A CENTRAL REPOSITORY FOR FINAL DISPOSAL OF THE SWEDISH LOW AND INTERMEDIATE LEVEL REACTOR WASTES

Lars B. Nilsson
Swedish Nuclear Fuel Supply Co/Division KBS
Stockholm, Sweden

GENERAL BACKGROUND

The Swedish Parliament has decided that the nuclear power program in Sweden shall be limited to 12 reactors and that none of these shall be operated beyond the year 2010. The foresight and permanency of this decision can of course be debated. From a realistic point of view, however, this limitation gives a base for an estimate of the total quantity of the different kinds of radioactive wastes, that have to be taken care of.

The Swedish legislation lays the responsibility for handling and final disposal of radioactive wastes on the producers of the waste which means the nuclear power utilities. A special national authority supervises and controls that a waste management program is prepared and accomplished in a proper way and in due time by the utilities. The legislation gives options for both reprocessing and direct disposal of spent fuel. The four Swedish nuclear power utilities have delegated the responsibility for the waste management to a jointly owned company, the Swedish Nuclear Fuel Supply Co, SKBF.

SKBF has divisions for

- fuel supply
- agreements for reprocessing abroad
- construction and operation of facilities for transportation, intermediate storage and final disposal
- R&D-work

The R&D-work is performed within the division KBS, which is also responsible for preliminary design studies for the facilities.

The general plan for SKBF's work is shown in Fig. 1. The approach is to go forward step by step and to collect and evaluate the necessary data and know-how for implementation of the different phases, when they are needed.

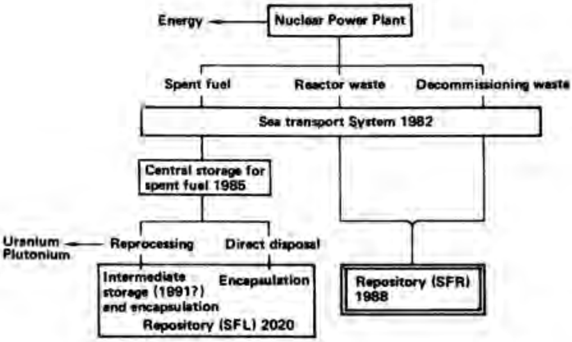

Fig. 1. General plan for the implementation of the Swedish radioactive waste management program.

Currently a central intermediate storage facility for spent fuel (AFR) is under construction and scheduled for operation in 1985. A complete transport system for radioactive waste products is also under construction and will start operation late this year.

The next step of implementation will be the construction of a final repository for reactor wastes. Reactor wastes are defined as wastes continously produced during the operation of the reactors. They consist mainly of ion-exchange resins and trash from maintainance and repair work. These wastes have up till now after treatment been stored intermediately at the reactor sites. If a final repository becomes available in the near future considerable costs for extending the intermediate storage facilities can be avoided. As the necessary basic know-how for the design and construction of a repository for low and medium level wastes now is at hand, there is no good reason to wait. The plans for this repository for reactor wastes, called SFR (earlier ALMA) will be decribed in this paper.

TYPES AND AMOUNTS OF WASTES IN SFR

Most of the activity in wastes coming from the operation of reactors is found in ion-exchange resins. These will also constitute the main inventory in the SFR repository. They are solidified at the reactor sites either in concrete or bitumen and will be deposited either as concrete cubes with the side 1,2 m or as 220 l bitumen drums, Fig. 2. The total amount of solidified ion-exchangers to be deposited in SFR up to the year 2010 is estimated to be about 60.000 m^3 (2 million ft^3).

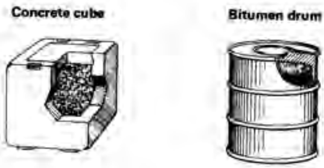

Fig. 2. Ion-exchange resins solidified in concrete cubes or bitumen drums.

Some of the low-level activity ion-exchangers from the condensate clean-up systems are being dewatered and stored in concrete tanks with an inner volume of 6 m^3. For these tanks special space will be reserved in SFR.

Space will also be provided in the repository for low level solid waste, such as trash and scrap material, some of which only are potentially radioactive.

The total volume of all kinds of operational wastes from the 12 Swedish reactors and from the central AFR-facility, is estimated to be about 100.000 m^3 (3,5 million ft^3). Additional space for radioactive wastes from other sources than power production will be provided in the repository for example from medical, scientific and industrial institutions.

The repository site has been investigated and will be prepared to allow for future extension for deposition of radioactive decommissioning wastes. Future deposition of core components including fuel boxes at the same site is also considered.

SITE SELECTION

In Sweden sea-dumping of wastes is forbidden by law. Therefore only land disposal has been studied in the planning of the SFR repository.

Shallow land burial similar to the concept being regarded as a first-hand option in US has been looked at. In Sweden, however, the overburden on the bedrock is normally very thin and the groundwater level normally very near the ground surface. Thus, due to the lack of favourable natural conditions this concept has not been seriously considered.

The host media clay, peat and bedrock have been looked at. Deep clay deposits are not very frequent in Sweden and they mostly occur in highly developed agricultural areas. In addition the cost for a clay repository has shown to be high and therefore the clay option has been rejected. There are appreciable areas of peat in Sweden. The peat, however, is considered a potential future energy source. Consequently the bedrock option has been found to be the best one. A broad experience from rock excavation and underground construction is also available in Sweden. The main site requirement will be the existence of a rock body of sufficient volume and quality.

For licensing and economic reasons the repository should be located adjacent to an existing nuclear facility. Therefore the qualifications of the 4 reactor sites as well as the area around Studsvik research station have been investigated. This showed that the Forsmark site on the Baltic coast offered the best conditions. This site was therefore scrutinized in more detail and deep core drillings and in-hole measurements were performed. The result was that a certain area outside the Forsmark site below the sea bottom was chosen, see Fig. 3.

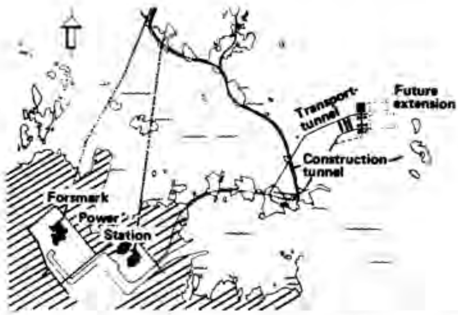

Fig. 3. Proposed site for a central Swedish repository for reactor wastes, SFR

The reason for the location underneath the bottom of the sea have been the following:

a) The hydraulic gradient in the rock mass underneath the sea is low if any and therefore the groundwater flow also is very small. This means that the groundwater has a very low transport capacity for species, which might corrode the engineered barriers or for radionuclides, which might escape from the repository.

b) If small quantities of radionuclides should escape through the barriers, they will be highly diluted in the large sea water volume if not caught in the bottom sediments.

c) If a repository site underneath the land surface should become unknown in the future, somebody might drill a water well through or very close to the waste. For a repository below the sea this risk can be neglected.

d) The location underneath the sea bottom causes no extra investments except some small extra costs for the investigation drillings, as they have to be performed from special platforms.

The depth of water at the chosen site is 5 m. The rate of land uplift in this region is about 6 mm per year, and the site will not become dry during the next few hundred years.

DESCRIPTION OF THE REPOSITORY

General

A general layout of the repository is shown in Fig. 4.

Silo Repository

The main part of the wastes, with regard to volume as well as activity, will be stored in the so called silo repository, Fig. 5.

The silos consist of concrete cylinders with an inner diameter of 28 m and a hight of 51 m. Internally the silo has a system of mainly square cells, but also some circular, with a size adapted to the dimensions of a couple of waste packages. The outer cylindrical wall and the internal cell walls serve as foundation for the handling equipment and also make it possible to deposit the waste packages in an orderly and controlled way. The outer wall is also the main barrier for isolation of the radionuclides. The space between the concrete cylinder and the rock wall is filled with a clayish material with swelling properties. This filling will support the rock and prevent it from caving in. In addition it will reduce the groundwater flow along the concrete surface and thus protect the concrete from deterioration.

A comparative study has been made of horizontal and vertical rock caverns. The vertical silo-concept showed to have advantages with regard to rock-mechanics as well as to construction and operational costs. The possibility to slipform the complete concrete structure in one step in the vertical silo-concept is very favourable with regard to construction costs.

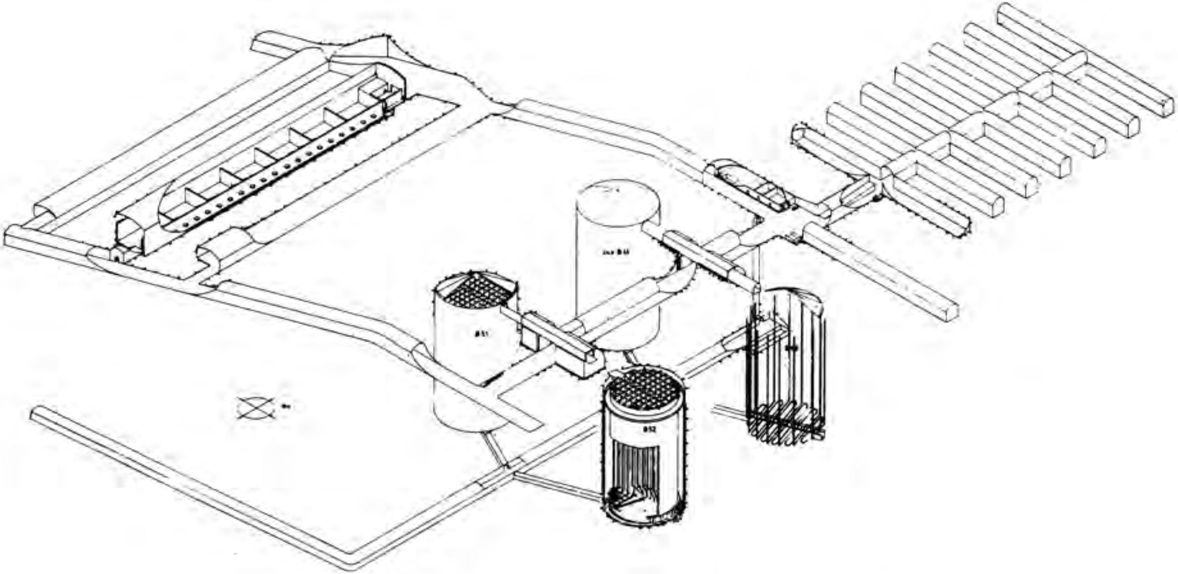

Fig. 4. General layout of the SFR repository.

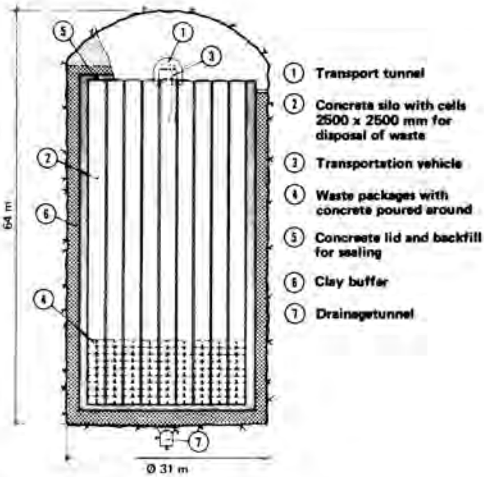

Fig. 5. Silo repository.

The waste packages - mainly concrete cubes and bitumen-filled drums - will be transferred into the silos through a shielded air lock by remotely controlled equipment. Special shielding equipment will be available to handle bitumen drums with high surface dose rates. When two layers of waste packages are placed in the cells concrete slurry is poured around them and filling the remaining empty space.

When one silo has been filled with waste it is permanently sealed by a concrete lid and filling the top of the cavern with clayish material. Finally the transport openings are sealed.

Repository for concrete tanks

The concrete tanks with low activity ion-exchange resins are deposited in tunnels, Fig. 6. When a first layer of tanks is emplaced, concrete is poured around it. When a second layer is emplaced,this is also covered with concrete.

The tanks are transported to their final position by shielded forklift trucks.

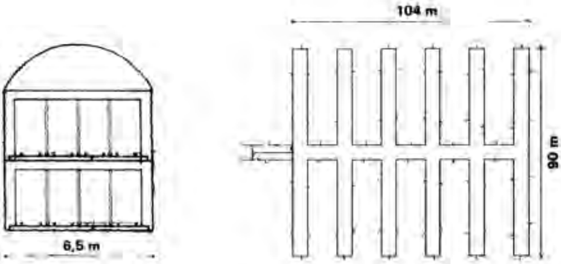

Fig. 6. Repository for concrete tanks.

Repository for trash

As the trash has a very low content of activity this part of the repository is of very simple design. It consists of untreated rock caverns, where the compacted trash is deposited in standard containers brought there by standard trucks. When the rooms are filled no special arrangements are foreseen but sealing of the openings.

Currently most of the burnable trash is incinerated and the ashes are contained in steel drums with a concrete liner as radiation shield. These drums with ashes will be finally stored in the silo repository. It is unclear, however, if it is cost-effective to incinerate the trash. Therefore the option is kept open to deposit the whole estimated quantity of trash, burnable or not, in SFR.

Some existing waste has been packed in steel drums without a clear declaration of the content. It is known, however, that these drums can contain cellulose. When deteriorating due to bacterial attack the cellulose will cause increased steel corrosion and as a consequence increased gas generation. For these wastes a special room will be reserved, where the design allows for a slow release of gases through the rock fissures.

Transports

All the wastes will be transported to the site by ship in containers with shielding capacities adapted to the following classes of waste with regard to surface dose rate:

1 <30 mrem/h

2 30 mrem/h - 50 rem/h

3 > 50 rem/h

At the harbour a buffer store will be arranged so that the deposition work may run continuously and smoothly. Special vehicles will be designed for the transfer of the waste from the harbour to the repository.

Possible future expansions

As mentioned earlier, the site has been investigated and prepared for two possible extensions of the repository. One of these, SFR-2, is a repository for spent fuel boxes, control rods, internal parts etc. Their long-time activity is governed by the content of ^{59}Ni. As solubility of Ni is very low at high pH-values it is intended to pour concrete around the metal pieces before or when they are finally disposed of. Thus the SFR-2, in its final shape will consist of a solid concrete body, surrounded by rock and constituting a matrix for the metallic waste.

The other likely extension of the facility is a repository for the decommissioning waste, that due to its radioactivity may not be disposed of at the reactor sites. This repository may be of a silo-type but with a less sophisticated design than the silos for reactor wastes.

COSTS, TIME SCHEDULE

The total cost for construction of the first phase of the repository, SFR-1 for operational wastes, is estimated to 1,000 MSEK in the price level of 1981/82. This is equivalent to about 200 MUSD and includes costs for operation up to the year 2020 and for sealing of the repository. If the cost is distributed over the energy production that corresponds to the waste to be deposited in SFR-1 (1.400 TWh), it means about 0,001 SEK/kWh, which is equivalent to about 0.0002 USD/kWh.

The current time schedule for SFR is shown in Fig. 7.

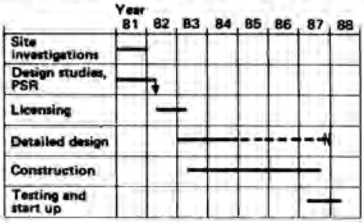

Fig. 7. Master time schedule for the SFR repository.

SAFETY ANALYSIS

General

Two different safety aspects have to be assessed - the operational safety and the long-term environmental impact. The operational safety analysis is based on current practice and can - although important - be regarded more or less as a standard procedure.

When it comes to the long-term environmental impact, there does not exist any established practice or codes and regulations.

Long-term safety requirements

The approach has been based on the following requirements.

1. In Sweden a dose of 10 mrem/year to the critical group is used as a design target for nuclear sites. As SFR will be located adjacent a nuclear power station the two facilities together have to keep within this limit. Therefore, SFR shall be designed to give a dose that represents only a minor part of 10 mrem/year during the period when the power plant is still in operation.

2. When the power plant has been decommissioned the dose caused by SFR shall not exceed 10 mrem/year.

3. In the long time perspective it is not meaningful to describe possible release scenarios in great detail. It should be shown, however, that even a pessimistic scenario will not result in doses over prolonged periods exceeding 100 mrem/year (as recommended in ICRP, publ. 26).

Dose calculations

In order to get an idea of the magnitude of the dose problem, the doses were as a first step calculated for a completely unrealistic scenario where the total inventory of activity is supposed to be instantaneously released and dissolved in the local water of the Baltic. The dose caused by such an imagined release at different times is shown in Fig. 8. The figure shows that ^{137}Cs is by far the dominating nuclide during the first few hundred years and that some kind of containment or barrier is needed during this period.

In the next step it was studied whether the present conceptual design, worked out mainly to meet constructual and handling requirements, also fulfilled the safety requirements,

90-95 % of the activity in the whole repository will be deposited in the silos. Therefore, they are of primary interest in the safety studies. The main barrier in the silos is the 0,9 m thick outer cylindrical concrete wall. Through this wall the radionuclides can only be transported by diffusion in the water-filled pores. Also the clayish layer between the concrete and the rock wall will retard the nuclides. In the safety analysis, however, the sorbing effect of the clay has not been taken credit for.

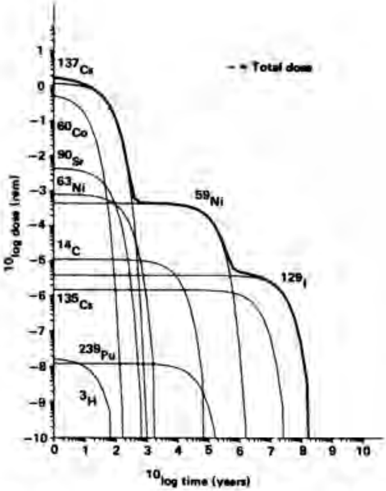

Fig. 8. Doses from an instantaneous release of the total activity content in the repository. The horizontal scale refers to the time for an imagined total release.

The clay has been regarded only as a medium to screen off the concrete surface from flowing groundwater and thereby guarantee a long-time integrety of the concrete barrier. Theoretical studies as well as observations made on old concrete structures give high confidence that the concrete barrier in the actual environment will preserve its good function well beyond 1000 years.

The SFR-1 respository will be used only for wastes, which can be regarded as harmless after a few hundred years of storage. Thus no TRU-wastes will be deposited in SFR. It cannot, however, be avoided that some tracer amounts of TRU-species can be present in the ion-exchangers and sludges, due to leaking fuel rods. As no good method is available for determining the content of α-emitters in the resins, their possible occurance will be estimated from analyses of the crud and the water, that has been in contact with the fuel. If there - under abnormal conditions - are signs of greater amounts of TRU species, the waste will be sorted out and stored for later deposition in a future repository designed for long-lived radionuclides. The worst consequence caused by the very limited amounts of TRU species in SFR should occur if a water well is drilled through waste packages containing TRU elements. This could possibly happen about 1000 years from now, when the sea bottom has become land. The maximum dose from TRU elements in SFR is then calculated to be about 50 mrem.

The results of the dose calculations are summarized in Fig. 9. It is found that even under very pessimistic assumptions the doses from the repository will be far below the levels given in the acceptance criteria. In reality the doses will be even lower as the chemical retention in the clay and the bedrock has not been taken into account, nor the effect of the waste form itself.

Obviously the proposed concept will give a very high degree of long time safety. The design is, however, primarily drawn up to meet construction and handling requirements. In our opinion this has given a safety margin, that is more than high enough. In a year or so we will know if the licensing authorities share this judgement.

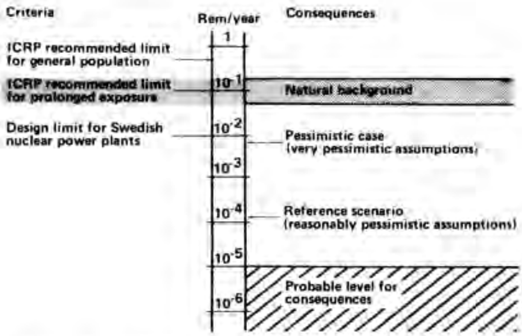

Fig. 9. Calculated doses from the SFR repository compared with applicable or recommended limits.