Nuclear Waste Management in Europe

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This contribution briefly summarizes nuclear waste management activities in Europe. Information was selected from a series of articles published recently in *Nuclear Europe*.[1,2]

Nuclear power is being widely used in Europe and contributes greatly in some countries to the total generation of electricity (Figure 1). Most countries with large nuclear power programs have decided to reprocess rather than dispose of spent fuel. The use of nuclear power is associated with the generation of large amounts of radioactive waste, i.e., low and intermediate waste from reactor operation, reprocessing, and fuel fabrication. The high-level waste arises only from reprocessing. All these wastes must be handled, conditioned, stored, and disposed of safely. This requires industrial management and the involvement of independent licensing authorities.

Low and Medium-Level Waste

In France, the long-term disposal of radioactive waste is managed by l'Agence Nationale pour la Gastion des Dachets Radioactifs (ANDRA). This agency is responsible for conceiving, setting up, building, and running disposal sites; for drawing up and controlling the technical specifications for packaging and disposal; and for performing research and development activities. France has 15 years of experience in shallow land burial. In the Manche center near the La Hague reprocessing plant, 260,000 m^3 of low and medium waste have been managed and disposed of. Only the short-lived beta-gamma wastes (800,000 m^3 by the year 2000) are suitable for shallow land burial in concrete coves. These wastes will decay to negligible levels within 300 years. Alpha-bearing wastes (75,000 m^3 by the year 2000) and vitrified wastes (3,000 m^3 by 2000) must be disposed of elsewhere.

In the United Kingdom, the Nuclear Industry Radioactive Waste Executive (Nirex) is in charge of managing low and medium-activity wastes and in identifying and studying potential sites for their final disposal. Two repositories, one trench and one deep site, are needed in the next 50 years. Relevant research and development is in progress and several sites have been named for further studies. While deep sea disposal of packaged radioactive wastes was practiced at one time, it was suspended in 1983 as a result of a resolution of the Convention on the Disposal of Wastes at Sea (London Dumping Convention). Since then 400 tonnes of waste have been prepared for sea disposal but have been stored at UK establishments.

In Belgium, ONDRAF/NIRAS (Belgium's National Agency for Radioactive Waste and Fissile Materials) is in charge of radioactive waste management. Low and medium-activity wastes were dumped into the North Atlantic up to 1983, when this disposal means was suspended. Since then, ONDRAF/NIRAS has investigated the land burial option, but a suitable site in the country may not become operational before 1996. In the meantime, adequate storage facilities must be provided for the waste to await further handling and final disposal.

Like Belgium and the United Kingdom, the Netherlands dumped their low and medium-level wastes into the sea until 1982. Thereafter, COYRA, the central organization for radioactive waste, has begun to develop alternative options for the conditioned wastes. At present, the packages are stored by COYRA in a facility at Petten, the location of the Netherlands Energy Research Foundation. The modular storage buildings will be expanded to provide 50-100 years capacity. A final disposal site will then be selected, probably in the salt formations.

In Switzerland, low and medium wastes are conditioned using established techniques, i.e., incineration, compaction, bitumination, and cementation. The products are stored at the power stations and at the Swiss Federal Institute for Reactor Research (EIR). The Swiss Cooperative for the Storage of Radioactive Wastes

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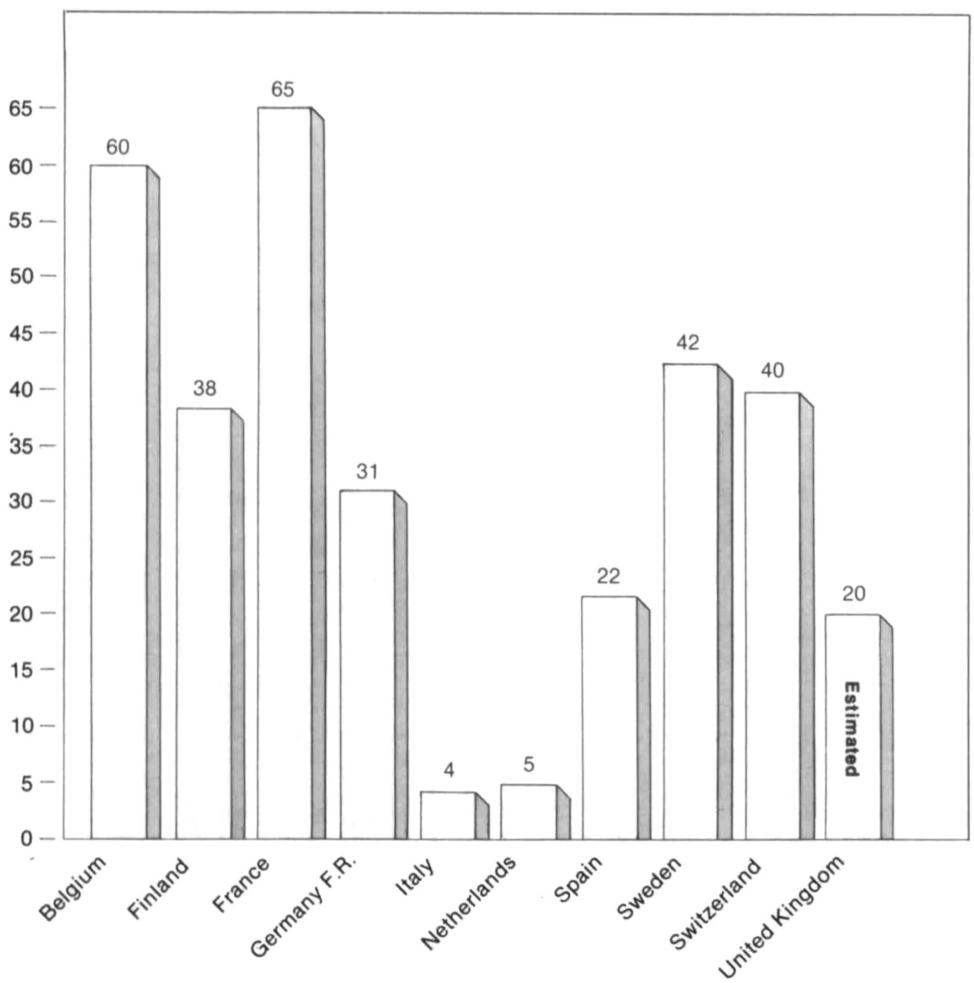

Figure 1. Nuclear share of total electricity generated in European countries (NEA data document 1985).

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(NAGRA) is responsible for planning the final disposal of all radioactive wastes in the country. At this time, only low and medium-level waste are in the country, and research and development activities are focused on planning appropriate repositories for ultimate disposal. High-level waste will be returned to the country when Swiss spent fuel is reprocessed abroad. For this purpose a repository for high-level waste disposal in crystalline rock is envisioned. Switzerland has recently completed a "warranty project" (Gewahr),[3] describing projects for the disposal of all categories of radioactive wastes.

In West Germany, low and medium-level wastes are stored in engineered storage facilities. Approximately 65,000 m^3 of such waste accumulated prior to 1986 came from research centers, nuclear power plants, and reprocessing at Karlsruhe (WAK) and other sources. For conditioning these wastes, various techniques such as compaction, incineration, cementation, decontamination, and reuse are available and in use. Before 1979 some conditioned waste was disposed in the Asso II salt mine, Germany's experimental underground laboratory. Since 1979 these wastes have been safely stored at various places until final disposal in an underground repository is possible. Two sites have been selected for this purpose: Konrad (a former iron ore mine) and the salt dome at Gorleben. Exploration of the Konrad site has been concluded. The safety report describing the repository and the consequences of the project is being evaluated by authorities. Operation of the repository is expected in a few years.

High-Level Waste

Both storage and disposal options for used fuel (Sweden) and reprocessing wastes (France, Belgium, West Germany, and the United Kingdom) are being pursued in Europe. The high-level liquid waste from reprocessing has been stored as a liquid in tanks. Solidification of these wastes into borosilicate glass was begun in 1978 by France and in 1985 by Germany.

A continuous two-stage process has been used for AVM (Atalier de Vitrification de Marcoule). The liquid radioactive waste in nitric acid is fed continuously into a rotary calciner. The solution is dried and the nitrates decomposed at temperatures between 600 and 900°C (step 1). The calcine leaving the rotary furnace is mixed with premelted glass frit and introduced into a melting pot. The glass is formed and refined in a pot (Inconel 601, lifetime 6,000 hours) by raising the furnace temperature to 1100°C (step 2). Induction heating is used. The production rate is 15 kg/h. The glass is poured every eight hours via a freezing valve into the pot. Each container holds 360 kg of glass, and three pourings are necessary to fill one container. Over 1,100 containers were filled by the end of 1984, corresponding to almost all the waste (750 m^3) at Marcoule. Two vitrification plants will be built at La Hague in northern France to solidify the high-level waste streams from the reprocessing plants UP2 800 and UP3. The first vitrification plant to be associated with UP2 is called "R7." To be commissioned in 1987, the plant features three parallel vitrification lines and is designed to solidify the high-level waste from 800 tons/year of reprocessed burnt nuclear fuel. The second plant, called "T7" and scheduled for 1989, will be associated with the reprocessing plant UP3 and will have the same capacity as R7. For R7 and T7, the AVM continuous two-stage process will be used, and the production rate will be increased to 25 kg/h per line.

The German PAMELA facility at the Eurochemic site in Mol, Belgium, was constructed to vitrify the liquid high-level wastes from previous operations of the Eurochemic reprocessing plant. A continuous one-step process is used. The main component is a joule-heated ceramic-lined melting furnace. The waste solution and the glass frit are fed simultaneously into the melter. Evaporation and calcination (denitration) take place in the upper part, and glass formation and refinement in the lower part of the furnace. The furnace is equipped with air-cooled plate electrodes made of Inconel 690. The volume of the glass melt is 250-300 L; the temperature is 1150°C; and the glass production rate is 30 kg/h. By May 1986, some 64 tons of radioactive glass had been produced and placed in 411 canisters, each holding 154-157 kg. Additionally, 8.8 tons of radioactive glass were produced as beads and 100 vitromet blocks prepared. (Vitromet is an acronym for the composite waste form glass-lead.) The glass beads are embedded in a continuous lead metal matrix.

The PAMELA plant is now awaiting further solidification campaigns, e.g., the vitrification of 800 m^3 of MTR-type waste. This campaign started in October 1986 and will fill 3,000 containers with borosilicate glass. In conjunction with the vitrification plant, Belgium has constructed and operated an interim storage facility for the vitrified waste. The PAMELA vitrification process will be used for solidifying the high-level waste from the German 350 tons/year reprocessing plant, WAW. Construction of this plant has begun in Wackersdorf, Bavaria.

In 1981-82 British Nuclear Fuels Ltd. adopted the French process and purchased glassmaking equipment for the Windscale Vitrification Plant (WVP) to be built in the Windscale works at Sellafield. The WVP plant will consist of two separate vitrification lines of equal size and its operation is planned for early 1989. With the two vitrification lines, it will be possible to solidify 200 m^3 of high-level waste per year.

Final Disposal of High-Level Waste

There is general agreement among the European countries that high-level waste and spent fuel should be buried in deep geological formations. Different land-based media are under investigation, depending on the regional geological conditions in Europe, mainly crystalline rock, salt, and clay.

The geology in Sweden is dominated by granitic and gneissic formations. The Swedish Nuclear Fuel and Waste Management Co. (SKB) is performing an extensive site investigation for the disposal of spent fuel and vitrified high-level waste. Vitrified high-level waste will be delivered from France (Cogema) after reprocessing of Swedish fuel. The site possibilities, which currently include ten sites, will be narrowed to two or three by 1990, and to one by the end of the century. After licensing, the start of construction is projected for the year 2010. The present program has been accompanied by research and development on waste package design and by field lab tests to acquire additional data.

Finland, with essentially the same geology as Sweden, has a comparatively small site selection program for ultimate disposal of spent fuel. Finnish policy requires spent fuel to be disposed of outside Finnish territory. Presently, spent fuel is irrevocably transported to the USSR. In this sense, the site selection program is a backup if the Finnish utilities can no longer make such contracts.

In Belgium a research and development program was started in 1975 to investigate a clay formation (the Boom clay), 5,000 km^2 and about 100 m thick. An underground experimental facility, 225 m below ground level, was completed. The research and development program aims at having an underground facility available in the next decade in which tunneling, waste handling, emplacement, backfilling, etc., have been demonstrated.

In France, which has the largest nuclear power program in Europe, the government approved a national program for radioactive waste management in 1984. Provisions must be developed to store and finally dispose of an overall quantity of 10,000 m^3 of vitrified high-level waste and 200,000 m^3 of transuranic (TRU) waste, which includes conditioned sludges, cladding hulls, etc. Important steps toward ultimate disposal in the deep underground include:

1983-84, identification and mapping of about 30 zones covering four geological environments (clay, salt, granite, and schist);

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1985-87, confirmation of four or five of the most attractive sites;
1988-89, validation of the candidate site and construction of an Underground Site Validation Laboratory (USVL);
1990-92, implementation of the USVL.
Thereafter, the construction of a deep underground repository is envisioned, with top priority being given to the disposal of TRU wastes before the end of the century. For vitrified waste, a 20-30 year cooling period is foreseeable, with storage in air-cooled surface facilities prior to ultimate disposal.

In West Germany, the vitrified high-level waste will be disposed of in a domed salt formation near Gorleben. Germany has a long tradition of salt mining, and extended areas are available as potential waste disposal sites in the northern part of the country. The above-ground site exploration and evaluation program at Gorleben has been completed. Deep exploration drillings have provided information on the structure of the salt dome, and work is in progress to explore the salt dome in detail. Two shafts are under construction, and exploratory galleries will be constructed between 1988 and 1992. Thereafter, the exact location of the disposal field must be identified. Boreholes, 300 m deep, will be drilled from the floor of the galleries, which are located at a depth of about 800 m. The waste canisters will be stacked in the holes on top of one another, and the holes and the gallery backfilled with crushed salt. Non-high-level wastes will be disposed of in this repository using boreholes, or in caverns, depending on heat generation. Licensing and other requirements make it likely that operation of the repository could be started in the late 1990s. In addition to the work at Gorleben, research and development programs have been continued in the Asso II salt mine, e.g., to study effects of heat and radiation from the high-level waste on the salt.

Denmark has many salt formations and is pursuing this as an alternative to disposal in mines. This concept is cheaper for the small amount of waste to be disposed of in this country and is expected to provide additional safety by drilling holes up to 2,500 m deep.

Finally, research and development in field management and disposal has been extensively supported by the Commission of the European Communities (CEC) in the form of joint programs. These results have been compiled in two conference proceedings [4,5] and give an excellent overview of activities in the member countries.

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