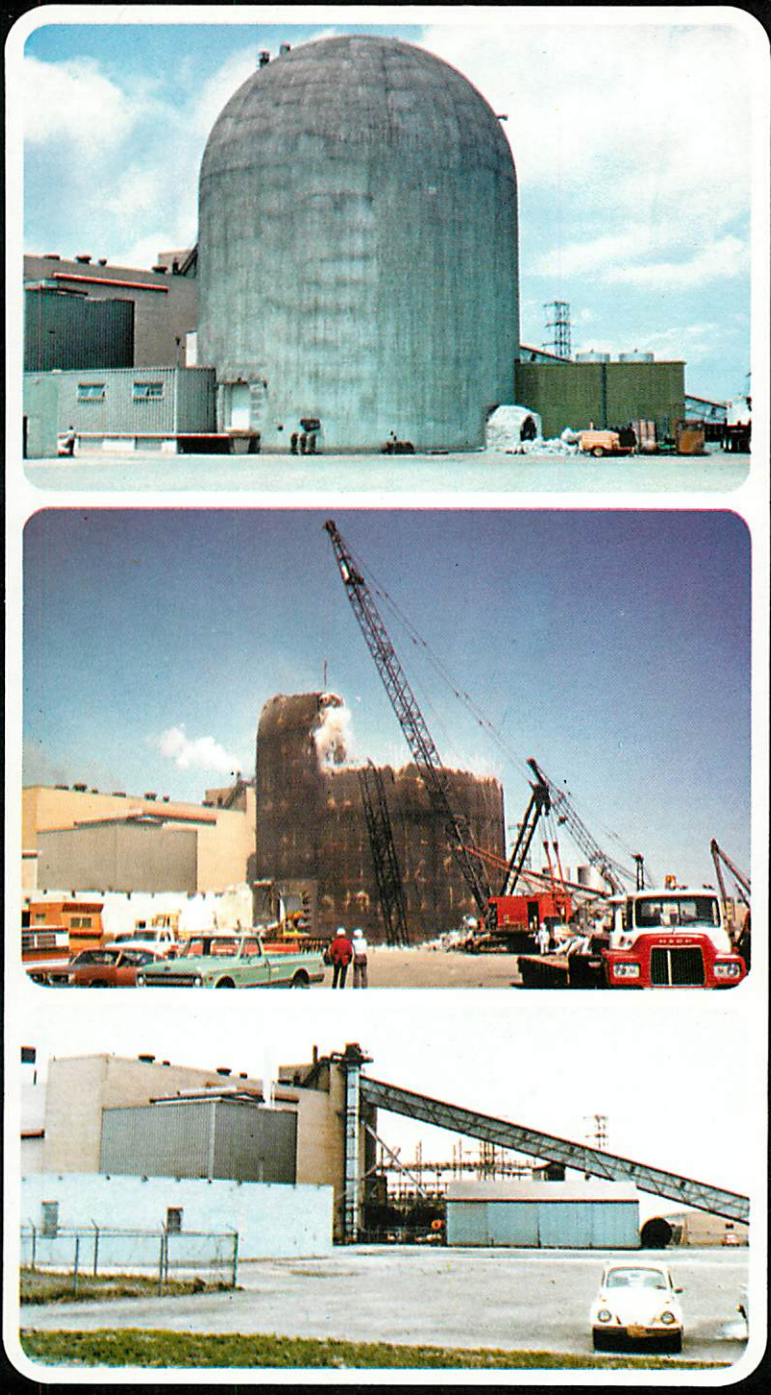
THE DECOMMISSIONING OF NUCLEAR PLANTS



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WHAT IS DECOMMISSIONING?

Taking an industrial plant out of operation and shutting it down permanently is called "decommissioning". In the past factories and conventional power plants were simply demolished or converted to other uses when they became uneconomic or were worn out. Generally, no special care was taken to prevent hazardous materials from being spread into the environment once the plants had been torn down or abandoned. In some cases, these past practices have had serious local consequences.

This stands in sharp contrast to the nuclear industry. In **nuclear** plants, the potential risk lies in the radioactivity of the materials to be handled. Because the risks of radiation have been understood from the outset, a comprehensive system of rules has been developed for avoiding or minimizing them. Similarly, procedures for decommissioning nuclear installations have been developed over the last 20 years, before they were required and with a knowledge of the risks and problems involved.

OBSOLETE NUCLEAR PLANTS CONTAIN RADIOACTIVE MATERIALS

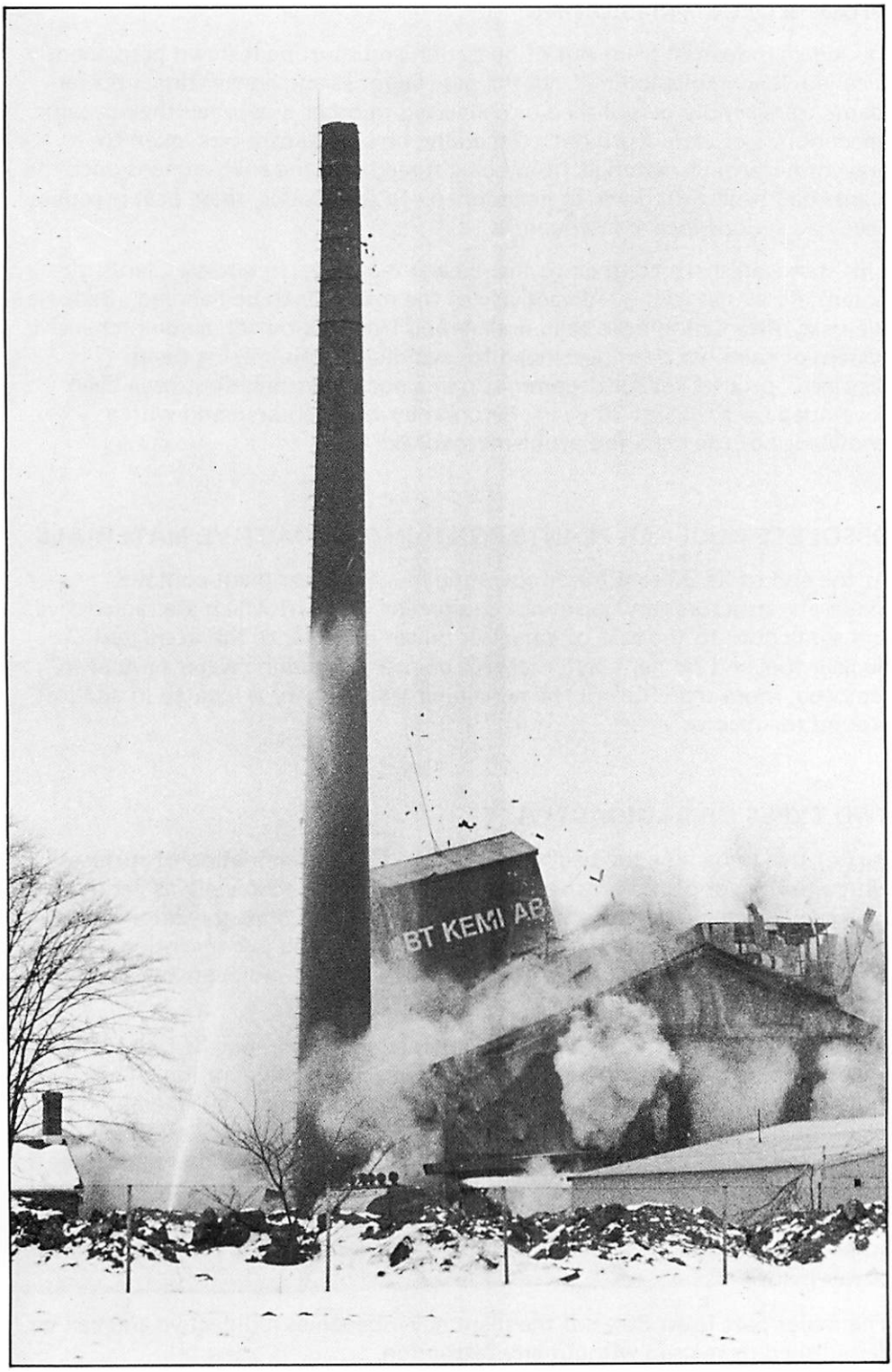
At the end of its 30 to 40 year operating life, a nuclear plant contains materials, structures and worn-out equipment, some of which are radioactive, and some not. In the case of a nuclear power plant, once the irradiated nuclear fuel and (in light-water reactor plants) the cooling water have been removed, more than 95% of the remaining radioactivity is located in and just around the reactor vessel.

TWO TYPES OF RADIOACTIVITY

Part of this remaining radioactivity is due to the **contamination** of surfaces with a thin layer of radioactive material (referred to technically as "crud"). This can be removed by special cleaning devices, high pressure water jets, brushing, etc. The techniques are similar to those used in conventional chemical plants. The resulting fluid is treated like the radioactive waste produced during plant operation.

Another part of the radioactivity is contained in the equipment that was exposed to neutron irradiation while the reactor was in operation. This **induced** radioactivity is present in the core structural material (metal) and in some of the surrounding construction material (mainly concrete). Such induced radioactivity can be allowed to decrease through natural decay (see figure 2), the activated equipment and structures can be dismantled and surface layers removed from the concrete. Most of the resulting scrap metal and other rubble is then handled like normal solid waste from a commercial nuclear power plant.

The major part (over 80%) of the plant never becomes radioactive and can be demolished or re-used without any restriction.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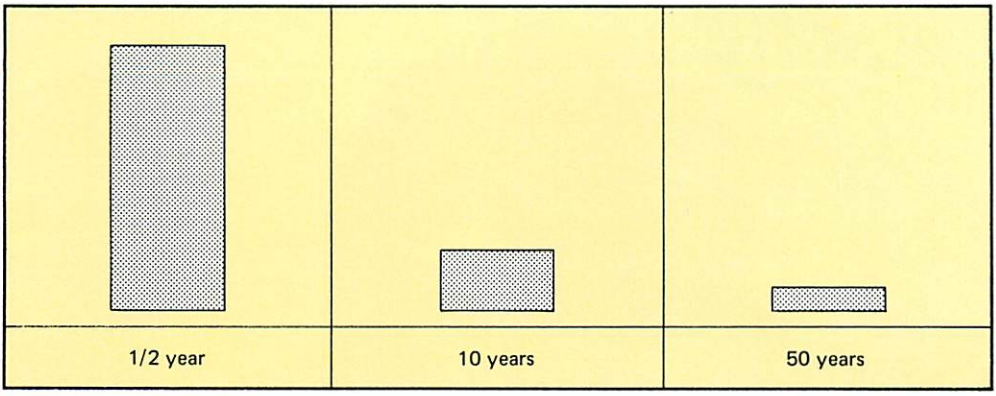


Figure 2. In a nuclear power plant, the level of radioactivity falls rapidly during the time just after plant shut-down. The figure illustrates this decrease in radioactivity (contamination and induced radioactivity) in a 1000 MWe light-water reactor after shut-down.

WHEN SHOULD DECOMMISSIONING BE CARRIED OUT?

The question of timing depends on an optimization in each case. If the final decommissioning step is delayed for a significant time (perhaps up to 50 years) in order to take advantage of radioactive decay, radiation doses to personnel can be kept low and the costs for direct dismantling operations and waste handling also become lower. On the other hand, such a delay necessitates on-site inspections, maintenance and restricted access for some years and questions of financing and responsibility must be clearly resolved from the outset in order to facilitate final decommissioning.

THREE DECOMMISSIONING STAGES

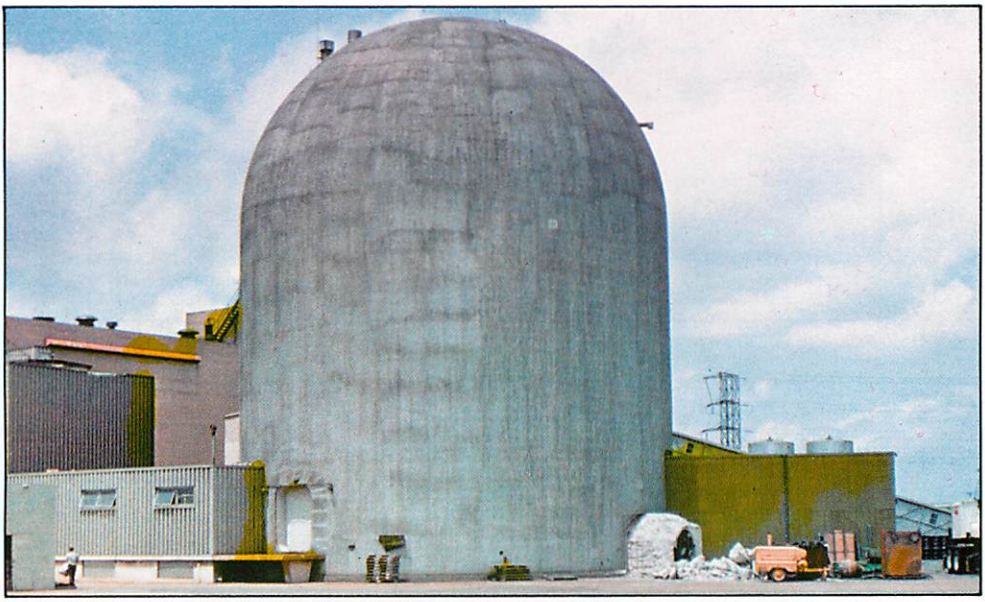
The most extensive decommissioning, dismantling, is often referred to as **"Stage 3 decommissioning".** It involves removing all radioactive material above acceptable levels* so that the remaining parts of the plant and the site can be re-used without further control or so that the land can be used (after demolition of the plant) for other purposes (housing, offices, industry).

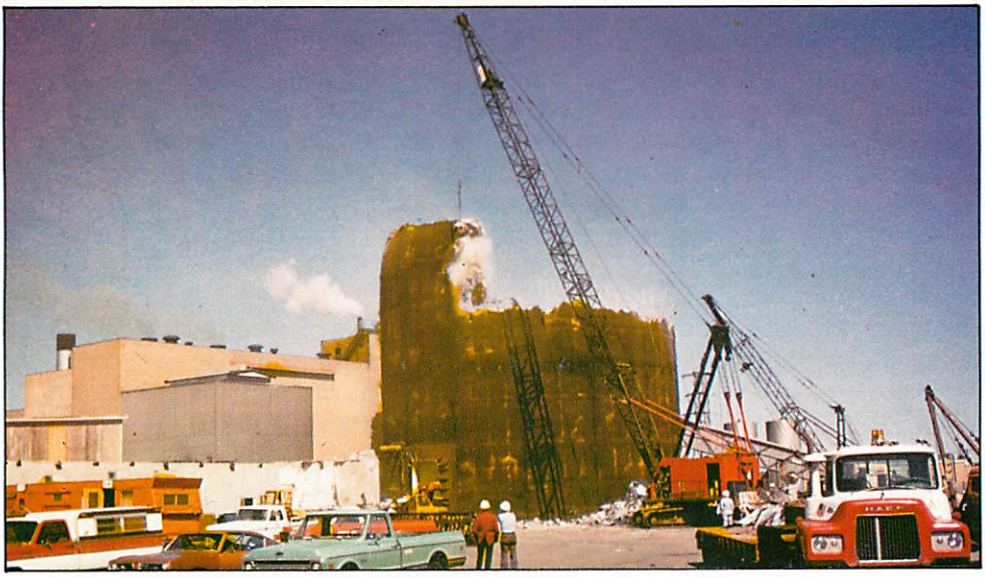
In some cases it may be more practical only to proceed to **"Stage 2 decommissioning",** sealing off those parts of the plant where the highest radioactivity levels remain and allowing them to decay further. The less radioactive parts

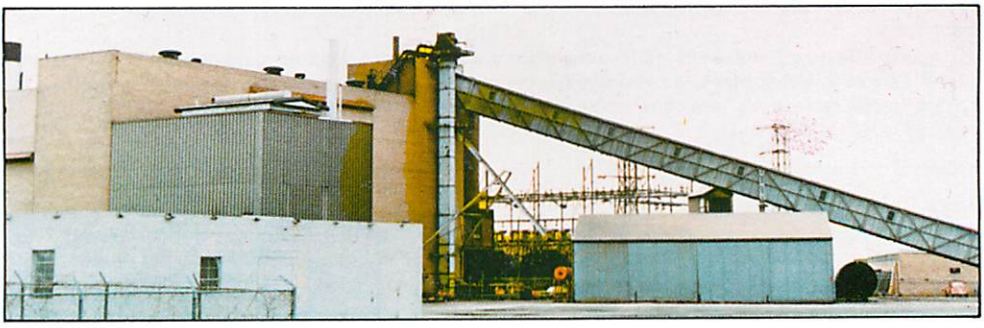
* "Acceptable levels" are set by national regulatory authorities to describe materials whose radioactivity levels are so low that they can be handled in the same way as "non-radioactive" materials. In this case, "acceptable levels" are comparable to those that existed before the nuclear station was built.

◀ Figure 1.

The waste disposal practices of some industrial operations have led to present day health problems. This chemical factory in Sweden was closed down and demolished and a clean-up of the property undertaken when it was found that discarded chemical wastes were affecting the health of local residents. (Photo: Copyright Pressens Bild Stockholm)







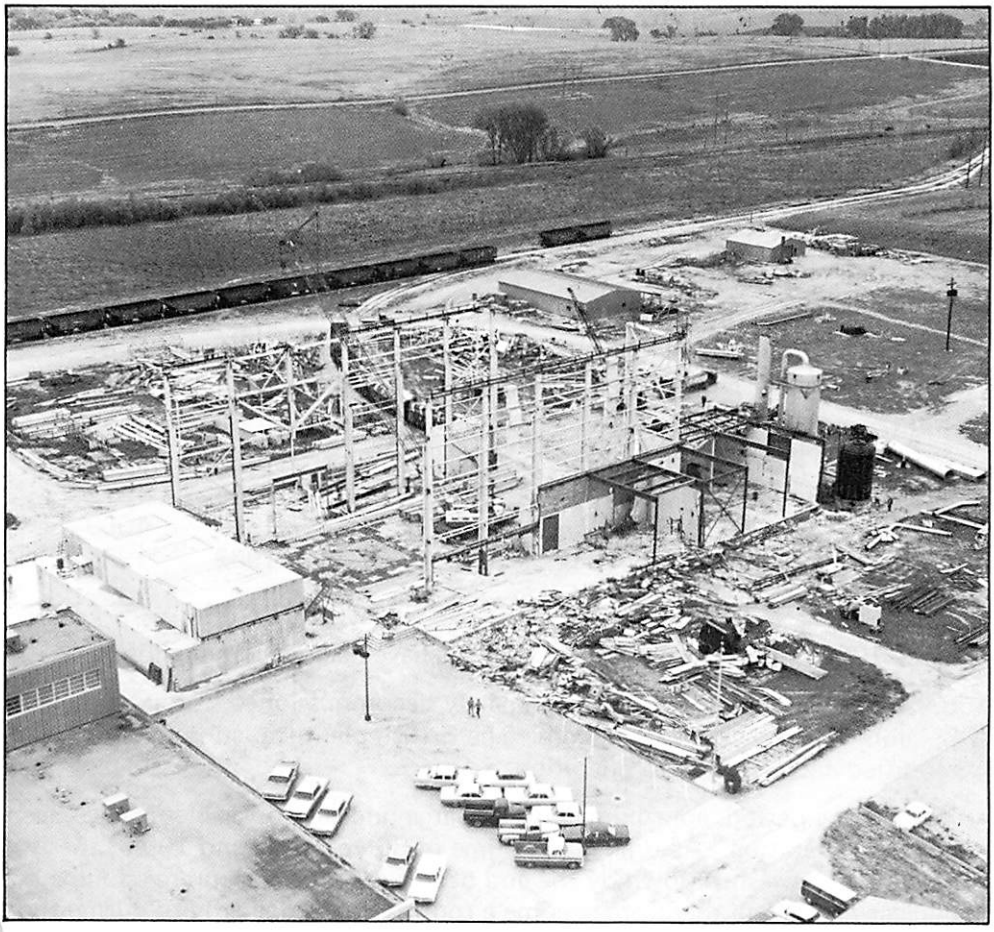


Figure 4.
The Hallam reactor in the USA was decommissioned to Stage 2; the work is shown here nearing completion. (Photo: Rockwell International)

are decontaminated and removed. This procedure requires only little surveillance at fairly low costs.

Many nuclear reactors have already been taken to **"Stage 1 decommissioning"** which means that all easily accessible radioactive materials are removed, but machinery, components and structures are left intact. In this case, a maintenance and monitoring staff remains on duty at the station. This stage is generally considered to be suitable only as an interim measure prior to final decommissioning.

◀ Figure 3.
The Elk River reactor was completely dismantled and removed from its site in 1974, an example of Stage 3 decommissioning. In the bottom photo, the operation is complete. (Photos: UNC Nuclear Industries Inc.)

TABLE 1. SOME DEMONSTRATION AND POWER REACTORS DECOMMISSIONED

Reactor	Country	MWth	Stage	Operation	
				Start	Stop
G1	France	46	1	1956	1968
Chinon 1	France	300	1	1963	1973
Agesta	Sweden	80	1	1964	1974
Lucens	Switzerland	30	2	1967	1969
Elk River	USA	73	3	1963	1974
Bonus	USA	50	2	1964	1970
CVTR	USA	56	2	1963	1970
Hallam	USA	256	2	1963	1972
Pathfinder	USA	190	2	1964	1972
Piqua	USA	46	1	1963	1969
Peach Bottom	USA	115	1	1962	1974

- Since 1960 more than 65 nuclear reactors have been decommissioned.
- Reprocessing plants have also been partly decommissioned, for example in Belgium and the United Kingdom. The British plant was subsequently modified and returned to operation.
- In the same period, approximately 200 large nuclear power plants have been put into operation. Assuming a life-time of 30 years, around 100 of these plants will have shut down by the end of this century. Decommissioning of nuclear plants will therefore become a routine industrial activity during the next 20 years.

HOW IS IT DONE?

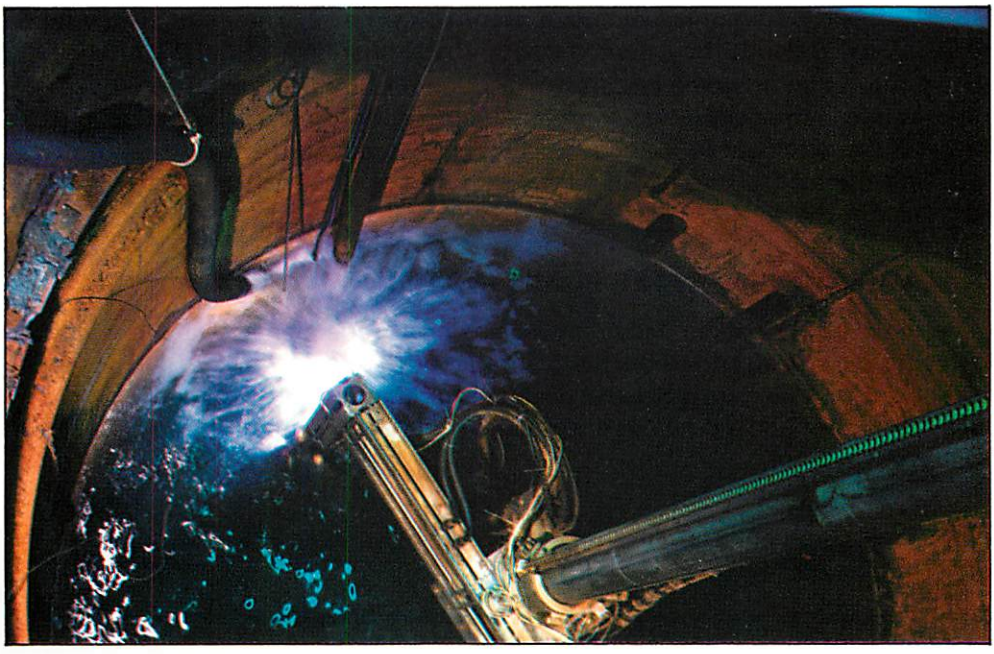
The dismantling of the reactor itself involves a combination of standard methods and specialized techniques.

For most of the plant, standard demolition and salvage techniques can be used, since electricity generating equipment, offices, ancillary buildings and some service buildings do not involve radioactive material. Some of the scrap steel, equipment and construction material can be sold or re-used just as for non-radioactive installations.

The most radioactive parts of a nuclear plant (core components, heat exchangers and piping) have to be dismantled using remotely controlled equipment. Radioactive surface layers of structural materials and concrete are removed by chemical cleaning, scraping and other techniques. Special precautions are taken to prevent the spread of dust and fumes containing radioactive material. For example, some of the components are submerged in water while being dismantled.

Figure 5.
Standard or slightly modified demolition techniques can be used for many decommissioning operations. (Photo: Rockwell International)

Figure 6.
For some decommissioning operations, radioactive metal components are dismantled using special underwater cutting tools. (Photo: Rockwell International)



RADIOACTIVE WASTE FROM DECOMMISSIONING

All of the radioactive material arising from the demolition of the radioactive structures and components are dealt with in a similar manner as is the reactor waste resulting from normal plant operation, with the exception of a few per cent that require special handling (core components). Depending on the time delay before decommissioning to **Stage 3**, the quantities of waste from a 1000 MWe light-water reactor amount to

- a few hundred cubic metres which can be placed in deep underground disposal;
- a few thousand cubic metres of slightly contaminated material (or material with induced radioactivity) which is disposed of together with the waste from normal reactor operation;
- something like 50 000 cubic metres of non-radioactive waste which can be re-used or taken away as landfill.

EXPERIENCE: INTERNATIONAL CO-OPERATION

Direct decommissioning experience exists in a number of countries (among others Belgium, France, Switzerland, UK, USA). A large body of related experience has also been built up in more than a dozen countries during the last 20 years. This has been acquired in modification and repair work on radioactive plant components and in the course of introducing new equipment into reactors and reprocessing plants which had been in active operation. This experience is directly applicable to large-sacle decommissioning work.

National research and development programmes and international exchange of information on decommissioning have been carried out for over 15 years. The European Community (Belgium, Denmark, France, The Federal Republic of Germany, Ireland, Italy, Luxembourg, the Netherlands and the United Kingdom) has an on-going research project on decommissioning and a major international symposium on decommissioning, sponsored by the IAEA and OECD/NEA, was held in Vienna in 1978. Here it was confirmed that both the tools and the methods that will permit all types of reactors to be decommissioned are available today.

DECOMMISSIONING AFTER PLANT INCIDENTS

Experience even exists in decommissioning prototype plants where incidents involving the spread of radioactivity throughout the plant have occurred (e.g. Lucens). No significantly greater problems or amounts of waste were encoutered, but additional costs were incurred ($1–2 million in the case of Lucens).

Figure 7.
Part of the Lucens decommissioning operations: in this container, being lowered onto a transporter, is the Lucens reactor vessel. (Photo: S.A. l'Energie de l'Ouest-Suisse)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TRANSPORTS MORGES

FEEDBACK OF INFORMATION

Decommissioning is a factor that can and should be taken into account during the design of a nuclear plant. The feedback of practical decommissioning experience to designers assists them in providing features to reduce the problems of decommissioning without compromising the safety or reliability of the plant.

COSTS

The question of decommissioning costs has often been raised. The major cost items are: 1) initial confinement operations followed by continuous surveillance in the period until the decommissioning operation is finished; 2) the final decontamination and dismantling operations; and 3) waste handling.

Waste handling is generally the dominating cost. Past experiences as well as calculations for future operations indicate total decommissioning costs for large nuclear power plants of around 10% of the original plant cost. On the basis of the electricity produced by the plant this amounts to less than 0.5 mill/kWh*.

In some countries, such as Finland, Switzerland and the United Kingdom, the funds needed to finance decommissioning are being accumulated during the time that the plant is in operation.

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* 1 mill = 0.001 US dollar.

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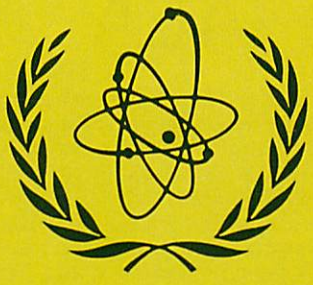

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