SKB

TECHNICAL REPORT

92-24

Plan 92
Costs for management of the radioactive waste from nuclear power production

Swedish Nuclear Fuel and Waste Management Co

June 1992

SVENSK KÄRNBRÄNSLEHANTERING AB

SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO

BOX 5864 S-102 48 STOCKHOLM

TEL 08-665 28 00 TELEX 13108 SKB S
TELEFAX 08-661 57 19

PLAN 92
COSTS FOR MANAGEMENT OF THE RADIOACTIVE WASTE FROM NUCLEAR POWER PRODUCTION

Swedish Nuclear Fuel and Waste Management Co

June 1992

CONTENTS

SUMMARY

The Swedish nuclear power utilities are responsible for adopting such measures as are necessary in order to ensure the safe management and disposal of spent nuclear fuel and radioactive waste from the Swedish nuclear power reactors. In order to fulfil this responsibility, the nuclear power utilities have commissioned SKB, the Swedish Nuclear Fuel and Waste Management Co, to plan, build, and operate the necessary facilities and systems.

This report presents a calculation of the costs for implementing all of these measures. The cost calculations are based on a scenario for management and disposal of the radioactive waste products, which has been prepared by SKB and is described in this report.

Since disposal of the high-level (long-lived) waste will not commence until some time into the 21st century, continued RD&D activities (Research, Development and Demonstration) may reveal new methods, that can affect both system design and costs. This is expected to lead to overall simplifications in the design.

The facilities and systems that exist are:

- Transportation system for radioactive waste products.
- Central interim storage facility for spent nuclear fuel, CLAB.
- Final repository for radioactive waste from reactor operation, SFR 1.

Future facilities under planning are:

- Encapsulation station for spent nuclear fuel.
- Final repository for long-lived waste.
- Final repository for decommissioning waste.

The cost calculations also include costs for research and development and for decommissioning and dismantling of the reactor plants etc.

The total future costs of the Swedish waste management system, starting in 1993, have been calculated to be SEK 46.4 billion in January 1992 prices. These costs will be incurred over a period of about 60 years. SEK 8.7 billion has been spent up to the end of 1992.

This cost calculation is presented annually to SKI, the Swedish Nuclear Power Inspectorate, which uses it as a basis to propose a fee on the nuclear electricity production in order to cover all future expenses. The fee for 1992 is on average 1.9 öre/kWh (0.019 SEK/kWh).

Before 1992-07-01 this function of SKI was the responsibility of the National Board for Spent Nuclear Fuel (SKN), which has now been incorporated in SKI.

ABBREVIATIONS

ES	Encapsulation station for spent nuclear fuel and core components
BWR	Boiling water reactor (ABB-ATOM)
CLAB	Central interim storage facility for spent nuclear fuel
RD&D	Research, development and demonstration
GA	Common facilities
GD	Common parts of a facility
NPP	Nuclear power station
PWR	Pressurized water reactor (Westinghouse)
SFL	Deep repository for long-lived waste
SFL 2	- for spent nuclear fuel
SFL 3	- for long-lived waste from Studsvik and certain operating waste from CLAB (as from 2012) and the encapsulation station
SFL 4	- for decommissioning waste from CLAB and ES
SFL 5	- for core components etc
SFR 1	Final repository for radioactive waste from reactor operation
SFR 3	Final repository for decommissioning waste
SKI	Swedish Nuclear Power Inspectorate
SKB	Swedish Nuclear Fuel and Waste Management Co
SKN	National Board for Spent Nuclear Fuel
SSI	Swedish Radiation Protection Institute

1. PREMISES

1.1 GENERAL

SKB prepares every year, on behalf of the nuclear power utilities, a calculation of the costs for all the measures that are required in order to manage the spent nuclear fuel from the reactors and the radioactive waste deriving from it and to decommission and dismantle the reactor plants. The calculations are based on a scenario for energy production, waste quantities and required measures that is presented in this report. The cost calculation is submitted to the National Board for Spent Nuclear Fuel, from 1992-07-01 to the Nuclear Power Inspectorate (SKI), and is used as a basis for calculating the fee for management of the radioactive waste products of nuclear power that is levied on nuclear-generated electricity.

The premises for the cost calculations have been chosen in such a manner that the future costs should not be underestimated. Thus, the waste management system presented here is based on the KBS-3 method /ref. 1/, which has been reviewed in connection with the fuelling applications for Forsmark 3 and Oskarshamn 3 and has been found to meet high standards of safety and radiation protection. In this report the experiences from the safety analysis work, SKB-91, /ref.2/ has been incorporated.

Through continued research and development within the waste management field, it will probably be possible to introduce simplifications in the disposal system. Other technological progress will also contribute to such simplifications. These factors are not taken into account in the cost calculations.

Facilities for which sites have not yet been decided have, for the purpose of cost calculation, been assumed to be located inland. The transportation of the waste is assumed to be made by ship to the nearest harbour and thereafter by rail.

In order to obtain a basis for the design of the waste management system, certain assumptions have to be made regarding the conditions of operation for the nuclear power plants. The amount of spent fuel and radioactive waste to be handled is dependent on operation time and power output as well as on the factor of energy utilization for each reactor. In order to cover the largest scope of the system, within the present resolution of parliament, this report is based on the amount of spent fuel and radioactive waste given by the operation of all reactors up to and including the year 2010.

The Financing Act only deals with costs that are attributable to management and disposal of spent nuclear fuel and waste deriving from the fuel and to decommissioning and dismantling of the reactor plants. SKB's plan for management of the radioactive waste has also taken into account operating waste from nuclear power plants and waste from non-electricity-generating facilities, mainly in Studsvik, which is estimated to constitute a few percent of the total waste volume.

1.2 ENERGY PRODUCTION AND WASTE QUANTITIES

Electricity generation and fuel consumption are summarized in Table 1.1.

Table 1.1 Electricity production and fuel consumption for the Swedish nuclear power plants.

Reactor and date of com. operation		Thermal capacity MW	Net electrical capacity MW	Energy production TWh through 1991	Energy production TWh per year from 1992	Energy production TWh Total	Uranium consumption, tU Discharged through 1991	Uranium consumption, tU Total
B1	75-07-01	1800	600	64	4.1	142	260	611
B2	77-07-01	1800	600	60	4.1	138	233	585
R1	76-01-01	2500	800	70	5.5	174	228	713
R2	75-05-01	2570	870	72	5.6	177	216	630
R3	81-09-09	2780	920	55	5.9	167	153	591
R4	83-11-21	2780	920	51	5.9	163	153	579
O1	72-02-06	1375	440	54	3.0	111	226	519
O2	74-12-15	1800	600	67	4.1	145	250	604
O3	85-08-15	3300	1160	51	7.9	202	131	752
F1	80-12-10	2930	970	72	6.6	198	251	812
F2	81-07-07	2930	970	67	6.6	193	215	772
F3	85-08-22	3300	1150	51	7.9	200	128	747
BWR		21735	7290	557	49.9	1504	1922	6119
PWR		8130	2710	179	17.3	508	522	1797
All		29865	10000	735	67.2	2012	2444	7916

Energy utilization factor for BWR = 0.78 Burnup for BWR: 38 MWd/kgU
Energy utilization factor for PWR = 0.73 Burnup for PWR: 41 MWd/kgU

Energy production in the Swedish nuclear power plants totalled 74 TWh in 1991, which corresponds to an average energy utilization factor of 84%. During 1989 and 1990 the abundance of hydro electric power resulted in a decrease in the utilization of the nuclear power plants. The average energy utilization factor in 1989 was 73% and in 1990 75%. In the calculation of estimated future electric power generation, the energy utilization factors of 78% and 73% are used for BWR and PWR respectively. The real factors of energy utilization are expected to be higher. The factors above are assumed to give ample room for possible disturbing events in the future. The same factors are also used in the planning of future expansion of power production.

The electricity production in the nuclear power plants has been estimated to reach a total of 2 012 TWh by 2010. The corresponding fuel consumption is approximately 7 920 tonnes of uranium, of which 6 120 from BWR and 1 800 from PWR.

Most of the spent fuel will be stored in CLAB for about 40 years and then encapsulated and emplaced in a final repository. Only 140 tonnes of uranium are planned to be reprocessed by BNFL, from which no waste will be returned. No reprocessing of Swedish fuel is planned to take place by Cogema. During the late 80s, SKB has transferred the Cogema reprocessing contract to one Japanese and eight German utilities. For the purpose of covering some transition costs, a sum of MSEK 500 has been included in the cost summary.

Table 1.2 Main types of radioactive waste products to be disposed of.

Product	Principle origin	Unit	No. of units	Volume in final repository m^3
Spent fuel		canisters	4 400	9 800
α-contaminated waste	Low- and intermediate-level from Studsvik	drums and moulds	1 900	1 500
Core components	Reactor internals	moulds	2 400	19 700
Low- and intermediate level waste	Operating waste from NPPs and other nuclear facilities	drums and moulds	56 000	91 500
Decommissioning waste	From decommissioning of NPPs and other nuclear facilities	10-20 m^3 containers	5 500	111 500
Total quantity			70 200	234 000

In addition to the amount of fuel accounted for in Table 1.1, there will be 24 tonnes of German Mox-fuel and approximately 20 tonnes of fuel from the Ågesta and R1 reactors to be handled. The German fuel has been exchanged for 57 tonnes of Swedish spent fuel, shipped to Cogema at an earlier stage.

In addition to spent fuel, the Swedish nuclear power program gives rise to low- and intermediate-level operating waste from the nuclear power reactors, CLAB and the encapsulation station, as well as decommissioning waste when the plants are dismantled. Estimated waste quantities are summarized in Table 1.2. They are described in detail in Appendix 1. The activity content of the different waste types varies widely. The handling and disposal requirements will therefore be dependent on waste type.

1.3 PRINCIPLES OF THE WASTE MANAGEMENT SYSTEM

As a basis for the timetable for the Swedish waste management system and for the design of the facilities, it is assumed in this report that:

- Short-lived waste will be disposed of immediately after it is obtained.
- Spent fuel will be stored for about 40 years before it is placed in a final repository. Heat generation in the final repository is thereby limited.
- Other long-lived waste will be disposed of in connection with the final disposal of spent fuel.

These premises also constitute the planning basis for the research and development activities. The premises may be modified in the future, both in view of the results of the continued RD&D work and as a consequence of future political decisions. Studies have shown that the system contains considerable flexibility /ref. 3/.

In their review of SKB's RD&D-programme of 1989 /ref. 7/, the National Board for Spent Nuclear Fuel, SKN, made the suggestion that SKB should make a study regarding a step-by-step implementation of the final disposal programme. This could be achieved by commencing with a demonstration facility for 5-10% of the total amount of spent fuel. The full scale facility could in that way be postponed. An evaluation of such a strategy is ongoing within SKB and will be presented in SKB's RD&D-Programme 92. The cost consequences of such a strategy will also be studied as part of that work.

2. FACILITIES AND SYSTEMS

2.1 GENERAL

In order to handle and dispose of the radioactive waste products in Sweden, a number of facilities have to be planned, built and operated. A scenario has been established as a basis for the cost calculations. This chapter presents in outline form the facilities, systems and other activities included in this scenario. Their function and design are briefly described. A more detailed description is provided in the appendix portion of this report.

The Swedish system of radioactive waste management are presented in Figure 2.1. Some of the facilities are in operation, e.g. CLAB, SFR1 and the transportation system, which provides a good basis for the cost calculations. In the case of future facilities, the final design has not yet been chosen. However, as a basis for the cost calculations, a possible waste handling scheme has been described in detail and tentative layout drawings have been prepared.

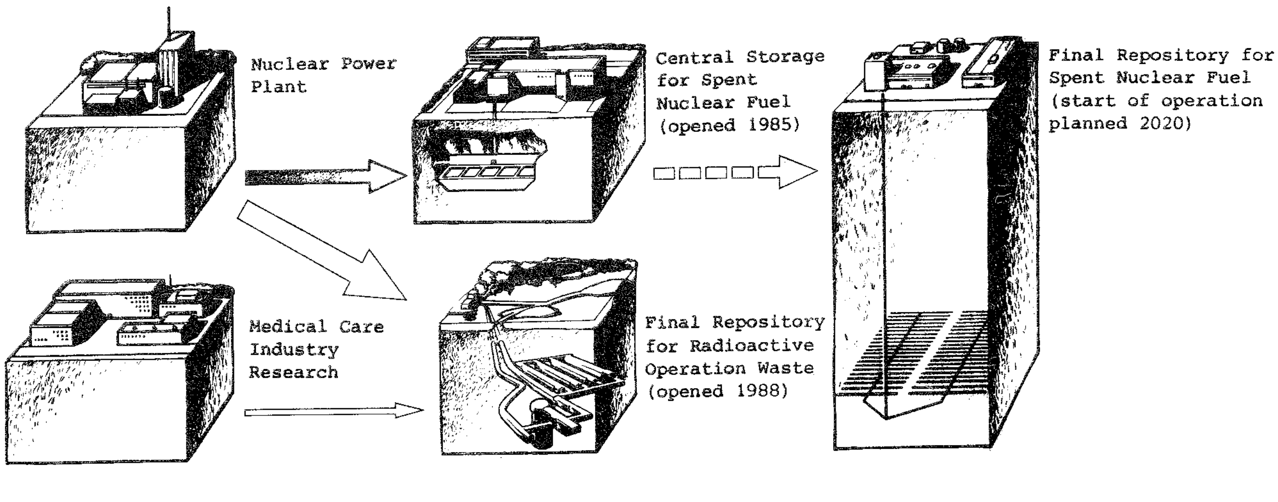


Figure 2.1 The Swedish Radioactive Waste Management System

In this report it is assumed that the Encapsulation Station and all repositories for the long lived waste are located to the same place.

The process and layout of the Encapsulation Station have been revised in this report compared with previous years. As a result of the SKB 91 safety analysis report /ref. 2/ a new design of the copper canister with 60 mm wall thickness instead of 100 mm has been introduced. The outer diameter of the canister, 800 mm, is maintained. Therefore, one canister can now hold up to 12 BWR-assemblies instead of previously 9. The layout of the deep repository has also been somewhat changed. The height of the deposition tunnel has been reduced due to modifications to the deposition equipment. Furthermore, the repository for long lived low and intermediate level waste (SFL3-5) is located within a range of 1 km from the repository for spent fuel (SFL2) and connected to it by tunnel. Thus all transports to the repository level, including the waste, can be done through common shafts.

Figure 2.2 shows facilities included and how the waste products are planned to be managed.

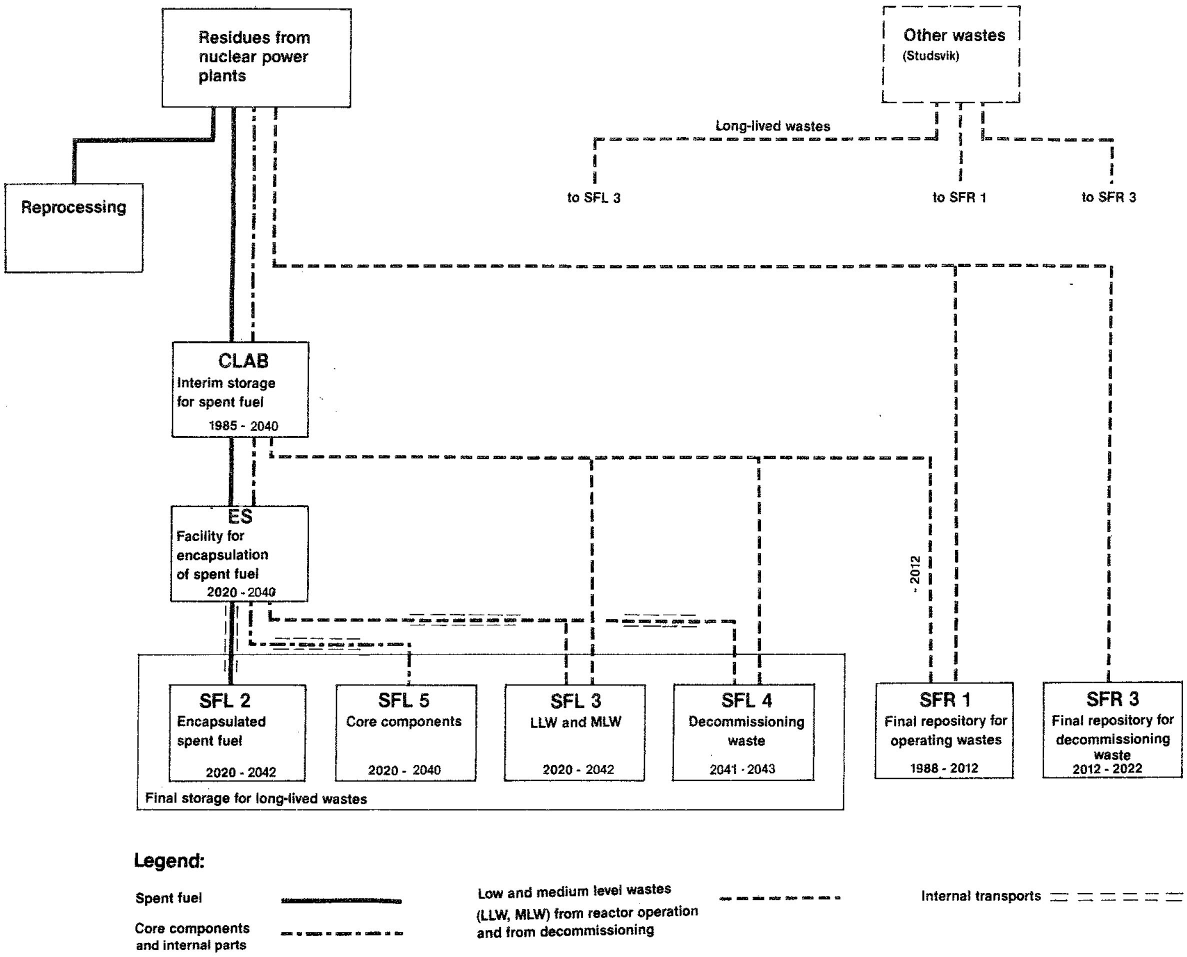


Figure 2.2 Scheme of the handling of radioactive waste products in Sweden

Since the high-level (long-lived) waste will not be finally disposed of until some decades into the next century, new methods may lead to changes in design as well as in costs for construction and operation.

The timetable for the construction and operation of the facilities that is assumed for the cost calculation in this report is presented in Figure 2.3.

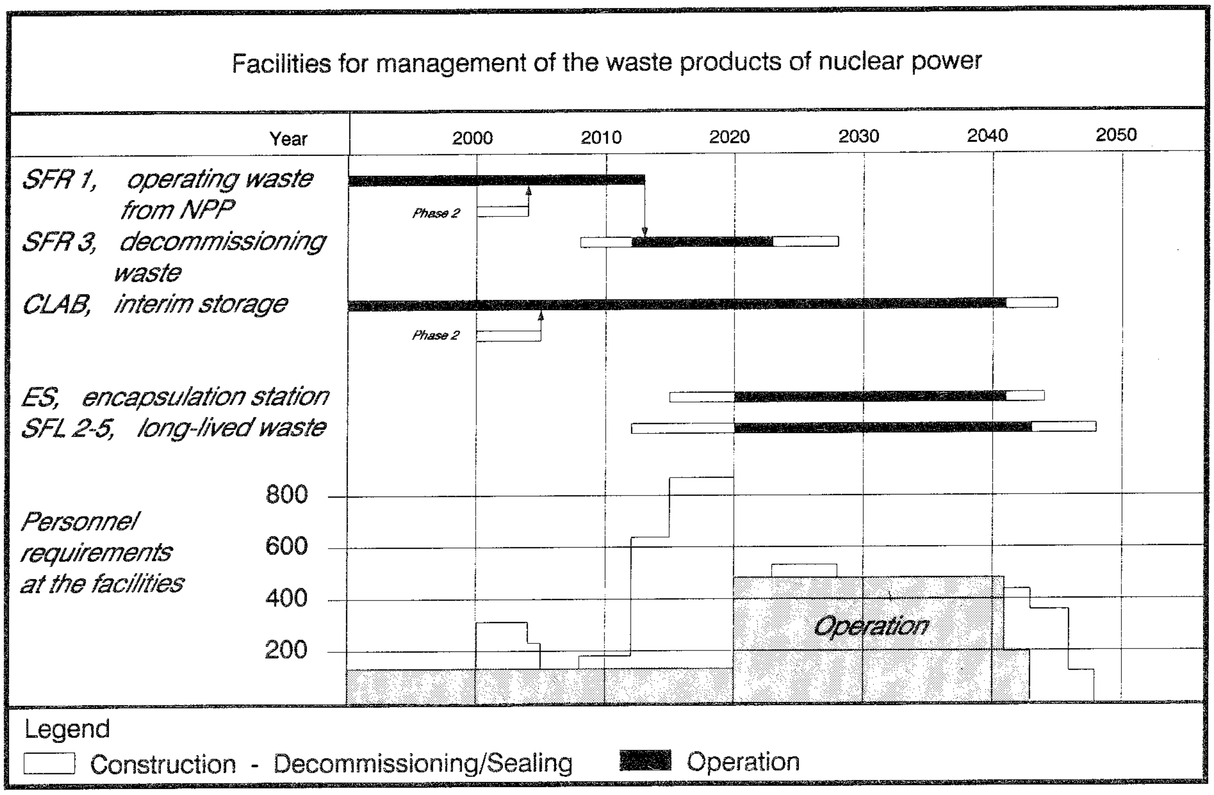


Figure 2.3 Facilities for management of the waste products of nuclear power. Timetable and personnel requirements.

2.2 RESEARCH, DEVELOPMENT, AND DEMONSTRATION

The purpose of SKB's research, development, and demonstration activities (RD&D) is to gather the necessary information and data to realize a safe final disposal of spent fuel and other long-lived radioactive waste. An updated research and development programme is presented by SKB every third year. The latest programme was presented in 1989 /ref. 6/ and a review report by SKN was presented in March 1990 /ref. 7/. At present, SKB is analyzing the comments given by SKN in their report. PLAN 92 is therefore based on data and assumptions presented in SKB's RD&D-programme 89.

A new RD&D-programme is now in the final preparation and will be presented in September 1992.

The aim of the RD&D work during the 1990s will be to establish an adequate basis for a specific Siting Application to be submitted not later than 2003. By that time the system should be optimized and it should be possible to describe it in relation to a specific site. To the Siting Application there should be attached, among others, a detailed analysis concerning the long-term safety of the repository. The analysis has to be based on thorough investigations of the proposed site.

During the 1990s, the RD&D work will be shifted from research and development towards development and demonstration. The selection of a principle system design is planned to take place in the mid 1990s. Candidates sites for the location of the final repository will be selected and detailed investigations of two of the candidates will start in good time so that a completion of the Siting Application can be possible in 2003.

One important step in the RD&D work is the establishment of an underground hard rock laboratory - the Äspö Hard Rock Laboratory - in the Community of Oskarshamn. In April 1990, the Government gave permission for the laboratory to be built, under the Act of Management of Natural Resources. The construction work at the site started in October 1990. The level 500 m below the surface will be reached during 1994. The Äspö Laboratory is essential for the testing, verification and demonstration of investigation methods to be used for the detailed investigations of the candidate sites for the final repository. An explanatory sketch of the laboratory is shown in Figure 2.4. In April 1992 the entrance tunnel had reached about 1 300 m and to a depth of about 180 m below the Äspö island.

This report covers all calculated RD&D costs up to the year 2010. Costs after 2010, at which time the construction work for the final repository starts, are not separately accounted for. The RD&D costs from that time on are included in the owner's planning and design costs, which are part of the investment costs.

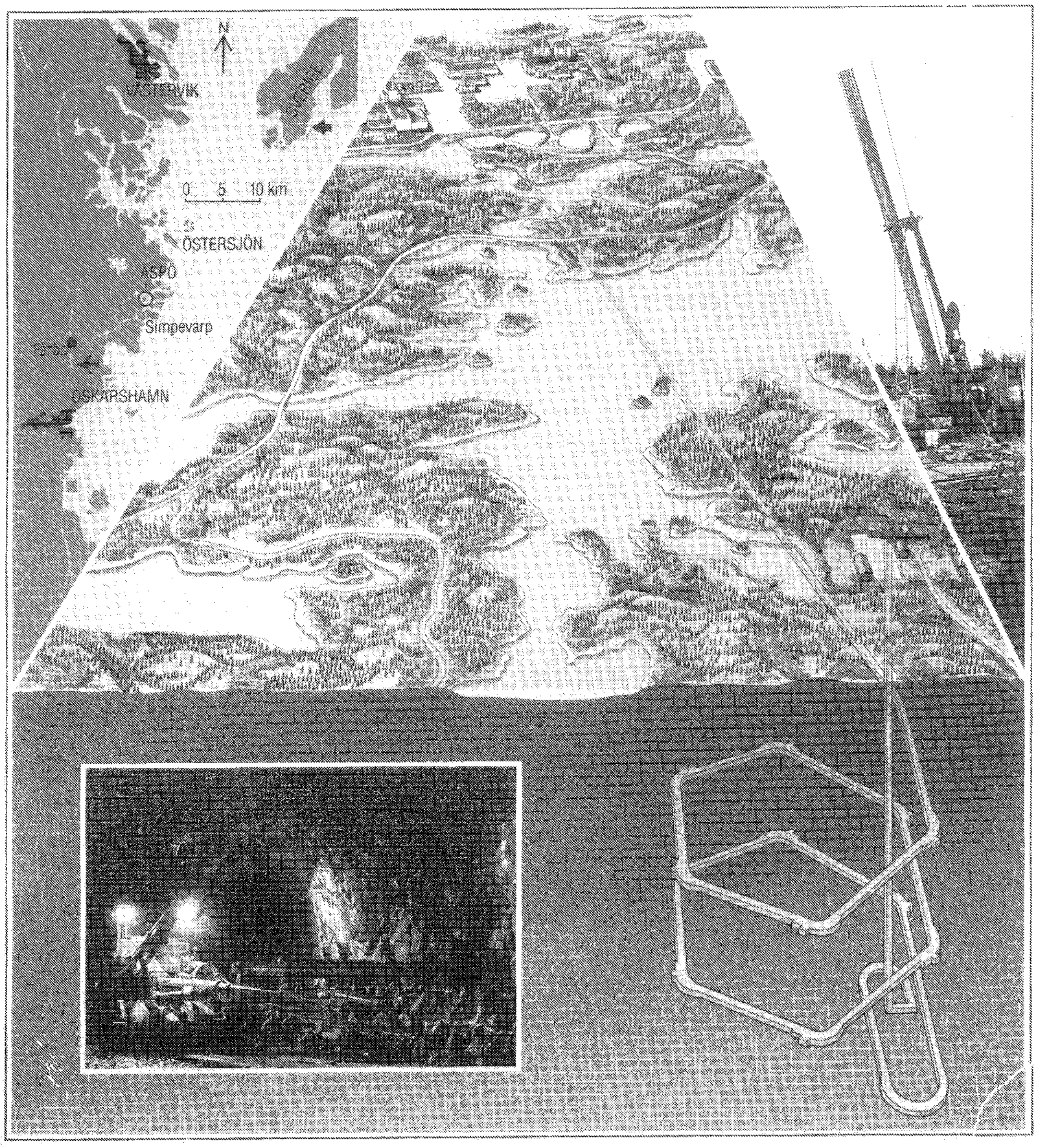


Figure 2.4 The Äspö Hard Rock Laboratory.

2.3 TRANSPORTATION SYSTEM

The transportation system is based mainly on sea transport and its main components are one ship, M/S Sigyn, transport containers and equipment for transport at the nuclear power plants and at the other facilities. The system is designed for accommodating all types of radioactive wastes. Reference is made to Appendix 2.

M/S Sigyn has a payload capacity of 1 400 tonnes and is designed as a roll-on/roll-off ship. Loading/unloading by crane is possible as well.

Since 1985, about 1 500 tonnes of fuel have been shipped from the nuclear power plants to CLAB and during the same time about 8 000 m^3 low and intermediate level waste to SFR.

Containers designed to meet high demands as regards radiation shielding and to withstand large external loads are used for the transport.

Spent nuclear fuel, core components, and core internals are transported in cylindrical casks. One cask can hold about 3 tonnes of fuel.

During loading and unloading, the containers are transported short distances between the vessel and the storage facilities by special terminal vehicles, see Figure 2.5. At present five vehicles are used.

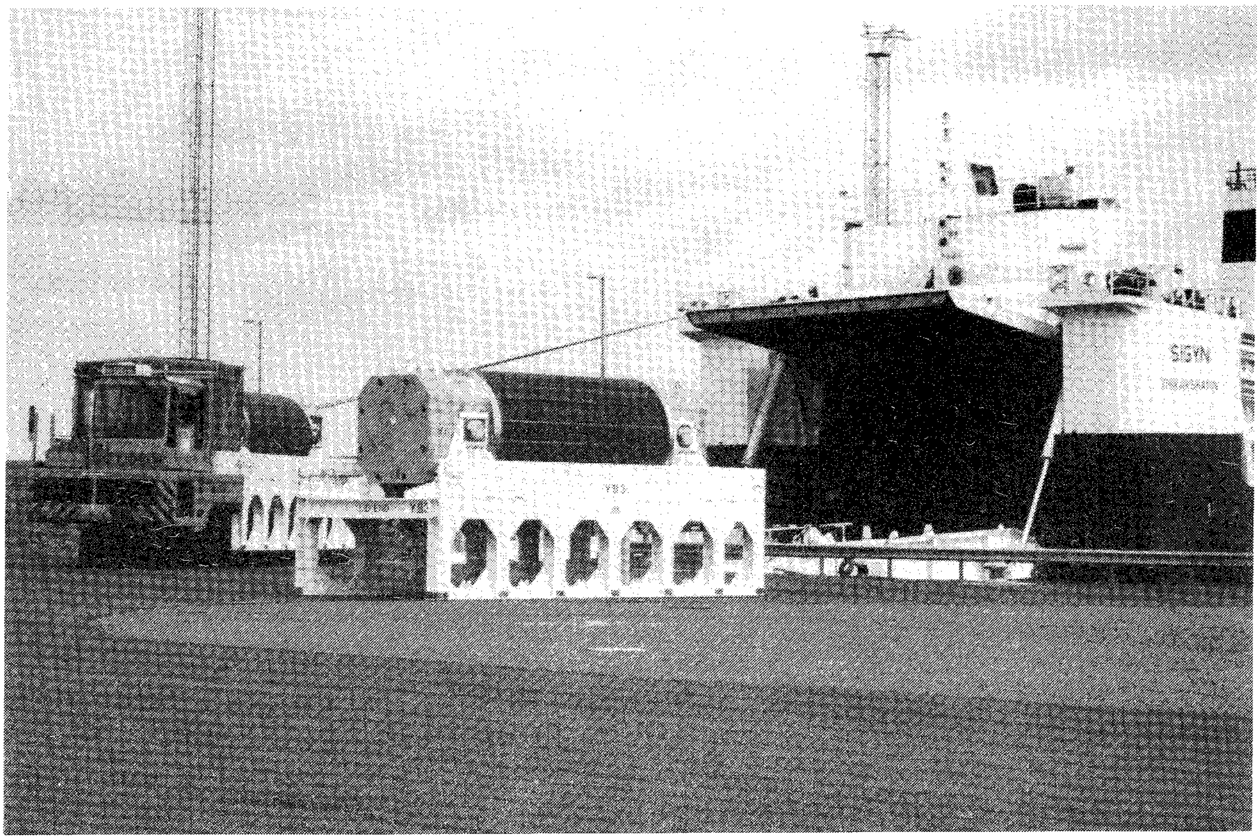


Figure 2.5 Loading of a fuel transport container onto the M/S Sigyn.

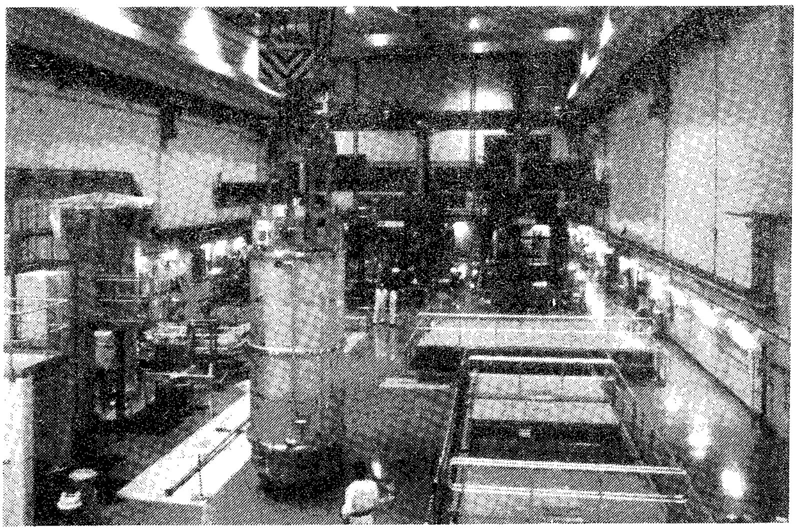
Since the site of the final repository for long-lived waste, SFL, is not yet determined, it has conservatively been assumed in the cost calculations that about 750 km of sea transportation will be needed from CLAB to a harbour, and a further 200 km by rail to SFL. As the spent fuel has then been stored for about 40 years, new types of transport casks with a capacity of about 15 tonnes are assumed to be used.

For the transport of intermediate level waste to SFR, radiation shielding steel containers, called ATB, are used. A common type holds about 20 m^3 of waste and the total weight is 120 tonnes. For low level waste standard shipping containers will be used.

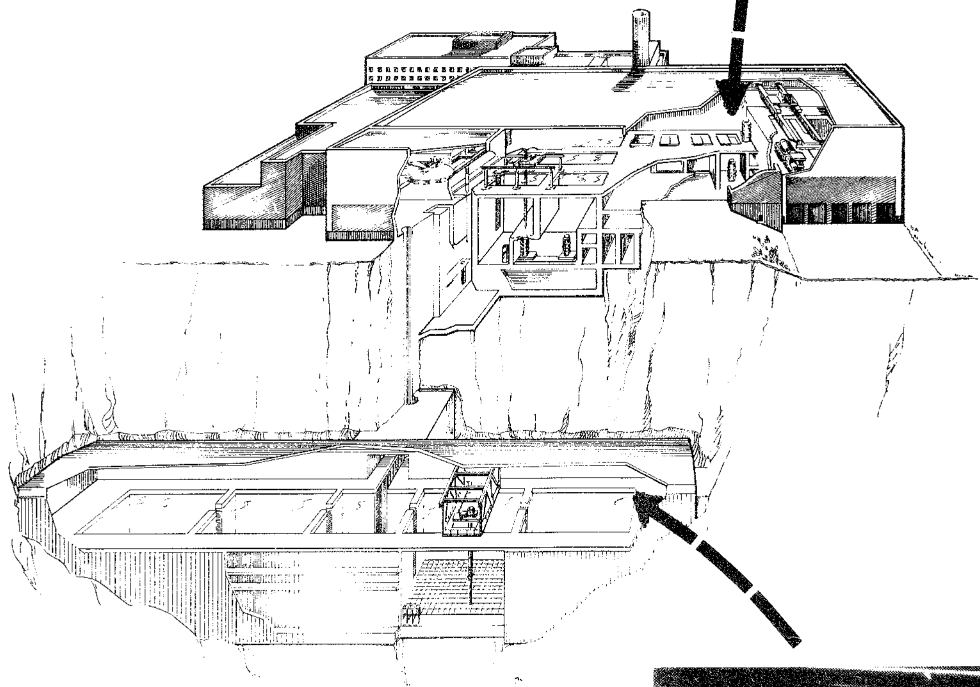
In January 1990, SKB's system included 10 fuel casks, 2 casks for core components and 27 ATB.

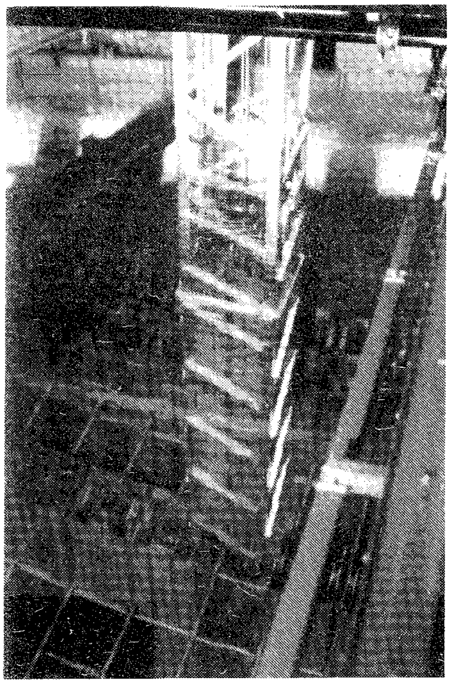
2.4 CENTRAL INTERIM STORAGE FACILITY FOR SPENT NUCLEAR FUEL, CLAB

The central interim storage facility for spent nuclear fuel, CLAB, is situated adjacent to the Oskarshamn power station. The storage facility was taken into operation 1985. It was originally designed to store about 3 000 tonnes of fuel (uranium weight) in four pools. By the introduction of new storage canisters the capacity of these pools has been increase to about 5 000 tonnes.



The handling of
transport casks in the
receiving section





The handling of
storage canisters in
the storage section

Figure 2.6 CLAB.

At the beginning of 1992, fuel corresponding to 1 500 tonnes of uranium was stored in the facility.

In the late 1990s, the capacity of the facility will be expanded in order to hold all fuel from the Swedish nuclear power program. Core components and reactor internals will also be stored in the facility prior to final disposal in SFL.

CLAB consists of an above-ground complex for receiving the fuel and an underground section with the storage pools. The above-ground complex also contains equipment for ventilation, cooling and purification of water, waste handling, electrical systems etc as well as premises for administration and operating staff. Reception of fuel and all handling is made under water.

The storage pools are located in rock caverns with a rock cover of about 30 m. The first cavern, at present in operation, is 120 m long, 21 m wide and 27 m high. The storage pools are made of concrete with stainless steel lining. The fuel is at present stored in canisters with either 16 BWR-elements or 5 PWR-elements. The new canisters which will be in use from 1992 can take 25 BWR-elements or 9 PWR-elements. One pool contains 300 canisters.

The storage capacity is planned to be expanded by the construction of a new rock cavern parallel to the existing one. The new cavern will hold 4 pools for spent fuel and one for core components and reactor internals. These are stored in canisters similar to those for the spent fuel.

When a fuel transport arrives at CLAB, the transport vehicle with the cask is driven into the air lock underneath the reception hall floor. The cask is inspected, and after removal of the shock absorbers it is coupled to one of the main overhead cranes by means of a lifting frame. The cask is raised upright and lifted through the hatch in the roof of the air lock for transfer to one of the cooling cells.

The cask is provided with a protective skirt in order to protect the cooling fins against mechanical damage and contamination during the subsequent reception work. The annular space between the cask and the skirt is filled with water, which is circulated via hoses connected to a separate skirt cooling circuit in the cooling system.

2.5 ENCAPSULATION STATION FOR SPENT FUEL, ES

The spent fuel is encapsulated in copper canisters prior to disposal in accordance with the method described in KBS-3 /ref. 1/. The empty spaces in the canisters are filled with lead in order to enable the canister to resist the high hydraulic pressure prevailing at the repository level.

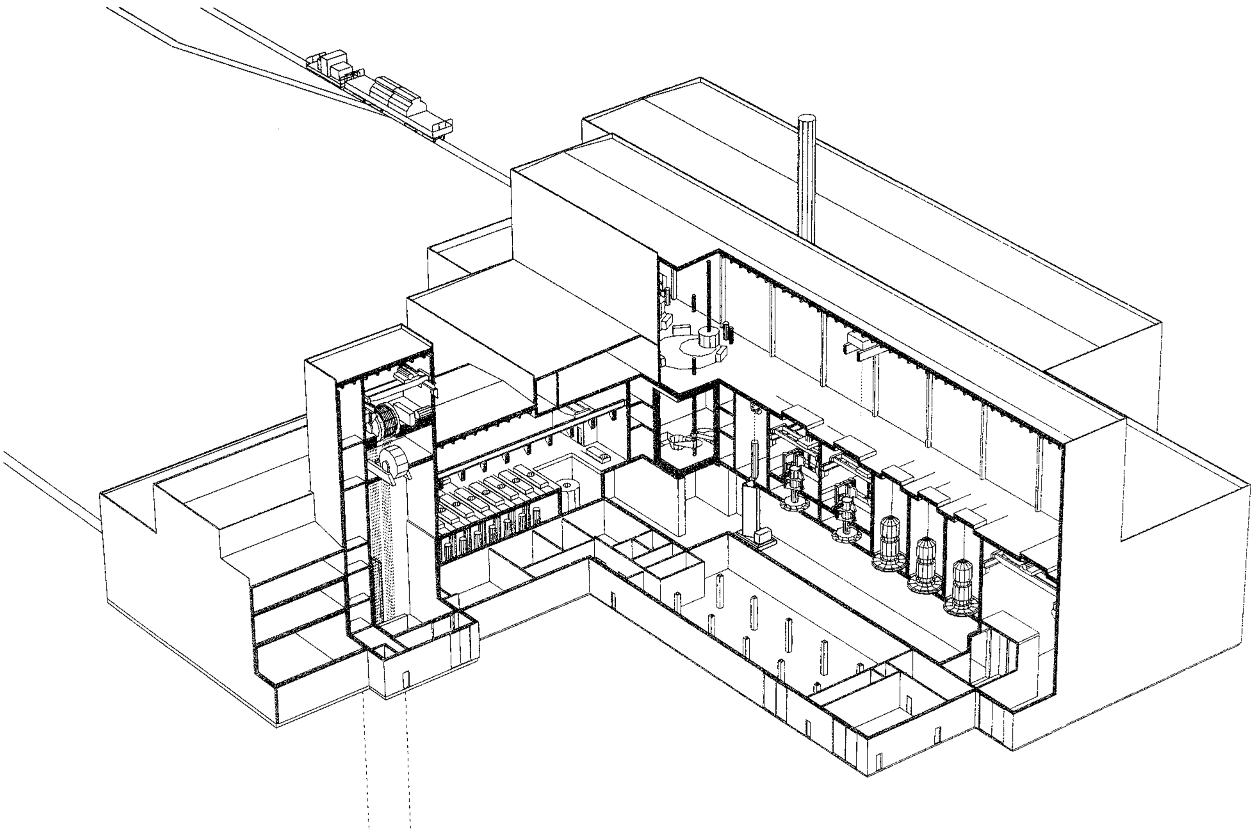


Figure 2.7 Encapsulation station for spent fuel.

In the scenario chosen for this report, the encapsulation station is located directly above the final repository for the spent fuel. It is situated above ground.

The facility consists of the following main sections:

- Arrival and receiving section.
- Encapsulation and dispatch section for fuel, with elevator down to the repository area.
- Encapsulation section for core components etc.
- Service section containing stores, lead melting equipment etc.
- Auxiliary systems with cooling and purification systems as well as electricity and control equipment.

- A side building that houses personnel and office quarters.

Transport casks containing fuel or core components etc. arrive at the encapsulation station by rail. The spent fuel is transported in large transport casks with a capacity of about 15 tonnes of fuel. These are also used for buffer storing of the fuel in case of transport interruption during the winter period, about 3 months. Dry handling of the fuel in a hot cell is assumed. Before the fuel is placed in copper canisters the fuel boxes are separated from the fuel.

The lead-filling of the canisters is made in special induction ovens. The canisters are thereafter moved to a work station for lid welding and checking and further on to a buffer storage before transportation down to the repository.

The encapsulation line for fuel consist of one hot cell for fuel, three induction ovens for lead filling and two work stations for machining, welding and final inspection of the canister.

The facility is designed for an average annual capacity of 210 fuel canisters (one canister per day for 10 months). The facility is mainly operated in the daytime. In total, approximately 4 400 canisters will be processed in the encapsulation station during the period 2020 - 2040. The facility will thereafter be dismantled.

2.6 DEEP REPOSITORY FOR LONG-LIVED WASTE, SFL

Common facilities

The deep repository for long-lived waste, SFL, and the encapsulation station for spent fuel, ES, are in this report assumed to be situated inland. The transports are assumed to be made by ship to an existing harbour and from there by rail to the final repository.

Service facilities such as housing, workshops, water supply and sewerage, electricity supply, concrete station, canteens, guard room etc. will be built at the SFL. A plant for compacting the bentonite and a plant for crushing rock material will also be provided on the site.

The common facilities also include the central administration building for the site organization.

There are four different final repository areas at the SFL:

SFL 2 for spent fuel

SFL 3 for low- and intermediate-level operating waste from CLAB (after 2012) and long-lived waste from Studsvik

SFL 4 for decommissioning waste from the CLAB and ES

SFL 5 for core components and reactor internals

A previously planned unit, SFL 1, for vitrified waste from reprocessing has been omitted.

SFL 2

SFL 2, the final repository for spent fuel, is situated directly below the encapsulation plant at a depth of about 500 m, see Figure 2.8.

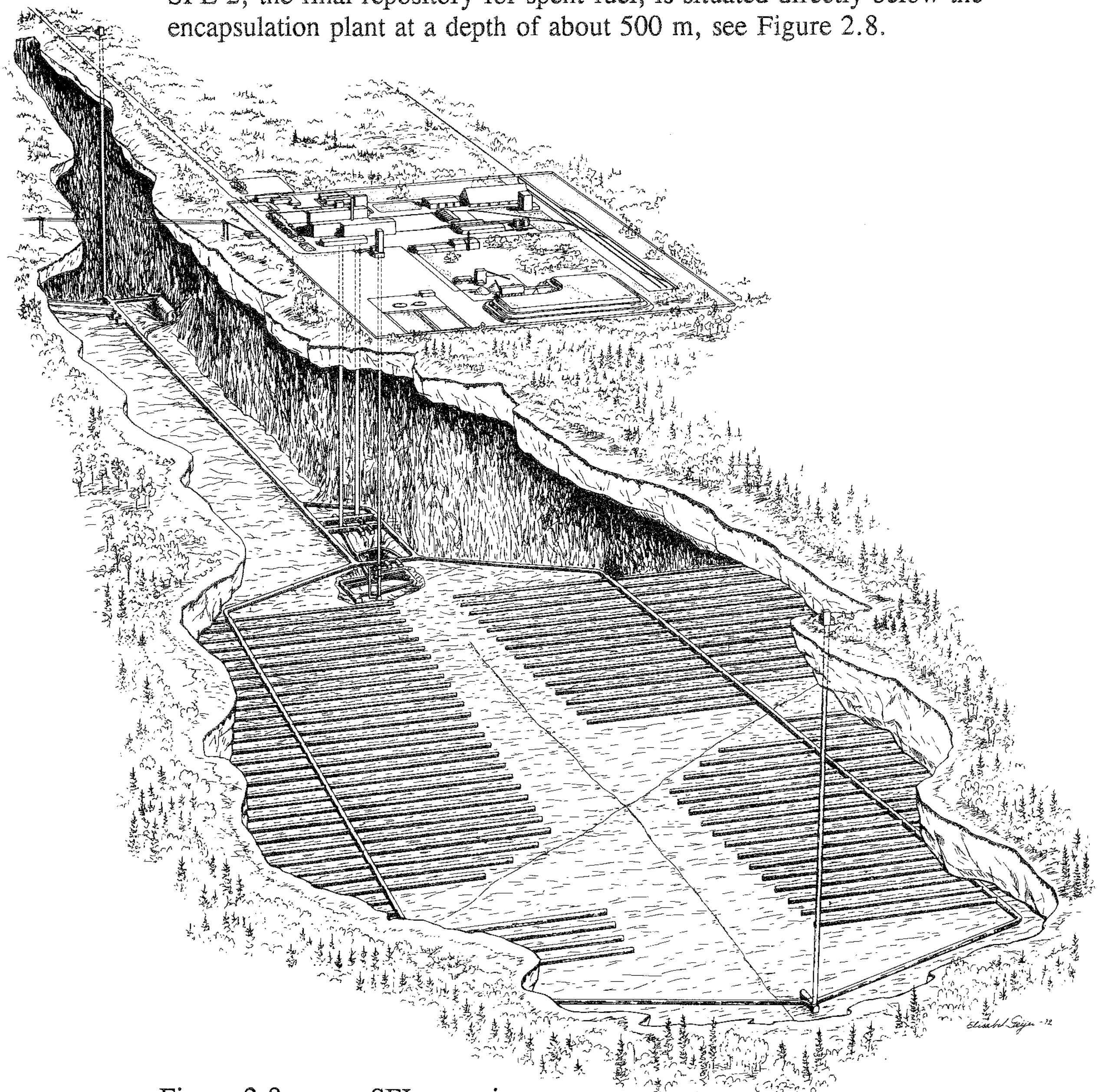


Figure 2.8 SFL overview

It consists of a series of parallel deposition tunnels, 40 m apart, with a cross section of 12.5 m^2 total and a length of appr. 35 km. The deposition tunnels are connected by transport tunnels.

The copper canisters are placed in vertical holes, drilled in the bottom of the deposition tunnels, and surrounded by a layer of compacted bentonite. The spacing of the canisters is determined by the thermal restrictions. The temperature in the bentonite shall not exceed 80° C. The total number of deposition holes is about 4 400. Costs for an extra 10% tunnelling are included assuming that deposition is not feasible in certain areas.

The copper canister is transported down in a radiation-shielding elevator cage from the encapsulation station to the repository level, where it is picked up by a specially designed transport vehicle and driven out to the entrance of a deposition tunnel. The canister will then be transferred to an electrical driven deposition vehicle on rail. At the deposition location the canister is lowered into the deposition hole. Before the emplacement of the canister, a set of cylinder shaped bentonite blocks is placed in the hole. After emplacement additional blocks are stacked on top of the canister by means of the remotely operated deposition vehicle.

The deposition tunnels are backfilled with a mixture consisting of 15% bentonite and 85% quartz sand.

The emplacement of copper canisters will proceed during the period 2020-2040. The repository will thereafter be sealed and all service tunnels, vaults, and shafts will be backfilled.

SFL 3-5

All low- and intermediate-level operating waste disposed of after 2012, when SFR 1 has been closed, is placed in SFL 3, 4 or 5, depending on type of waste. No consideration has to be taken to the temperature since the heat emission is negligible. The storage chambers, which are located at a depth of about 500 m, are reached through shafts common for all repositories, including SFL 2. SFL 3-5 are connected to the central area by a tunnel approximately 1 km long.

SFL 3 consists of a 70 m long rock cavern. The width of the cavern is 18 m and the height about 21 m. The long-lived waste from Studsvik and the operating waste from CLAB (after 2010) and the encapsulation station are deposited in SFL 3. The waste is stacked in concrete cells, 2.5 m square, after which the remaining empty space in the cells is filled with concrete. All handling is remotely controlled. The space between the concrete cells and the rock is filled up with a sand-bentonite mixture.

SFL 4 occupies the tunnel system that has to be built for SFL 3 and SFL 5. Low-level decommissioning waste from CLAB and ES, transport casks etc, that are finally deposited at a late stage, will be placed in SFL 4 shortly before the facility is sealed.

SFL 5 consists of two, about 350 m long caverns in which the concrete moulds for core components etc. are stacked and embedded in concrete. The moulds are handled by a remotely operated overhead crane.

2.7 FINAL REPOSITORY FOR REACTOR WASTE, SFR

A final repository for operating waste from the nuclear power stations is in operation since 1988 at Forsmark nuclear power station. The facility is situated underneath the Baltic Sea with a rock cover of about 60 m. From the harbour at Forsmark, two 1 km long tunnels lead to the repository area. A final repository for decommissioning waste from the nuclear power plants, SFR 3, is planned in connection with SFR 1. SFR 2, which was intended for core components etc., is assumed in this report not to be built, being instead replaced by SFL 5.

Radioactive waste from CLAB and similar radioactive waste from non-electricity-producing activities, including Studsvik, will also be disposed of in SFR.

SFR 1

When completed, SFR 1 will consist of five to six 160 m long rock vaults and two 70 m high cylindrical rock caverns containing concrete silos, see Figure 2.9. The waste containing most of the radioactive substances will be placed in the silos. The first construction stage, which was completed in 1987, comprises four rock vaults and one silo. The second construction stage will be carried out at the end of the 1990s. In all, SFR 1 will hold 90,000 m^3 of waste, of which about 37,000 m^3 in silos.

The concrete silo stands on a bed of sand and bentonite. The silo is divided into vertical shafts, where the waste is deposited and surrounded with concrete grout. The space between the silo and the rock is filled with bentonite.

The handling of the intermediate level waste is remotely controlled, while the low active waste is handled by a fork-lift truck.

A crew of about 20 persons operates the facility. To this number should be added some services that are obtained from the nearby nuclear power plant.

Up to April 1992, 8 000 m^3 waste have been deposited in SFR. The facility is expected to be sealed in the early 2010s.

SFR 3

The decommissioning waste from the nuclear power stations and Studsvik will be deposited in SFR 3. SFR 3 is planned to consist of five rock vaults of a type similar to those in SFR 1. Most of the decommissioning waste can be transported in standard containers which are emplaced in the rock vaults without being emptied. A total of 104,000 m^3 of decommissioning waste will be disposed of in SFR 3.

SFR 3 will be in operation during the period when the nuclear power plants are dismantled.

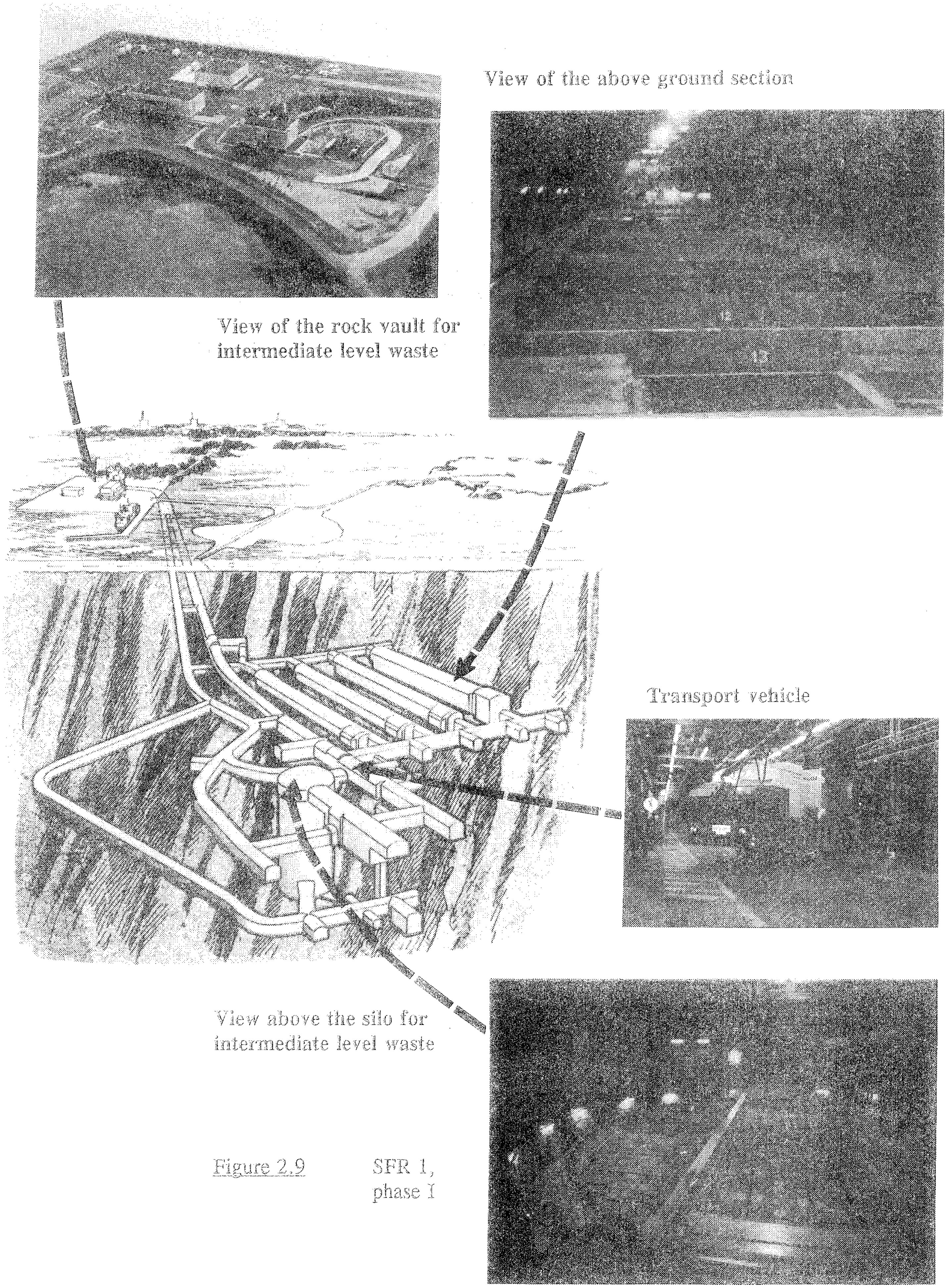


Figure 2.9 SFR 1, phase I

2.8 DECOMMISSIONING OF NUCLEAR POWER PLANTS

The measures required for management of the radioactive waste products of nuclear power also include decommissioning of the facilities after they have been taken out of operation /ref. 5/.

The timetable for decommissioning of the nuclear power plants is influenced by a number of different factors. Dismantling can be carried out in a safe manner a short time after shutdown, but there are certain advantages with deferred dismantling. Here it is assumed that the plants are dismantled early.

With regard to resource utilization and the reception capacity in CLAB and in SFR, it is suitable to stagger the start of dismantling of different units. Here the time between the start of dismantling of units at the same station is assumed to be two years.

During the period from when the unit is taken out of operation until dismantling, removal of fuel, decontamination and preparations for dismantling (shutdown operation) take place. During this period, the personnel can be gradually reduced. The actual dismantling work is expected to take five years per unit and employ an average of a couple of hundred persons.

The radioactive waste from decommissioning is all low- and intermediate-level waste. However, the activity level varies considerably between different parts. The waste with the highest activity, the reactor internals, is assumed to be stored in CLAB for a period of about 30-40 years before being disposed of in SFL 5. Other radioactive decommissioning waste will be transported directly to SFR 3 and deposited there. A large quantity of the decommissioning waste can be declassified, some of it after decontamination.

3. COSTS

3.1 GENERAL

All costs for the management and disposal of the radioactive waste products described in section 1.2 are reported in this chapter. The cost calculations have been based on the scenario and the facilities, systems etc that are described in chapter 2.

In the accounting system, costs incurred up to and including 1992 are distinguished from future costs. The future costs are estimated at January 1992 prices. Previously incurred costs are quoted in current prices.

Cost calculations have been carried out for all facilities and systems based on the new arrangements of ES and SFL and the revised time schedule. The experience from the construction and operation of CLAB, SFR and the transportation system has thereby been incorporated.

The costs are reported in detail in a computerized cost scheduling system called BECOST, which permits present value calculations and variation analyses as well as distribution of the costs among different nuclear power plants etc.

The costs for different facilities are reported here broken down into the following items: investment, reinvestment, operation, decommissioning and sealing. Normally, only those costs that arise before a facility or part of a facility is taken into operation are attributed to investment costs. In SFL 2, where the deposition tunnels will be excavated continuously during the deposition phase, the costs for this work have, however, been assigned to the investment costs.

Some costs that do not fall under the Financing Act are also reported (operating waste from the nuclear power plants, spent fuel from Ågesta and waste from Studsvik).

3.2 CALCULATION METHOD

The cost calculations are based on functional descriptions for each facility, which result in layout drawings, equipment lists, personnel forecasts etc. For facilities and systems that are in operation, this background material is very detailed, while the degree of detail is lower for future facilities.

The costs of the future facilities are calculated in several steps. For each cost item, a base cost is calculated, after which a contingency allowance for unforeseen costs is added. the base costs include:

- quantity-calculated costs
- non-quantity-calculated costs
- secondary costs

Quantity-calculated costs are costs that can be calculated directly with the aid of the design specifications and with knowledge of unit prices, e.g. for concrete casting, rock blasting and operating personnel. In estimating both quantities and unit price, experience gained in construction of the nuclear power plants, CLAB and the SFR has been drawn on.

All details are not included on the drawings. These non-quantity stipulated costs can be estimated with good accuracy on the basis of experience from other similar work.

The final item included in the base costs is secondary costs. These include costs for administration, engineering, purchasing and inspection as well as costs for temporary buildings, machines, housing, offices and the like. The amounts allowed for these costs are also relatively well known, and have been calculated on the basis of the assumed service requirements during the construction phase.

A contingency allowance is added to the calculated base costs for unforeseen items. The size of the contingency allowance is determined object-by-object on the basis of the risks of additional work and the engineering level of the facility. On an average it is about 27%.

3.3 REPORTING OF FUTURE COSTS

The costs reported in this section are given in the price level January 1992. The costs are distributed in time, which permits discounting with different values for the real interest rate.

Table 3.1 shows the future costs for waste management. The costs are distributed by object and category of cost. The total future costs from 1993 amount to MSEK 46 400.

Table 3.1 also separates costs under the Financing Act, i.e. the total cost less costs for low- and intermediate-level operating waste and waste from Studsvik and Ågesta. The future costs under the Financing Act from 1993 amount to MSEK 45 000.

Figure 3.1 shows the annual future costs.

Table 3.2 shows the future costs broken down by object and distributed over time.

Table 3.1 Future costs (MSEK) from 1993, including contingency allowance for unforeseen items (Jan. 1992 prices).

Object	Cost category	Total future costs	Total future costs per object	Future costs under Financing Act[1]
SKB, Adm, RD&D	-	3 998	3 998	3 998
Transports	Reinvestment	538		
	Operation	893	1 431 *	1 274
Decommissioning	Shutdown operation	1 341		
NPP	Dismantling	10 424	11 765	11 765
CLAB	Investment	807		
	Reinvestment	891		
	Operation	4 179		
	Decommissioning	363	6 240 *	6 209
SFL-ES GA	Investment	3 600		
	Reinvestment	215		
	Operation	1 416		
	Decommissioning	253	5 484 *	5 421
ES	Investment	2 749		
	Reinvestment	107		
	Operation	4 233		
	Decommissioning	224	7 313 *	7 276
SFL 2	Investment	3 215		
	Reinvestment	40		
	Operation	840		
	Sealing	2 476		
	Decommissioning	91	6 662 *	6 628
SFL 3-5 GD	Investment	209		
	Reinvestment	2		
	Operation	125		
	Decom. + sealing	152	488 *	456
SFL 3	Investment	184		
	Operation	10		
	Decom. + sealing	43	237 *	184
SFL 4	Investment	22		
	Operation	15		
	Decom. + sealing	2	39 *	38
SFL 5	Investment	128		
	Operation	26		
	Decom. + sealing	62	216 *	211
SFR GD	Investment	40		
	Decom. + sealing	3	43 *	1
SFR 1	Investment	301		
	Operation	515		
	Decom. + sealing	94	910 *	27
SFR 3	Investment	427		
	Operation	200		
	Decom. + sealing	56	683 *	658
Reprocessing[2]	-	866	866	866
Total			46 359	45 032

* Also includes costs outside the Financing Act. Total over all concerned objects:
Waste from Studsvik, Ågesta etc MSEK 258
Other low- and intermediate- level waste MSEK 1 107

1) Future costs less costs for Studsvik waste etc and other low- and intermediate-level waste
2) Costs of reprocessing including costs at BNFL and for transition of contracts with COGEMA

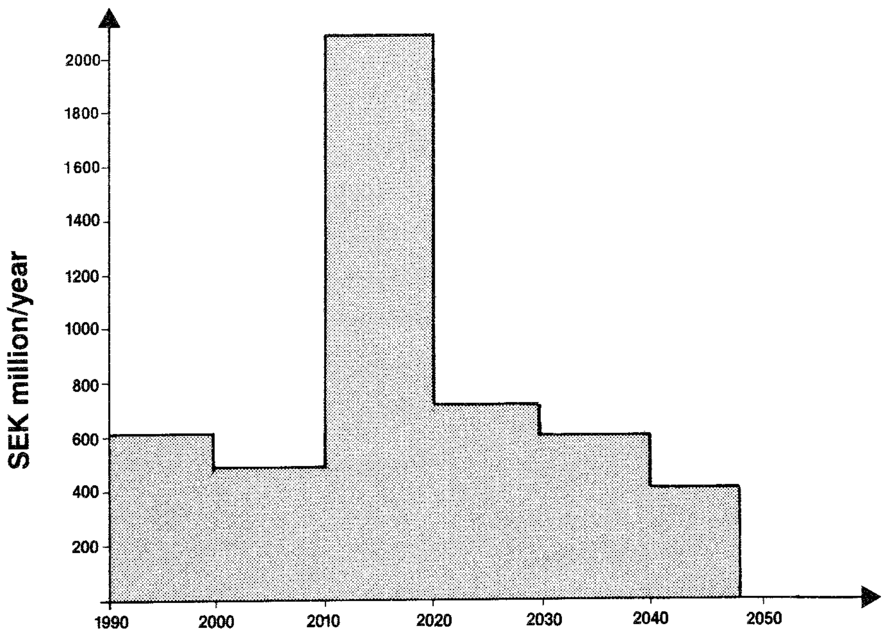


Figure 3.1 Annual future costs (January 1992 prices)

Table 3.2 Future costs (MSEK) per object under the Financing Act distributed over time. (January 1992 prices)

Year	SKB Adm,RD&D	Transp.	Decom. NPP	CLAB	SFL- -ES	SFR 1 + 3	Reproc.	Total costs	Accumulated costs
1993-94	502	33	0	218	0	2	755	755	755
1995-99	1 117	63	0	1 096	0	14	693	2 983	3 738
2000-2009	2 379	265	0	1 204	153	208	193	4 402	8 140
2010-2019	0	245	10 721	1 013	8 211	339	0	20 539	28 679
2020-2029	0	406	1 044	1 186	4 349	123	0	7 108	35 787
2030-2039	0	177	0	975	4 841	0	0	5 993	41 780
2040-2049	0	85	0	517	2 650	0	0	3 252	45 032
Total from 1993	3 998	1 274	11 765	6 209	20 214	686	886	45 032	

3.4 PREVIOUSLY INCURRED COSTS

Table 3.3 reports costs incurred through 1991, in current prices excluding interest, and 1992 budgeted costs.

Table 3.3 Incurred and estimated costs through 1992. (MSEK current prices)

Object	Cost category	Costs incurred through 1991	Estimated costs 1992
SKB (RD&D, Info, Adm)	-	1 332	226
Transports	Investment	254	-
	Operation	241	17
CLAB	Investment	1 747	-
	Operation	643	119
SFR 1	Investment	751	-
	Operation	102	29
Reprocessing	-	3 276	-
Total		8 346	391

The distribution of the total cost among different facilities are shown in Figure 3.2. Incurred cost are indexed to January 1992 price.

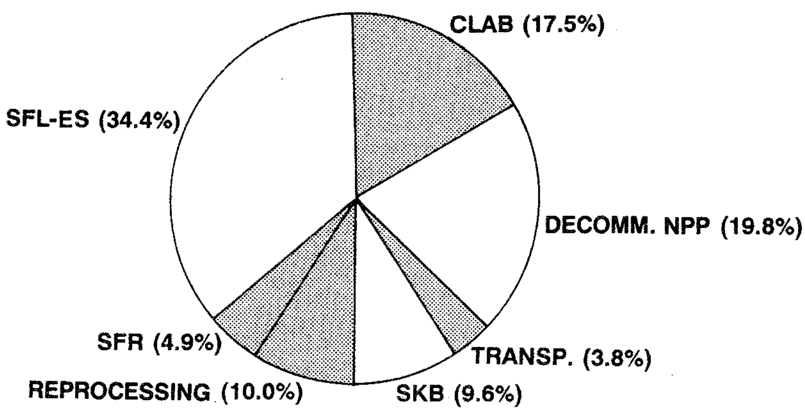


Figure 3.2 Distribution of the total cost.

3.5 MARGINAL COSTS

The costs of the facilities per unit are presented in Table 3.4, both as average cost and as marginal cost. The marginal costs have been calculated on the basis of an estimate of the variable cost portion for each facility section. The capacity of the encapsulation station has been kept constant, so that a change in fuel quantity leads to a change in operating time.

The marginal costs given in the table are relatively roughly estimated and only apply within a limited interval (approx. 20%) of the quantities given in column 3.

Table 3.4 Marginal costs for certain parts of the system. (January 1992 prices)

OBJECT	COST MSEK		QUAN-TITY	UNIT (PARAMETER)	kSEK/ UNIT	MARG. COST kSEK/UNIT	REMARKS
TOTAL FACILITIES ETC FOR MANAGEMENT OF FUEL							
Facilities for management of fuel incl. core components and RD&D	37 000		7 763	ton fuel	4 770	2 240	
DIFFERENT PARTS OF THE SYSTEM							
TRANSPORTS							Includes costs for all transports of the waste
Total	2 255		10 700	trpt unit	211		Ship-transported fuel and waste. The trpt. unit is a cask or container
Spent fuel	1 284		7 763	ton fuel	165	45	Cost incl. core components and LI waste from CLAB. 1 735 tonnes of fuel internally transported OKG-CLAB
Operating waste from NPP	342		57 600	m³ LM waste	5,9	0,5	By ship transport from NPP to SFR 1 of total 72 800m³
Decommissioning waste from NPP	545		68 000	m³ decommissioning waste	8,0	1,1	By ship transport from NPP to SFR 3 of total 100 000 m³. Incl. internals to SFL 5
Studsvik waste	84		15 500	m³ waste	5,4	0,5	Various wastes
INTERIM STORAGE FACILITY							
CLAB	10 440		7 763	ton fuel	1 345	580	Incl. core components and reactor internals (max. 10% of storage volume)
FINAL DISPOSAL							
SFL-ES total	20 461		7 763	ton fuel	2 636	1 550	
		alt.	4 419	copper canister	4 630	2 720	
ES	9 985		7 763	ton fuel	1 286	700	Incl. part of SFL GA and core comp.
		alt.	4 419	copper canister	2 259	1 220	
SFL 2	9 098		7 763	ton fuel	1 172	820	Incl. part of SFL GA
		alt.	4 419	copper canister	2 059	1 430	Incl. part of SFL GA
SFL 3	656		5 500	m³ LM waste	119	33	Incl. part of SFL GA and SFL 3-5 GD
SFL 5	616		2 380	mould	259	81	Incl. part of SFL GA and SFL 3-5 GD
		alt.	7 763	ton fuel	79	27	Incl. part of SFL GA and SFL 3-5 GD
SFR 1	2 219		88 000	m³ LM waste	25	13	Incl. SFR GD
SFR 3	683		104 000	m³ decom. waste	6,6	4,0	

3.6 WASTE MANAGEMENT FEE

According to Swedish law, the costs for the back-end of the nuclear fuel cycle and for the decommissioning of the reactors shall be borne by the owners of the reactors. To make sure that funds shall be available a fee is levied on the production of electricity in nuclear power plants. The level of the fee is determined annually by the Government. The decision of the Government is based on a proposal by SKI, which has been calculated using the results of the annual cost calculations presented by SKB in this report and its predecessors.

In making the proposal, SKI has to consider all relevant factors, such as total costs, expected operation time of the reactors and interest on the money collected in funds. Separate fees are proposed for each reactor owner. For 1992 the fee has been 1.9 öre/kWh (SEK 0.019/kWh) on average.

The fees are paid into funds at the National Bank of Sweden. The funds are controlled and administered by SKI. Before 1992-07-01 this function of SKI was the responsibility of the National Board for Spent Nuclear Fuel (SKN), which has now been incorporated in SKI.

REFERENCES

1. Final Storage of Spent Nuclear Fuel - KBS-3
Parts I-IV
Svensk Kärnbränsleförsörjning AB
May 1983

2. SKB 91
Final disposal of spent nuclear fuel
Importance of the bedrock for safety
April 1992

3. Kärnkraftens slutsteg
Alternativa tidplaner för hantering av använt kärnbränsle
- konsekvenser för planering, säkerhet och kostnader
(Alternative timetables for handling of spent nuclear fuel - consequences for planning, safety and costs")
Svensk Kärnbränslehantering AB
December 1985

4. SKB Annual Report 1991
Technical Report 91-64
Svensk Kärnbränslehantering AB
May 1992

5. Technology and costs for decommissioning a Swedish nuclear power plant, Technical Report 86-16
Svensk Kärnbränslehantering AB
May 1986

6. SKB R&D-Programme 89
Management and final disposal of waste from nuclear power production.
Programme for research, development and other activities
September 1989.

7. SKN R&D-Programme 89
Review by the National Board for Spent Nuclear Fuel
Dnr 93/89, March 1990

APPENDICES

1	Spent fuel and radioactive waste in Sweden assuming operation of all plants through 2010.
2	Transportation system.
3	Central interim storage facility for spent nuclear fuel, CLAB.
4	Deep repository for long-lived waste, SFL and encapsulation station for spent fuel, ES.
5	Final repository for radioactive operational waste, SFR.
6	Decommissioning of the nuclear power plants.

APPENDIX 1

SPENT FUEL AND RADIOACTIVE WASTE IN SWEDEN ASSUMING OPERATION OF ALL PLANTS THROUGH 2010

Waste category	Dimensions of waste units in m ϕ = diameter (Dimensions before encapsulation for final disposal)	No. of packages	No. of transport units casks/ containers	Volume in final repository m³	Final destination
Spent BWR fuel	0.14 x 0.14 x 4.383	33 394	451		
Spent PWR fuel	0.21 x 0.21 x 4.103	3 858	117	9 800	ES/SFL 2
Other spent fuel (MOX, Ågesta, Studsvik)	Various	641	21		
Core components in storage canisters	0.8 x 0.8 x 4.6	450	450	19 700 *	ES/SFL 5
Reactor internals in storage canisters	0.8 x 0.8 x 4.6	555	555		
Operating waste from CLAB to silo	1.2 x 1.2 x 1.2	1 150	96	2 000	SFR 1
		2 000	167	3 450	SFL 3
Operating waste from CLAB to rock vault	1.2 x 1.2 x 1.2	290	24	500	SFR 1
Waste from Studsvik to silo**)	ϕ0.6, L=0.9	3 750	50	1 200	SFR 1
	1.2 x 1.2 x 1.2	690	58	1 200	SFR 1
	ϕ0.6, L=0.9	1 200	70	400	SFL 3
	1.2 x 1.2 x 1.2	660	55	1 100	SFL 3
Waste from Studsvik to rock vault**)	ϕ0.6, L=0.9	8 750	150	2 800	SFR 1
	1.2 x 1.2 x 1.2	690	58	1 200	SFR 1
	ISO-cont.	200	200	7 600	SFR 1
Operating waste from encapsulation station to silo	1.2 x 1.2 x 1.2	300	25	500	SFL 3
Operating waste from nuclear power plants to silo	ϕ0.6, L=0.9	3 375	45	1 100	SFR 1
	1.2 x 1.2 x 1.2	8 650	721	15 000	SFR 1
Operating waste from nuclear power plants to rock vault	ϕ0.6, L=0.9	18 200	350	5 900	SFR 1
	1.2 x 1.2 x 1.2	5 770	481	10 000	SFR 1
	ISO-cont.	750	750	28 500	SFR 1
	3.3 x 1.3 x 2.15	1 100	365	10 200	SFR 1
Decommissioning waste from nuclear power plants to rock cavern	ISO-cont. etc.	4 800	4 800	100 000	SFR 3
Decommissioning waste from Studsvik to rock cavern	ISO-cont.	100	100	3 800	SFR 3
Decommissioning waste from CLAB and ES to rock cavern	2.4 x 2.4 x 2.4	530	530	7 320	SFL 4
Transport containers		22	22	330	SFL 4
Total approximately		102 000	10 700	234 000	

*) Incl. the grouted-in BWR fuel boxes that are transported with the fuel.

**) Incl. total about 3 500 m³ of waste within NPP sphere of responsibility.

APPENDIX 2

TRANSPORTATION SYSTEM

Handling of the radioactive waste involves a considerable transport undertaking for moving the waste from the sites of production to final repositories. The spent fuel and the core components also have to be transported to and from the interim storage facility. All existing nuclear facilities are located on the coast, permitting sea transports. The site of the final repository for the long-lived waste, SFL, has not yet been decided. In the event of an inland siting of this facility, which is the assumption made in this report, the transportation system will be augmented with a rail link between the SFL and a suitably situated harbour. Existing rail lines will hereby be used to as great an extent as possible.

The transportation system includes transport containers and casks, ship and terminal equipment.

Transport containers holding a number of waste units are used to protect the transport workers and the public against radiation and the load against damage during transport.

The transport cask for spent fuel consists of a cylinder made of thick steel and provided with a neutron-shielding layer and cooling fins on the surface. The ends are protected by shock-absorbers. See Figure A2.1. The cask is designed to resist extreme stresses in accordance with the IAEA's regulations for type B packages. The casks currently being used, TN17/MK2, hold 17 BWR assemblies or 7 PWR assemblies and have a total weight of about 80 tonnes, of which the uranium weight constitutes about 3 tonnes. Larger casks will be used for transports from CLAB to the final repository. It is assumed that the new transport casks for fuel will have a transport weight of about 110 tonnes, of which the uranium weight constitutes about 15 tonnes. For transport of core components and reactor internals it is assumed that casks with the same design and capacity as the ones used today. During transport, the cask is carried on a transport frame, functionally adapted to the terminal vehicle and the ship's cargo hold.

Intermediate-level waste is transported in radiation-shielding containers, called ATB containers. A common type holds about 20 m^3, equivalent to 12 waste concrete moulds with a surface dose rate of up to 60 mSv/h. There are also larger containers with thinner walls for waste packages with a lower surface dose rate. The transport frame of the container has a design similar to that of the frame for the spent fuel cask, permitting uniform handling, see Figure A2.2.

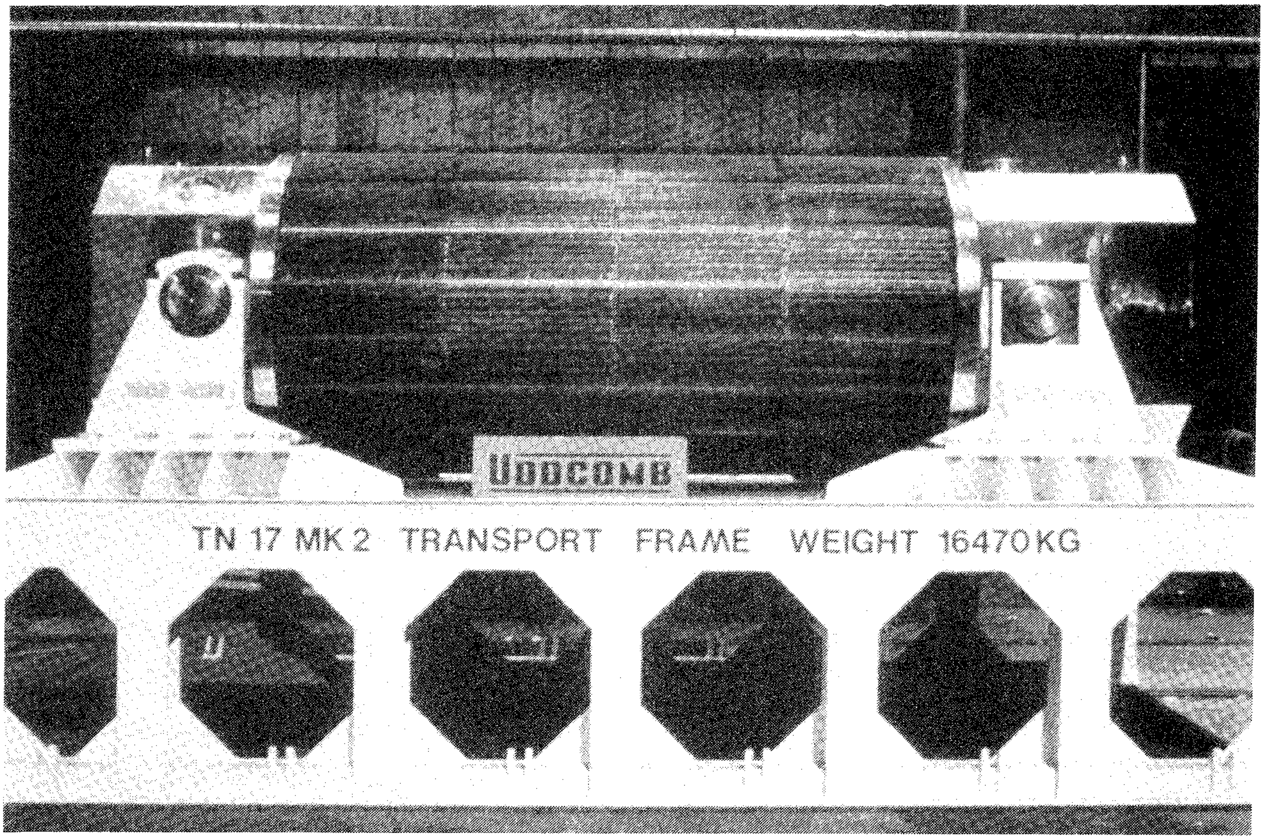


Figure A2.1 Model of TN17/Mk 2 transport cask for spent nuclear fuel.

The total weight is max 120 tonnes, of which the waste accounts for about 50 tonnes. Low-level waste from reactor operation and decommissioning is transported in standard ISO containers, which are deposited in the final repository.

Figure A2.2 also illustrates the terminal vehicles. The vehicle consists of a 7-axle unit with separate drive on each wheel pair. The bed can be raised and lowered hydraulically, which is utilized to pick up and off-load the cargo. The vehicle's ground speed is low, less than 5 km/h, and it is therefore only used for short hauls.

The sea transports are carried out primarily by a specially-built ship, M/S Sigyn, see Figure A2.3. The ship is a combined roll-on/ roll-off and lift-on/lift-off vessel, which means that the cargo can either be driven in over the ramp or lifted down through the cargo hatches into the cargo hold. The ship has a deadweight tonnage of 2 000 tonnes and an overall length of about 90 m. Payload capacity is 1 400 tonnes. The transport casks are placed in fixed positions in the hold and the transport frames are lashed to the vessel. Corner and side fittings welded to the deck prevent shifting of the cargo.

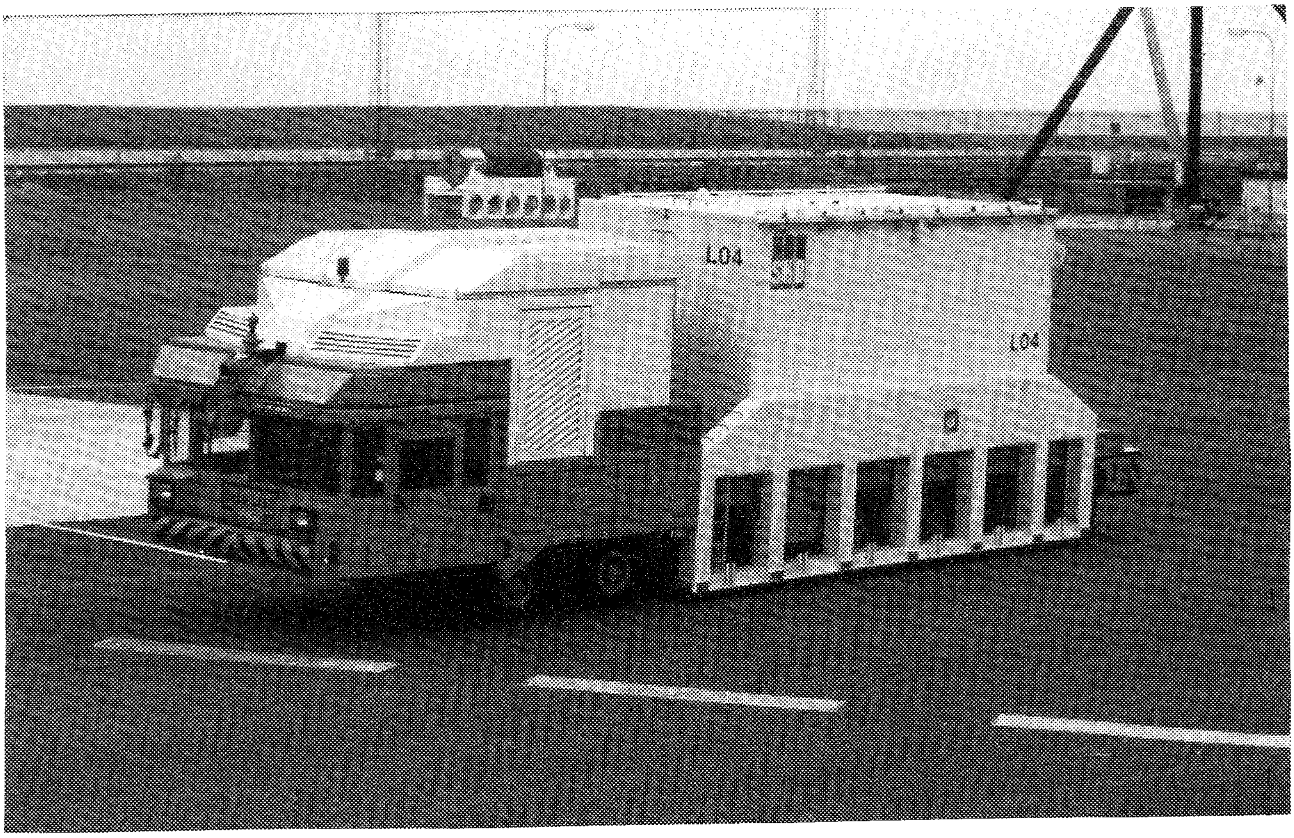


Figure A2.2 Terminal vehicle at SFR with radiation-shielded transport container for intermediate-level waste.

The ship is equipped with extensive safety systems for radiation and fire protection and, in the event of an accident, systems to facilitate search and salvage.

The transportation system, which has been in service since 1983, has transported 57 tonnes of fuel to France and 1 500 tonnes to CLAB up to April 1992. Approximately 8 000 m^3 low and intermediate level waste from reactor operation has been transported to SFR.

The transport system will be in operation until the last of the decommissioning waste from CLAB has been transported to the SFL. This is assumed to occur about year 2040. Owing to the length of the operating period, about 60 years, it is assumed that the ship will have to be replaced twice.

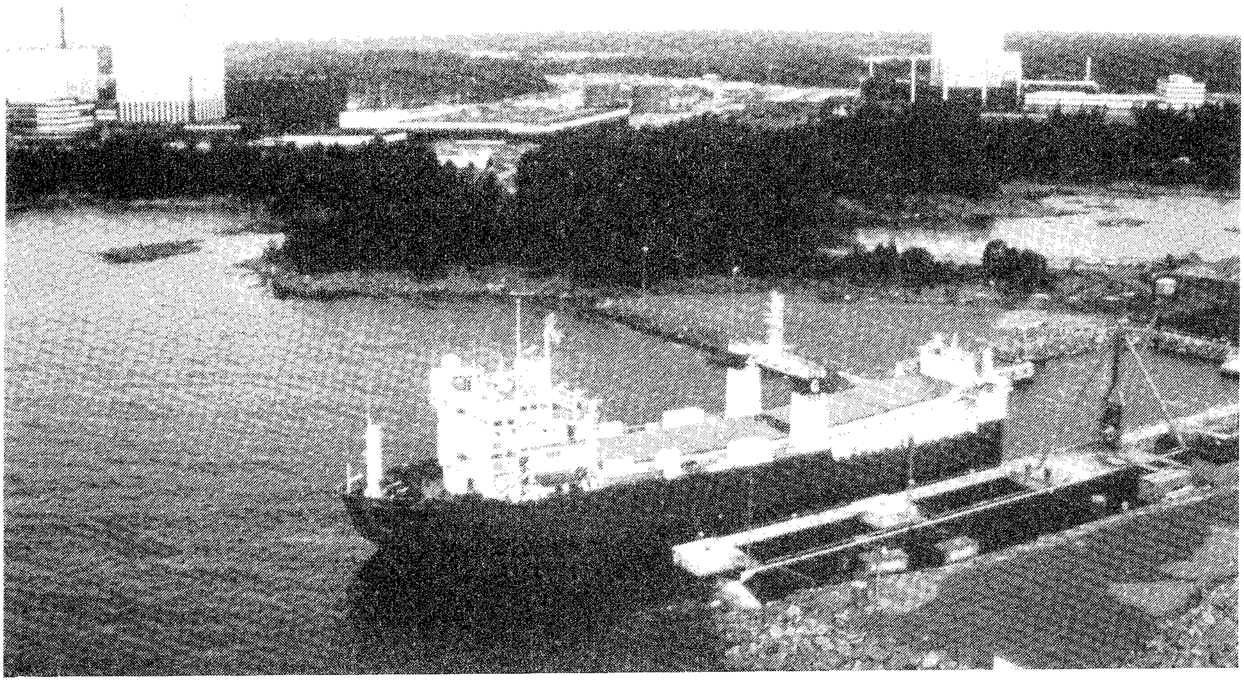


Figure A2.3 M/S Sigyn at the Oskarshamn harbour.

APPENDIX 3

CENTRAL INTERIM STORAGE FACILITY FOR SPENT NUCLEAR FUEL, CLAB

DESIGN

CLAB, situated at the Oskarshamn nuclear power station is an interim storage facility for spent nuclear fuel. The purpose of the facility is to provide efficient means of storing all spent fuel discharged from the Swedish nuclear power plants pending encapsulation and final disposal. The storage capacity at the CLAB facility will therefore be sufficient, when fully expanded, to accommodate a fuel quantity equivalent to about 8 000 tonnes of uranium.

In addition to the spent fuel, certain replacement items (core components) and decommissioning products that have been activated during reactor operation will be stored in CLAB pending future final disposal.

CLAB consists of an above-ground complex and an underground complex housing the storage pools, see Figure A3.1.

The facility is being built in two phases. Phase 1 was taken into operation in 1985 and encompasses the above-ground complex plus a rock cavern with storage pools originally designed for approximately 3 000 tonnes of uranium. By the introduction of a new type of storage canister starting from 1992, the capacity will gradually increase to approximately 5 000 tonnes. In phase 2, the storage section will be expanded to full capacity. This will take place in the late 1990s. In this report, it is assumed that phase 2 will be implemented by construction of a rock cavern parallel to the existing one.

The above-ground complex consists of several interconnected buildings, see Figure A3.2. In terms of function, the buildings can be divided into a reception building, an auxiliary systems building and an electrical building. The reception building mainly houses the equipment required to unload and load the transport casks in connection with reception and dispatch of fuel and core components.

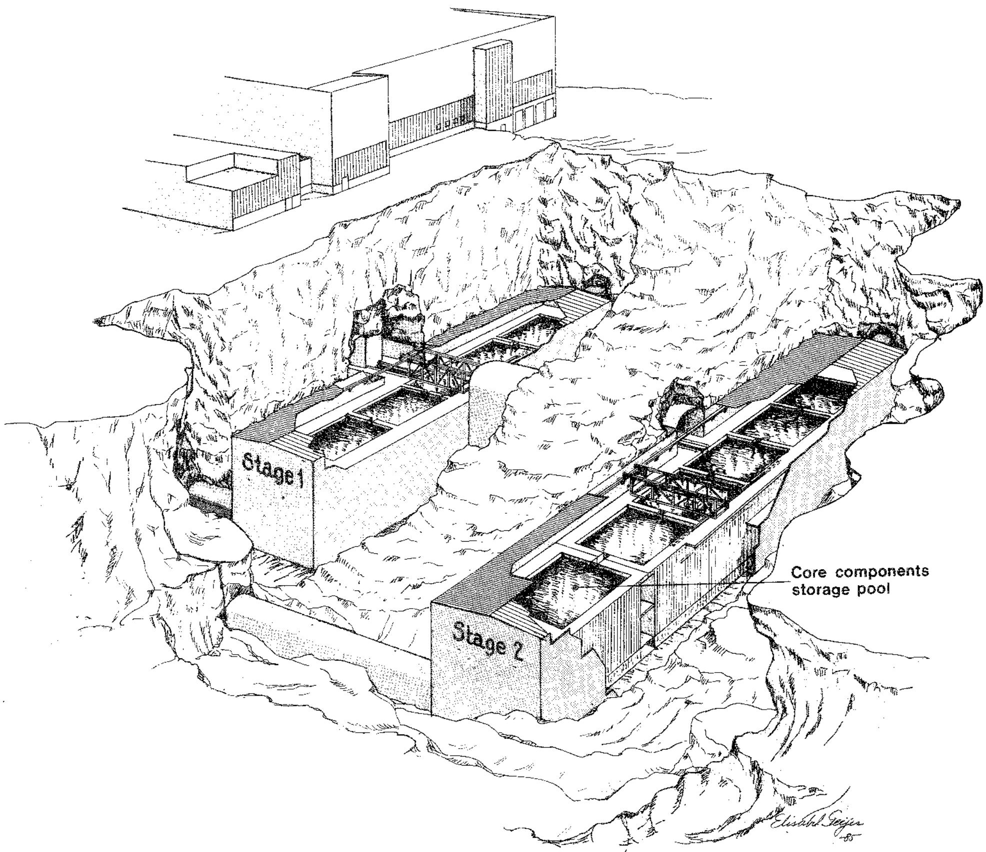
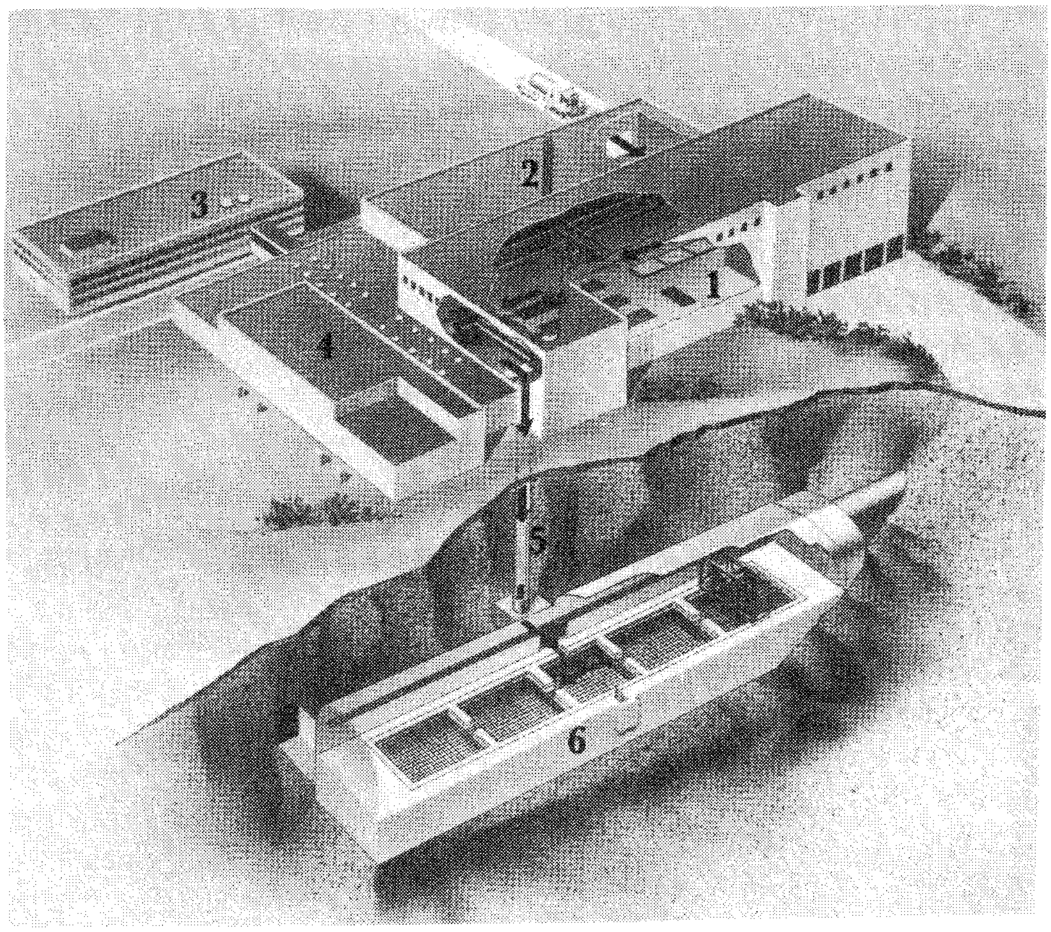


Figure A3.1 CLAB storage section, phases 1 and 2.

All handling of fuel in the reception building, as in the rest of the facility, is made in water-filled pools, which provide good cooling and effective radiation protection for the personnel. The pool block in the reception building contains seven pools, four of which are used for the two unloading lines and the others for temporary storage and for certain other requirements, for example in connection with the receipt of non-standard transport casks and in connection with service.

Connected directly to the reception building is a building that houses auxiliary systems for cooling and water purification, waste handling, ventilation etc. The electrical building houses the operations centre as well as all equipment for power supply, control and monitoring of the facility. Separate passages lead to these buildings from a free-standing office and personnel building.

The storage section consists of rock caverns whose roofs are located about 30 m below the surface. They are reinforced with rock bolts and lined partly with concrete. The rock cavern in the first phase is 120 m long, 21 m wide and 27 m high. It contains four storage pools, each with 300 storage positions for the transportable storage modules (canisters) plus a smaller central pool connected to an elevator shaft



1. Reception building
2. Building for auxiliary systems
3. Office building
4. Electrical building
5. Fuel building
6. Storage building

Figure A3.2 CLAB phase 1.

via a transport channel. The pools are made of reinforced concrete and lined with stainless steel. Each pool holds 3 000 m^3 of water and can accommodate about 1 200 tonnes of uranium.

The second building phase will comprise a rock chamber parallel to the existing one. The basic design will be the same. One pool will be reserved for core components.

OPERATION

When a fuel transport arrives at CLAB, the transport vehicle with the cask is driven into the air lock underneath the reception hall floor. The cask is inspected, and after removal of the shock absorbers it is coupled to one of the main overhead cranes by means of a lifting frame. The cask is raised upright and lifted through the hatch in the roof of the air lock for transfer to one of the cooling cells.

The cask is provided with a protective skirt in order to protect the cooling fins against mechanical damage and contamination during the subsequent reception work. The annular space between the cask and the skirt is filled with water, which is circulated via hoses connected to a separate skirt cooling circuit in the cooling system, see Figure A3.3.

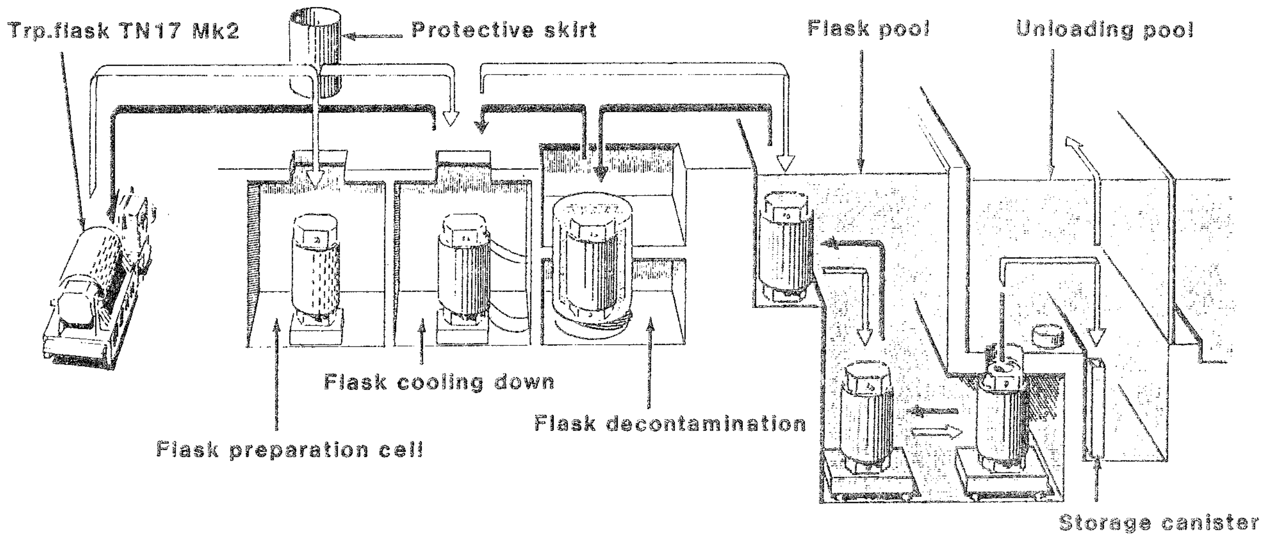


Figure A3.3 Handling of fuel casks and unloading at CLAB

The top and bottom orifices in the cask are fitted with special tools by means of which the sealing plugs can be unscrewed. The tools are fitted with hoses which are also connected to the cooling system. Through the circuit that is established, the cask can be filled with water and cooled to a low temperature. The circulating water also flushes out the cask, thereby reducing the quantity of loose active particles in the cask. The particles are collected on a filter in the cooling system, which is back-flushed as needed to a replaceable filter cartridge.

The outer cover on the cask and the circular flange that locks the cask cover are removed. Adapters for connecting the cask to the unloading pool are fitted to the top of the cask and to the cask cover.

The cask is now ready for transport to the cask pool, where it is lowered and placed on a transport wagon that runs on rails in the bottom of the pool. The wagon takes the cask into a channel that leads in under the unloading pool. In the roof of the channel is a connection device that is lowered down onto the cask. The purpose of the connection device is to keep the uncontaminated water in the cask pool separated from the water in the unloading pool.

The cask is opened by a pole crane, which lifts up the cask cover and the sealing plug in the connection device as a single unit. The pole crane travels on an overhead track that rests on columns along the pool.

The pole crane is provided with a grab for the fuel assemblies, which are then lifted up out of the cask, one by one, and transferred to the fuel canister.

From here on, the canister constitutes a transport unit for the continued handling.

Several types of canisters are used in the facility to cover the various storage needs. A canister for BWR fuel holds 16 fuel assemblies, while a PWR canister holds five, see Figure A3.4.

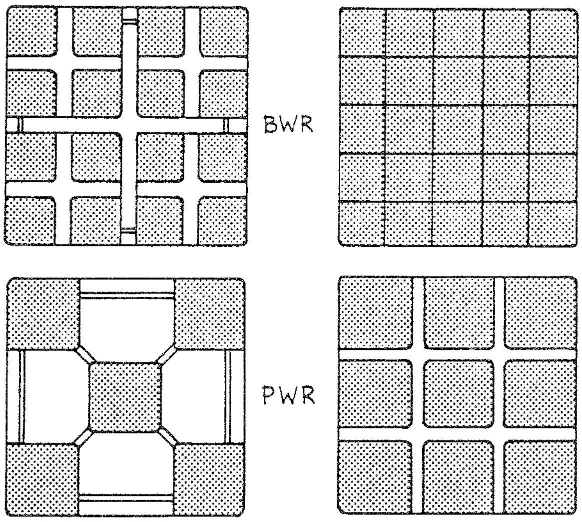


Figure A3.4 Design of the old and new canisters at CLAB.

From 1992 new canisters are introduced that are able to take 25 BWR fuel assemblies or 9 PWR fuel assemblies.

Another pole crane whose working range covers all pools in the reception section is used to transport canisters from the unloading pool to the fuel elevator. The canisters are taken in the elevator down to the storage section.

In the storage section, the canister is transferred from the elevator to its storage position by an overhead handling crane. The empty casks are transported back to the same cooling cell where they were previously cooled. The water in the cask is drained, and after the removed cask components are reinserted, a final inspection is carried out of the integrity of the casks before they are removed from the facility.

Filling of transport casks for removal of fuel from CLAB follows the same procedure as unloading.

The permanent personnel force during operation is about 50 persons. In addition, service personnel are currently being utilized mainly from OKG's regular operating organization. On average, they are equivalent to about 60 full-time employees. During periods when no loading-in or loading-out is taking place, the work force can be reduced.

After all fuel and other waste has been removed from CLAB to final disposal, the above-ground complex will be dismantled, along with those parts of the storage pools that have become active. Radioactive waste is sent to the SFL.

APPENDIX 4

DEEP REPOSITORY FOR LONG-LIVED WASTE, SFL AND ENCAPSULATION STATION FOR SPENT FUEL, ES

GENERAL

The spent nuclear fuel and other long-lived radioactive waste will be finally disposed of in geologic repositories located in the bedrock approximately 500 m below the ground surface. Four types of repositories are planned, intended for different types of waste.

- SFL 2, intended for encapsulated spent fuel. The repository consists of tunnels where the waste is deposited in holes drilled in the tunnel floor.

- SFL 3, intended for transuranic waste and intermediate-level operating waste. The repository consists of concrete troughs placed in a rock vault.

- SFL 4, intended for decommissioning waste, mainly from CLAB and ES. The repository consists of the tunnels and other rock chambers that are left over after filling of SFL 3 and 5 are concluded.

- SFL 5, intended for core components and reactor internals embedded in concrete moulds. The repository consists of tunnels in which the moulds are stacked and grouted with concrete.

Prior to deposition in the repository, the spent fuel will be encapsulated in copper canisters. This takes place in the encapsulation station, ES. In this report, it is assumed that ES will be co-located with SFL. Co-located means that the fuel can be taken directly after encapsulation via an elevator shaft down to SFL 2. The arrangement is illustrated in Figure A4.1.

It is also assumed that SFL 3-5 cannot be located immediately adjacent to SFL 2, but will be situated approximately 1 km away. These repositories are reached via the same shafts as for SFL 2 and a separate transport tunnel connect the two repository areas.

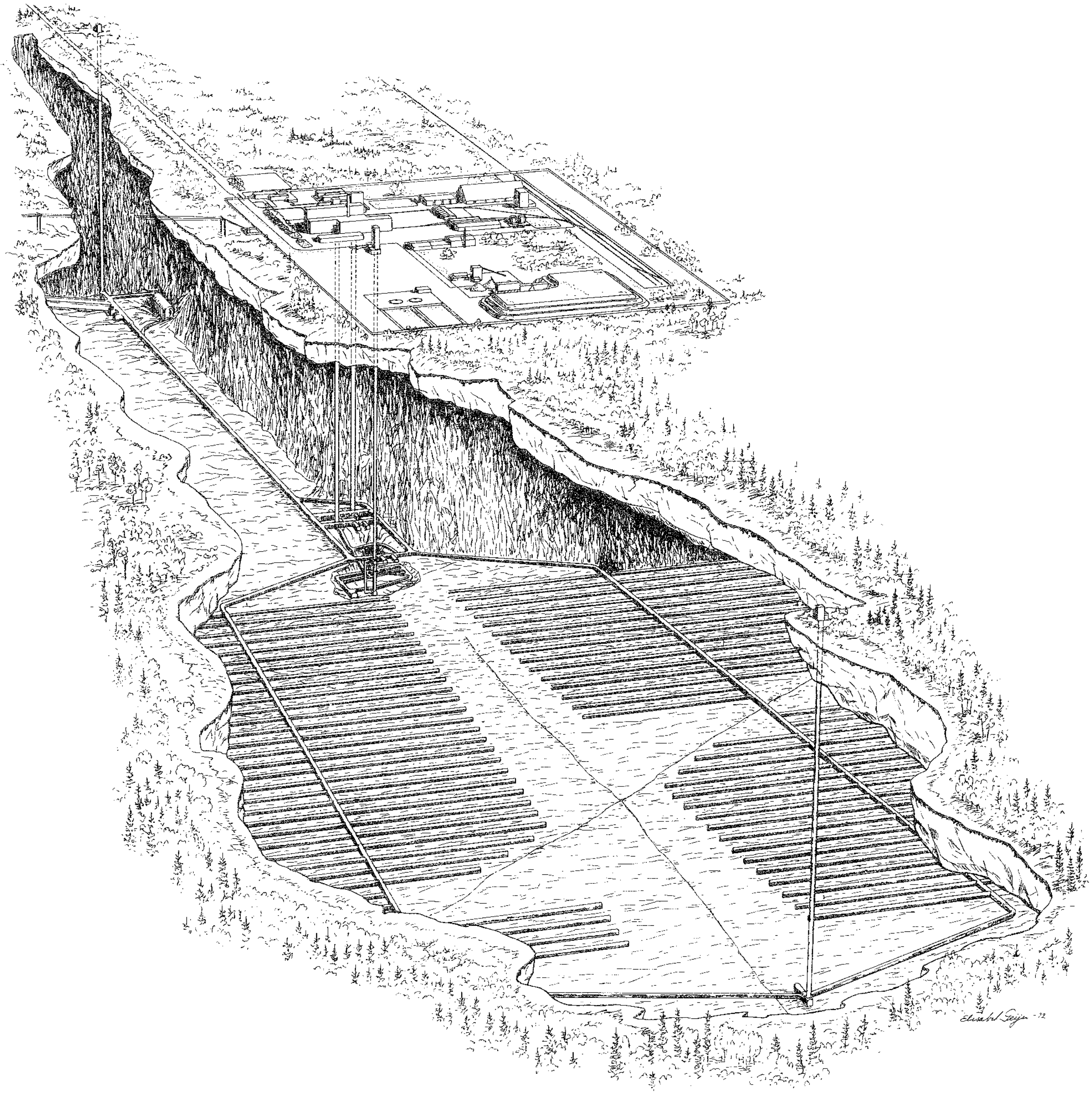


Figure A4.1 Repository - overview.

A total of about 350-400 men will be employed at the SFL and the ES during the operating period. Approximately 800 men will be required during the construction period.

COMMON FACILITIES

Through collocating of ES and the different SFL repositories, a number of supply and service systems can be made common. This applies above all to the transportation system and the station site.

The waste coming from CLAB and Studsvik is transported by ship to the nearest available harbour that can be considered suitable for this type of transport after certain improvements of the navigation channel and the quay area. In the cost calculation, the harbour has been supplemented with a separate ro/ro quay, a widened and deepened approach channel, harbour apron, guard house etc. The waste is then transported in its containers by rail to SFL. It is hereby assumed that 50 km of railway will have to be built. In addition, rolling stock will have to be acquired, ie locomotives and specially-built cars.

The layout of the station site is illustrated by Drawing 4.1. Aside from ES, which is the dominant building, there will be personnel facilities including housing, goods reception station, workshops, vehicle service, concrete station with crusher, storage and handling of bentonite etc. Water supply and sewerage will also be required.

Facilities for handling of the sealing materials include the following functions. Bentonite granulate will be stored indoors (in a silo), along with the bentonite/sand mixture that will be used to seal tunnels and rock caverns. Storage capacity is equivalent to approximately one year's operation (during the deposition phase). It is assumed that the material will be transported to the site by rail. Some of the bentonite is compacted in a high-pressure press and moulded into blocks for filling out the deposition hole around the copper canister or for other purposes, e.g. plugging of tunnels and shafts. The remaining bentonite is used in the sand/bentonite mixture (85/15) which is utilized as backfill. Mixing is carried out above ground and the material is then packed in containers that are taken down to repository level by elevator via the central shaft.

The operating staff for the common facilities is estimated to amount to about 150 men, including all administrative personnel for the SFL-ES.

After completed deposition, all facilities will be dismantled and the site will be restored as close to the original state as possible. Radioactive decommissioning waste, primarily from ES, will be placed in SFL 4. All activities are estimated to be concluded by the year 2045.

ENCAPSULATION STATION FOR SPENT FUEL, ES

Layout

The spent fuel will be received and encapsulated in copper canisters in the encapsulation station, ES, Figure A4.2. The design of a copper canister is illustrated in Figure A4.3. ES is designed for an encapsulation rate of one canister/day, equivalent to 210/year. The total number of copper canisters will be about 4 400.

ES will also be a receiving station for core components and reactor internals, which are embedded in concrete moulds in a special part of the facility. The design of the mould is illustrated in Figure A4.4.

A large portion of the core components consists of fuel boxes that are transported together with the fuel. Also some operational waste from CLAB and Studsvik will be received in the ES before disposal.

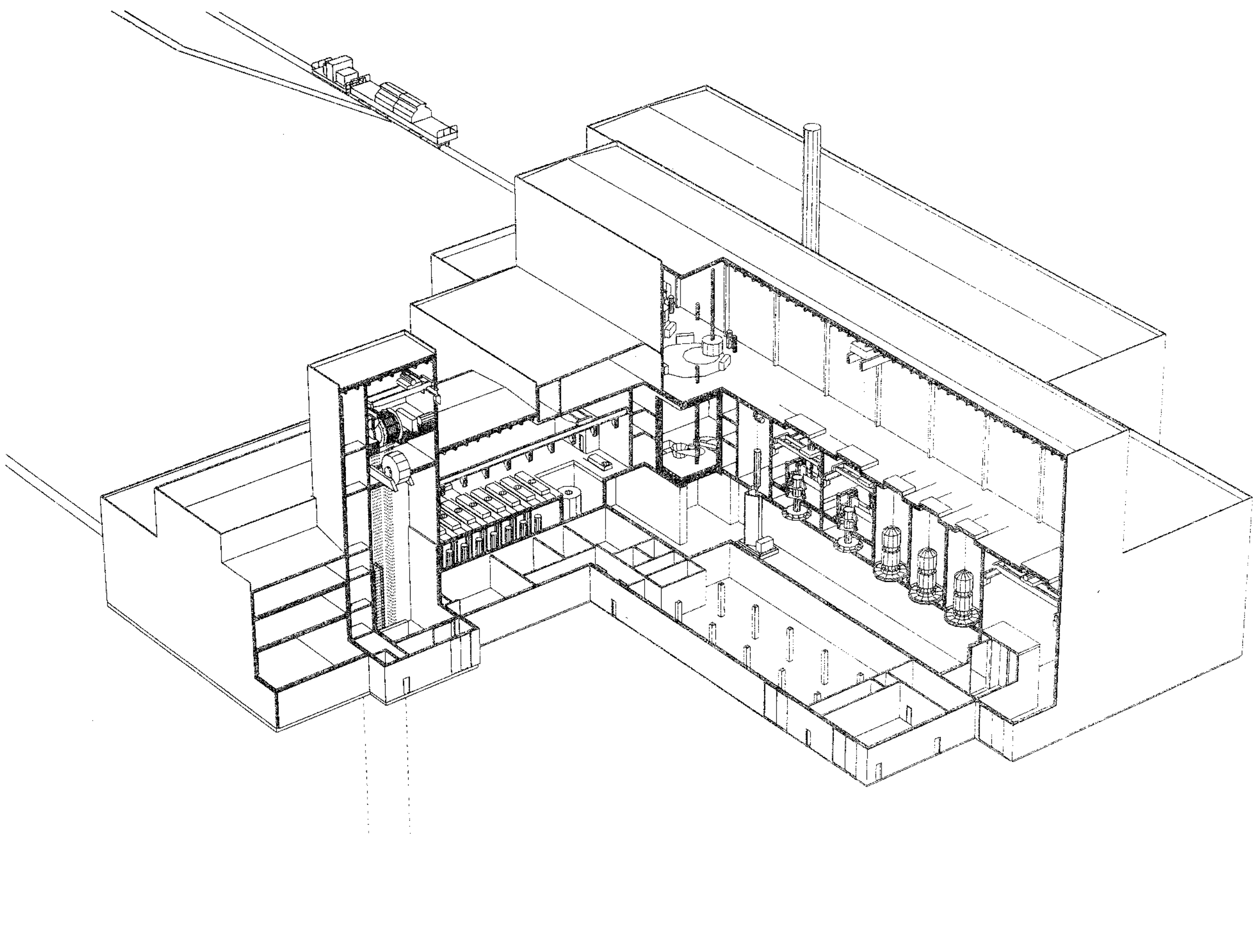


Figure A4.2 Encapsulation station.

The layout of the Encapsulation Station is based on available information regarding main functions, rules and regulations, system and process equipment, personnel requirements, etc. Drawings 4-2 to 4-6 shows the preliminary layout of the Encapsulation Station for the copper canister. In the following sections the main work sequence is explained as well as the layout of the individual functional area.

The total building volume is 180 000 m^3. The maximum length of the building is about 115 m and the height is about 35 m. In order to meet demands on radiation shielding and ventilation tightness, the building is made primarily of concrete.

The facility can be divided functionally into the following main parts:

- Arrival and storage section for fuel and core component casks.

- Encapsulation section where the unloading of casks, fuel handling and encapsulation takes place including canister lid welding.

- Encapsulation section for core components (concrete casting).

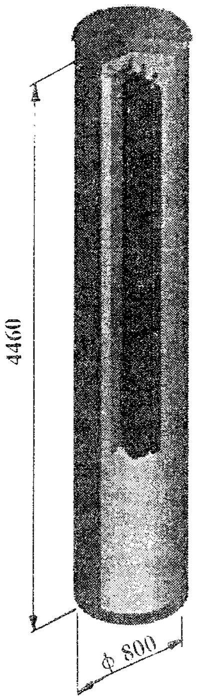
- Dispatch section for canisters and other waste types and the elevator down to the final repository.

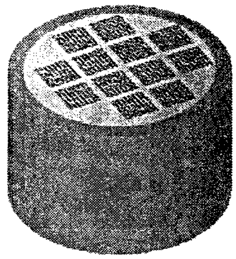
- Service section, located alongside the encapsulation section and containing stores, etc.

- Auxiliary systems section, primarily for cooling and purification systems as well as for internal handling of active operating waste.

- Electrical and control section.

A side building houses personnel and office quarters as well as a superstructure and service systems for the central personnel and material elevator shaft down to the final repository. See Drawing 4-7.





Estimated weight (kg)

Canister	5 900
Fuel assembly	3 240
Cast lead	13 230
Total weight	**22 370**

Figure A4.3 Copper canister

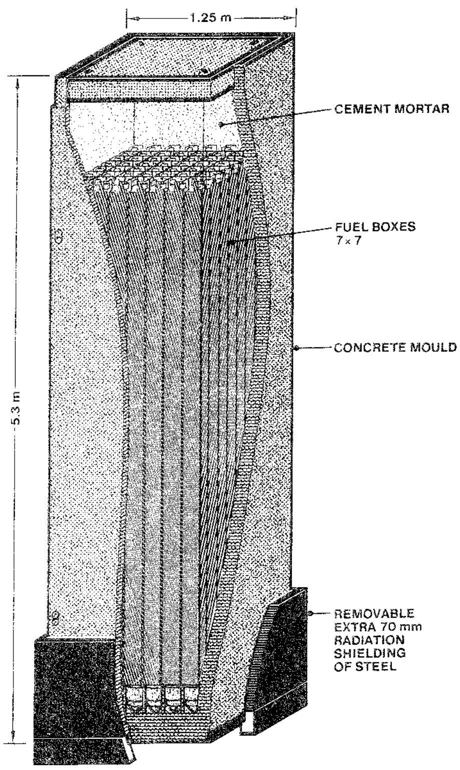


Figure A4.4 Concrete mould with fuel boxes.

The principle layout or keyplan for the Encapsulation Station can be seen in Figure A4.5. Encapsulation of fuel takes place in functional areas 1-6. Intermediate storage of filled canisters is done in area 9 and the loading into the elevator for transfer down to the repository is done in area 10.

Encapsulation of core components and reactor internals is done in areas 7 and 8. Buffer storing of filled moulds is done in area 9 and the loading into a transport container for transfer down to the repository is done in area 10. Operational waste from CLAB and Studsvik is received in area 11 and the waste is loaded into suitable shielded transport containers for transfer down to the repository area.

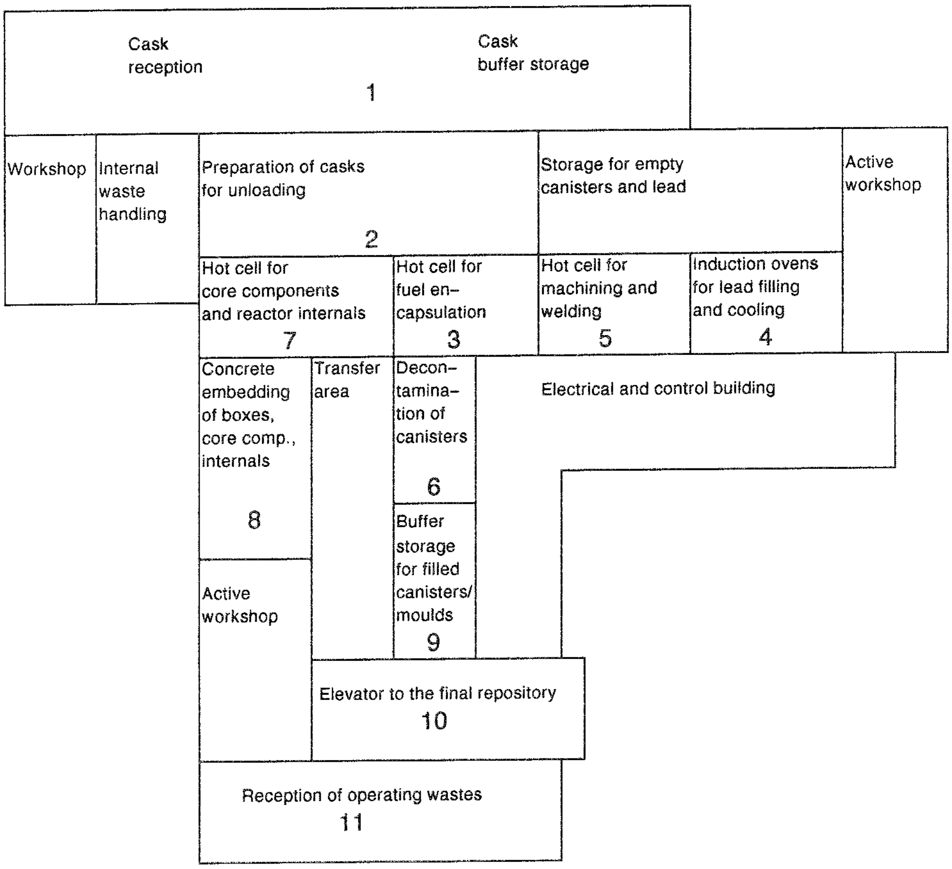


Figure A4.5 Keyplan for the Encapsulation Station

Operation

The fuel is assumed to be transported to the Encapsulation Station in big transport casks with a capacity of 33 PWR or 74 BWR fuel assemblies in each cask. The long-lived ILW in form of core components and reactor internals are transported in smaller core components casks of the type used today. The transport of the casks is assumed to be done by rail, but the layout of the Encapsulation Station will also accept road transports.

Cask Receiving and Storage Area

The purpose of these areas is to check the casks on arrival to the Encapsulation Station, (e.g. the transport documentation, possible transport damages or external contamination on the casks) and to unload the spent fuel casks from the railcar or transport vehicle.

- In the arrival section the cask is prepared for unloading from the railway car or the transport vehicle. The weather and dust protection covers over the cask are removed. These covers and the railway car may sometimes be washed in a separate building outside ES. The shock absorbers are removed from the cask and the cask is checked for any external contamination.

- The transport of the casks from the Storage Area into the Cask Preparation Area is done on load platforms moved by four air bearing elements (air cushion pads). The air cushion transport vehicle (ACTV) is used for all internal transport of casks and canisters with their radiation shield. The general arrangement for the ACTV can be seen on Figure A4.6.

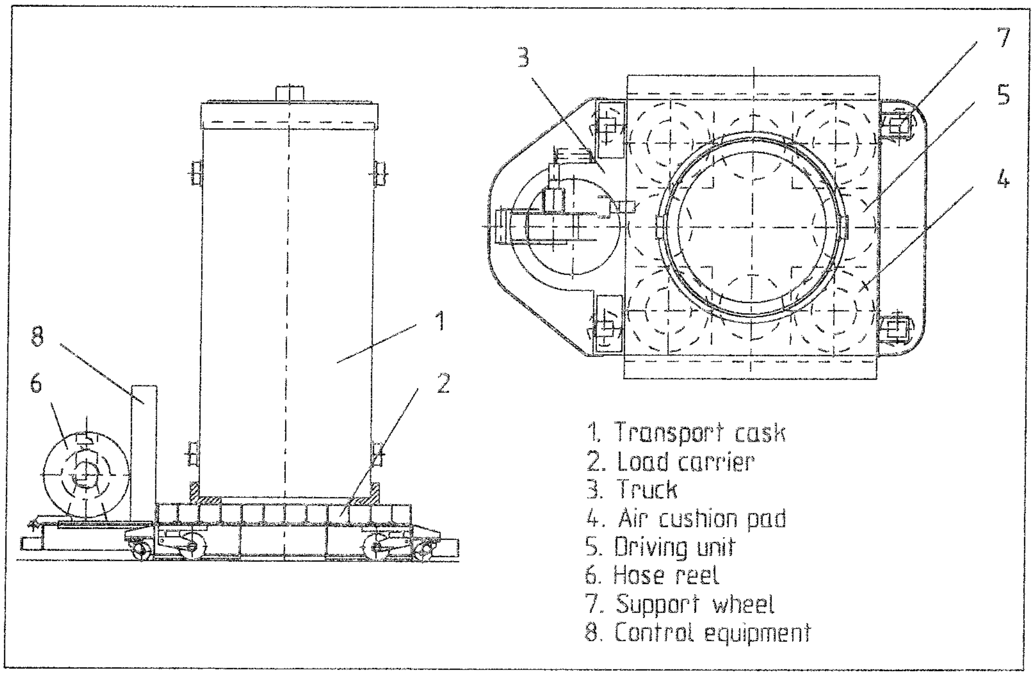


Figure A4.6 Air Cushion Transport Vehicle (ACTV) for casks.

- The final check of the transport documentation including safeguards documentation will be carried out at this point of time.

- With an overhead crane the cask is lifted in vertical position. If the cask will be stored for some time before unloading the overhead crane will be used for transferring the cask into the storage area. The storage area can hold up to 15 empty or filled casks.

Cask Preparation Area

The purpose of this area is to prepare the casks for unloading of the fuel. The area is equipped with an overhead crane for handling of the cask outer lid, adapters, tools etc. The Cask Preparation Area is separated from the Receiving Area. With regard to the risk for spreading of surface and air-borne contamination the personnel will enter this area via a shoe change room which also serves as an air lock.

The layout arrangement of the cask preparation area is shown on Figure A4.7.

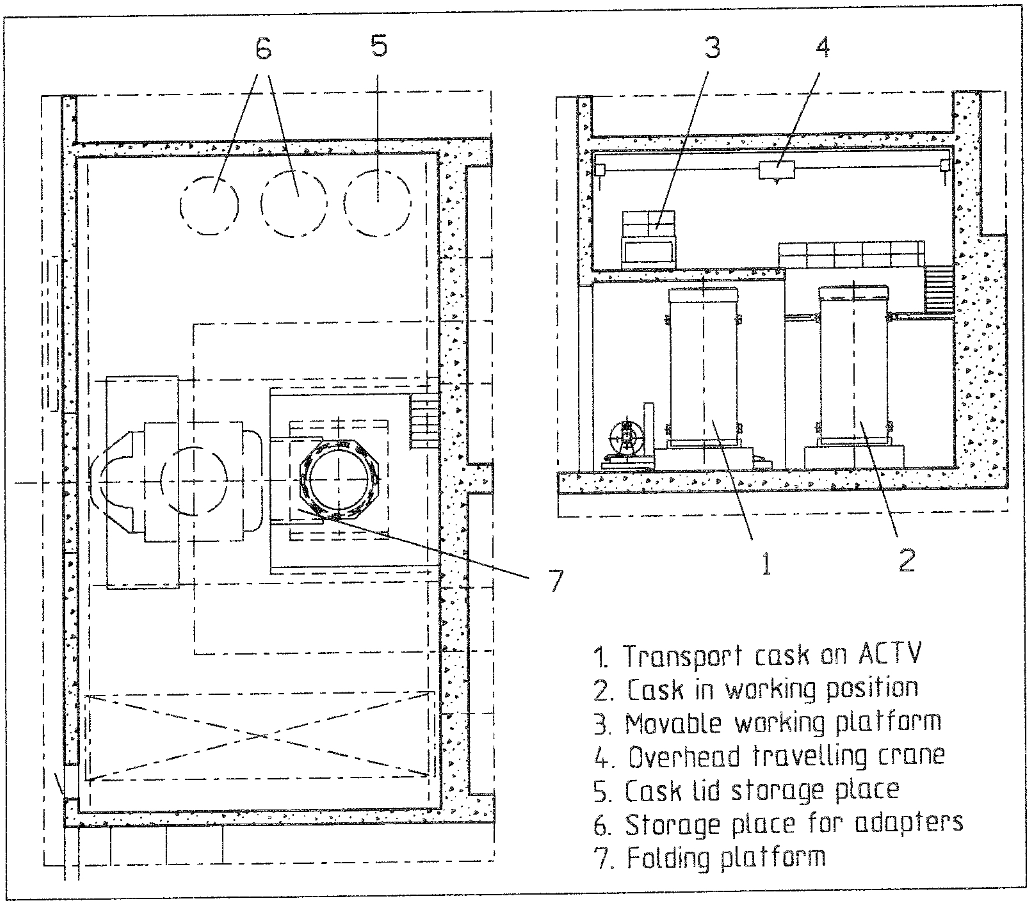


Figure A4.7 Cask Preparation Area

The main work sequence in this area is as follows:

- The cask is placed in the working station by the ACTV. The bolts for the outer lid of the cask are removed. The lid is removed with the overhead crane and placed on a support frame. The cask is connected to a gas sampling and monitoring system. The moisture contents and activity of the gas is measured and registered.

- The inert gas inside the cask is replaced by air. Later on, the bolts for the inner lid are removed and the cask adapter is mounted as well as the adapter for the inner lid. The purpose of the cask adapter is to get a good seal between the cask and the hot cell. The function of the second adapter is to make it possible to lift the inner lid from inside the hot cell, and also protect the lid from contamination during unloading of the cask.

- When the adapters have been mounted the cask can be transferred and connected to the hot cell. After the fuel has been removed the cask is returned to the work station and the adapters are removed, bolts for the inner lid are fastened and the outer lid with its bolts are also fastened. If the cask contains BWR fuel boxes the cask is transferred to the other cell for the unloading of the boxes before removal of the adapters.

The arrangement with the different adapters and cask docking to the hot cell is shown on Figure A4.8.

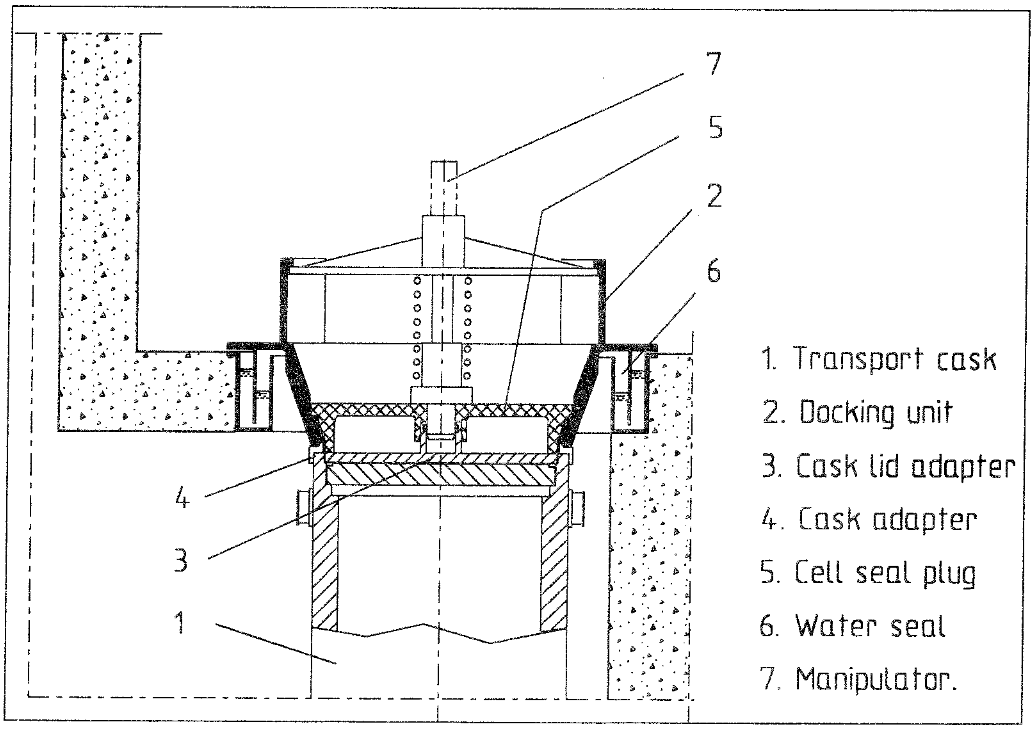


Figure A4.8 Cask and Lid Adapter including connection to the Fuel Hot Cell

Fuel Hot Cell Area

The fuel hot cell area is were the fuel is removed from the cask and placed in racks inside the hot cell or directly into the canister. The layout arrangement of the hot cell area is shown on Figure A4.9.

The main work sequence in the fuel hot cell area is as follows:

- First, the fuel cask is connected to the hot cell. As the air inside the hot cell will contain air-borne contamination and possibly fission gas, e.g. ^{85}Kr, the hot cell will be at a slight underpressure. The connections between cask and cell must be reasonably tight. The connection is such that an outer sealing is pressed down on the cask adapter. Then the inner lid with its adapter can be removed. The inner lid is placed on a swinging arm and removed from the working area of the telescopic pole crane. The upper surface of the inner lid is protected by the adapter when inside the hot cell.

- Before starting removal of the fuel from the cask a protective funnel will be put on top of the cask, using a second swinging arm. The purpose of this funnel is to prevent crud or other particles from falling on the flange surface, gaskets or in the slit between the insert and the cask structural body.

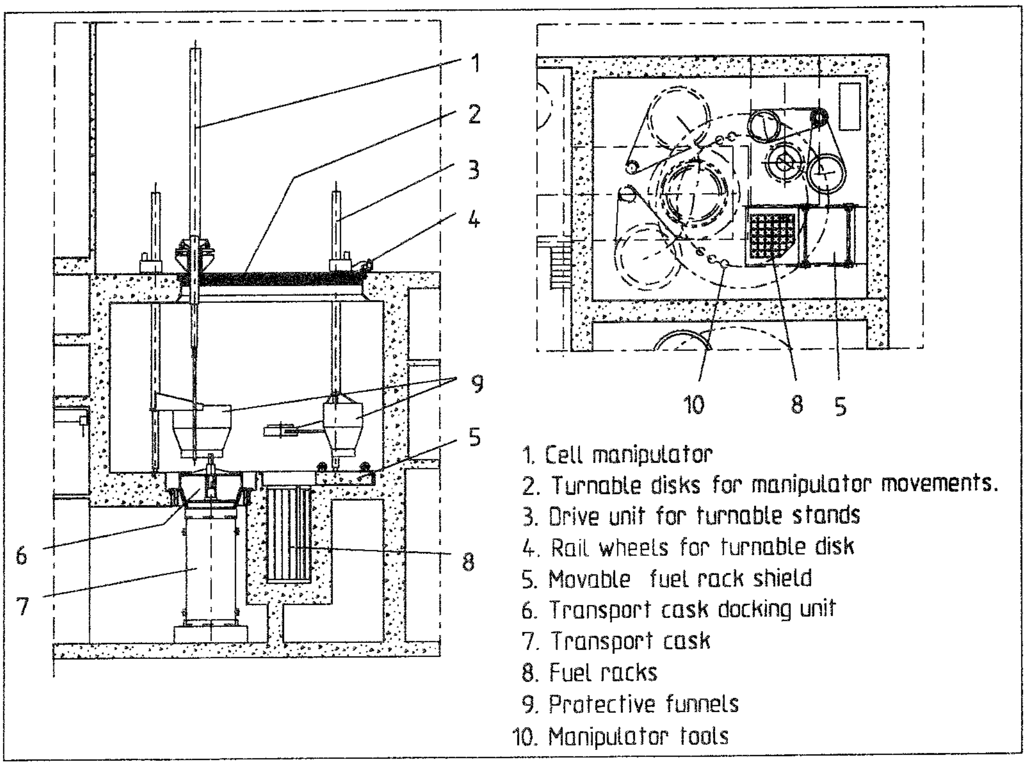


Figure A4.9 Hot cell for fuel encapsulation

- The fuel is then removed from the cask and put into the fuel storage racks inside the hot cell. The fuel boxes/channels for the BWR:s are removed from the fuel assembly when they are unloaded from the cask. The capacity of the storage racks, for PWR and BWR fuel assemblies are equal to one cask load of PWR or BWR fuel.

- The canisters are connected to the hot cell in the same way as the fuel cask. The canister will be provided with a special protective cover that is needed in the induction oven and at lead filling. This cover will be protected from contamination in the fuel hot cell by use of a lid adapter.

- The BWR/PWR fuel assemblies are placed in the canister with the telescopic pole crane.

- After that the canister has been loaded with correct amount of fuel and the safeguards control has been done, it can be disconnected from the fuel hot cell and transferred to one of the three induction ovens for lead filling.

- The motors, control equipment and instrumentation of the hot cell telescopic pole crane are installed outside the hot cell in order to make the maintenance and repair of the equipment as easy as possible.

- Entrance into the hot cell should normally not be required. However, the layout of the hot cell includes an opening from the Service Hall which can be used by personnel entering the hot cell, if necessary, in an air pressurised suite. Provisional rooms for washing and changing of clothing can also be arranged in the Service Hall adjacent to the entrance opening.

Induction ovens

The layout arrangement for one of the induction ovens is illustrated in Figure A4.10. The oven has a capacity to heat the canister with fuel to 380 °C within 6 hours. The canister can then be filled with molten lead to a predetermined volume and level in the canister. The canister with lead is then cooled in a controlled way in order to avoid cavities in the lead matrix during solidification. When the lead is solidified the canister is cooled down from 327 °C to about 60 °C in about 12 hours. The theoretical time needed for heating, lead filling and cooling of the canister in the oven is about 24 hours. The capacity of the plant is however based upon about 48 hours turn round time.

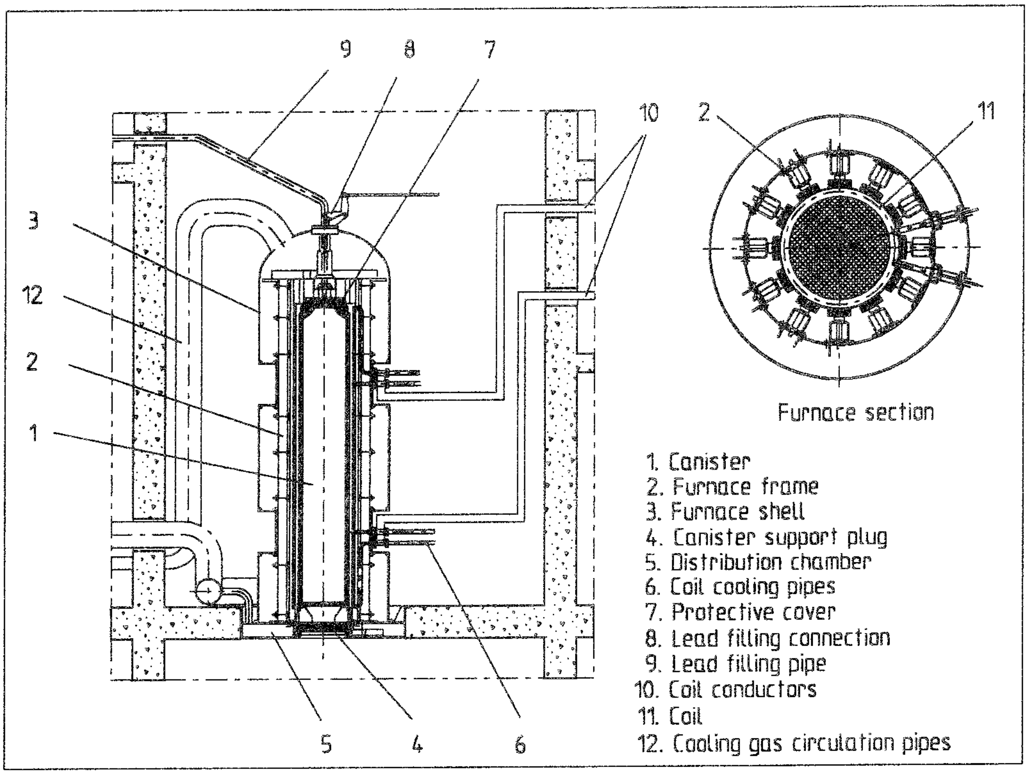


Figure A4.10 Induction oven for canister heating, lead filling and cooling

Machining and Welding Station

The purpose of this area is to machine the upper lead surface to a correct level before the canister lid is welded to the canister body. For welding, the Electron Beam Welding Method (EB) will be applied. In case of defect welding, the work station will be equipped with facilities to make it possible to remove the entire lid if required and prepare for a new weld joint. However, if a weld defect should occur, normally that area can be rewelded with the EB without any machining work. There will also be equipment for ultrasonic inspection of the weld joint.

The layout of the machining and welding station is shown in Figure A4.11.

The main work sequence is as follows:

- First, the canister with its transport shield is transferred from the induction oven to the work station by the ACTV. The arrangement of the ACTV with the radiation transport shield is shown on figure A4.12.

- With the canister in correct location under the work station the canister is placed in position with the lifting equipment installed in the canister transport shield. When the canister has reached the correct level the chucks in the work station will be activated and hold the canister.

- The canister protective cover is removed and machining of the lead surface can be done. After checking that correct dimensions are achieved and that the canister joint surface is clean, the copper canister lid is placed on top of the canister for welding.

- The lead material that is removed might be contaminated with crud from the fuel and must be treated as active waste, i.e. solidified together with the core components in the concrete moulds.

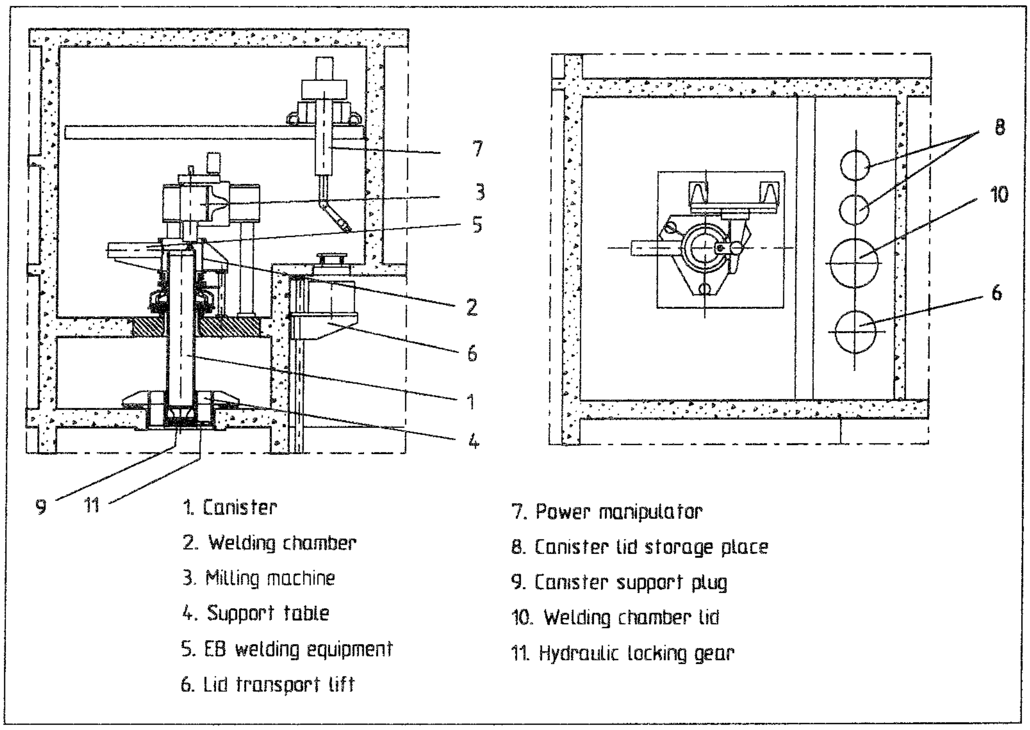


Figure A4.11 Machining, welding and inspection cell

- The cover of the welding chamber is placed on the chamber by the pole crane in the work station. With the chamber sealed the vacuum pumps can be started.

- The EB welding is carried out with the fixed positioned EB gun. The canister will be rotating during the operation.

- The cover of the welding chamber is removed at atmospheric pressure in the chamber.

- The ultrasonic inspection of the canister is done by placing the ultrasonic head on top of the canister and rotate the canister in the same way as during the welding.

- After completion of the inspection and approval of the weld the canister is taken to the canister storage area.

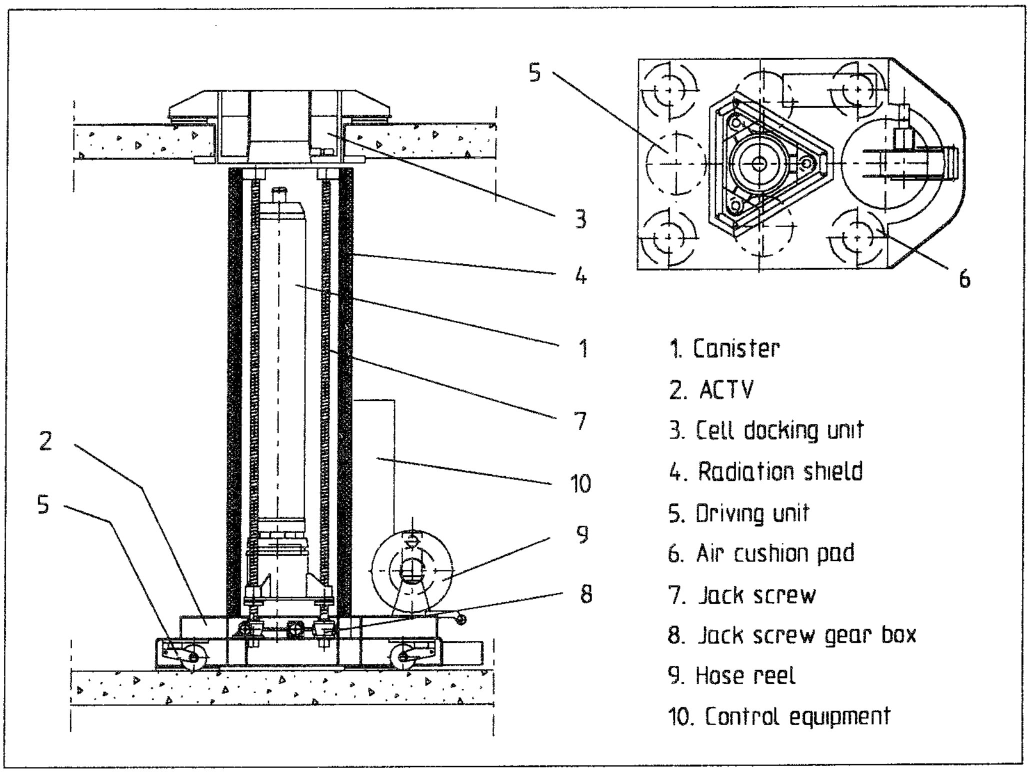


Figure A4.12 Canister in transport shield.

Treatment of core components and reactor internals

The canister with core components and reactor internals are transported to the Encapsulation Station in core components casks. These casks are prepared and connected to the hot cell for long lived ILW in the same way as the fuel casks.

The transport canister inside the cask are lifted out with a pole crane and normally placed directly into the concrete mould. It would also be possible to just place the transport canister inside the cell and remove the core component cask.

When the canister has been placed inside the concrete mould the latter will be transferred to the concrete filling position outside the cell. The void inside the canister and mould is filled with a concrete mortar. The lid of the mould will be bolted on when the concrete has cured. A contamination check of the mould surface is done before it is transferred to the mould storage area.

The layout arrangement of the hot cell for handling of core components and reactor internals including the concrete filling station is shown in Figure A4.13.

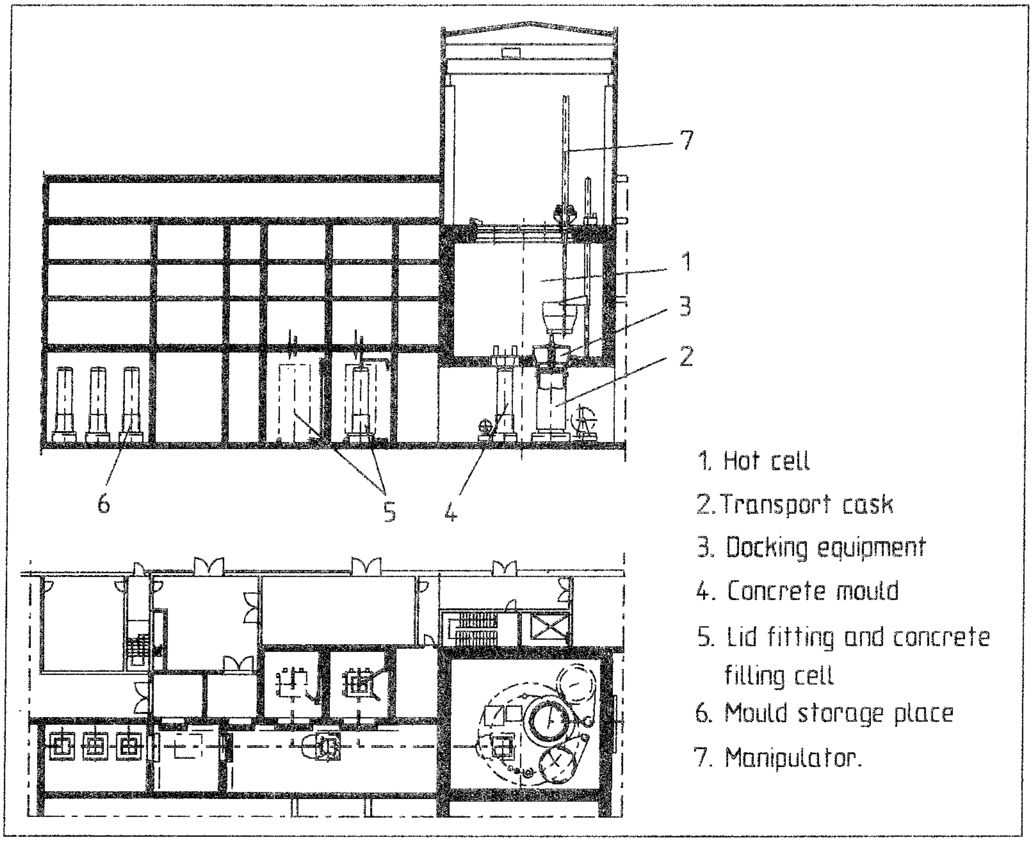


Figure A4.13 Treatment of core component and reactor internals

For the BWR boxes a steel grid with a thickness and openings suited to the end pieces of the boxes lies in the bottom of the mould. The grid stops about 50 mm above the bottom of the mould, providing the necessary space for distribution of the cement mortar. The boxes are picked up and placed in the mould so that the end pieces stick down into the holes in the grid. This prevents the boxes from falling over and thereby impeding the filling process. One concrete mould can be filled with 49 BWR boxes.

Other metal components to be embedded in moulds consist of different replacement parts, mainly control rods and detector probes, but also of decommissioning products from the internal parts of the reactor vessels.

In some cases, owing to a higher radiation intensity, the mould must be arranged so that the concrete cover is considerably thicker than the mould wall. This is achieved by placing a peripheral row of boxes around the sides of the mould before the more active material is placed in the mould.

FINAL REPOSITORY FOR SPENT FUEL, SFL 2

Layout

The final repository for spent fuel is situated in the bedrock approximately 500 m below the surface and can be reached via an elevator shaft from ES. The repository consists basically of a system of parallel deposition tunnels, with a total length of about 35 km, with appurtenant transport tunnels, service areas and shafts to the ground surface, occupying a total surface area of about 1 km^2. The total area is determined above all by the heat generation in the deposited fuel. Its layout is illustrated in Drawing 4.8. The waste canisters are deposited in vertical holes drilled in the bottom of the deposition tunnels, a total of about 4 400 holes.

The repository is divided into two or more parts, at level -500, to permit a simple physical separation of the deposition work from other activities, such as excavation and sealing works. The deposition tunnels will be excavated as deposition proceeds. It should be pointed out that the division of the repository as it is shown on the drawings is only schematic. In practice, the configuration of the repository will be adopted to the fracture geometry of the rock. In order to determine this fracture geometry, extensive exploratory drilling will be carried out during the excavation phase.

The repository consists of a central section, containing service areas, located directly beneath the encapsulation station, and a deposition section. The central section provides connection with the ground surface via three shafts:

- The central shaft, comprising the main entrance to the repository for both personnel and materials via two elevators. The repository is supplied with air, water, electricity etc via this shaft.

- The skip shaft, provided with rock hoisting equipment. The skip shaft is the first shaft to be excavated and is accordingly driven in the form of a sunk shaft.

- The waste shaft, with elevator for lowering of the canisters, the concrete moulds and the operating waste from CLAB, ES and Studsvik.

There is another shaft at the opposite end of the repository. It normally serves as an exhaust air shaft, but in an emergency it can also be used for personnel evacuation.

The total excavated rock volume is about 700 000 m^3 of which the deposition tunnels account for about 440 000 m^3. The deposition tunnels have a cross-sectional area of about 12.5 m^2, which is a minimum area to permit passage of the deposition vehicle. It is assumed that the deposition tunnels are excavated by means of conventional tunnelling technique with a blasting rate that minimizes cracking of the tunnel walls. Blasting and excavation take place with a certain lead time as deposition proceeds, and in stages of about 4 km tunnel length.

Operation

Figure A4.14 shows a cross section of a deposition tunnel with canister after deposition and sealing. The canister is placed in a hole drilled in the bottom of the deposition tunnel. The holes have a diameter of 1.5 m and a depth of 7.4 m and are spaced at a distance of 6.5 m.

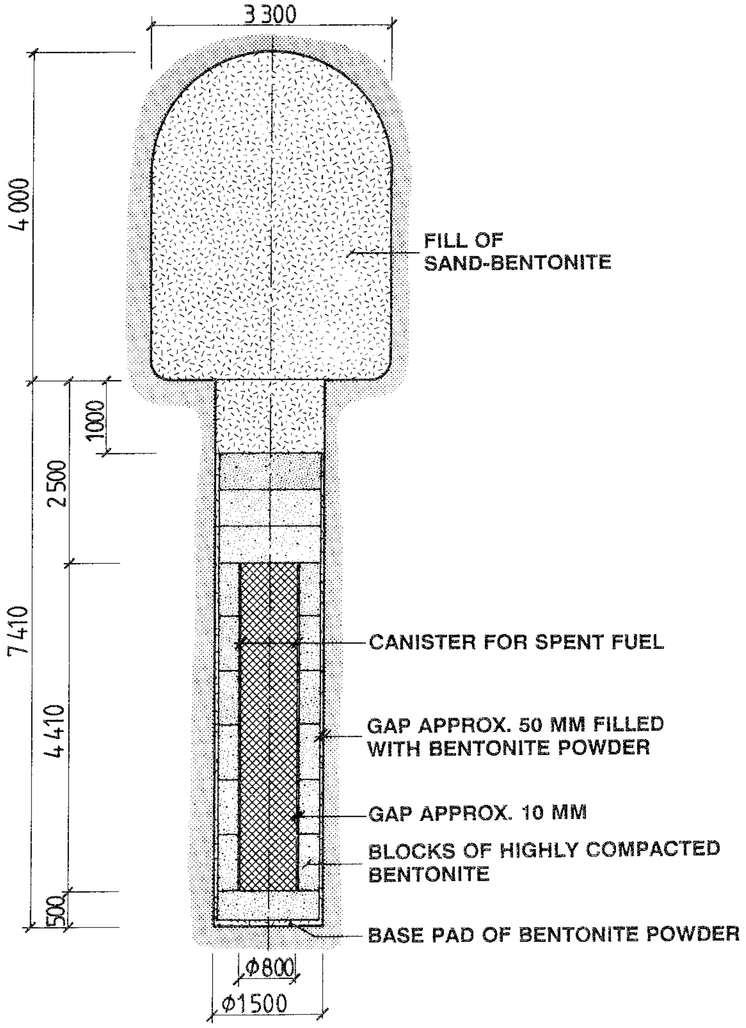


Figure A4.14 Deposition hole with canister and buffer material.

The copper canister is lowered into the hole by an electrically driven deposition vehicle, which picks up the canister from the transport vehicle in the transport tunnel. The vehicle that transport the canister from the elevator is diesel driven. During the transport the canister lies protected in a radiation-shielded tube.

The deposition procedure begins with the placement of all ring-shaped bentonite blocks in the hole. All handling of the bentonite blocks is done with the deposition vehicle.

The transport of the canister from the elevator to the deposition tunnel, handling of bentonite and lowering of the canister in the deposition hole is illustrated in Figure A4.15.

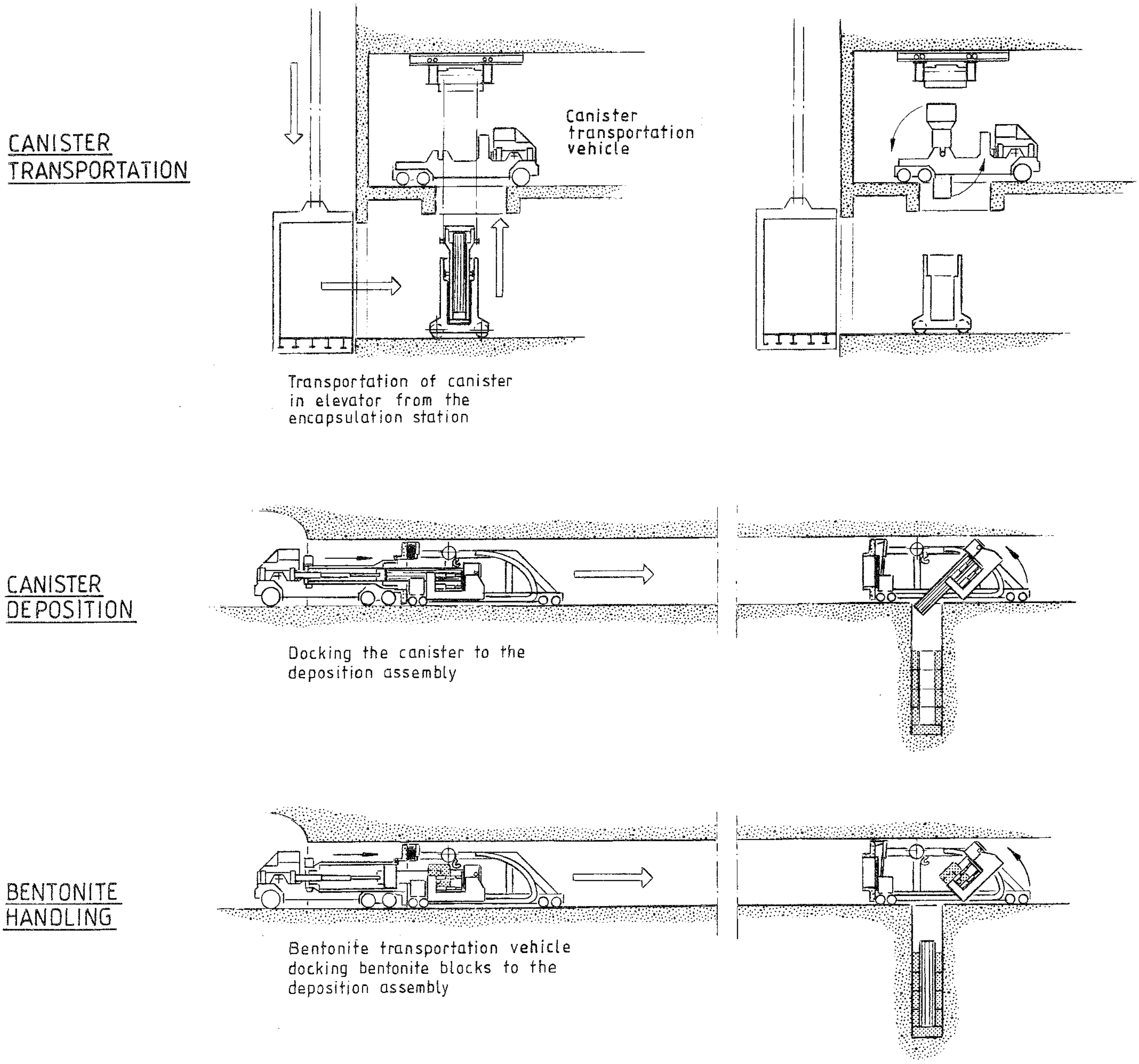


Figure A4.15 Transport and disposing of canister.

After the canister has been lowered the remaining bentonite buffer is placed in the hole on top of the canister. The hole is then capped with a watertight seal. The seal is allowed to remain in place until all holes in the tunnel have been finished and backfilling is about to commence.

When a number of deposition tunnels are completed, the work of sealing them begins. The temporary seal is hereby removed and the tunnels are filled with sand/bentonite. The tunnel mouths are sealed off with a temporary steel wall, which is removed in connection with backfilling of the central tunnel. See Figure A4.16.

After concluded deposition of all canisters, the entire facility is sealed with sand/bentonite. The shafts are hereby provided with plugs of compacted bentonite in certain sections.

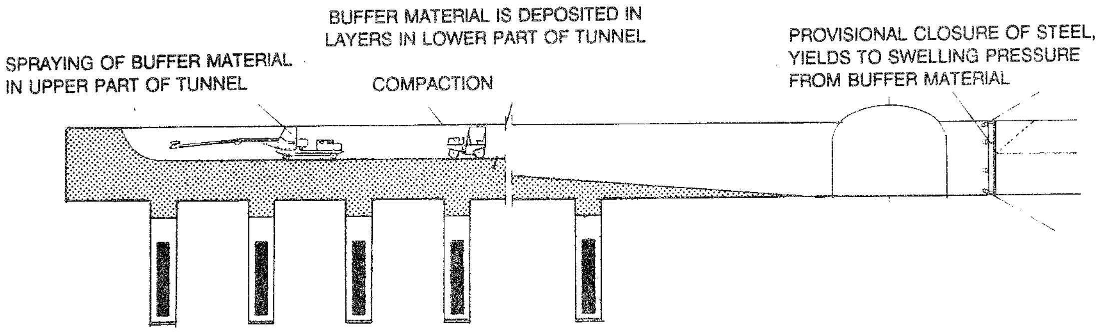


Figure A4.16 Backfilling of deposition tunnel.

At most, the operating staff amounts to about 120 persons, including rock workers for excavation of the deposition tunnels.

FINAL REPOSITORIES FOR LONG LIVED LOW- AND INTERMEDIATE-LEVEL WASTE, SFL 3-5

SFL 3, 4 and 5 are located in one repository area and thus equipped with a number of common areas and functions. The repositories are located at a depth of about 500 m in the bedrock and are reached via the same shaft as the repository for spent fuel, SFL 2. However, SFL 3-5 are located about 1 km from SFL 2 and reached via a tunnel. The rock cavern layout is shown in Drawing 4.9. The total rock volume amounts to 140 000 m^3.

Waste is transported down to the repository level by the same elevator as the canisters. The elevator is designed to take all types of waste packages and other loads, e.g. the large moulds with core components. The latter weigh about 20 tonnes. Down in the receiving area at repository level, the waste is transferred to a radiation-shielded transport wagon, which takes it to the appropriate storage area via the 1 km long tunnel. The low-level waste can be handled in a simpler manner with a radiation-shielded forklift truck.

SFL 3

SFL 3 consists of a number of concrete troughs located in a 70 m long rock vault with a width of 18 m and a height of 21 m. Operating waste from CLAB and ES will be deposited in SFL 3 after SFR 1 has been closed. However, the extensive safety arrangements around the repository are dimensioned by the disposal of the long-lived Studsvik waste, which has some transuranic content.

The positioning and design of the concrete troughs exhibit many similarities with the silo concept in SFR 1. Thus, the troughs is surrounded by sand/bentonite or by pure bentonite. It is also divided into square cells into which the waste is lowered and grouted. Handling is done by remote control with the aid of a deposition machine of an overhead crane type, which runs on the long walls of the trough. After concluded deposition, the throughs are covered with a concrete lid and all nearby service areas are filled with concrete. Adjoining tunnels are plugged and the cavities are filled with sand/bentonite.

SFL 4

SFL 4 is intended to receive active decommissioning waste from mainly CLAB and ES as well as transport casks. Consequently, it will be in operation when all other waste has been deposited.

The repository consists of the tunnel system remaining after deposition in SFL 3 and SFL 5 has been concluded and the repositories sealed. The waste, which arrives in small steel containers, is placed in the tunnels which thereafter are backfilled, possibly with crushed rock material. Finally, the shaft is backfilled, whereby a number of plugs of compacted bentonite are installed.

SFL 5

SFL 5 consists of two tunnels, each about 350 m long and with a cross section of 55 m^2, in which the concrete moulds with core components are stacked in a lying position five abreast and four high. The handling is made with a remotely operated overhead crane. As deposition proceeds, the space between moulds and rock is filled with shotcrete.

The moulds have dimensions 5.3 x 1.25 x 1.25 m and are designed so that, when they are stacked in the tunnel, they provide adequate radiation shielding through their own concrete thickness and thereby permit access to the tunnel. The total number of moulds is about 2 400.

APPENDIX 5

FINAL REPOSITORY FOR REACTOR WASTE, SFR

FINAL REPOSITORY FOR REACTOR OPERATION WASTE, SFR 1

A final repository for short-lived low- and intermediate-level waste located at the Forsmark nuclear power station has been in operation since 1988. The waste derives primarily from reactor operation, but also from non-electricity-producing activities. In the latter case, the waste comes mainly from Studsvik. In all, SFR 1 will hold about 90 000 m^3 of waste, of which about 37 000 m^3 in silos.

The site plan of the repository is shown in Drawing 5.1. Two tunnels lead from the power station harbour out under the Baltic Sea to the rock cavern repository, which is built with a rock cover of at least 60 m. The water depth on the site is 5-6 m.

SFR 1 is being built in two phases. The first phase, currently in operation, consists of one cylindrical rock cavern containing a concrete silo plus four 160-m-long rock vaults. The appearance of the repository, SFR1 phase I, is illustrated schematically in Figure A5.1.

The concrete silo contains intermediate-level waste. Three of the rock vaults contain low-level waste, handled by a radiation-shielded truck. The fourth rock vault contains intermediate-level waste and handling is remote controlled. The second building phase comprises one additional silo and one or two rock vaults, see Drawing 5.2. The total volume of rock excavated for the two building phases will amount to about 600 000 m^3.

The rock chamber for the silo is 70 m high and has a diameter of 30 m. A free-standing concrete silo is being built inside the rock cavern. The silo stands on a 1.5 m thick bed of compacted sand/ bentonite. The space between the silo wall and the rock wall, about 1 m, is filled with bentonite granulate.

Internally, the concrete silo is divided into cells of square cross section, 2.6 x 2.6 m. This cellular division provides a stiffening of the silo wall and facilitates emplacement and grouting of the waste packages.

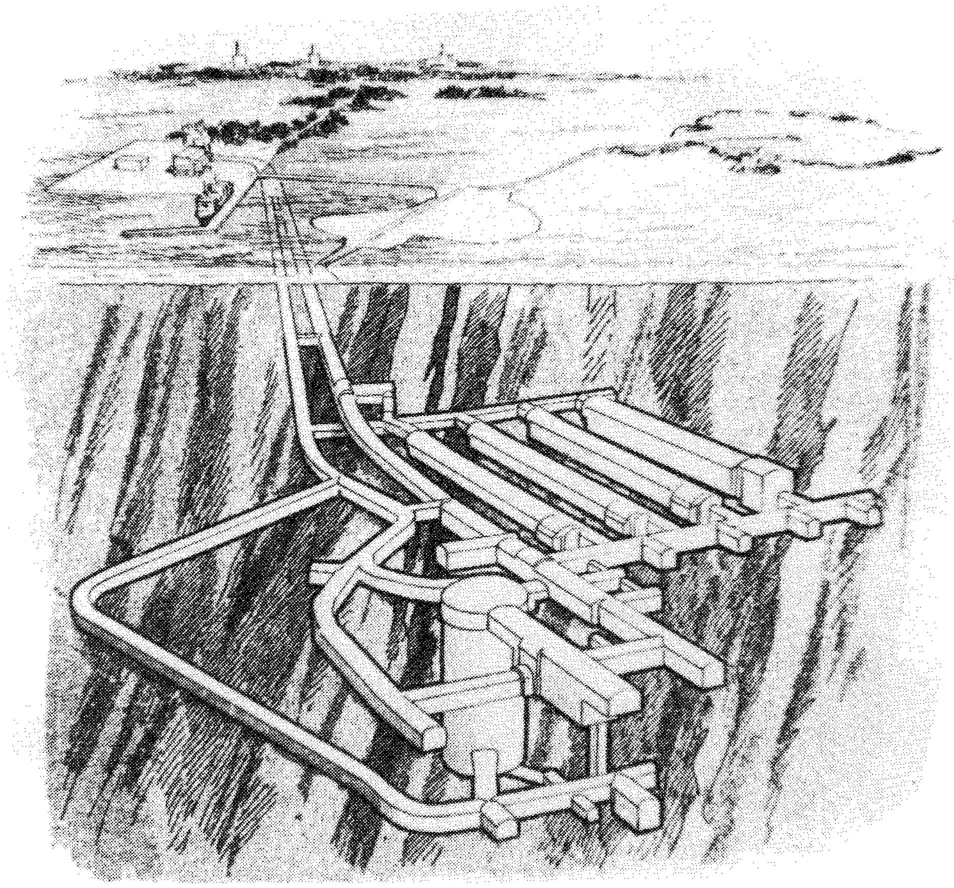


Figure A5.1 SFR 1, phase I.

The procedure for depositing waste in the silo is schematically illustrated in Figure A5.2. The transport container with the waste packages is brought down into the repository by an electric-powered terminal vehicle and placed in a receiving room. Above the room runs a tunnel that is connected to the upper part of the silo and contains a railbound remote controlled polar crane. The deposition vehicle picks up the waste packages, one at a time, out of the transport container, drives out onto the polar crane over the silos, goes to the right position and lowers the package into one of the cells. When three layers of waste have been emplaced in the cell, they are grouted with a low-viscosity cement mortar. After completion of deposition, a concrete lid is poured over the silo and all remaining cavities are filled with sand/bentonite and backfill materials.

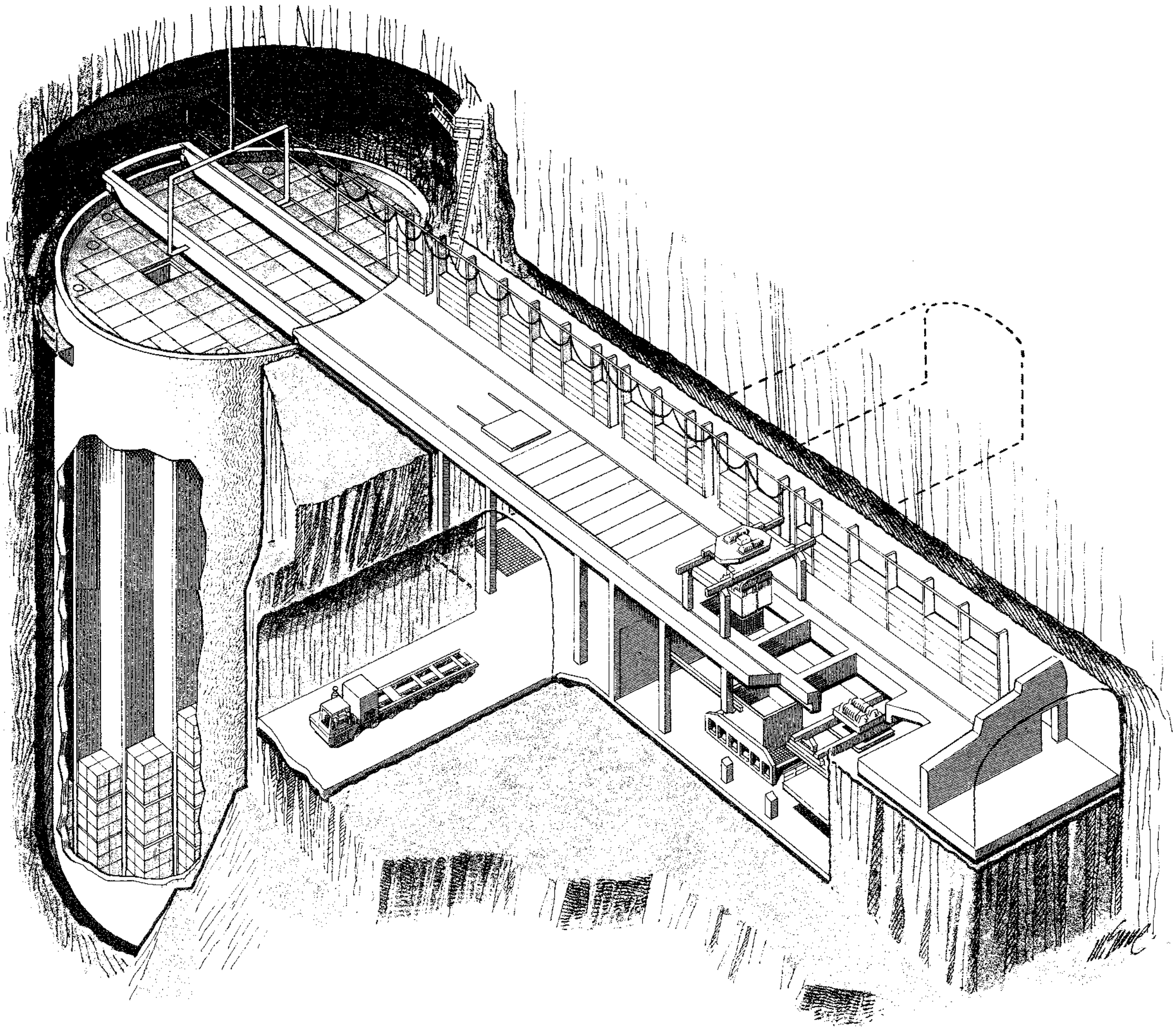


Figure A5.2 Deposition in silo, SFR 1.
Schematic illustration.

The principle arrangement of the caverns and the handling of the waste is schematically illustrated in Figure A5.3.

The intermediate-level waste emplaced in the rock caverns is also grouted, while the low-level waste is not.

The repository also includes surface facilities situated in the area around the tunnel mouths. See Drawing 5.3. The total building volume is about 30 000 m^3. The buildings include a ventilation building (for the rock chambers), an office and workshop building and a terminal building where the transport units are temporarily stored prior to transport down to the repository.

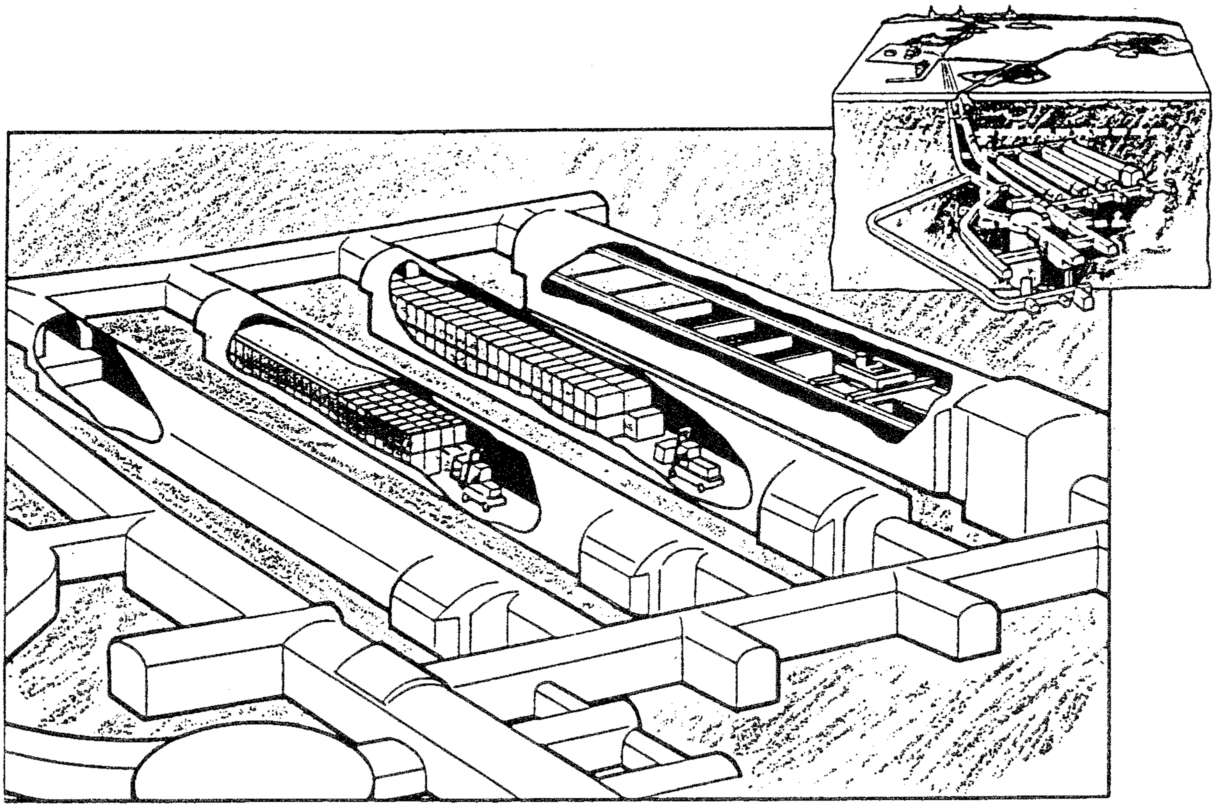


Figure A5.3 Rock caverns for low and intermediate-level waste

SFR 1 is scheduled to be sealed in the mid 2010s. The operating organization will amount to 20 men.

FINAL REPOSITORY FOR DECOMMISSIONING WASTE, SFR 3

SFR 3 is intended for decommissioning waste from the nuclear power plants and Studsvik. The total waste quantity may amount to about 100 000 m^3. The site of SFR 3 has not yet been determined, but it is assumed at present that SFR 3 will constitute an expansion of SFR 1. SFR 3 will be in operation at the same time as the nuclear power plants are being decommissioned. Activities at SFR 1 will then have ceased and SFR 3 can be run by the same personnel as SFR 1. The operating and service buildings constructed for SFR 1 can also be utilized.

SFR 3 will consist of four rock caverns of a similar type as in SFR 1. See Figure A5.3 and Drawing 5.4. The decommissioning waste will primarily be transported to the repository packed in standard ISO containers that are deposited with their contents. ATB containers are used for waste that requires radiation shielding during transport and are emptied by means of a remote-controlled overhead crane.

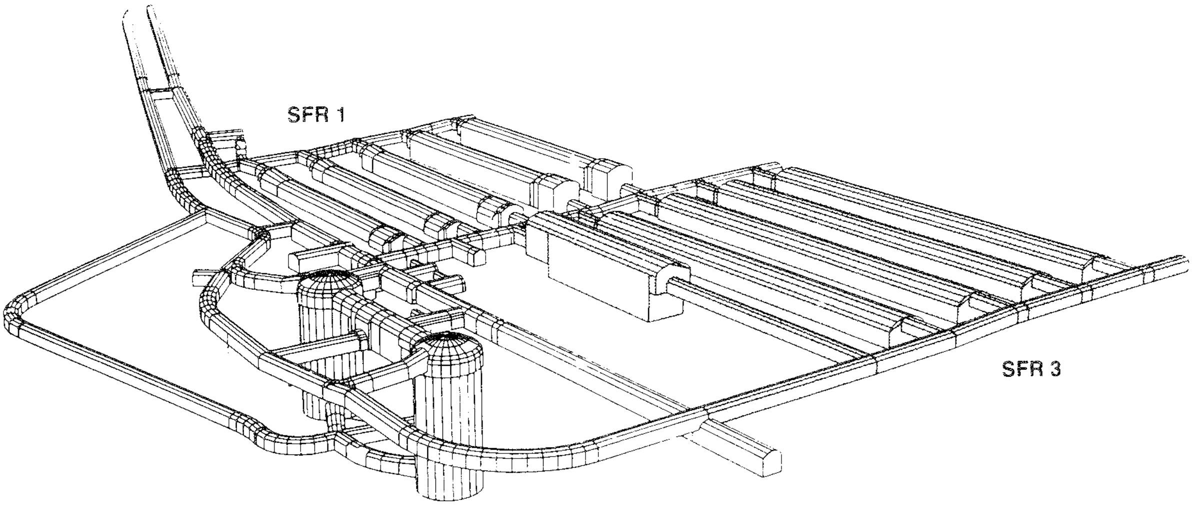


Figure A5.3 SFR1, phase I and II plus SFR3

APPENDIX 6

DECOMMISSIONING OF THE NUCLEAR POWER PLANTS (Summary from Ref. 5)

When a nuclear power plant is retired from service, parts of it are radioactive and must be dismantled and disposed of in a safe manner. The procedures and costs involved in decommissioning nuclear power plants are described in the study.

The study shows that, from the viewpoint of radiological safety, a nuclear power plant can be dismantled immediately after it has been shut down and the fuel has been removed, which is estimated to take about one year. Most of the equipment that will be used in decommissioning is already available and is used routinely in maintenance and rebuilding work at the nuclear power plants. Special equipment need only be developed for dismantlement of the reactor vessel and for demolishing of heavy concrete structures. Examples of existing equipment that can be used for this after minor modifications are given in the study.

The dismantling of a nuclear power plant can be accomplished in about five years, with an average labour force of about 200 men. The maximum labour force required for Ringhals 1 has been estimated at about 500 men during the first years, when active systems are being dismantled on a number of fronts in the plant. During the last years when the buildings are being demolished, approximately 50 men are required.

In order to limit the labour requirement and the dose burden to the personnel, the material is taken out in as large pieces as possible. This means, for example, that pipes are cut into lengths of 2-5 m and packed directly in refuse containers, and that certain items of equipment are taken out and transported intact.

The study has focused on immediate dismantling. By waiting ten years or so, certain advantages can be gained due to the fact that the radioactivity in the plant declines. In the case of immediate dismantling, the same effect can be achieved by system decontamination. A number of other factors also influence the choice of time of dismantling, for example availability of personnel, need for the site and the availability of a final repository. Non-technical factors will also be of importance. The choice of time of dismantling can therefore vary for different plants.

Cost figures below are taken from Technical Report 86-16 /ref. 5/ and adjusted to the 1992 price level by using the price index.

The cost of decommissioning a boiling water reactor (BWR) of the size of Ringhals 1 has been estimated to be about MSEK 830 in January 1992 prices, and for a pressurized water reactor (PWR, Ringhals 2) about MSEK 700. The costs for the other Swedish nuclear power plants lie in the range of MSEK 630 to 1 160. These are the direct costs for the decommissioning work, to which must be added the costs of transportation and disposal of the decommissioning waste, about 100 000 m^3. These costs have been estimated to about MSEK 1 000 for the 12 Swedish reactors.

Additional costs are incurred for the shutdown period from the time the nuclear power plant is finally taken out of operation until the dismantling work is begun. During this period, the fuel is transported away and some decontamination is carried out. The costs for the shutdown period are heavily dependent on how long the shutdown period will last.

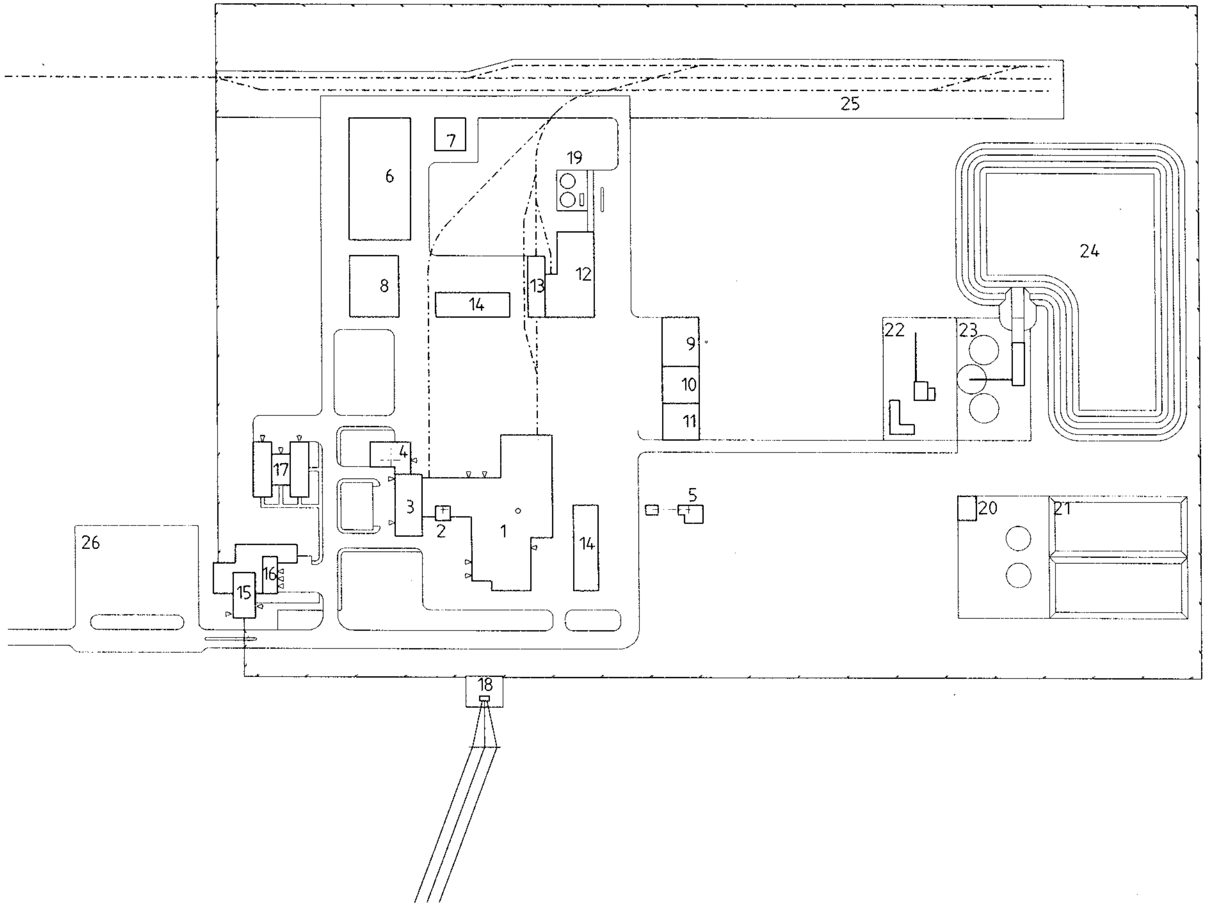
There are considerable quantities of spare parts, materials and equipment on the reactor sites that can be sold when the plants are closed down. The total value of these materials for all nuclear power plants is estimated to be MSEK 1 370. To this must be added the value of the land and the infrastructure.

The table below presents the costs of immediate dismantling of the Swedish nuclear power plants.

Table S-1: Costs (MSEK) for decommissioning of the Swedish nuclear power plants.
January 1992 price level

	Barsebäck 1-2	Ringhals 1-4	Oskarshamn 1-3	Forsmark 1-3
Shutdown operation[1)]	180	520	320	320
Decommissioning	1 480	2 990	2 540	3 410
Transport and final disposal of waste	150	315	250	285
Total	1 810	3 825	3 110	4 015
Residual value	-230	-460	-340	-340

1) An extra contingency adjustment of 10% has been added to these costs in the systems cost calculations.



1	Encapsulation station, ES
2	Waste elevator
3	Administration building
4	Service building for central shaft
5	Head-frame building for skip shaft
6	Sand storage and mixing plant
7	Silos for bentonite
8	Plant for moulding of bentonite blocks
9	Heating plant
10	Water treatment and fire-fighting water reservoir and pumps
11	Workshop
12	Vehicle workshop and transport depot
13	Hall for defrosting and cleaning of cask waggons
14	Store
15	Entrance and information building
16	Fire station
17	Canteen and first aid
18	Switch gear plant 220/10 kV
19	Tank farm for fuel and heating oil
20	Sewage plant
21	Settling ponds
22	Concrete plant
23	Rock crusher and sorting plant
24	Rock pile
25	Shunting yard
26	Parking

Drawing 4.1

50m 0 50 100 150 200m
1:2000

SKB SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO. Box 5864 102 48 Stockholm Tel 46 8 6652800

VBB VIAK

RITAD HOS | KONSTR AV AGE | GRANSKAD AV | ARBETSNUMMER S0148

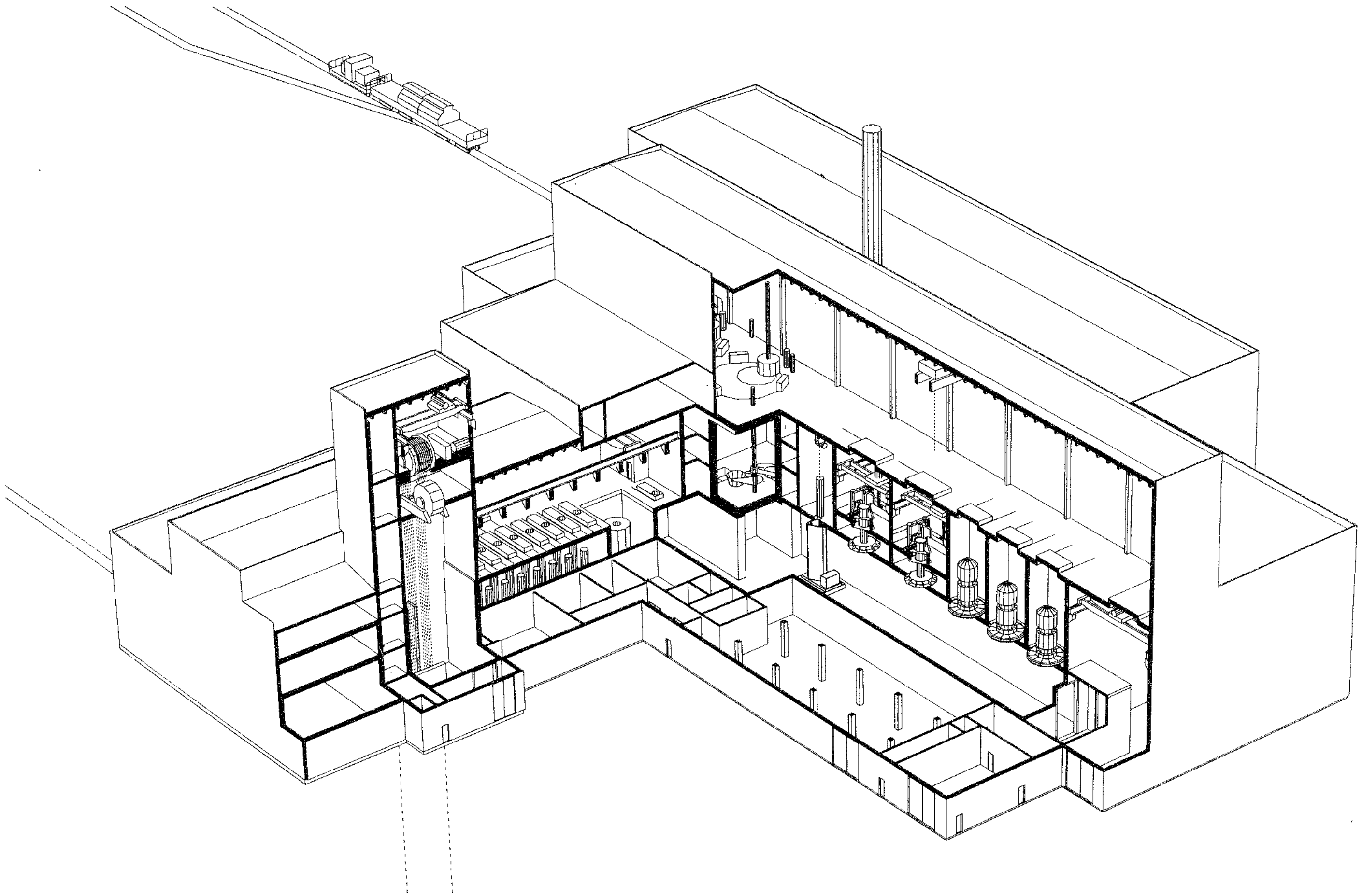
STOCKHOLM 92-06-01

REG | ANT | REGISTRERINGEN AVSER | SIGN | DATUM

SFL
SITE LAYOUT
GROUND FACILITIES

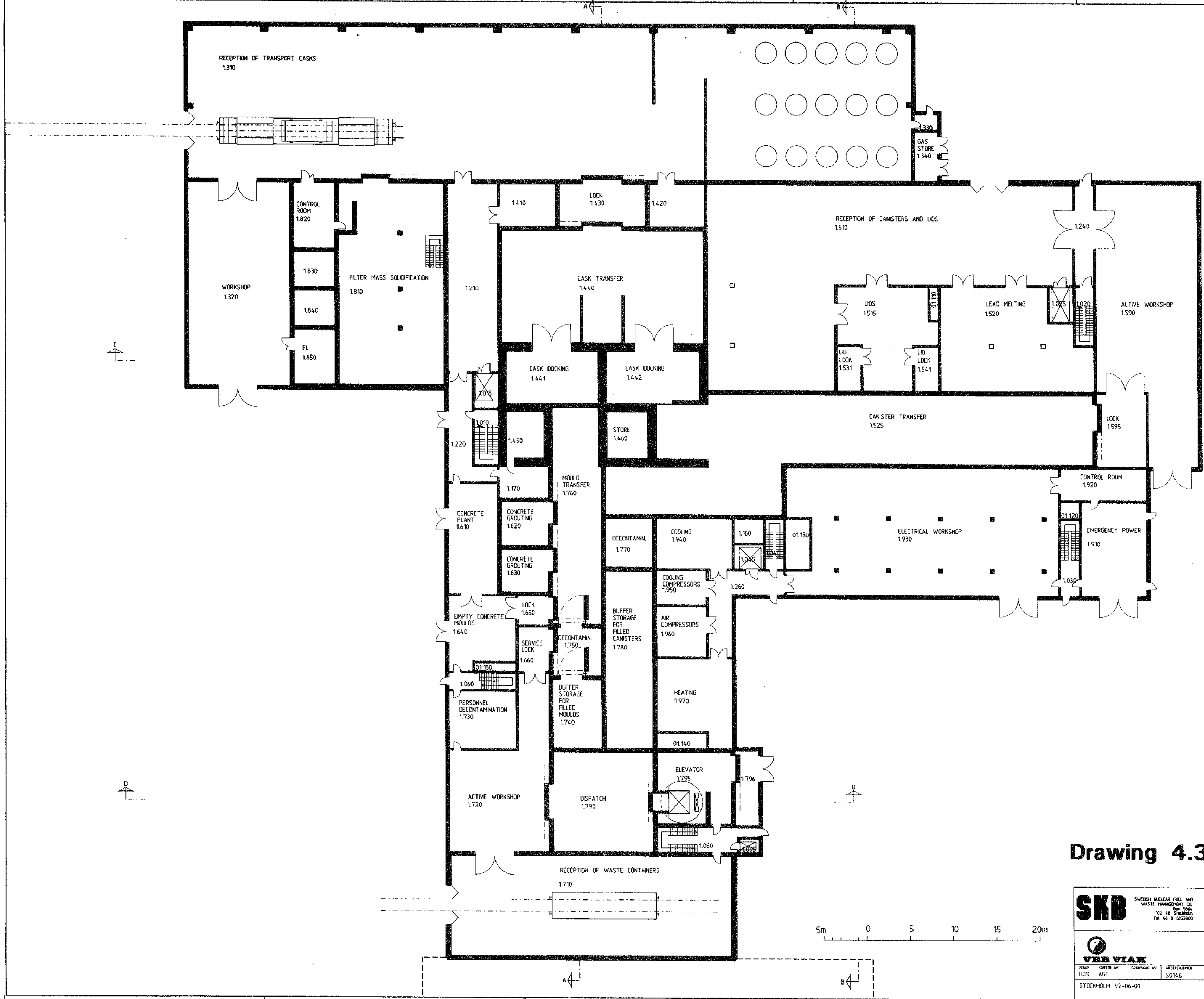
SCALE 1:2000

KOD TYP POS | RITNINGSNUMMER SFL-92-001 | REG



Drawing 4.2

SKB SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO. Box 5864 102 48 Stockholm Tel 46 8 6652800		REG | ANT | REGISTRERINGEN AVSER | SIGN | DATUM	
VBB VIAK		ES ENCAPSULATION STATION LAYOUT	
RITAD HOS	KONSTR AV AGE	GRANSKAD AV	ARBETSNUMMER S0148
STOCKHOLM 92-06-01		SCALE 1200	
XOD TYP POS		RITNINGSNUMMER BS-92-301	REG



Drawing 4.3

SKB SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO.

VBB VIAK

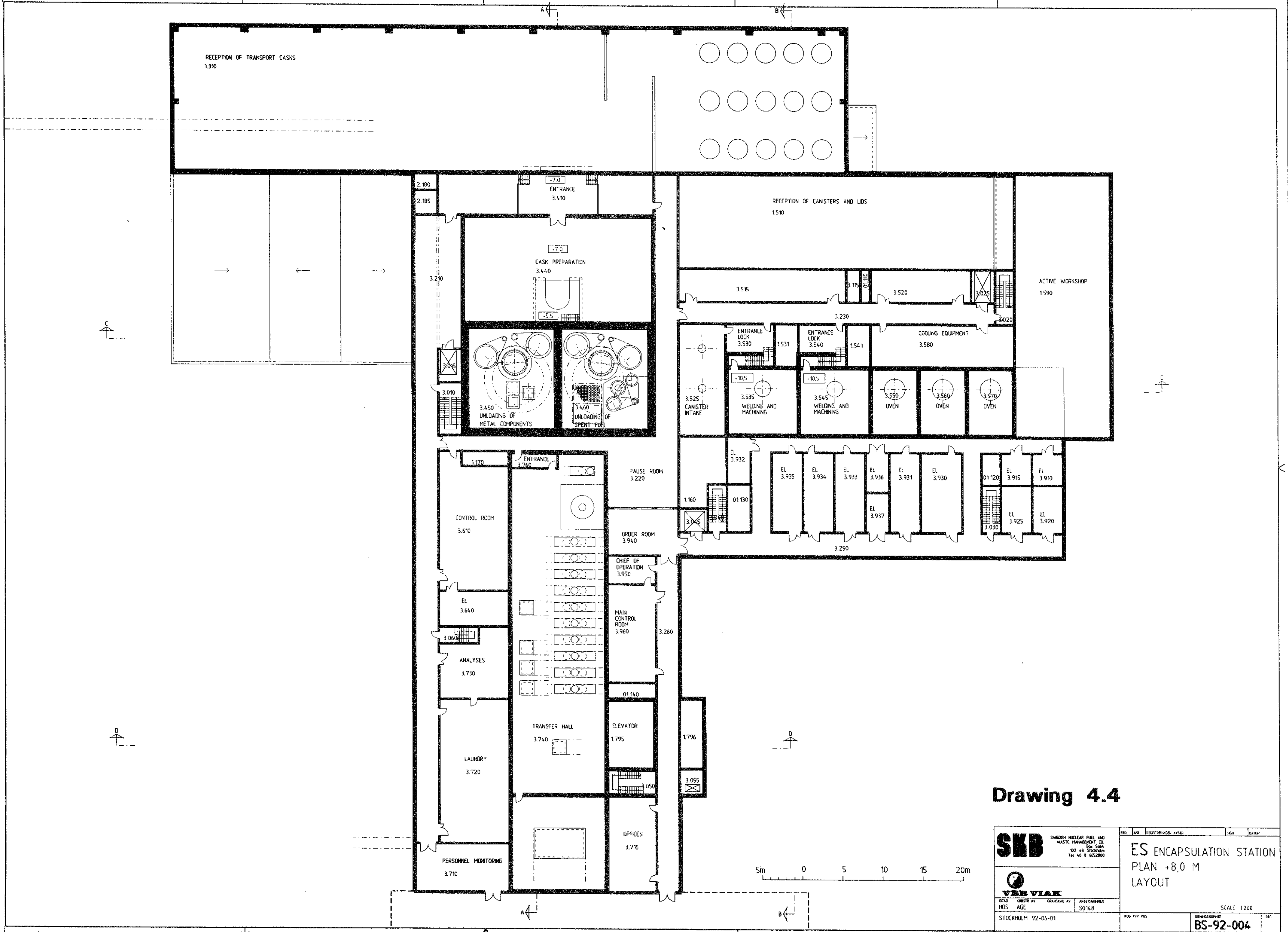
ES ENCAPSULATION STATION
PLAN +0,0 M
LAYOUT

HDS AGE S0148

STOCKHOLM 92-06-01

SCALE 1:200

BS-92-002



Drawing 4.4

SKB SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO.

VBB VIAK

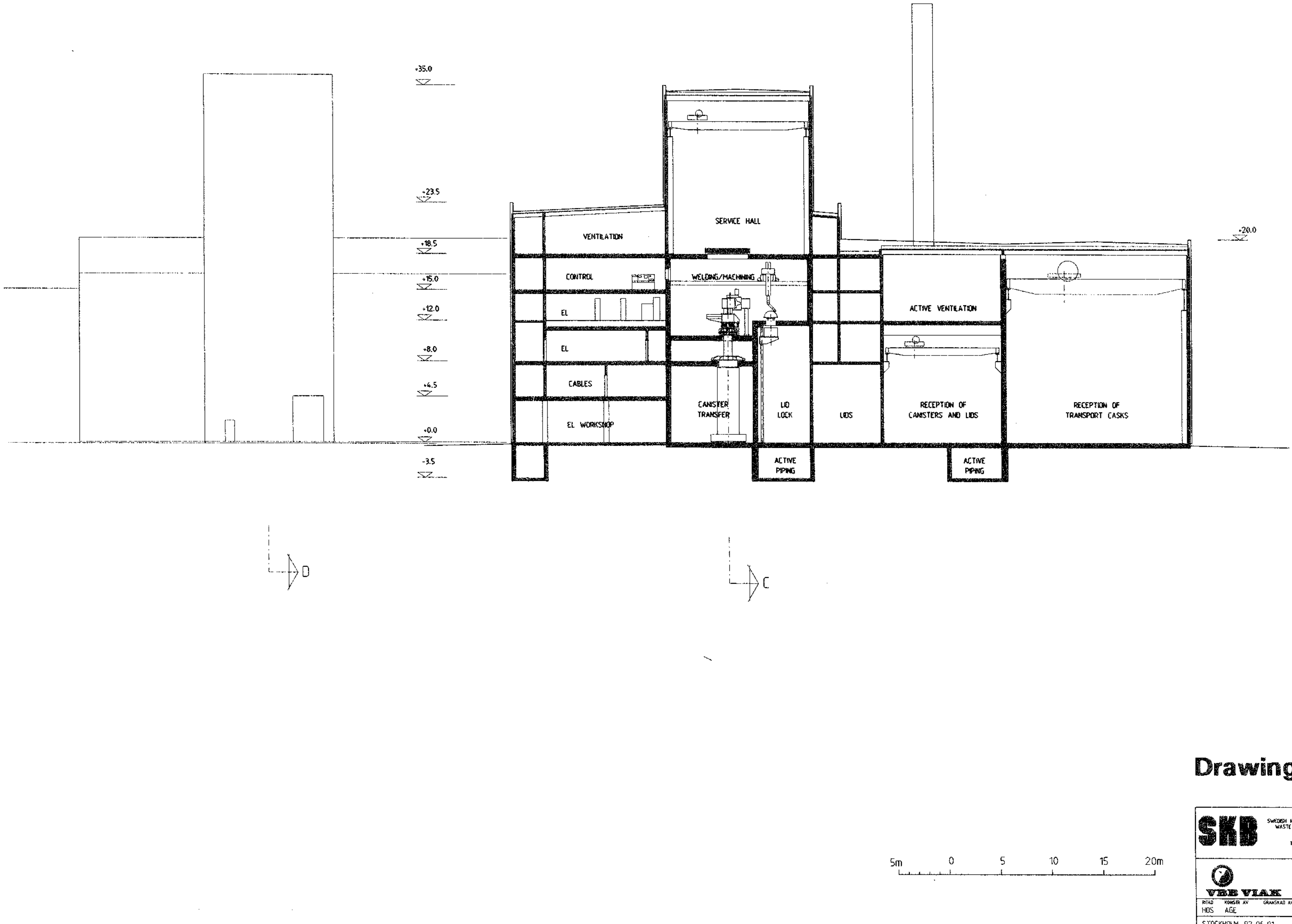
ES ENCAPSULATION STATION
PLAN +8,0 M
LAYOUT

HOS AGE S0148

STOCKHOLM 92-06-01

SCALE 1:200

BS-92-004



Drawing 4.5

SKB SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO. Box 5864 102 48 Stockholm Tel 46 8 6652800

VBB VIAK

RITAD	KONSTR AV	GRANSKAD AV	ARBETSNUMMER
HOS	AGE		S0148

STOCKHOLM 92-06-01

REL	ANT	REGISTRERINGEN AVSER	SIGN	DATUM

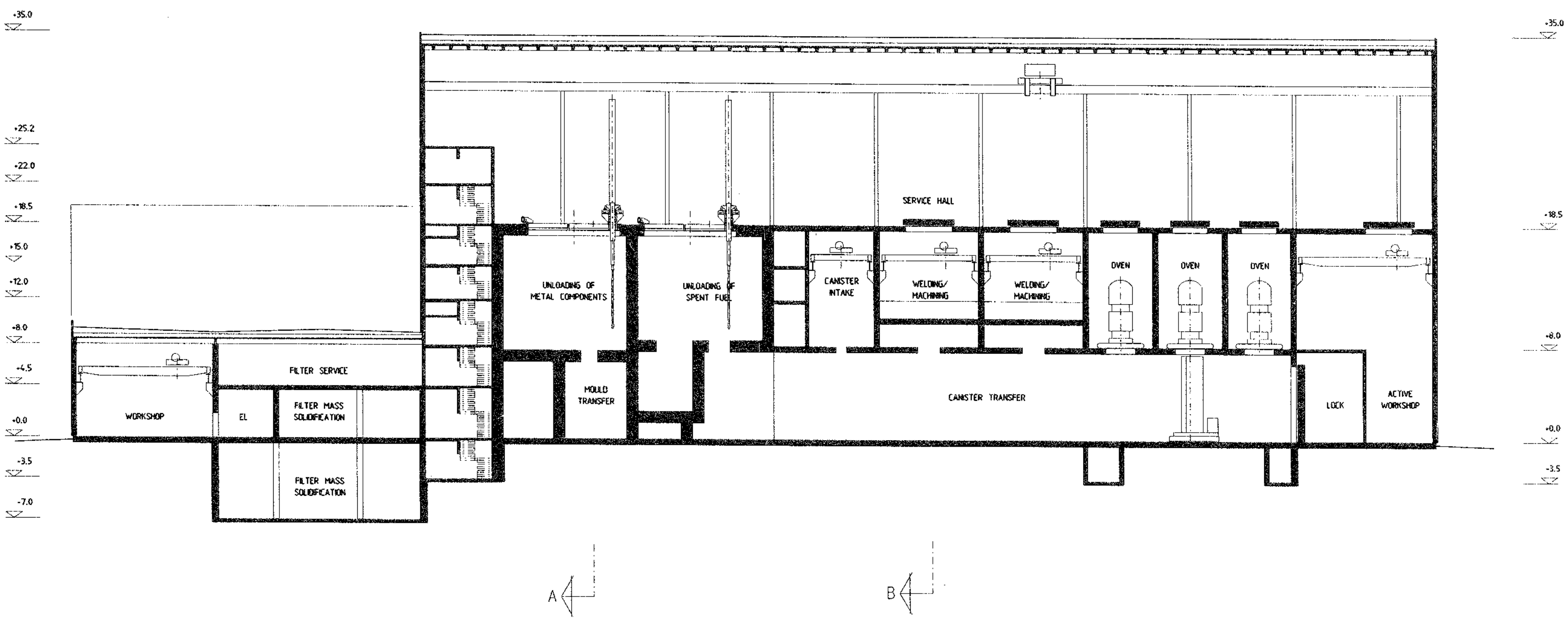
ES ENCAPSULATION STATION
SECTION B
LAYOUT

SCALE 1:700

RED TYP POS

RITNINGSNUMMER BS-92-011

REG



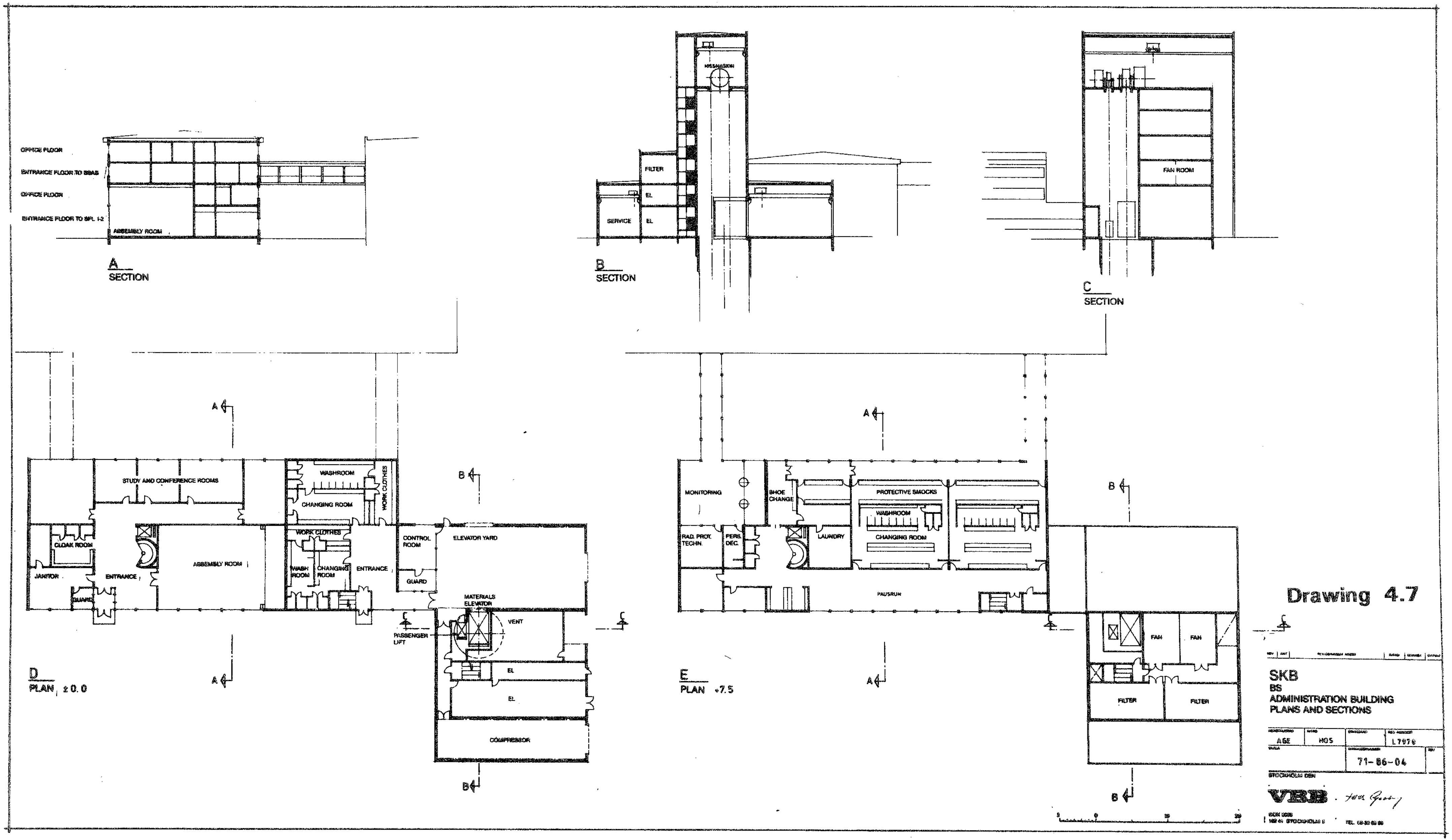
Drawing 4.6

SKB
SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO.
Box 5864
102 48 Stockholm
Tel 46 8 6652800

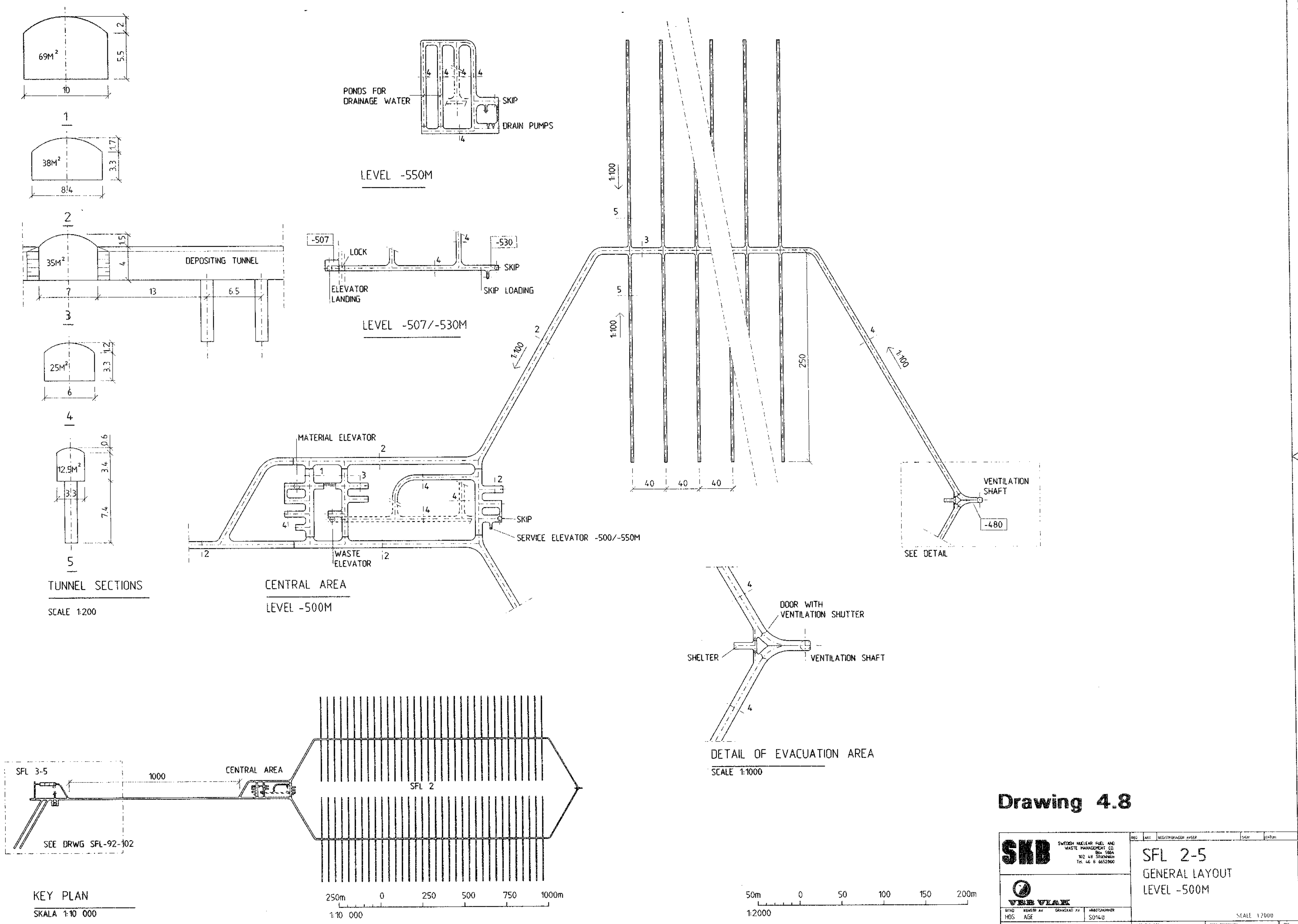
VBB VIAK

ES ENCAPSULATION STATION
SECTION C
LAYOUT

HOS AGE 50148
STOCKHOLM 92-06-01
SCALE 1:200
BS-92-012


OFFICE FLOOR
ENTRANCE FLOOR TO SBAB
OFFICE FLOOR
ENTRANCE FLOOR TO SFL 1-2
ASSEMBLY ROOM
A
SECTION
FILTER
EL
SERVICE
EL
B
SECTION
FAN ROOM
C
SECTION
STUDY AND CONFERENCE ROOMS
WASHROOM
CHANGING ROOM
WORK CLOTHES
CLOAK ROOM
JANITOR
ENTRANCE
GUARD
ASSEMBLY ROOM
WORK CLOTHES
WASH ROOM
CHANGING ROOM
ENTRANCE
CONTROL ROOM
GUARD
ELEVATOR YARD
MATERIALS ELEVATOR
PASSENGER LIFT
VENT
EL
EL
COMPRESSOR
D
PLAN ±0.0
MONITORING
SHOE CHANGE
PROTECTIVE SMOCKS
WASHROOM
CHANGING ROOM
RAD. PROT. TECHN.
PERS. DEC.
LAUNDRY
PAUSRUM
FAN
FAN
FILTER
FILTER
E
PLAN +7.5
SKB
BS
ADMINISTRATION BUILDING
PLANS AND SECTIONS
AGE
HOS
L7970
71-86-04
VBB

Drawing 4.7



Drawing 4.8

SKB SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO.

VBB VIAK

STOCKHOLM 92-06-01

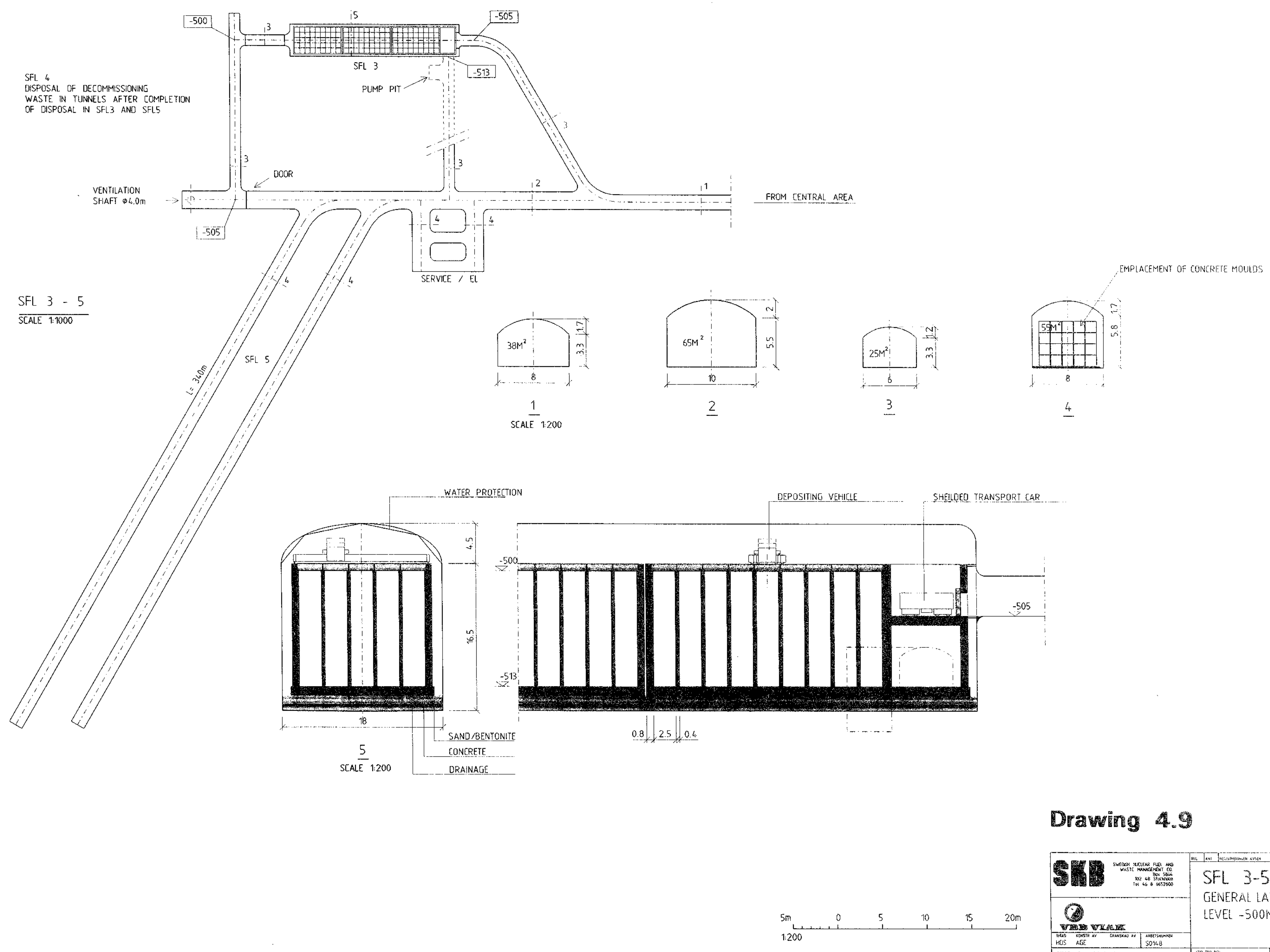
SFL 2-5

GENERAL LAYOUT

LEVEL -500M

SKALE 1:2000

SFL-92-101



Drawing 4.9

SKB — SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO.

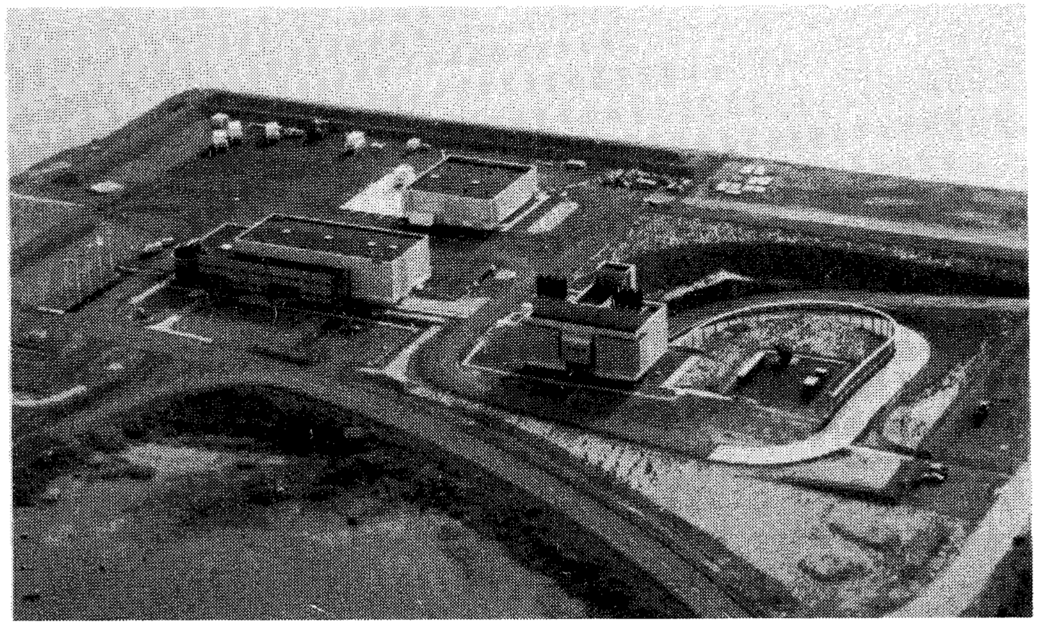
VBB VIAK

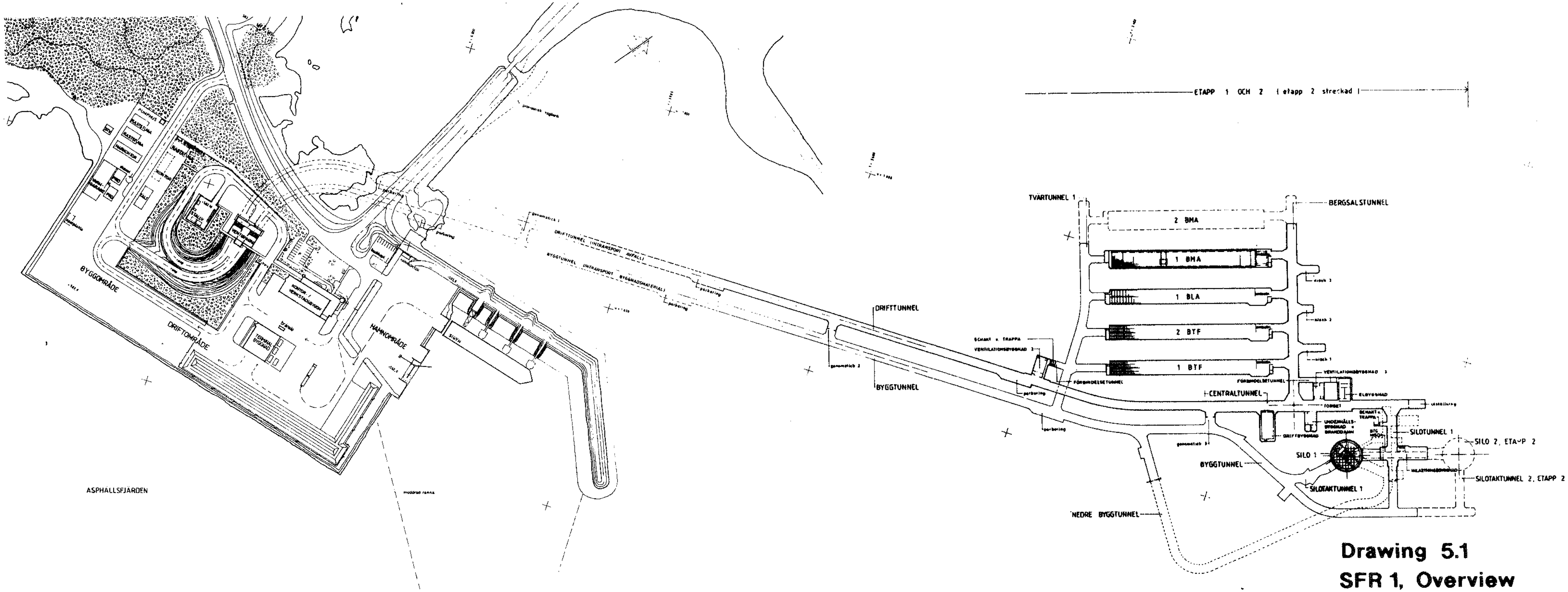
HDS AGE S0148

STOCKHOLM 92-06-01

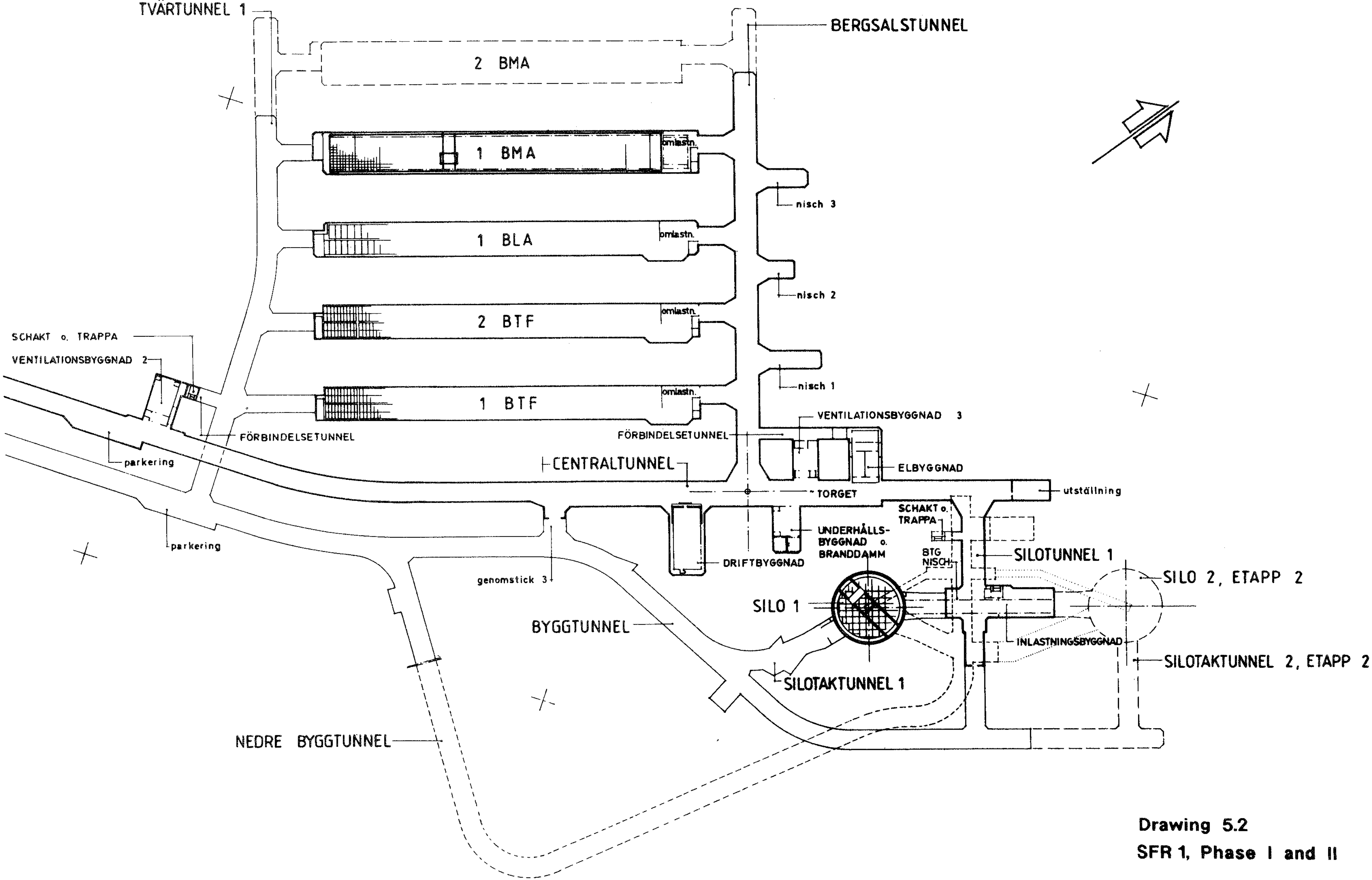
SFL 3-5
GENERAL LAYOUT
LEVEL -500M

SFL-92-102

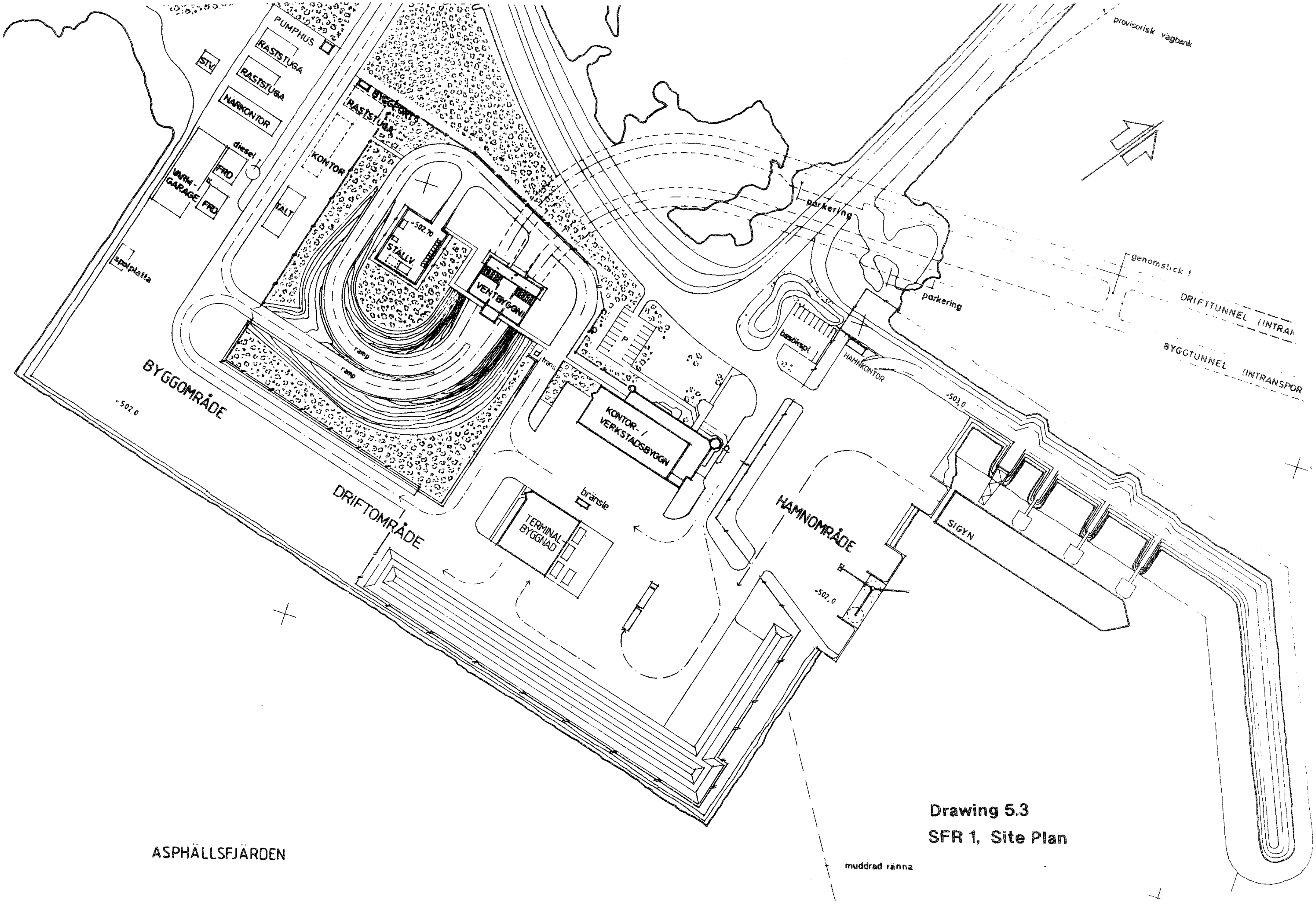




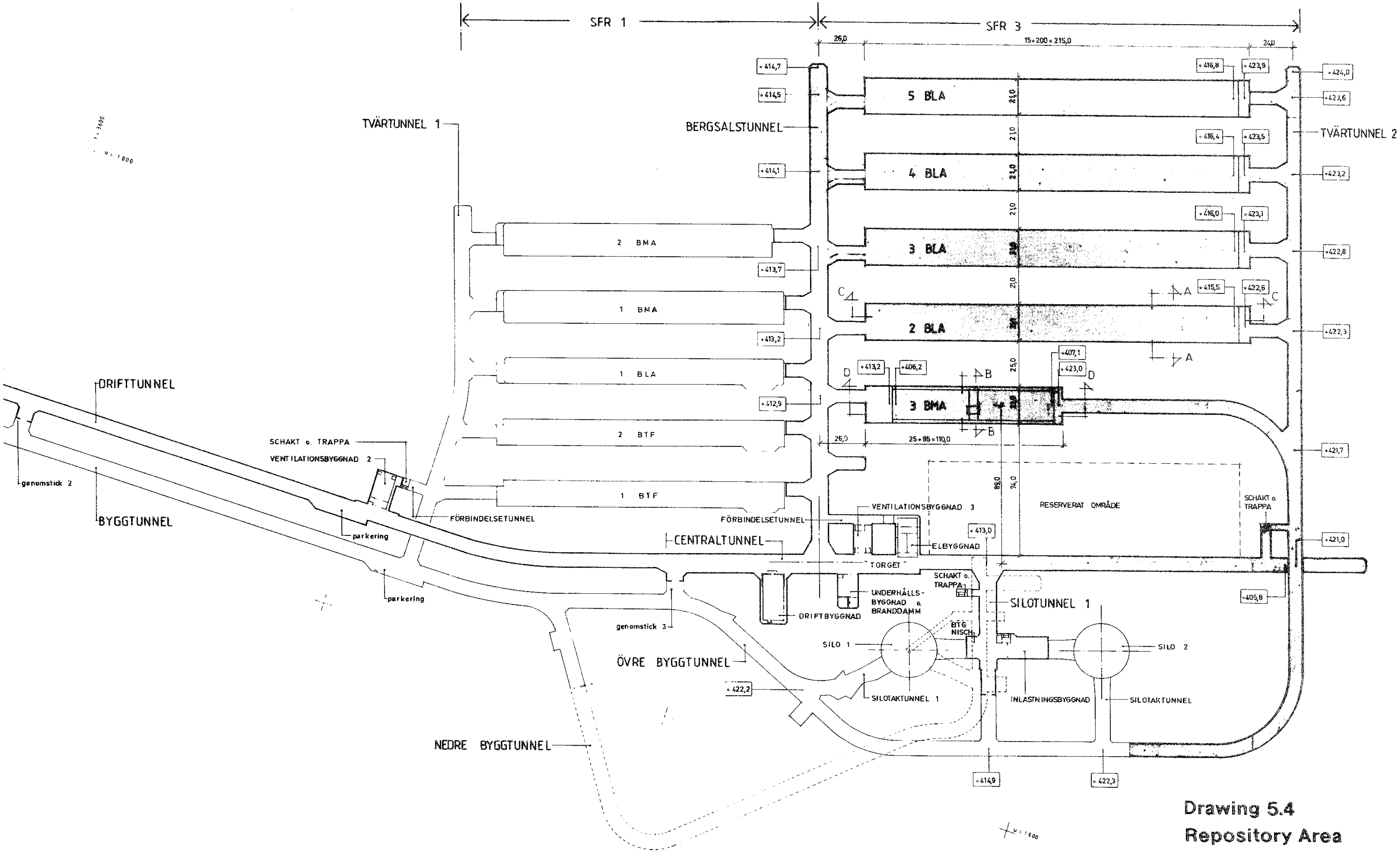
Drawing 5.1
SFR 1, Overview



Drawing 5.2
SFR 1, Phase I and II



Drawing 5.3
SFR 1, Site Plan



Drawing 5.4
Repository Area

List of SKB reports

Annual Reports

1977-78
TR 121
KBS Technical Reports 1 – 120
Summaries
Stockholm, May 1979

1979
TR 79-28
The KBS Annual Report 1979
KBS Technical Reports 79-01 – 79-27
Summaries
Stockholm, March 1980

1980
TR 80-26
The KBS Annual Report 1980
KBS Technical Reports 80-01 – 80-25
Summaries
Stockholm, March 1981

1981
TR 81-17
The KBS Annual Report 1981
KBS Technical Reports 81-01 – 81-16
Summaries
Stockholm, April 1982

1982
TR 82-28
The KBS Annual Report 1982
KBS Technical Reports 82-01 – 82-27
Summaries
Stockholm, July 1983

1983
TR 83-77
The KBS Annual Report 1983
KBS Technical Reports 83-01 – 83-76
Summaries
Stockholm, June 1984

1984
TR 85-01
Annual Research and Development Report 1984
Including Summaries of Technical Reports Issued during 1984. (Technical Reports 84-01 – 84-19)
Stockholm, June 1985

1985
TR 85-20
Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01 – 85-19)
Stockholm, May 1986

1986
TR 86-31
SKB Annual Report 1986
Including Summaries of Technical Reports Issued during 1986
Stockholm, May 1987

1987
TR 87-33
SKB Annual Report 1987
Including Summaries of Technical Reports Issued during 1987
Stockholm, May 1988

1988
TR 88-32
SKB Annual Report 1988
Including Summaries of Technical Reports Issued during 1988
Stockholm, May 1989

1989
TR 89-40
SKB Annual Report 1989
Including Summaries of Technical Reports Issued during 1989
Stockholm, May 1990

1990
TR 90-46
SKB Annual Report 1990
Including Summaries of Technical Reports Issued during 1990
Stockholm, May 1991

1991
TR 91-64
SKB Annual Report 1991
Including Summaries of Technical Reports Issued during 1991
Stockholm, April 1992

Technical Reports
List of SKB Technical Reports 1992

TR 92-01
GEOTAB. Overview
Ebbe Eriksson[1], Bertil Johansson[2], Margareta Gerlach[3], Stefan Magnusson[2], Ann-Chatrin Nilsson[4], Stefan Sehlstedt[3], Tomas Stark[1]
[1]SGAB, [2]ERGODATA AB, [3]MRM Konsult AB
[4]KTH
January 1992

TR 92-02
Sternö study site. Scope of activities and main results
Kaj Ahlbom[1], Jan-Erik Andersson[2], Rune Nordqvist[2], Christer Ljunggren[3], Sven Tirén[2], Clifford Voss[4]
[1]Conterra AB, [2]Geosigma AB, [3]Renco AB,
[4]U.S. Geological Survey
January 1992

TR 92-03
Numerical groundwater flow calculations at the Finnsjön study site – extended regional area
Björn Lindbom, Anders Boghammar
Kemakta Consultants Co, Stockholm
March 1992

TR 92-04
Low temperature creep of copper intended for nuclear waste containers
P J Henderson, J-O Österberg, B Ivarsson
Swedish Institute for Metals Research, Stockholm
March 1992

TR 92-05
Boyancy flow in fractured rock with a salt gradient in the groundwater – An initital study
Johan Claesson
Department of Building Physics, Lund University, Sweden
February 1992

TR 92-06
Characterization of nearfield rock – A basis for comparison of repository concepts
Roland Pusch, Harald Hökmark
Clay Technology AB and Lund University of Technology
December 1991

TR 92-07
Discrete fracture modelling of the Finnsjön rock mass: Phase 2
J E Geier, C-L Axelsson, L Hässler,
A Benabderrahmane
Golden Geosystem AB, Uppsala, Sweden
April 1992

TR 92-08
Statistical inference and comparison of stochastic models for the hydraulic conductivity at the Finnsjön site
Sven Norman
Starprog AB
April 1992

TR 92-09
Description of the transport mechanisms and pathways in the far field of a KBS-3 type repository
Mark Elert[1], Ivars Neretnieks[2], Nils Kjellbert[3],
Anders Ström[3]
[1]Kemakta Konsult AB
[2]Royal Institute of Technology
[3]Swedish Nuclear Fuel and Waste Management Co
April 1992

TR 92-10
Description of groundwater chemical data in the SKB database GEOTAB prior to 1990
'Sif Laurent[1], Stefan Magnusson[2],
Ann-Chatrin Nilsson[3]
[1]IVL, Stockholm
[2]Ergodata AB, Göteborg
[3]Dept. of Inorg. Chemistry, KTH, Stockholm
April 1992

TR 92-11
Numerical groundwter flow calculations at the Finnsjön study site – the influence of the regional gradient
Björn Lindbom, Anders Boghammar
Kemakta Consultants Co., Stockholm, Sweden
April 1992

TR 92-12
HYDRASTAR – a code for stochastic simulation of groundwater flow
Sven Norman
Abraxas Konsult
May 1992

TR 92-13
Radionuclide solubilities to be used in SKB 91
Jordi Bruno[1], Patrik Sellin[2]
[1]MBT, Barcelona Spain
[2]SKB, Stockholm, Sweden
June 1992

TR 92-14
Numerical calculations on heterogeneity of groundwater flow
Sven Follin
Department of Land and Water Resources,
Royal Institute of Technology
June 1992

TR 92-15
Kamlunge study site.
Scope of activities and main results
Kaj Ahlbom[1], Jan-Erik Andersson[2], Peter Andersson[2], Thomas Ittner[2], Christer Ljunggren[3], Sven Tirén[2]
[1] Conterra AB
[2] Geosigma AB
[3] Renco AB
May 1992

TR 92-16
Equipment for deployment of canisters with spent nuclear fuel and bentonite buffer in horisontal holes
Vesa Henttonen, Miko Suikki
JP-Engineering Oy, Raisio, Finland
June 1992

TR 92-17
The implication of fractal dimension in hydrogeology and rock mechanics. Version 1.1
W Dershowitz[1], K Redus[1], P Wallmann[1], P LaPointe[1], C-L Axelsson[2]
[1]Golder Associates Inc., Seattle, Washington, USA
[2] Golder Associates Geosystem AB, Uppsala, Sweden
February 1992

TR 92-18
Stochastic continuum simulation of mass arrival using a synthetic data set. The effect of hard and soft conditioning
Kung Chen Shan[1], Wen Xian Huan[1], Vladimir Cvetkovic[1], Anders Winberg[2]
[1] Royal Institute of Technology, Stockholm
[2] Conterra AB, Gothenburg
June 1992

TR 92-19
Partitioning and transmutation.
A review of the current state of the art
Mats Skålberg, Jan-Olov Liljenzin
Department of Nuclear Chemistry,
Chalmers University of Technology
August 1992

TR 92-20
SKB 91
Final disposal of spent nuclear fuel.
Importance of the bedrock for safety.
SKB
May 1992

TR 92-21
The Protogine Zone.
Geology and mobility during the last 1.5 Ga
Per-Gunnar Andréasson, Agnes Rodhe
September 1992

TR 92-22
Klipperås study site.
Scope of activities and main results
Kaj Ahlbom[1], Jan-Erik Andersson[2], Peter Andersson[2], Tomas Ittner[2], Christer Ljunggren[3], Sven Tirén[2]
[1]Conterra AB
[2]Geosigma AB
[3]Renco AB
September 1992

TR 92-23
Bedrock stability in Southeastern Sweden. Evidence from fracturing in the Ordovician limestones of Northern Öland
Alan Geoffrey Milnes[1], David G Gee[2]
[1]Geological and Environmental Assessments (GEA), Zürich, Switzerland
[2]Geologiska Institutionen, Lund, Sweden
September 1992