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PRACTICES AND DEVELOPMENTS IN THE MANAGEMENT OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE IN SWEDEN

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ABSTRACT

In the Swedish nuclear power program ten reactors are in operation and two more under construction. About 100 000 m^3 of low and intermediate level radioactive waste will be produced from the operation of these reactors until the year 2010 and about 150 000 m^3 from their decommissioning. All burnable radioactive wastes are sent to the Studsvik incineration plant for incineration. Spent resins are incorporated into cement or bitumen. The volume of non-combustible solid waste is reduced by compaction where possible.

At the Studsvik research centre a substantial program for improved management of accumulated and future radioactive waste is at the beginning of its implementation. This includes advanced treatment and intermediate storage in a rock cavity. An R&D program on volume reduction of spent resins has reached the point of process verification and equipment design.

All low and intermediate radioactive waste will be disposed in a rock cavity planned for commissioning by 1988. The paper reviews actual management experience and development efforts for low and intermediate level radioactive waste in Sweden.

Contribution to the Seminar on the Management of Radioactive Waste, Taipei, Taiwan, 25-26 June, 1983.

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SUMMARY

The Swedish nuclear power programme as approved by Parliament in 1980 includes 12 power reactors of in total 9 500 MWE. Of these reactors 10 are in operation and 2 under construction, for commissioning in 1985. Since the start-up of the first unit in 1972 an experience of 50 reactor-years has been gathered and 9 000 m^3 of low and intermediate level operating radioactive wastes in their conditioned final form have been produced.

The wastes from reactor operation may be divided into 4 categories:

- spent resins (and sludges)
- non-combustible solid waste
- combustible solid waste
- other low and intermediate level waste.

The spent resins are immobilised in concrete or in bitumen or, for the most low-active resins, just drained and stored in concrete tanks. With these techniques they will constitute about 70% of all low and intermediate level operating wastes from nuclear power sent to disposal.

The combustible waste has up to now been sent to a central plant at Studsvik for incineration. It is foreseen, however, that licensing of shallow land burial will decrease the future volume of waste sent to incineration.

Non-combustible, solid waste is compacted where possible and plants for segregation-compaction have been commissioned. Volume reduction factors are of the order of 3-4.

An underground facility for the storage of spent nuclear fuel (CLAB) is under construction and planned for commissioning in 1985. A repository for all low and intermediate level waste (SFR) has been planned with commissioning of its first stage in 1988. A construction license application, based on a preliminary safety report, was approved in April 1983.

At the Studsvik research centre a project is underway (AMOS) to construct new treatment plants for liquid and solid wastes. An intermediate storage facility for conditioned wastes will be constructed in a rock cavity on-site.

STUDSVIK is continously engaged by the nuclear utilities and the authorities in improvement on current waste management technology and operations. Based on internal funding also a new process has been developed for the treatment of spent resins (ATOS), yielding a stable inorganic waste product of low volume. The process has been verified on laboratory scale and partly tested with good results in the large scale incineration plant.

1. INTRODUCTION

1.1 The Swedish nuclear power programme

The Swedish nuclear power programme as approved by Parliament in 1980 includes 12 power reactors of in total 9500 MWe (table 1). They are located on

Name	Type	Power/MW	In operation
Oskarshamn 1	BWR	440	1972
Oskarshamn 2	BWR	580	1974
Barsebäck 1	BWR	580	1975
Ringhals 2	PWR	820	1975
Ringhals 1	BWR	760	1976
Barsebäck 2	BWR	580	1977
Forsmark 1	BWR	900	1980
Ringhals 3	PWR	915	1980
Forsmark 2	BWR	900	1981
Ringhals 4	PWR	915	1982
Oskarshamn 3	BWR	1050	1985
Forsmark 3	BWR	1050	1985

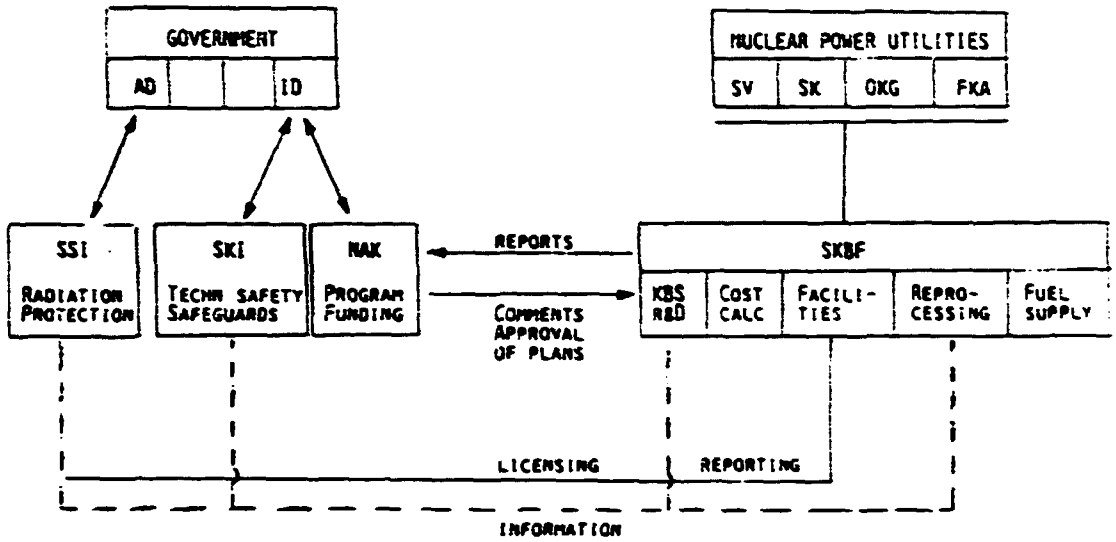
Table 1 The Swedish nuclear power program.

4 sites: Barsebeck (2 BWRs), Oskarshamn (3 BWRs), Ringhals (1 BWR, 3 PWRs) and Forsmark (3 BWRs). The first unit, O 1, started operation in 1972. During 1983 10 reactors are in operation. The last two, O 3 and F 3, are scheduled for commissioning in 1985 -86.

An underground facility for the central storage of 3000 tonnes of spent nuclear fuel (CLAB) is under construction and planned for commissioning in 1985. This facility will contribute to the generation of low and intermediate level waste in Sweden. A repository for low and intermediate level waste from the operation and decommissioning of nuclear facilities has been planned for commissioning of its first stage in 1988. A construction licence application was approved by the Nuclear Power Inspectorate (SKI) in April, 1983.

The 4 nuclear power utilities have formed the Swedish Nuclear Fuel Supply Co (SKBF), which is in charge of the supply of front end and back end services of the nuclear fuel cycle. The dominating part of the R&D in the waste field is financed and sponsored by the SKBF. The utilities are required by law to pay each year to a fund for all future costs for the back end of the nuclear fuel cycle and may then borrow back money from this fund, for the establishment of facilities and for financing R&D, under the supervision of the Board for Spent Nuclear Fuel (NAK). This supervisory responsibility of the NAK is limited, however, to spent nuclear fuel, wastes from reprocessing and wastes from the decommissioning of nuclear facilities, and does not include wastes from the operation of nuclear power plants (1). The relationships between utilities, authorities and Government is illustrated in figure 1.

It is foreseen that a new Act, the Nuclear Technological Activity Act, will replace several of the present Acts which regulate responsibilities in the nuclear field, and be operative from 1 January 1984.



AD = Department oc Agriculture
ID = Department of Industry
SSI = National Institute of Radiation Protection
SKI = Nuclear Power Inspectorate
NAK = Board for Spent Nuclear Fuel
SKBF = Nuclear Fuel Supply Company

Figure 1 Relations between utilities, authorities and Government in Sweden

1.2 Studsvik Energiteknik AB

Studsvik Energiteknik AB (STUDSVIK) is a stock holding company wholly owned by the Government represented by the Ministry of Industry. Of its 880 employees about 350 are engaged in nuclear research and development in the Nuclear Division. The Waste Technology Department has about 110 people.

Besides the management of radioactive wastes from its own operations, STUDSVIK receives low level wastes from nuclear power stations and hospitals, institutions etc, for incineration and solidification. Laboratory scale research &

development and investigations are performed for domestic and foreign utilities and authorities, as well as decontamination of components and systems, design/construction of waste treatment facilities and systems, and analyses related to safety and environmental consequences of nuclear activities.

2. WASTE MANAGEMENT PRACTICES

2.1 Background

The forecasts of waste production from the total Swedish nuclear programme is based on 300 reactor-years or 250 GWe-years. The total requirements for the operation of such a system is illustrated in figure 2. The total generation of reactor wastes will be of the order of 100 000 m^3 and from the ultimate decommissioning 150 000 m^3.

The low and intermediate level wastes from reactor operation may be divided into 4 categories:

- spent resins
- non-combustible, solid waste
- combustible, solid waste
- other radioactive waste.

2.2 Spent resins

Regeneration of spent resins is not a common practice in Sweden, and the arising of evaporator concentrates is thus very limited.

The total annual arisings of spent resins from the 12 reactors and the CLAB facility have been estimated (2) to 180 m^3 of medium level activity resins (50% dry weight) and 700 m^3 low level resins (15% dry weight). The specific arisings of spent resins in bead or powder form from Swedish BWRs and PWRs are given in table 2 and typical concentrations of Co-60 and Cs-137 in table 3.

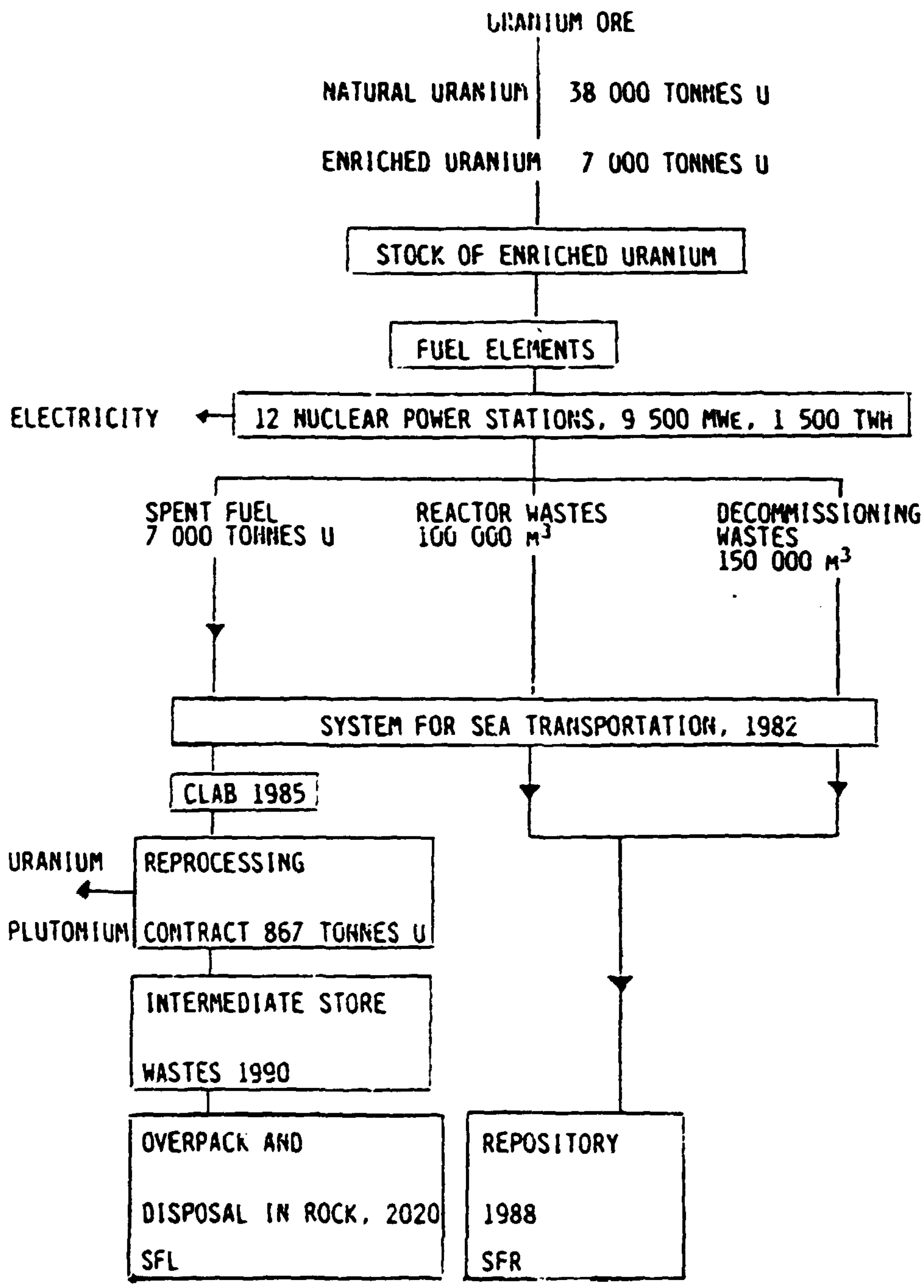


Figure 2 The Swedish nuclear fuel cycle

Resin type		Source	m^3/year
BWR			
	bead resins	- reactor water clean-up system	10-20
		- rad waste system	5-10
	powder resins	- condensate clean-up	50-100
		- pool water clean-up	2-6
PWR			
	bead resins	- primary system	5-10
		- secondary system	10-15

TABLE 2 Annual production of spent resins of different types in a BWR and a PWR from different sources.

Resin type	Typical activity contents			
	Co-60		Cs-137	
	GBq/m^3	(Ci/m^3)	GBq/m^3	(Ci/m^3)
Bead resins				
BWR	370	(10)	740	(20)
PWR	370	(10)	1 850	(50)
Powder resins				
BWR	11	(0.3)	6	(0.15)

TABLE 3 Typical concentrations of Co-60 and Cs-137 in spent resins from BWR and PWR operation.

Two different techniques for the solidification of spent resins are in use in Sweden:

- cementation at Oskarshamn and Ringhals,
- bituminisation at Barsebeck and Forsmark.

Cementation

The low level powder resins and filter material at Oskarshamn, mainly from the condensate clean-up system, is not solidified but drained in movable concrete tanks of 6 m^3 inner volume with filter cartridges at the bottom.

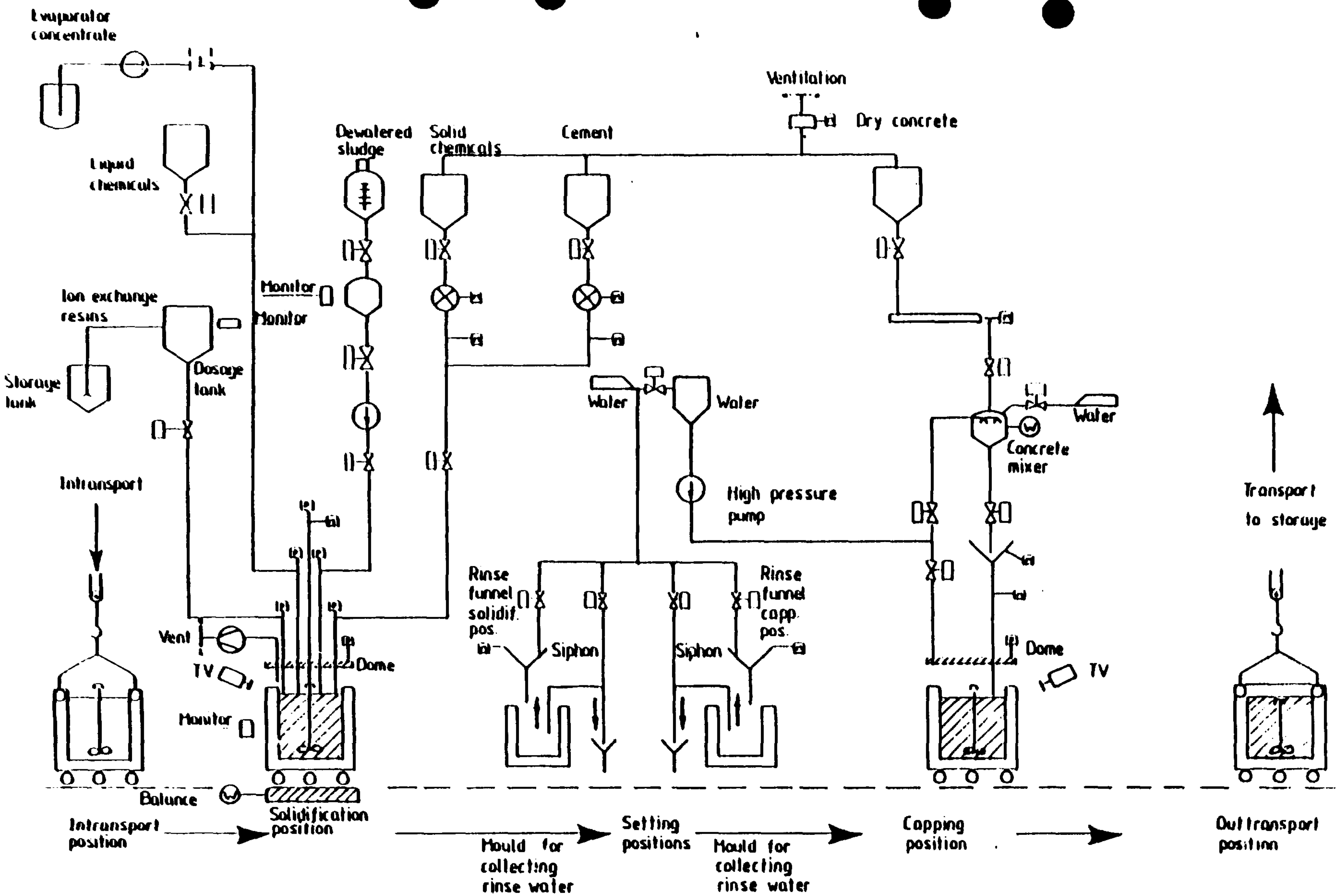


Figure 3 ASEA–ATOM – RINGHALS CONCRETE SOLIDIFICATION SYSTEM

The cementation process used at Ringhals is illustrated in Figure 3. The spent resins are metered into prefabricated concrete moulds (1.2x1.2x1.2 m) and mixed with additives before the addition and mixing with cement. The mixer is left in the filled-up mould, and after two days of curing a lid of concrete is poured on top of the mould.

Until 1982 about 2000 moulds had been produced at Ringhals and about 1300 moulds at Oskarshamn.

Bituminisation

The bituminisation plants at Barsebeck and Forsmark are of different types.

A flowsheet for the Barsebeck plant is shown in Figure 4. Bead resins are ground to powder in a wet grinder before transfer to the feed tank. The bitumen, Mexphalte 40/50, is stored at 120°C. The resin slurry is heated to 60°C and mixed with sodium sulphate and emulsifying agent before feeding with bitumen to a thin film evaporator, heated by 230°C oil to a bitumen product temperature of 160°C. The product drums are filled in two stages: after filling to 70% the drum is left to cool for at least 12 hours before filling is completed. The process is run batchwise during four-day periods.

Operating experience has been presented (3). While the evaporator has proved reliable and easy to operate a number of modifications of equipment and procedure were necessary. Over the last 3 years operation has run smoothly, however. By 1 January 1983 1049 drums of bituminised powder resin were produced since the commissioning in 1975, at the 15-20% resin level.

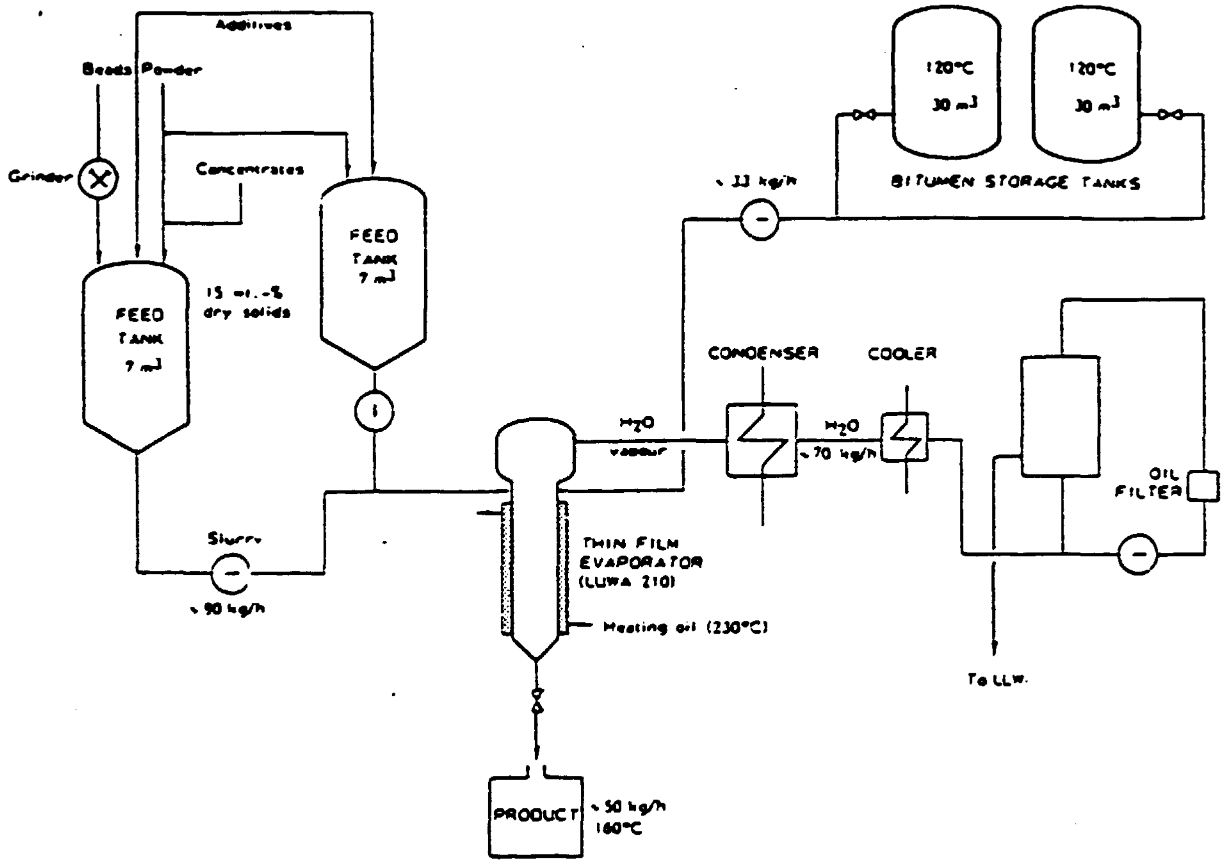


Figure 4 Bituminisation of spent resins at the Barsebeck nuclear power plant.

At Forsmark the bituminisation plant for spent resins from the reactors F1 and F2 includes the following main components:

- waste feed system
- rotary drum dryer
- mixing tank
- drum filling system.

The original process design included a milling step for bead resins. However, due to licensing problems for the rotary dryer no bead resins have been bituminised in this plant. Since active start-up in October 1981 about 800 drums of bituminised powder resins have been successfully produced at the 40% resin level, however.

2.3 Non-combustible solid waste

The annual production of non-combustible solid waste (NCSW) from one BWR-unit is around 80 m^3 per year containing 0.05 TBq. Arisings of spent core components have been estimated at about 10 m^3 per year containing 4000 TBq (4).

The core components of high induced activity are presently stored in the fuel pools on-site. It is foreseen to solidify these wastes into concrete at a later stage (5).

At the Forsmark plant a compaction system for NCSW, designed and delivered by STUDSVIK, was installed in 1980. The waste is collected, examined, sorted and compacted in 400 liter aluminium boxes in a vertical press. A large variety of low level NCSW has been compacted, such as mineral wool insulation, metal waste, cables, gypsum plates etc. The waste volume is reduced in this plant by a factor of 3-4.

2.4 Combustible, solid waste

Some 20-30 tonnes per year of miscellaneous low level radioactive waste is produced at each plant, such as plastic, cloth, wood, paper, rubber etc. Similar radioactive waste of non-nuclear origin arises at hospitals, research establishments, universities, and industry (6).

Since 1976, the major part of such waste has been incinerated in the STUDSVIK incinerator. After a steady increase about 300 tonnes of waste were incinerated in this plant in 1981 and 314 tonnes in 1982. In 1979 two bag filter units were installed in the system. Surface dose rates up to 0.1 mSv/h are allowed for wastes as-received, while 10% of the waste may have a surface dose rate up to 1 mSv/h. The release limits are

- 6 GBq/y unspecified β/γ activity
- 5.5 TBq/y tritium activity.

Actual releases are of the order of a few percent of these limits.

The ashes from the incineration have been up to now collected in 100 liter drums, which are in turn put into 200 liter drums with concrete poured around and on top. However, a homogeneous incorporation of the ashes into concrete is under development and will be applied at a later stage.

2.5 Other low and intermediate level waste

Odd, voluminous wastes which cannot be put in any of the preceding categories, is packed in containers. It has been estimated to account for about 5% of total operating waste volumes.

2.6 Waste transportation and disposal

One main condition for the disposal of radioactive waste in Sweden, is that sea dumping is prohibited by Swedish law, since 1 January 1972. Also shallow land burial has not been permitted until recently, when the National Institute of Radiation Protection took a principle decision to consider on-site burial of certain low level radioactive wastes, to be licensed from case to case. Parts of the waste from the decommissioning of the R 1 research reactor will thus be disposed at Studsvik. It is also foreseen that some of the burnable wastes from the nuclear power stations may be more economically buried on-site rather then incinerated at Studsvik.

As mentioned earlier a repository for low and intermediate level waste has been planned for commissioning in 1988. A construction licence was applied for in March 1982 and approved by the Nuclear Power Inspectorate (SKI) in April 1983. The repository (SFR, Swedish acronym for final store for reactor waste) is located 1 kilometer from the shore at the Forsmark nuclear power station, under the sea bottom with 5 meter of water and 50 meter of rock on top of the repository. The design of the underground part is shown in figure 5.

The vertical silos (A), of 26 m diameter and 51 m height, are surrounded by a 1.3 m thick clay barrier. The silos will receive spent resins solidified in concrete and in bitumen.

The small tunnels (B) will receive concrete containers with drained low level resins. Larger tunnels will be used for the disposal of medium level waste in drums (C) and for low level waste in standard containers (D).

One condition in the licence issued by the SKI stipulates that only limited quantities of bituminised resins be disposed in the SFR. The reason for this is that the authority was not convinced swelling of the resins after up-take of water could not endanger the stability of the

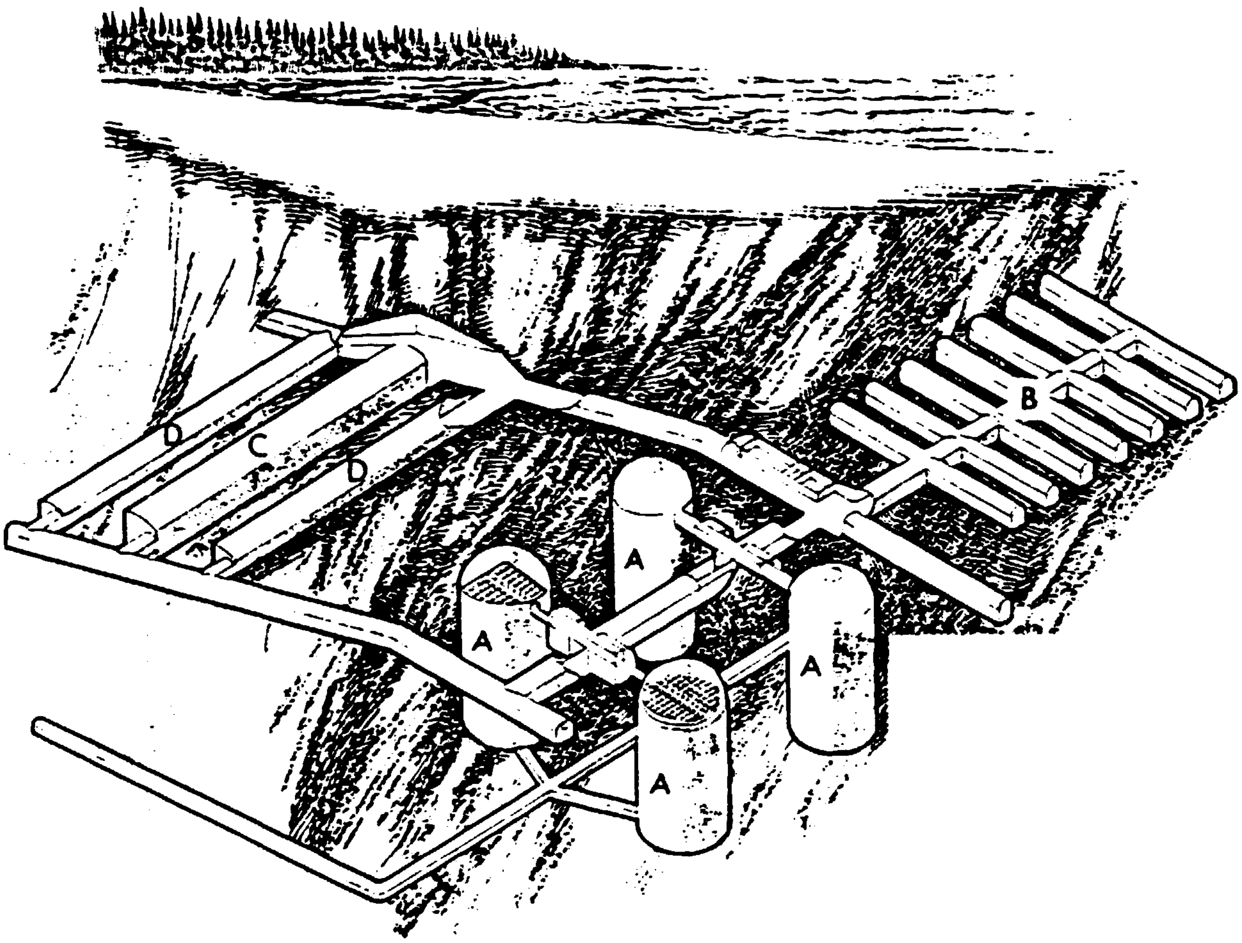


Figure 5 Design of the SFR underground facility

A silos for solidified resins
B small tunnels for concrete tanks with drained resins
C large tunnel for medium level waste
D large tunnels for low level waste

silo construction. It therefore now seems likely that at least one nuclear power station will cease to bituminise spent resins and look for other alternatives.

It should be noted that in the present planning for the SFR, the spent resins in final solidified form will occupy about 70% of the disposal volume of the repository.

A sea transportation system for both spent nuclear fuel and reactor wastes is in operation since the end of 1982. The m/s Sigyn, of 2000 tonnes deadweight constructed for ro-ro operation, can take 1100 tonnes payload. Conditioned wastes are stored in on-site facilities until transportation of low and intermediate level wastes by this ship starts at the end of the 1980's.

3. DEVELOPMENTS

3.1 Spent resins

An alternative route for the treatment of spent resins was developed in Sweden during the 70's. Known as the PILO process it was based on the idea to transfer long-lived activity of significance, mainly Cs-137 and Sr-90, from the resins to inorganic ion exchangers (zeolites and titanates) that can be sintered to stable end products. The development work behind the PILO process has been published (8) as well as a conceptual system study (2).

The advantage of this process is the volume reduction of the most hazardous nuclides in a stable matrix. The disadvantages are the arisings of secondary wastes and features such as the fairly complicated loading - unloading of active materials in columns, where only bead resins can be handled. Combined with a central incineration of all low level resins including eluted PILO resins potential cost savings of the order of 100 MSEK were found for the total Swedish programme.

A simplified process with greater over-all volume reduction potential is now under development at Studsvik Energiteknik AB. It has been named the ATOS process, from Activity Transfer from Organic resins to inorganic Stable solids.

In the ATOS process the spent resins, beads or powder, are mixed simultaneously with an eluting agent and an inorganic sorbent. The slurry is dried and incinerated - calcined under controlled conditions. The incineration residue is e.g.

sintered or melted with additives to a stable end product, suitable for disposal.

One main problem in the incineration of radioactive waste is the volatility of cesium. The cesium retention capability of the incineration stage of the ATOS process in laboratory scale was demonstrated to exceed 99.9%, while mixing-in of 5 kg pre-treated resin batches in medical waste incinerated in the Studsvik large scale incineration plant showed a Cs-137 release on the ppm level. The release of Co-60 was of the same order of magnitude.

The present work includes equipment design and testing on the kg/h scale in the laboratory. A prestudy of a pilot plant at Studsvik has been performed for cost calculations.

3.2 The AMOS project

The facilities for the treatment of liquid and solid wastes at Studsvik were commissioned around 1960. They have been completed later with an on-ground storage facility for drummed wastes and with the incineration facility.

A project is now underway to establish a complete waste treatment/intermediate storage system at Studsvik - the AMOS project. The aim of the AMOS project is to provide improved or extended facilities for the following purposes:

- conditioning of liquid waste from laboratory operations
- treatment of intermediate level liquid waste
- immobilization of wet waste: spent resins, sludges, evaporates

- conditioning of intermediate level solid waste to a form adequate for intermediate storage, transport and disposal
- intermediate storage in a rock facility at Studsvik for later transport to a repository (SFR or other)
- waste transport by the establishment of a harbour facility.

Preliminary safety reports for conditioning plants and the storage and harbour facilities were submitted to the authority in December 1982 and January 1983. Successive commissioning of the different new facilities is foreseen during the years 1984-1986.

3.3 Related projects

A computerized register of radioactive waste inventories was initiated by the Swedish Nuclear Power Inspectorate during 1979. Waste is recorded at the time it has received its final form for storage. Numerical modes have been worked out for different categories of waste and containers and for different modes of conditioning. Information recorded includes also volumes, weights, activity contents, dose rates and the date of conditioning, transfer, activity monitoring and dose rate estimations.

For process waste (spent resins etc), activity is monitored by gamma spectrometry. From this analysis a number of nuclides are recorded, mainly Co-60, Zn-65, Cs-134, Cs-137, Mn-54, Co-58, Zr-95, Nb-95 and Ag-110m. Amounts of Sr-90 and eventual actinides, such as U-238, Pu-239 and Cm-242, are recorded annually, based on radiochemical analysis and alpha spectrometry.

A detailed print-out of all the actual waste data is readily available with this type of register to support management decisions in the case of abnormal events.

A project initiated by the Swedish Nuclear Power Inspectorate is underway to identify safety related properties of all types of reactor waste. The result will be used in the process of defining quality requirements for various categories of waste and for the introduction of quality control programmes. A progress report on this project was presented at the IAEA waste symposium in Seattle, USA, in May 1983 (9).

4. CONCLUSION

A system for the integrated management of low and intermediate level waste in Sweden will be complete with the disposal stage in operation by 1988. The treatment and interim storage stages have been in operation since many years. From the operating safety point of view the present treatment practices are considered adequate with some adaptation necessary to disposal safety requirements. Quality control programmes in progress will assure overall safety in the future. Considerable economic incentives still exist, however, to reduce waste volumes, primarily for spent resin wastes.

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