A Decade of Successful Domestic Sea Transports of Radioactive Waste in Sweden 1982-1992

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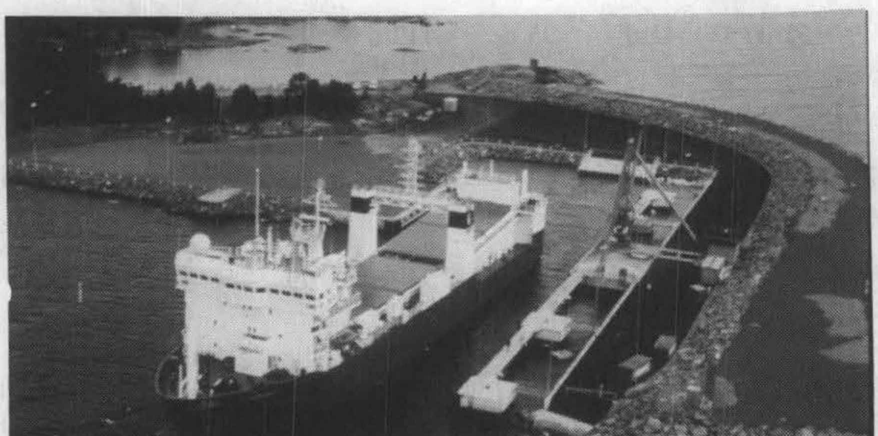
INTRODUCTION

In november 1982 the purpose built ship M/S Sigyn was launched at a shipyard in France.This occasion was the starting point for a successful decade of transports of spent fuel and radiative waste in Sweden. Up to now (september 1992) 9792 m3 of reactor waste has been transported to the final repository for low and intermediate level waste , SFR, and 1600 tonnes of spent fuel to the intermediate storage facility for spent fuel, CLAB. The transports have been performed using a sea transportation system where the ship M/S Sigyn is an important and the most well known part.



M/S Sigyn

During an average year about 250 tonnes of spent fuel and 2-3000 m3 of reactor waste are transported to CLAB and SFR respectively , corresponding to around 30 sea voyages with the ship.

THE TRANSPORTATION SYSTEM

M/S SIGYN

The ship M/S Sigyn is specially designed for shipments of spent nuclear fuel and radioactive waste. It is a combined roll-on/ roll-off and lift-on/lift-off vessel with a double bottom and a double hull, built for unrestricted ocean service. M/S Sigyn can carry either 10 transport casks for spent fuel or 10 shielded steel containers for reactor waste or a combination of these on each trip. For the purpose of radiation shielding the cargo hold is surrounded by a large water tank in the front and concrete walls on the sides. The communication systems enable the transport centre on shore to determine the ship's position at sea at any time.

M/S Sigyn was taken into operation in 1983. For a limited period of time she was used for transporting spent fuel from Sweden to France for reprocessing. Since 1985, when CLAB was taken into operation, the ship is used for domestic transports only. One exception was the transportation of spent MOX fuel from Germany to Sweden between 1987 and 1988. These transports emanated from of a swap agreement between Sweden, Germany and France. Table 1 shows how the ship has been utilized during the period 1985 - 1991.

Table 1 Utilization of M/S Sigyn

	1985	1986	1987	1988	1989	1990	1991
Time at sea	52 d	41 d	95 d	112 d	97 d	123 d	78 d
Maintenance	-	26 d	4 d	-	12 d	-	5 d
Sailed distance	13499'	10776'	24764'	30127'	26015'	33388'	20352'
Number of departures	64	46	90	94	99	120	89

M/S Sigyn is owned by SKB and since 1985 operated by the Swedish shipping company, Rederiaktiebolag Gotland. The crew of 2 x 12 persons has mainly stayed with the ship from the start, which means that they have gained considerable experience of the ship and the special harbours at the nuclear power plants.

The performance of the ship has been excellent. It is large enough for the transport volume required. The handling and lashing operations of the waste containers and transport casks on board the ship are fast and efficient which reduce the dose rates to the crew to a minimum.

The ship has been maintained at regular intervals. Every third year a major inspection has been performed, including control of bottom, hull, rudders, engine etc.

At an early stage M/S Sigyn was equipped with an extra bowtruster and enlargement of the rudders was done. These improvements resulted in a much better manoeuvring capability of the ship in narrow channels and in small harbours. In 1991 a new satellite navigation and communication system was installed and in 1993 a new radar equipment will be installed in the ship. This is in order to keep the ship with the most modern systems.

Since 1985 M/S Sigyn has sailed in total around 185.000 n.m. with an average of some 25000 n.m. a year. The radiation measurements have shown no larger doses to the crew than those obtained from the background radiation. The permissible maximum annual dose rate per individual is 5 mSv.

Physical protection during transport

During transport of spent fuel the ship is followed by a land based control centre which at any time could determine the ship's position, direction and speed. If something happens to the ship, the control centre is responsible for taking the correct actions and contacting the necessary organizations and authorities. The system was tested under realistic conditions in 1991. Besides the ship and the control centre, the local and national police, the coast guard and other authorities were involved in the test. The exercise resulted in valuable information, i.e. improvement of some communication links.

TRANSPORT CONTAINERS

The overall safety of the transportation system is guaranteed by the design and strength of the different types of transport containers and casks. The SKB transportation system comprises containers for high-level, intermediate-level and low-level waste.

Transport casks for spent fuel

SKB operates 10 transport casks for spent fuel of the french design TN 17/2. The TN 17/2 cask is made of forged steel and has a length of about 6 meters and a diameter of about 2 meters. Its weight is 80 tonnes and the loading capacity is about 3 tonnes of spent fuel. The transports are performed under dry conditions and the cask is cooled by natural air circulation around the 40 000 cooling fins.

The number of casks transported to CLAB 1985 - 1991 is shown in table 2.

Table 2 Number of casks/year received at CLAB

Year	Casks for Spent fuel	BWR	PWR	Casks for core components
1985	34	24	10	9
1986	89	85	4	9
1987	85	53	32	9
1988	76	68	8	9
1989	71	71	0	3
1990	79	49	30	2
1991	52	52	0	2
Total	**486**			**43**

By the end of 1991, 1514 tonnes of spent fuel have been transported to CLAB, which represents about 30% of the storage capacity in CLAB. The storage capacity in CLAB has recently been increased to 5000 tonnes by introducing borated stainless steel canisters.

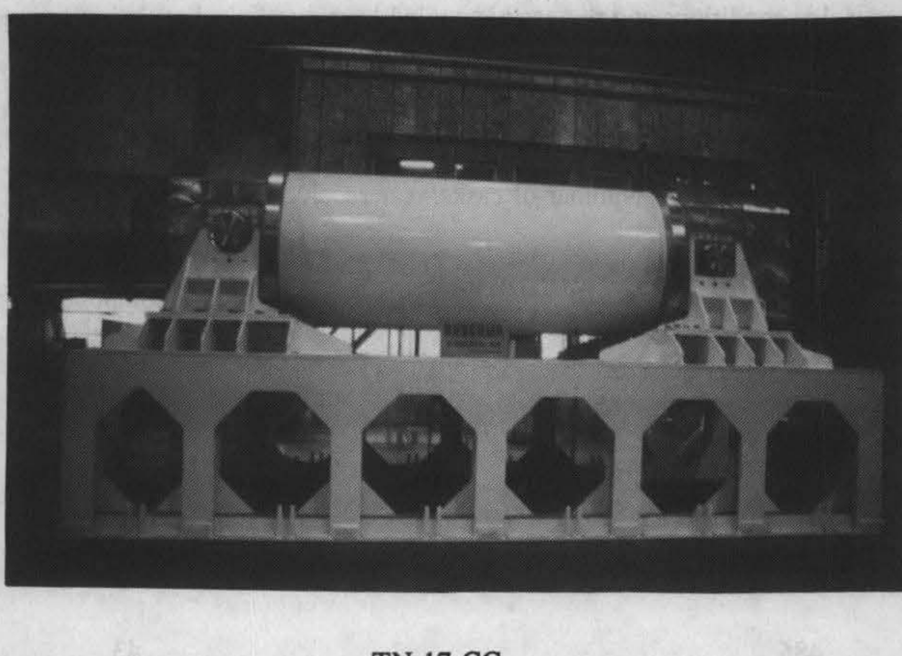
The TN 17/2 casks are today licensed for BWR fuel elements with a max. enrichment of up to 4 % U 235 and a max. burn up of 55000 MWd/tU. The decay time must not be less than 180 days. The corresponding figures for PWR fuel elements are 3,5 % U235, 55000 MWd/tU and a cooling time of at least 180 days, according to the license for the cask.

However, the dose rate limits for the cask, according to the transport regulations, are close to the acceptance levels (0,1 mSv/h at 2 m) when transporting fuel elements with a burn up of 43000 MWd/tU and a cooling time of 20 months. For burn up figures of 55000 MWd/tU the cooling times required would be very long.

On behalf of SKB the cask designer, Transnucleaire, has performed a study on how to modify the cask to allow transport of high burn up and high enriched fuel. The result showed that by increasing the resin thickness of the cask by 25 - 40 mm, high burn-up fuel could be transported after a cooling time of 2 years. Planning is now going on for increasing the resin thickness on 4 casks in 1993.

Transport cask for core components

SKB operates two specially designed casks for transport of core components, TN 17-CC. The main features of the casks correspond to TN 17/2. The cooling fins and one bottom penetration are omitted. With this design the TN 17-CC casks fit into the transportation system and handling at CLAB without any special arrangements and common spare parts for the two types of cask can be used.



TN 17-CC

Until september 1992, 43 transports with core components, e.g. control rods, have been performed to CLAB. The casks have been almost free from damages. This is due to the low frequency of operations, but also to the absence of cooling fins and neutron shielding, which makes the maintenance easier.

Inspection and maintenance

The casks have been inspected and maintained following the manuals and procedures in the so called "Green Book". This document describes the common policy of Cogema, BNFL, DNTL, NTL and SKB for inspection, maintenance and periodic testing of spent fuel casks and has been adopted to the CLAB conditions.

The frequency of maintenance has been decreased from every 10 transports to every 15, due to the good performances of the casks. Each fuel transport cask has gone through 4 or 5 such maintenance periods. A more extensive maintenance is made after 60 cycles.

Damages and irregularities found on the casks have been registered by a computerized system in CLAB. This information is used when deciding what should be changed on the casks or of the handling equipment being used. Also handling instructions at CLAB or at the power plants have been improved as a result of gained experience.

As an example of the maintenance experience, changes of material have been made in some bolt disk to avoid surface damages. The trunnion bolts have been covered by small aluminium lids to reduce time when the silicon layers have to be removed.

Cask maintenance in CLAB

Meetings with the cask operators at the power plants have been performed on a regular basis to exchange information about damages found and improvements of handling of the casks. This has lead to a better understanding of the high demands which are put on handling of the casks at the power plants and CLAB and is one of the reasons for the good conditions of the casks.

Shielded containers for intermediate-level waste

For transporting intermediate-level waste,ILW, SKB has designed and developed large IP-2 steel containers, ATB, which fit into the transportation system. The containers are of different types depending on shielding requirements and size of the waste units.

Table 3 ATB-containers

Type	Wall thickness	Capacity, concrete moulds/drums	Max.dose rate level of waste
ATB 16K	70 mm	16/96	5 - 6 mSv/h
ATB 12K	130 mm	12/48	60 - 70 mSv/h
ATB 4K	200 mm	4/16	500 mSv/h
ATB 3T	80 mm	3 tanks	7 - 8 mSv/h

The weight of a loaded ATB is almost 120 tonnes.

From the start of SFR in 1988 almost 400 ATB and 130 containers have been transported from the power plants to SFR. Although M/S Sigyn can carry 10 ATB in one load, normally 5 - 6 ATBs are transported.

After the first years of transport of radioactive waste in ATB-containers SKB evaluated the dose rate measurements performed during the transport. The study showed the difficulties in measuring radiation under low intensity. For example:

- Dose rate measurements, which should give equal results, gave large variations.
- Dose rates outside different ATB of the same type with the same category of waste were different
- Dose rate measures before and after transport on the same ATB showed different values.
- Dose rates on surface and at distances on the same area of the ATB showed less correlation than expected.

The irregularities in the measurement results do not depend on faulty measurements but show the difficulties in practise to measure radiation with low intensity.

§ 422

ATB 12 K is designed for transport of waste packages with surface dose rates up to 60 mSv/h without exceeding the dose rate limits outside the ATB, according to the IAEA transport regulations. However, § 422 in the regulations states that the dose rate on 3 meters from the unshielded object must not exceed 10 mSv/h. This limits the use of ATB 12 K to transport waste packages with a surface dose rate up to 20 mSv/h. Thus this paragraph causes problems in the transports. As a result of this some transports have been performed under "special arrangement".

Today some power plants in Sweden have license to produce waste packages with surface dose rates up to 100 mSv/h. Even higher dose rates are foreseen in the future in order to reduce the waste volumes. To be able to transport this radioactive waste not only a new ATB with thicker steel walls must be constructed, but the problem with § 422 has to be solved.

Transport containers for low-level waste

Low-level waste have been transported in standard ISO containers. 8 standard containers can be transported in the cargo hold of Sigyn together with 10 ATB. By installing a special deck up to 80 containers can be transported at a time.

Waste type description

The waste packages and contents are described in standardized waste type descriptions which are approved by the authorities prior to transport and disposal. These documents contain information about the process and production methods of the package as well as transport conditions and final storage qualifications. The work with these descriptions has been much more extensive than expected.

COORDINATION OF TRANSPORT

Prior to transport, SKB, which is responsible and therefore also coordinating all transports of spent fuel and reactor waste, issues a transport message to all parties involved, including the control centre, authorities, national police etc.

The transport message contains information about the waste to be transported as well as time schedule and responsible persons for the transport.

SKB has developed a computerized programme which contains information of all individual fuel assemblies in the Swedish reactors. This programme is checking every fuel element for transport criteria before the transport message is printed. This data system has improved the handling of transport messages and increased the reliability in the fuel data information.

A similar system is used for checking of waste packages before transport.

PUBLIC ACCEPTANCE

The transports of spent fuel and reactor waste are performed during the whole year except for the summer period - June to August - when the reactors are shut down for maintenance. During the last four summers M/S Sigyn has been used as a floating exhibition for information about the Swedish system for handling of radioactive waste. The ship has sailed along the Swedish coast and visited about 30 different harbours. In total around 250,000 persons have been on board M/S Sigyn. This has resulted in quite a lot of good publicity for the ship and even perhaps a better public understanding of the handling of radioactive waste in Sweden.

During the spring of 1992 M/S Sigyn was engaged - free of charge -in two aid transports to the Baltic countries. The first voyage took place from the harbour at Ringhals nuclear power plant and consisted of agricultural equipment to the farmers of Estonia. The other voyage started from the harbour of Forsmark nuclear power plant and consisted of agricultural and electrical equipment. These transports were of course highly appreciated by the organizations involved, both in Sweden and Estonia and resulted in very positive articles in the news papers.

OTHER TRANSPORTS

When the time schedule has permitted, M/S Sigyn has been used on commercial basis for transports of heavy equipment.

In February 1992 a transformer was transported from Dundee in Scotland to Västerås in Sweden. Other examples are transports of a harbour crane and large generators. The ship has shown to be suitable for this kind of transports due to the combination of the Ro-Ro/Lo-Lo possibility and the small draught of the ship, permitting the ship to enter small harbours.

In June -91 M/S Sigyn was used for transport of UF_6-cylinders from St Petersburg in Russia to Västerås in Sweden. The cylinders were lifted on board the ship and placed in special frames manufactured only for this kind of transports. The transports of UF_6 will probably continue with M/S Sigyn.

SUMMARY

In 1982, when M/S Sigyn for the first time entered the harbour in Oskarshamn, demonstrations and bad publicity around the ship and the waste transports was not unusual.

Today the transports of radioactive waste in Sweden are done on routine basis without any negative publicity. An important contribution to this fact is probably the very good performance of the transport system and the receiving facilities. Since the start of operation of the transport system no accidents have occurred.

Almost 1600 tonnes of spent fuel and 10,000 m^3 of radioactive waste have been transported. The capacity and availability of the ship and of the transport system as a whole is large enough to cover all needs for transports of radioactive material in Sweden, at least up to the turn of this century.