LARGE SHIELDED CONTAINERS FOR TRANSPORT OF REACTOR WASTES TO THEIR FINAL REPOSITORY IN SWEDEN

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Abstract

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A central repository for reactor wastes (SFR) has been under construction in Sweden since 1983. The repository is situated in crystalline rock under the sea at the harbour of the Forsmark Nuclear Power Station. The repository will be in operation in early 1988. Since all Swedish nuclear facilities are located on the coast, a sea transport system has been found to be appropriate, and a specially designed ship has been built. This ship and the fuel transport flasks, together with special land transport vehicles, have been in operation since 1982 for the transport of irradiated LWR fuel. The same ship and the same types of vehicles will also be used for the transport of reactor wastes that require shielding. The shielded transport containers in which the reactor wastes will be transported to SFR must accept the following main waste packages: (1) Cubical moulds, 1.2 m side or 200 L drums with, for example, ion exchange resins solidified in cement or bitumen. (2) Large concrete tanks (3.3 m length, 1.3 m width, 2.3 m height) with dewatered, low level ion exchange resins. The surface dose rate on the moulds and drums can range between 10 and 500 mSv/h and up to 10 mSv/h for the large concrete tanks. The gross weight of the shielded transport container will be limited to 120 t. The limiting factor is the maximum payload for the ship. The ship can carry ten shielded transport containers. However, the vehicle transport in the tunnel down to the repository area will also restrict the load of these containers. A full-size prototype container with 80 mm wall thickness has been designed, manufactured and tested during 1985. The detailed design of all types of shielded containers started in the autumn of 1985. Manufacturing will take place during 1986 and 1987. The first containers will be needed by mid-1987 for testing of the various transport and handling systems at SFR.

1. BACKGROUND AND PURPOSE

In 1978, the Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering, SKB), acting on behalf of its owners, initiated the planning and design of a sea transportation system for spent fuel from Swedish nuclear

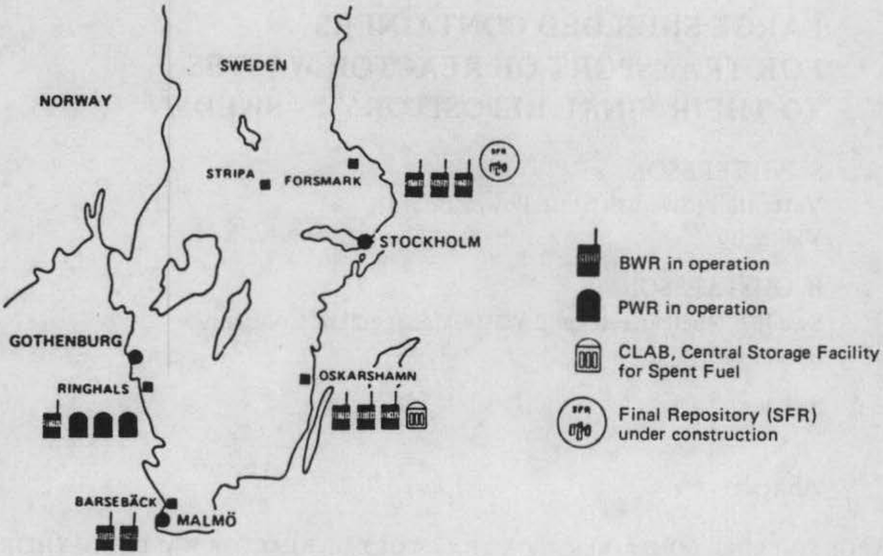

FIG. 1. Location of nuclear power plants, CLAB and the SFR in Sweden.

power stations. The transport system went into operation at the end of 1982. Since then, shipments have been made from Swedish nuclear power plants to the reprocessing plant at La Hague, France, and, from mid-1985, to the Central Storage Facility for Spent Fuel (CLAB) at Simpevarp, outside Oskarshamn.

The locations of the power plants, CLAB and the Final Repository for Reactor Waste (SFR) are shown in Fig. 1. The SFR is a geological repository for reactor wastes now under construction outside Forsmark. It will be in operation in early 1988. The ship M/S Sigyn, together with transport vehicles, will be used for the transport of reactor wastes. The transport system must therefore be supplemented with shielded containers for the transport of reactor wastes.

2. TRANSPORT SYSTEM

2.1. M/S Sigyn

M/S Sigyn is a roll-on/roll-off ship, 90 m long and 18 m wide. The transport casks for spent fuel can either be driven on board by a transport vehicle via an after ramp, or lifted on board by a crane. The casks, with their transport frames, are placed in fixed positions and lashed to the cargo deck. The ship can take a maximum of ten spent fuel transport casks or, alternatively, ten large shielded containers for reactor wastes. It will make about 15 domestic sea transports of

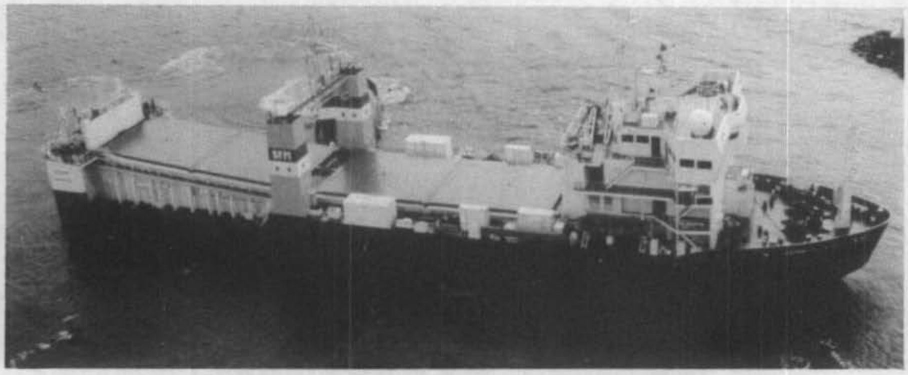

FIG. 2. M/S Sigyn.

spent fuel to CLAB, at Oskarshamn, every year and about 15 transports of reactor wastes to SFR, at Forsmark. M/S Sigyn is shown in Fig. 2.

2.2. Transport vehicles

Three transport vehicles for the transportation of spent fuel casks are now in operation. The vehicle, or vehicles, to be used for transportation of large shielded reactor waste containers at SFR are of the same type, but with some modifications. They will have 7 axles with 26 wheels and they will be hydraulically driven. The hydraulic system is powered by a diesel engine when operated above ground and by an electric motor in the tunnels and in the repository area. The vehicle is equipped with an automatic control system for remote operation in the tunnel and repository area. One such vehicle is shown in Fig. 3.

The total weight of the vehicle with load will be about 155 t. The maximum slope of the tunnels is 1:8 and the velocity of the vehicle will be about 3 km/h. Above ground, the maximum velocity will be about 10 km/h. These vehicles will also be used for transports between the Forsmark harbour, the SFR and the Forsmark power station.

3. DESIGN REQUIREMENTS FOR SHIELDED TRANSPORT CONTAINERS

3.1. General requirements

(1) The transport frame of a shielded container must have the same geometric dimensions as the frame for a spent fuel cask. This is necessary as these containers will be transported by the same types of transport vehicles and

FIG. 3. A vehicle for the transportation of spent fuel casks.

will be placed in the same fixed positions and lashed to the cargo deck as the spent fuel cask frames.

(2) The container and the frame must have the strength to withstand the additional forces associated with transport on a ship in rough seas. The design values for these acceleration forces are:

– In vertical direction	1.00g ± 0.85g
– Transversal of the ship	± 0.82g
– Longitudinal of the ship	± 0.36g

(3) The waste packages should not sustain damage during transport. This will require a support structure or frame inside the container. This frame should also keep the waste packages in place so that they can be easily unloaded at the repository.

(4) The container should fulfil the IAEA Transport Regulations with respect to radiation protection and safety during transport of the wastes.

(5) The container should withstand outdoor parking without damage to the function and should require a minimum of maintenance work.

TABLE I. MAIN TYPES OF WASTE PACKAGES REQUIRING SHIELDING DURING TRANSPORT

Package	Dimensions (m)	Surface dose (mSv/h)	Weight (t)
Concrete moulds with resins solidified in cement	1.2 × 1.2 × 1.2	<30	4
Drums with resins solidified in bitumen or cement	0.6 × 0.9 (dia.)	<500	0.3–0.5
Drums with trash and metal scrap	0.6 × 0.9 (dia.)	<0.3	0.5
Concrete tanks with dewatered resins and filter material	3.3 × 1.3 × 2.3	<10	20
Drums with 'crud' from basins at CLAB (these drums are placed in Type B(U) packages at CLAB)	1.3 × 1.6 (dia.)	<10	5

(6) The handling and transport of the container should be easy. Manual work or contact with the container when loaded should be kept to an absolute minimum.

(7) The maximum weight of the shielded container when loaded should not exceed 120 t.

3.2. Cargo: reactor wastes

The reactor wastes consist mainly of ion exchange resins and filter material from different water treatment systems. Other waste categories are contaminated components, trash and ash from the incineration of combustible wastes.

The waste producers – the nuclear power stations, CLAB and the Studsvik Research Centre – will condition the waste into packages. The main waste packages that need shielding during transport are listed in Table I. It should be noted that all waste packages have to meet a written specification for transport and final disposal.

3.3. The IAEA Transport Regulations

The IAEA's Safety Series No. 6, Regulations for the Safe Transport of Radioactive Material, 1985 Edition, will be followed in general.

The surface dose rate on the container should be less than 2 mSv/h, while the dose rate at 2 m should be less than 0.1 mSv/h. Owing to the size of the container, the 2 m value will be used. The dose rate in the driver's cabin should not exceed 0.01 mSv/h. As a result additional shielding of the cabin will be required..

The transport of reactor wastes will be carried out under "exclusive use", as defined in the Regulations. The reactor wastes can be classified, with some exceptions, as LSA-II, LSA-III or SCO-II, and the transport containers will meet the requirements for an industrial package Type 2 (IP-2).

According to paragraphs 311, 422 and 427, the total activity contents in a single package should be limited so that the dose rate at a distance of 3 m from an unshielded package should not exceed 10 mSv/h. This requirement cannot be met with Swedish reactor waste packages.

For a transport of ten fully loaded containers on M/S Sigyn, the total activity contents of the load of combustible LSA-classified wastes must not exceed $100 \times A_2$. A_2 is 0.4 TBq for ^{60}Co, which is the dominant nuclide in reactor wastes. The $100 \times A_2$ limit is also valid for SCO-classified wastes. For non-combustible LSA-classified wastes, there are no such limitations for the total activity contents.

3.4. Radiation shielding calculations

Radiation shielding calculations have been carried out for different types of waste packages in a transport container. The surface dose rate on the waste packages was limited to the following values:

- Concrete moulds $\leqslant$ 30 mSv/h
- Drums $\leqslant$500 mSv/h
- Concrete tanks $\leqslant$ 10 mSv/h.

The shielding calculation is somewhat simplified by assuming that the radiation comes from the dominating nuclides ^{137}Cs and ^{60}Co. Three combinations of these nuclides have been considered: 25/75, 50/50 and 75/25 (in percentages). Also, ^{134}Cs has been considered in the calculations.

The following wall materials have been studied:

- Concrete
- Steel
- Lead.

These calculations show that the dose rate at 2 m determines the wall thickness of the container.

Figure 4 shows the result of the calculations for a container with steel walls. Wall thickness as a function of surface dose rate of the waste package is given. The combinations of nuclides affect the wall thickness. A conservative assumption, with 75% of ^{60}Co and 25% of ^{137}Cs, gives extra margins for normal reactor waste packages.

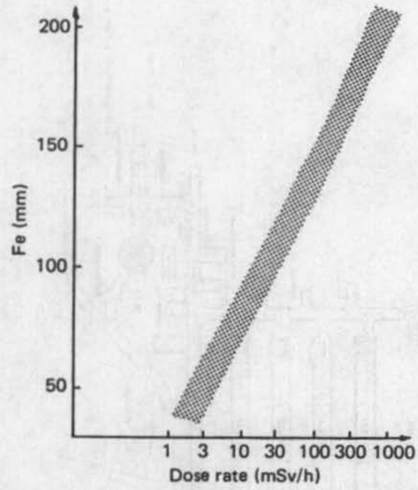

FIG. 4. Container wall thickness as a function of waste package surface dose rate.

3.5. Materials selection

Radiation shielding calculations and 'dimensioning' of the container with respect to maximum waste transport capacity, with the gross load limitation of 120 t, show that steel is the most suitable material. While concrete is basically a cheaper material than steel, the walls must be thicker, which negatively affects the transport capacity. The amount of reinforcement and cast-in material for a concrete container results in a higher total cost than for a steel container. The use of lead could reduce the wall thickness of the container. However, it makes the manufacturing more complicated and has therefore not been considered as a realistic alternative. A steel container can also easily be welded to the support frame and form an integrated unit that can withstand normal and abnormal conditions. There are also other factors that are favourable for a steel container, e.g. it is easier to decontaminate and make modifications if required later on.

4. SYSTEM FUNCTIONS

4.1. Normal operation

The normal operating sequences for a shielded transport container are as follows:

(1) Ten empty containers are transported by M/S Sigyn to a waste producer (Ringhals, Barsebäck, Oskarshamn, Studsvik).
(2) The filling of the containers is done indoors at the waste producers with a remotely operated overhead crane.

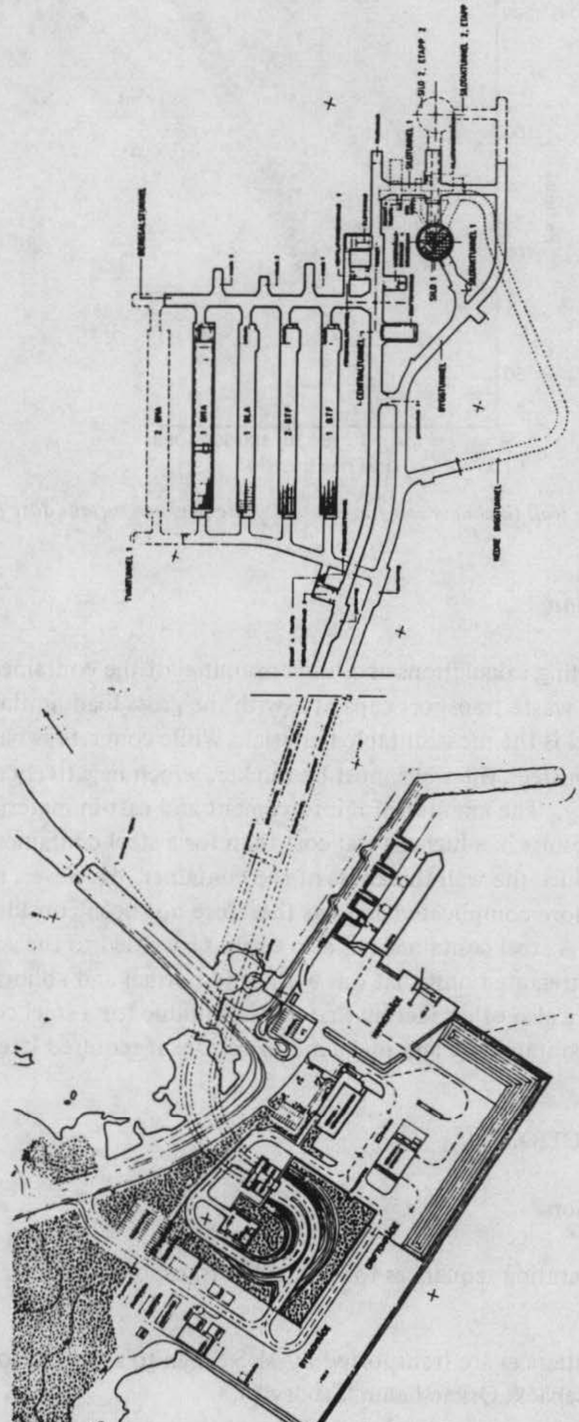

FIG. 5. SFR site plan and repository area.

(3) Ten loaded containers are transported on board M/S Sigyn and lashed to the cargo deck.
(4) At SFR, the loaded containers are transported to the Terminal Building. A site plan for SFR with the location of the harbour, Terminal Building (TB) and the repository, is shown in Fig. 5.
(5) The loaded containers are then brought down to the unloading areas in the repository. The transport vehicle can be manually or remotely operated when moving a container in tunnels or in the repository area.
(6) During transport with the vehicle the container is lifted a maximum of 300 mm above ground. Normal transport height is about 150 mm above ground.
(7) The lid of the container is remotely handled with a separate lifting device and an overhead crane. The containers for concrete tanks have doors which also will be remotely operated.

4.2. Abnormal operation

The following accident conditions have been investigated:

(1) The vehicle, with the container, runs over the quay.
(2) The container turns over on one side, e.g. the vehicle drives into a ditch.
(3) The vehicle, with the container, runs into the rock wall when going down the tunnel to the repository area.
(4) A fire in the vehicle while it is in the tunnel or repository area when transporting a container loaded with bitumen drums.

The most severe accident is if the vehicle, with the container, runs over the quay. With the assumption that the bottom is 8 m below the quay, the vehicle as well as the frame and the container will be damaged, e.g. welds in the walls may be cracked. The locking device for the lid can withstand the forces from the waste packages if the container turns over. If the vehicle runs into the rock wall, only the frame will get damaged if the velocity is below 4 km/h. At higher speeds the container may turn over, but the container will probably also withstand this. A big fire close to the container will give a high temperature inside the container and a release of air from the container will be required. The lid will therefore be provided with a suitable release valve.

5. PROTOTYPE CONTAINER

For the testing of a container with handling equipment for the lid and waste packages, a prototype container for 12 moulds, or 72 drums, has been manufactured. The internal dimensions of the containers are 3.94 m length, 2.60 m width and 2.75 m height and the wall thickness is 80 mm. The tare weight

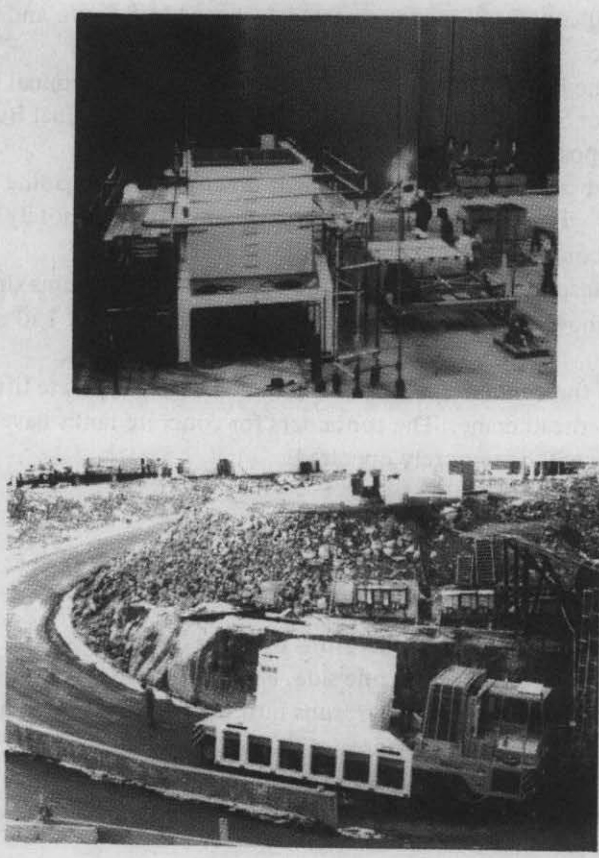

FIG. 6. Testing of waste handling equipment and a full-load transport test.

of this container with lid and frame is about 47 t. The payload is 48 t, as the weight of this container should be the same as for a fuel cask.

A complete test programme was carried out in mid-1985, including a transport test with a vehicle at the steepest part of the tunnel down to the repository. Figure 6 shows the tests with waste handling equipment in the workshop plus the transport vehicle and the container on the entrance slope to the repository.

6. TYPES AND NUMBERS OF SHIELDED TRANSPORT CONTAINERS

The following three types and numbers of shielded transport containers are considered necessary for our needs:

(1) '12K' for 12 moulds or 48 drums. A wall thickness of 130 mm will allow a surface dose rate for the waste packages of 100 mSv/h. Twenty containers of type 12K are considered to be required.
(2) '16K' for 16 moulds or 96 drums. A wall thickness of 80 mm will allow a surface dose rate for the waste packages of 10 mSv/h. Twenty containers of type 16K are considered to be required.
(3) '3T' for three concrete tanks. A wall thickness of 80 mm will allow a surface dose rate for the tanks of 10 mSv/h. Ten containers of type 3T are considered to be required.

Technical information about these containers has been presented to the national authority, the Swedish National Institute of Radiation Protection. It is intended that at least 25 containers will be ordered by mid-1986 for delivery by the end of 1987.

A limited number of other container types may be added later. The following types are under discussion:

(a) '8K' for eight concrete or steel moulds or 32 drums with a surface dose rate of 500 mSv/h. The wall thickness will be 200 mm.
(b) "6U" for six CLAB drums in their GNS MOSAIK-CLAB B(U) packages. The wall thickness would be about 100 mm.