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Clearance and Recycling of an INF-3 Ship

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Abstract

Swedish Nuclear Fuel and Waste Management Co (SKB) has recently completed the clearance and recycling of MV Sigyn, an INF-3 ship. MV Sigyn had successfully been used in the Swedish system for transports for 30 years before being replaced by the new build ship MV Sigrid in 2013.

Both the clearance and the recycling of MV Sigyn were carried out in Sweden, a country with high standards in respect to Radiation Protection, Environment, Health and Safety. The clearance and recycling of the ship were planned and executed in several steps in close cooperation with Swedish Radiation Safety Authority (SSM) and the Swedish Environmental Protection Agency.

The clearance process for the MV Sigyn was planned to fulfil both the requirement of The Swedish Radiation Safety Authority's regulations and the Swedish Nuclear Industry's praxis regarding clearance of buildings and materials. The clearance process was done in several steps including a first initial screening done internal by personnel from SKB followed by a comprehensive measurements and documentation by special trained personnel.
The initial plan of SKB was to recycle the ship abroad at a shipyard within EU with good reputation in recycling of ship. But due to several different circumstances the recycling finally was done at a shipyard in Sweden.

This paper will outline the clearance process, the lesson-learned and how SKB have implemented them in the operation of MV Sigrid.

Figure 1 Former Nuclear fuel carrier MV Sigyn

Introduction

Late 2013 Swedish Nuclear Fuel and Waste Management Company (SKB) took delivery of a new build ship MV Sigrid and it was time to clear and decommission MV Sigyn after 30 years of successful operations. MV Sigyn transported spent nuclear fuel and nuclear waste from Swedish nuclear power plants to Clab, the interim storage facility for spent nuclear fuel in Oskarshamn and the waste facilities at Studsvik and Forsmark. Over the years MV Sigyn also transported both active and inactive contract cargos. For example big contaminated components from European nuclear power plants to Studsvik for measurement, decontamination and melting. This paper describes the method used for characterization of the activity onboard and how the decommissioning was completed.

The Owner, the Ship and the Cargo

Swedish Nuclear Fuel and Waste Management Co

Nuclear power companies in Sweden jointly established the Swedish Nuclear Fuel and Waste Management Company (SKB) in the 1970s. SKB's assignment is to manage and dispose of all radioactive waste from Swedish nuclear power plants in such a way as to secure maximum safety for human beings and the environment. Twelve nuclear power reactors have been built in Sweden and ten of them are still in operation.

SKB is responsible for a system of facilities used to handle all waste from the Swedish nuclear power plants. These facilities today include a central interim storage facility for spent nuclear fuel (Clab) near Oskarshamn, and a final repository for short-lived radioactive waste (SFR) in Forsmark. In figure 2 an overview of all existing and planned facilities in the Swedish system for waste management is described.

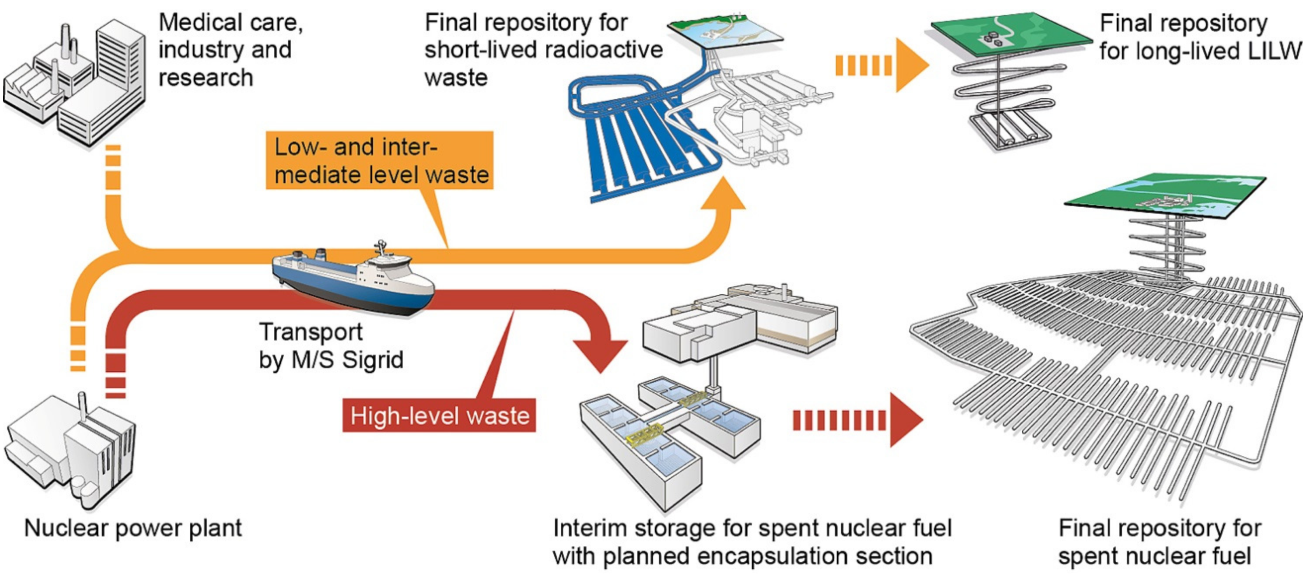

Figure 2 The Swedish System

Nuclear fuel from all Swedish nuclear power plants is stored at SKB´s interim storage facility, Clab. Today approximately 6,300 tons of spent nuclear fuel is temporarily stored in the facility.
After radioactivity decrease and cooling in interim storage, the spent nuclear fuel is ready for encapsulation and will be transferred to SKB's coming encapsulation facility and placed in impermeable copper canisters with ductile iron inserts. They will subsequently be transported to the final repository that SKB is planning to build in Forsmark. The canisters with the spent fuel will then be lowered into a system of horizontal tunnels, at a depth of about 450 meters in the crystalline bedrock. The radioactive waste from nuclear power plants consists largely of low- and intermediate-level operational waste, such as used protective clothing and replaced parts from the power plants.

The waste is deposited in rock vaults at our Forsmark facility (SFR). The Forsmark facility was commissioned in 1988. This waste is packaged in metal or concrete containers and stored at a depth of 50 meters in rock vaults that are kept under surveillance. After approximately 500 years most of the radioactivity from this waste is gone.
An extension of SFR is in under review at Authorities. The final repository including the extension will have a waste storage capacity of 200,000 cubic meters.

All Swedish nuclear power plants are located along the coast and have their own harbours. Therefore radioactive waste and spent nuclear fuel are mainly transported by sea in Sweden. To efficiently perform the transports of the spent fuel and waste from the nuclear power plants to the storage facilities a transport system with its key components: ship, transport casks and vehicles was created 30 years ago.

MV Sigyn

MV Sigyn was a nuclear fuel carrier and was built in 1982 by the French Société Nouvelle des Ateliers et Chantiers du Havre at Le Havre, France and transported spent nuclear fuel and nuclear waste from Swedish nuclear power plants to Clab, the interim storage facility for spent nuclear fuel in Oskarshamn and the waste facilities at Studsvik and Forsmark. In Sweden virtually all radioactive waste and spent nuclear fuel is transported by sea by SKB. The Swedish nuclear power plants lie by the coast and have their own harbors.

MV Sigyn was designed specifically for transporting radioactive materials in Sweden and had the International Maritime Organization’s highest classification level, INF 3, for ship used to transport radioactive material.

MV Sigyn is loaded and unloaded using the ro-ro method, which means that terminal vehicles drove into the hold through a stern ramp to load and unload transport casks and containers. It was also possibly to load and unload the ship using the lo-lo method and a crane in the harbor, but that method was seldom used.

The cargo

Over the years MV Sigyn also transported both active and inactive contract cargos. For example big contaminated components from European nuclear power plants to Studsvik for measurement, decontamination and melting.
But her main task was to transport Spent Nuclear fuel from the Swedish Nuclear Power plant to SKB:s central interim storage facility for spent nuclear fuel (Clab) near Oskarshamn and to transport low and intermediate leveled radioactive waste from Studsvik and the Swedish Nuclear Power plant to SKB:s final repository for short-lived radioactive waste (SFR) in Forsmark.

Decommissioning and clearance of MV Sigyn - How did we do it?

The decommissioning and clearance of the ship were done in four major steps;

1. **Initial determination of the radiological status and initial waste separation** (was done by SKB and Furetank Rederi AB, the Ship operator)

2. **Characterization and Clearance of the ship according to regulation and industry praxis**. (was done by SKB in cooperation with Studsvik Nuclear AB)

3. **Application for a clearance of the ship** according to the Swedish Radiation Safety Authority's (SSM) regulations and general advice concerning clearance of materials, rooms, buildings and land in practices involving ionising radiation, (SSMFS 2011:2, 2011). SKB also had to apply for an exemption since all requirement in SSMFS 2011:2 could not be fulfilled for a ship (was done by SKB)

4. **Recycling of the ship according to regulation and international praxis** (was done by Stena Recycling AB under supervision from SKB)

Initial determination of the radiological status and initial waste separation

As soon as the ship was taken out of operation SKB late 2013 did an initial determination of the radiological status of the ship.

This step included;

1. Sum up of the history of transports and cargo where contamination has been detected in the cargo hold or on equipment /transport casks transported in cargo hold. Contamination in the cargo hold has been found only twice during the lift time of the ship, both linked to the Chernobyl accident. There have been contamination/hotspots on the transport container, casks

and frames used for the transport of spent nuclear fuel and radioactive waste only a few times over the years.

2. Sum up of initial measurements and checks for radioactive substances on the ship made after MV Sigyn was taken out of operation late 2013. This measurements included spot-checks of the contamination on board the ship with both scintillation detectors and smear tests (Large Area Smears). Also sludge samples from tanks and scuppers was analysed. Measurements and checks were done both outside, in cargo hold, accommodation areas and in tanks and ducts.

3. SKB did an initial waste separation where for example all installed equipment for radiological measurements where removed from the ship. SKB also cleaned and measured the cargo hold sludge tanks where water and dirt from the cargo hold had accumulated over the years. This was a time consuming and difficult job which increased the risk for cross contamination of pipe ducts. The contamination levels of the sludge were low 25 Bq/kg (Co-60/ Cs-137) but the 0,2m2 of dehydrated sludge was sent for waste treatment at Clab.

Clearance of the ship according to regulation and industry praxis in Sweden

Analysis of nuclide distribution in contamination

By analysing the transports made by MV Sigyn, a general nuclide fingerprint was set for the activity on board the ship. According to the logbooks most of the transports that resulted in contamination were performed in MV Sigyn's early years. Contaminated internals and used fuel are normally stored on site for a few years; to account for this an assumed decay time of 20 years was used to calculate the nuclide distribution.

Categorization of surfaces

When scanning the ship for hotspots during the "Initial determination of the radiological status" one particle of about 4000 Bq Cs-137/1000 cps on the outside deck. The particle was removed and the remaining deck areas sought without any further hotspots found. After eliminating the risk for further hotspots, the surfaces and components on board was categorized by the risk for contamination. The risk category determined the number of measurements needed further on in the clearance process.
The categorization was based on how MV Sigyn had been used and on where the historical contamination had been found. The cargo hold of MV Sigyn was there for given the risk category 2 (contamination from Chernobyl and contaminated transport casks). Near by areas and room were given risk category 3 since eventual contamination in the cargo hold would have been spread by the feet's of the crew if they would have stepped in contamination in the cargo hold. In general the risk categories were lowered with one category per room away from the cargo hold. Ship's bulkheads (walls) were given one lower risk category than the deck (floor) in the same room.

Eventual contamination spread by air from components in the cargo hold would have passed through the ventilation system. The surfaces of the ventilation system were therefore categorized as category 2. The ceiling of the cargo hold was given risk category 3, one category less than the nearby ventilation. Areas where contamination could have been accumulated e.g. scuppers, sludge pumps, filters and the cargo hold bilge tanks was categorized as category 2.[3]

Table 1 Risk categories for Surfaces

Risk category	Risk categories for surfaces	Number of measurements	Number of areas	Area (m2)	Measurement points
1	Contaminated over clearance limits	1% of surface	0	0	0
2	Risk for contamination over clearance limits	1% of surface	19	1483	202
3	Low risk for contamination over clearance limits	0,1% of surface	8	980	995
4	Extremely low risk for contamination over clearance limits	0% of surface	1	-	0

Measurements

Based on the expected contamination of surfaces on board according to the characterization the ship and statistical physics the 27 areas to be measured was divided in to smaller units with assumed equal Gaussian distribution. Bayesian statistics could thereafter be used to analyze the resulting measurement done. In total approximately 1200 sample points were marked out randomly. Contamination measurements were made on these sample points. Additional sampling points was chosen by the measuring team based on their experience on were contamination could be present.
The results of measurement showed contamination levels which are hardly, or not at all, distinguishable from the background radiation. The statistical methods used are developed by Studsvik Nuclear AB.

Comparison with clearance levels in SSMFS 2011:2

The calculated activity (with a credibility of 95 %) for every unit was then compared to the clearance levels given in SSMFS 2011:2 [1]. None of the 27 areas was contaminated above the clearance limits. The “most” contaminated area was contaminated below 48 % of the clearance limits with 95 % credibility. On average the areas were contaminated below 15 % of limits with 95 % credibility if MV Sigyn was compared to the clearance levels for material in SSMFS 2011:2.

Application to The Swedish Radiation Safety Authority's (SSM)

According to the Swedish regulations SSMFS 2011:2, 'clearance' means that the Radiation Protection Act (1988:220) and the Act on Nuclear Activities (1984:3) shall no longer be applied to materials, rooms, buildings or land. The application to SSM to exclude the ship from the above regulations was quiet straight forward except for the fact that the ship could neither be fully seen as a building nor a material according to industry praxis or SSMFS 2011:2.

Initial SKB assumed that the best would be to see the ship as a building, since it in many ways is nothing but a "floating" building. However the dispersion- and dose calculations for the nuclide specific limits for buildings in the regulations stipulates that the building is made of concrete that are crushed in the demolition process while a ship are made of steel that are cut and recycled.

Second approach was to consider the ship to be material according to the regulation. After recycling/ decommissioning a ship is nothing but sorted material (metals, cables etc.). But if considered as material the regulation (SSMFS 2011:2) gave the nuclide specific limits for materials as an average over a maximum of 1000 kg. Unfortunately, 10 of the 27 areas weight more than 1000 kg and would have had do been divided in to another 172 units and the number of measuring points (due to the statistics) would have been unreasonable many.

In the application measured levels of activity was compared to both clearance levels for buildings for free use (Annex 3 SSMFS 2011: 2) and with clearance levels for materials (Annex 1 SSMFS 2011: 2).

SSM's assessment of the application gave that the clearance levels for buildings for free use would be applicable if m / s Sigyn would continue to be used, but if the ship where to be scrapped/recycled comparison should be made primarily with clearance levels for materials. Since the calculated activity was lower than clearance levels for both buildings and material SSM did not need to regulate the future use of the ship and SKB could choose it we would like to scrap/recycle the ship or continue to use/sell it without restrictions from radiation safety point of view.

Recycling of the ship

Sell or recycle?

Since SSM did not impose any requirement that the ship must be recycled/scrapped it was fully possible for SKB to sell MV Sigyn for further use without restrictions from radiation safety point of view.

SKB is investigating the market closely and showed the ship for several interested buyers before making the decision. SKB decided to recycle/scrap MV Sigyn instead of selling the ship for further use due to several circumstances;

- At the time (2014-2015) it was the "buyers" market for +20 years old ships and none of the

potential buyers offered more than 0,5-1 MEURO for the ship.
- If selling the ship SKB would not have any control of the coming use and scrapping of the ship. It could be used for just a few years and then be beached in Asia. That was a risk SKB was not willing to take, especially when the income for selling her was low.

Selection of shipyard

There were a hand full of shipyards in north western part of Europe that recycle ships regularly and meet the criteria of the SKB Corporate Policy for the Environment, Health and Safety, international regulation and The Industry Code of Practice for the recycling of ships. No shipyard further away from Sweden was considered due to the high cost for getting the ship there (potential towing cost, crew etc.) The selection of shipyard for recycling was not easy and the Basel convention strictly sets out the controls for the transboundary movement of hazardous wastes (ships planned to be scrapped are considered to be hazardous waste). Transboundary movements of hazardous wastes are only permitted if prior written notification by the State of export is given to the competent authorities of the States of import and transit.

SKB where given all necessary permits from the Swedish Environmental Protection Agency but the Environmental Protection Agency in the “state of import” did put tremendous requirement in respect to registration, control and documentation of the life cycle of the waste from the ship which the potential shipyard could not fulfill.
SKB had to change strategy and decided to do the recycling in cooperation with a Swedish Recycling company and hire a shipyard in Sweden to do the recycling.

The recycling

MV Sigyn was sold to the Swedish recycling company under a standard international contract for the recycling of ships. The BIMCO Demolishcon contract is used by the industry to sell end-of-life vessels. This contract was also used for the sale of the MV Sigyn for recycling. The contract Terms and Conditions were amended and agreed to satisfy certain criteria of the waste regulations and to give SKB additional control and supervision of recycling activities whilst the ship is no longer the owner’s asset.

The recycling started off with the MV Sigyn alongside a quay at the shipyard in Falkenberg where removal of non-nuclear hazards wastes in line with the Industry Code of Practice and national and local regulation. The strategy of the Recycling Company was to keep the ship “alive” as long as possible to be able to use technical systems on board (cranes, ventilations etc.). A lot of components (engines, mooring equipment, cranes, electronics, stern ramp) were possible to sell for further use. This was a huge environmental benefit. After 10 weeks the ship was towed in to the dry dock of the ship yard were the final cutting of the hull was done during 2-3 weeks.

Table 2 Material from recycling (components sold for reuse excluded)

Material	Weight (tonnes)
Cables	31
Cupper	9
Other metals	9
Steel	2030
Concrete	193
Waste (burnable)	27
Electrical waste	16

Lessons learned

To export a ship for recycling through the waste regulations that implicitly satisfy the International conventions and agreements on handling waste is a time consuming and expensive process. Only a few facilities with suitable licenses are situated in the northern part of Europe. The complex regulation regarding ship recycling is not to the full benefit of a environmental sound recycling since many ship owners finds ways to get rid of their end of life ships in another way due to the costs.

The clearance regulation and industrial praxis in Sweden only covers the most common objects like buildings, ground, and material. If any other object is to be cleared close cooperation with Authorities both in early planning stages and when compiling applications.

To keep track of the documentation regarding all clearance activities measurements of a large object, ship building and frequently sum up the result saves time and efforts in the end of life clearance process. SKB have for the new build ship enhanced and more detailed procedures for doing clearance measurements on a regular basis. After taking odd and/or contract cargos extra measurements are done. The result of the clearance measurements of the ship (especially the cargo hold) are summed up and saved every year.

New procedures for handling of cargo hold bilge was introduced at MV Sigrid after finishing the clearance of MV Sigyn. At MV Sigyn water sample of the cargo hold bilge (where water and dirt from the cargo hold ends up) was taken when the tank was full to ensure that the water was not contaminated. After that the water was pumped out down to a certain level but the sludge (dust and dirt from cargo hold) was left in the tank. The sludge accumulated over the years and at end of life cleaning of the tanks it was 30 cm sludge in the tanks with 20-40 Bq/kg Co and Cs-137 which had to be handled as radioactive waste and the tanks had to be decontaminated. This was a tricky and time consuming job that also risked that the contamination would have been transferred to other part of the ship. If water and sludge would have been mixed before each and every sample was taken no sludge would have been in the tanks at end of life and no contamination would have been accumulated.

By using statistics it was possible to clear the 2044 ton ship for use without restriction with only about 1200 scintillation measurement

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