RINGHALS NUCLEAR POWER PLANT - REACTOR WASTE MANAGEMENT 50 REACTOR YEARS OF OPERATING EXPERIENCES AND FUTURE PROGRAM

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ABSTRACT

The various instruments needed to complete the Swedish Nuclear Waste Management Program have been developed and taken into operation step by step. The essential parts of the Management Program already operating are:

- The transportation system for spent fuel and nuclear waste;
- The Central Storage for Spents Fuel (CLAB);
- The final repository for reactor waste (SFR).

Due to this fact, it is now possible to calculate the costs for the total reactor waste management from the production at the power plant to the final disposal in the repository at Forsmark (SFR). The costs for Ringhals Nuclear Power Plant are presented in detail in this paper and amount to 21.8 million SEK (3.49 MUS $ with 1 US $ = 6.25 SEK) for the four reactor units.

The treatment systems for various waste streams will now be optimized based on site requirements and also for the transport and final repository. Plant performance indicators are used to follow up, e. g., the waste volumes and cost per year.

NUCLEAR POWER AND WASTE MANAGEMENT IN SWEDEN

In Sweden, electrical production from the first commercial nuclear power unit commenced in 1972. There are now 12 reactor units in operation at four sites. The last two units were connected to the grid in the fall of 1985. The location of the four sites and some data about the Swedish reactors are shown in Fig. 1.

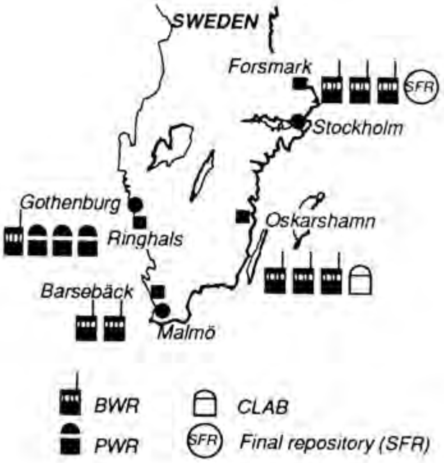
These 12 reactors produced in 1989 about 63 TWh of electricity with a total demand of 134 TWh in Sweden. The remaining 71 TWh are mainly covered by the hydroelectric power stations.

The total accumulated operating time for the reactor units in Sweden is about 140 reactor years and the operating records are very good. The Swedish parliament has, however, taken the decision that the nuclear power units shall be phased out not later than the year 2010, i.e., 20 years from now. Pending a parliamental decision, to be taken in 1990, the first two units may be shut down as early as 1995/1996. If all 12 reactors would be operated up to 2010, that would mean another 240 reactor years of operation. Independent of the parliamental decision, in 1990 the efforts in the waste management area will be given a continued high priority.

The producers of the wastes, in accordance with the Swedish law, have the primary responsibility for safe management and final disposal of the wastes. In order to achieve good coordination and efficiency in the waste management, the four Swedish nuclear power utilities have delegated the responsibilities to the jointly-owned Swedish Nuclear Fuel and Waste Management Co., SKB. This means that SKB is responsible for all measures required for the implementation of the national nuclear waste management program such as planning, design, construction and operation of waste facilities including the necessary R&D work. For financing of the waste management program, a special funding system has been established. The financing program is controlled by the authorities.

Essential parts of the Swedish nuclear waste management program are already in operation as can be seen in Fig. 2. The integrated sea transport system, ISTS, became operational in 1983, the central storage for spent fuel, CLAB, in 1985 and the final repository for low and intermediate reactor waste, in April 1988. The first phase of SFR has a capacity of about 60,000 m^3 of waste. The second phase is planned for an additional 30,000 m^3 reactor waste and the third for about 100,000 m^3 of decommissioning waste.

The Swedish Nuclear Fuel and Waste Management Company's main effort is now concentrated on the R&D program of the final repository for spent fuel. An important item in the geoscientific investigations is the planned Hard Rock Laboratory, HRL, in the neighborhood of Oskarshamn. In the HRL-facility, geological investigations will be performed at repository depth and site characterization methods are going to be tested. The construction li-



Reactor unit		MWe to the net	Commercial operation
Oskarshamn 1	BWR	440	1972
Oskarshamn 2	BWR	605	1974
Oskarshamn 2	BWR	1 140	1985
Barsebäck 1	BWR	600	1975
Barsebäck 2	BWR	600	1977
Ringhals 1	BWR	750	1976
Ringhals 2	PWR	840	1975
Ringhals 3	PWR	915	1980
Ringhals 4	PWR	915	1982
Forsmark 1	BWR	970	1980
Forsmark 2	BWR	970	1981
Forsmark 3	BWR	1 150	1985

Fig. 1. Main Data and Location of Swedish Nuclear Power Plants, CLAB and SFR.

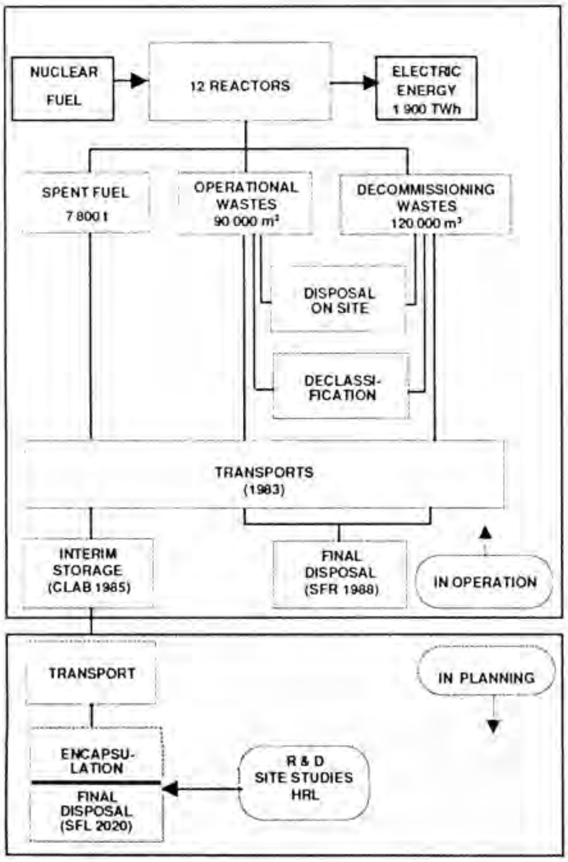


Fig. 2. Main Facilities in the Swedish Nuclear Waste Management System.

cense for the HRL is expected during 1990 and the construction work will then be completed in 1993.

RINGHALS NUCLEAR POWER PLANT

Ringhals nuclear power station with one BWR and three PWR units has accumulated about 50 reactor years of operation experience. The remaining operating time of at least 80 more years for the four units is obviously long enough to motivate improvements of the waste management and waste treatment system at the site in order to reduce waste volumes and costs.

REACTOR WASTE

General

Reactor wastes from the operation of NPP are normally defined as low-och intermediate level waste prior to the origin and the activity concentration. Spent fuel is not defined as reactor waste. Further, the reactor wastes have been divided into the following groups depending upon the origin and the properties:

- Waste from the treatment of radioactive waters, wet waste;
- Solid, combustible waste;
- Solid, non-combustible waste; and
- Other waste categories.

Wet Waste

Bead resins are used in both the BWR and PWR units for the treatment of contaminated primary reactor water, drainages from the components in the primary system and blow-down waters from the steam generators. Powder resins and filter aids are produced in the BWR-unit and the main sources are from the condensate polishing, waste water treatment and the fuel pool clean-up systems.

The treatments of the spent resins and filter aids are carried out a central waste treatment building, WTB. The waste slurries from the BWR-unit are transported to the WTB by pipelines. The spent resins from the PWR-units are transported in shielded flasks to the WTB.

The total gross weight of the transport flasks may not exceed 5,000 kg. The total gross weight limits the volume and amount of shielding.

At the WTB, spent resins and filter aids are solidified in cement. This is made by mixing the resin slurry with cement and additives directly in prefabricated, reinforced concrete containers with outer dimensions of 1,200 x 1,200 x 1,200 mm, and a wall thickness of 100 mm. The solidification volume is about 900 liters. The total volume of bead resins settled is about 450 liters and about 630 liters where powder resin slurry is processed. The solid contents in the powdered slurry are about 25%. On top of the container, a non-active concrete lid is cast.

During the last two years, steel containers with the same outer dimensions have been tested. The main advantage is the increase of net solidification volume from 900 to 1,500 liters. The surface dose rate will, however, increase to 60 - 100 mSv/h due to the decrease in wall thickness. The objective is to replace the concrete containers with this new container for all types of waste. The Swedish Nuclear Inspectorate is now considering an application from Ringhals NPP. The new type of containers will reduce the waste volume in the final repository by about 50% each year.

In the PWR units, filter cartridges are installed for mechanical filtration of process and waste water. The total number of installed filter cartridges in a PWR is about 25. The spent radioactive filter cartridges are placed in specially prepared concrete containers. The filter cartridges are sealed in the container by pouring concrete on it, as a lid.

The total volume of waste water released from the four units in 1988 amounted to about 240,000 m^3. This water is released into the cooling water outlet tunnels at the station.

Solid Combustible and Non-Combustible Waste

Low-level solid waste produced at the power plant is characterized by its relatively large volume before treatment and its low activity contents. It consists of trash, metal pieces, small components, insulating materials, etc. from controlled areas of the plant and it is mainly produced during the overhaul and maintenance periods.

The waste is sorted into two categories: Combustible and non-combustible waste. It is collected in plastic bags already at the source. At Oskarshamn and Forsmark, where a shallow land repository is used for this type of waste, the sorting is based on compressibility, dose rate and specific activity. All bags accepted for shallow land burial are compacted into bales before burial. A similar reactor site repository for this type of waste is planned at Ringhals NPP.

For handling and transportation of low level solid waste from the four units and the Central Active Workshop, CAW, special containers and transport vehicles are used.

Combustible wastes with a specified activity limit and containing no metal parts are transported to Studsvik for incineration until a license is granted for a shallow land disposal site at Ringhals. The incineration at Studsvik is made in an excess-air shaft-type furnace with an offgas system including a cooler and bag filter-units. The ashes from the incinerator are collected in 100 liter drums, which are then encapsulated into concrete shielded 220 liter drums.

Non-combustible compactable waste is normally compacted in 220 liter steel drums. Metallic scrap and active components are normally put into steel containers without any further treatment. With the shallow land disposal site in operation, the main part will be compacted, sealed and deposited on site.

Other Waste Categories

Contaminated oils are treated by filtration and centrifugation, thus, separating the oil from active particles and water. After that, the oil can be burned if the specific activity is below 5,000 Bq/kg, which is normally the case.

Up till now a limited amount of waste from the decontamination activities has been produced. Normally, this type of waste has been treated by precipitation. The sludge is then dewatered by centrifugation, filled into steel containers and solidified with cement.

Sludges from tanks, pump sumps, etc. are collected in a special shielded container and transported to the WTB for solidification.

Large components, e. g., two-feed water heaters weighing 70 tons each, have been transported to Studsvik for melting in their induction furnace. Melting of contaminated material will probably be used even more in the future in order to reduce waste volumes and, if possible, enable the release of material for unrestricted use.

INTERMEDIATE STORAGE AND TRANSPORT ON REACTOR SITE

A storage building with 700 mm thick concrete walls is used for intermediate storage of treated waste. The waste containers are transported on an underground conveyor system from the waste treatment building to the storage building. In the storage building, the waste containers will be handled with an overhead crane and also with a shielded fork lift truck in the storage area of the building. The storage building has a storage capacity of about 5,000 containers and 1,800 drums in a separate section of the building. In 1987, an extension was built for the filling of the SFR-transport containers to the final repository.

CENTRAL FINAL REPOSITORY AND TRANSPORTATION SYSTEM FOR REACTOR WASTE

A geological repository for the final disposal of reactor waste, called SFR, has been in operation since April 1988. The repository is located near the Forsmark NPP on the east coast of Sweden. Rock caverns are excavated in crystalline rock 60 m under the sea and 1,000 m from the Forsmark harbor.

Different types of storage rooms are needed for the various kinds of waste. The waste with the highest activity contents, mainly solidified ion-exchange resins from primary reactor water treatment, will be stored in a silo repository. Other less active wastes are stored in caverns with no barriers other than the surrounding rock and the waste package itself.

The Silo Repository

The handling of waste packages in the silo is fully remote. A special vehicle brings the waste in a shielded container to an unloading position. The lid of the container is removed by an overhead crane, and the waste packages are unloaded with a handling machine for transportation to the shafts in the concrete silo.

The Rock Caverns

For the less active waste, rock caverns will be used. All rock caverns have a length of 160 m and a width of 14 to 18 m. Two of the rock caverns, called BTF, will be used for storage of dewatered powder resins in concrete tanks from Oskarshamn and Barseback. These tanks will be stored in two layers and with four tanks in latitudinal direction. The third cavern (BLA) is designed for low level waste and will mainly accommodate standard 20 feet freight containers. These freight containers are handled with the same fork lift truck as the concrete tanks.

The fourth rock cavern (BMA) is designed to accommodate intermediate level waste which requires shielding during the transport and disposal. These packages are transported and handled in the same way in the silo. The cavern is divided into sections with concrete walls and an overhead crane is used for handling of the waste packages.

The cost in SFR depends on which type of repository is required due to the dose rate of the waste package and activity contents. The following types of repositories are available to the specified cost for effective waste volume. These costs refer to the April 1984 price level and include costs for all investments, operation and a closure of the repository.

Silo - 14,500 SEK/m^3 BTF - 9,700 SEK/m^3
BMA - 12,100 SEK/m^3 BLA - 8,000 SEK/m^3

The transportation of conditioned waste as well as spent fuel from the reactor sites will be performed with the specially built ship M/S Sigyn. The reactor waste from Forsmark NPP will of course be transported by road to the repository. The transportation capacity of the M/S Sigyn is ten radiation-shielded containers for reactor waste and additionally five freight containers with low level waste.

For the transport of reactor waste to SFR, the waste producers will pay a total of 2.5 MSEK/year for operating costs of the M/S Sigyn, an investment of 20 MSEK over 20 years for SFR-waste transport containers (ATB) and a yearly maintenance cost of 0.1 MSEK. The above-mentioned costs for waste transport, 3.6 MSEK yearly, are distributed between the waste producers with the same relations as for transport of spent fuel to CLAB. Ringhals NPP will therefore pay 34% of the total cost or 1,224 kSEK.

COSTS FOR REACTOR WASTE

Costs for Wet Waste

Table I shows the cost in kSEK for comsumable materials such as resins, filter cartridges, concrete molds, etc. Column Q in the table is the consumption of bead resins in m^3 and powder resins in dry weight tons. The number of molds (containers) produced from various waste streams are also shown as well as the transport and final repository cost.

Cost for Dry Combustible Waste

The total volume of dry combustible waste produced in 1989 amounted to about 600 m^3 with a weight of 60 tons. About 360 m^3 has been incinerated at Studsvik and 240 m^3 is stored at the site while waiting for permission to build a shallow land repository. If all the dry combustible waste

TABLE I

Cost for Waste from the Treatment of Radioactive Water

Consumables	R1 Q	R1 KSEK	R2 Q	R2 KSEK	R3 Q	R3 KSEK	R4 Q	R4 KSEK
Primary water Clean-up systems:								
– bead resins	1.3	34	3.1	169	3.1	268	2.8	260
Liquid radwaste systems:								
– bead resins	2.4	65	-	-	0.9	24	0.9	24
– powder resins	1.3	91	-	-	-	-	-	-
– filter aid	0.7	8	-	-	-	-	-	-
Secondary systems:								
– powder resins	7.2	550	4.6	385	3.8	320	4.0	336
– bead resins	-	-	12	336	4	112	10	280
Fuel pool clean-up								
– powder resins	0.2	15	-	-	-	-	-	-
– bead resins	-	-	0.9	24	0.9	24	-	-
Total, bead resins	3.7	99	16.0	529	8.9	428	13.7	564
Total, powder resins and filter aid	9.4	664	4.6	385	3.8	320	4.0	336
Filter cartridges		297		90		90		90
Water cost for back-flashing and regeneration		87		25		25		25
Cost for resins etc		1 147		1 029		863		1 015
No and costs for moulds incl. cement, chemicals etc.	No		No		No		No	
– bead resins	5	41	21	172	9	74	21	172
– powder resins	62	508	-		-		-	
– filter cartridges	–		2	20	1	10	1	10
– sludges, etc.	2	20	5	50	2	20	1	10
	69	569	28	242	12	104	23	192

Summary of cost for wet waste	R1	R2	R3	R4
– Consumables	1 716	1 271	967	1 207
– Transport	545	244	111	222
– Repository	1 463	674	288	569
Total in kSEK	3 724	2 189	1 366	1 998

would have been incinerated at Studsvik, it would have resulted in production of about 100 drums with ashes and an estimated cost for incineration and transport of about 3,500 kSEK.

The cost for the dry waste is distributed between the four units in relation to waste produced as follows: R1 - 29.6%, R2 - 34,0%, R3 - 17.1% and R4 - 19.3%. The high value for unit 2 is due to the steam generator replacement work during the summer of 1989. Table II shows the cost in kSEK for incineration of the combustible waste, number of drums with ashes and repository cost for these drums.

Cost for Non-Combustible Waste

This type of waste is compacted, if possible, in drums or steel boxes. If shielding is not required for the transportation, these drums and boxes are placed in 20' half freight containers (FC) and will be deposited in the rock cavern for Low Level Waste, BLA. Material needing shielding has to be transported in SFR-containers for deposited in the rock cavern for Intermediate Level Waste, BMA.

Totally, 57 drums were produced during 1989 and 74 boxes with a volume of 2.5 m3 each. Eight boxes can be placed in one 20' standard freight container with an outer volume of 38 m3. Table III shows the costs for drums, boxes and containers required for package of the waste for transport to the final repository and the repository costs.

Repository Cost

Table IV shows the repository costs for each reactor unit and for each type of repository used.

Personnel Cost for Waste Handling

The personnel cost of about 5,400 kSEK is distributed to each unit according to their production capacity.

Cost for Transport to SFR

The total cost for transport of conditioned wet waste and dry waste is 1,224 kSEK. This cost is shared between the four units in relation to the number of waste units requiring shielded transport containers for the transport to SFR.

SUMMARY

Table V shows a cost summary for each waste group and per reactor unit. The total cost for reactor waste during 1989 amounts to 21.8 million SEK (3.49 MUS $ with 1 US $ = 6.25 SEK) for the four reactor units.

The existing routines and treatment systems are now

TABLE II
Cost for Combustible Waste

Unit	Incineration	No of drums	Repository
R1	1 037	29.6	92
R2	1 189	34.0	106
R3	597	17.1	53
R4	677	19.3	59
Total in kSEK	3 500		310

TABLE III
Costs for Non-Combustible Waste

Unit	Cost for drums, boxes and FC	m^3 in BLA	m^3 in BMA	Repository
R1	50	104	5.4	897
R2	57	119	6.2	1 027
R3	29	60	3.1	518
R4	32	68	3.5	586
Total in kSEK	168			3 028

TABLE IV
Repository Costs per Reactor Unit

	R1	R2	R3	R4
Silo	125	527	226	527
BMA	1 405	222	100	84
BTF	92	106	53	59
BLA	832	952	480	544
Total in kSEK	2 452	1 807	859	1 214

TABLE V
Cost Summary

	R1	R2	R3	R4	Total
Cost for wet waste, comsumables	1 716	1 271	967	1 207	5 161
Cost for combustible waste	1 037	1 189	597	667	3 500
Cost for non-combustible waste	50	57	29	32	168
SFR disposal cost	2 452	1 807	859	1 214	6 332
Cost for transport to SFR	575	279	128	242	1 224
Personnel cost	1 184	1 326	1 445	1 445	5 400
Total in kSEK	7 014	5 929	4 025	4 817	21 785

followed up by various plant performance indicators. Some changes in the treatment of the waste streams are already in the planning stage, e.g., implementing a reactor site repository for low level waste instead of incineration. The work in progress to replace the concrete containers with steel containers will mean a significant reduction in waste volumes and costs. The treatment systems for ion exchange resins will also be optimized based on the requirement for waste products to SFR. Special waste management education and instructions will be given to our own operation and maintenance personnel as well as contractors, in order to minimize the waste volumes produced, especially during the maintenance periods.