios for Gentilly-1 were prepared using a programme that has the capability to estimate manpower, man-rem exposure of workers, radioactive waste volume, and cost.* During the decommissioning, the programme code has been validated with actual costs and compared against estimated amounts. This data base would be a good source of cost data for future decommissioning.

The estimated cost of the Gentilly-1 two-year decommissioning programme is $25 million (Canadian), and the project is expected to be completed on time (by April 1986) and within the cost estimate.

Due to the critical nature of the project, cost and project management schedules are computerized at site. Once a week, they are reviewed and updated so that actions can be taken to avoid potential delays.

* The programme, called DECOM, is more fully discussed in a paper, "Methodology of a computerized cost model for decommissioning of nuclear power plants", which was prepared in November 1984 by the author and John Saroudis as part of the IAEA Co-ordinated Research Programme on Decommissioning.