THE ÅGESTA REACTOR: EXPERIENCE OF 30 YEARS OF SAFESTORE

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ABSTRACT

The Ågesta Nuclear Power Plant was constructed during the years 1957-1962 in order to deliver heat for district heating and industrial processes as well as to supply electrical power to the Stockholm electricity grid. The reactor was of the Pressurised Heavy Water Reactor (PHWR) type. In 1963 the test operation with heavy water started and criticality was achieved. Operation of the station with the supply of energy for these purposes went on from 1964 to 1974, when the power station was shut down. The plant has been without on-site personnel since 1975.

In order to keep the plant safe the SSI (Swedish Radiation Protection Authority) has issued a set of regulations which has, in principle, been the same since the 70-ties. The current regulations were updated in 1999 and 2002.

Sampling and inspection frequencies are given in conditions from The SSI (Swedish Radiation Protection Authority). These include that the plant is inspected twice a year. Apart from the inspections the site is visited by Studsvik personnel at least once a month.

It can be stated generally that the plant is in a good condition after 30 years of Safestore.

INTRODUCTION

The Ågesta plant is located about 15 km south of Stockholm and close to the suburban centre of Farsta. It was designed and built as a co-operative effort between AB Atomenergi (the former Swedish research centre in Studsvik), the state owned Vattenfall AB and the Stockholm Electric Power Company. The reactor with associated systems were jointly financed by AB Atomenergi and Vattenfall AB, while the conventional part of the plant was financed by the Stockholm Electric Power Company. AB Atomenergi was responsible for the start-up of the reactor and its operation during the first full-power year, after which Vattenfall AB took charge over operations and staffing.

The reactor section of the plant, i.e. the reactor vessel with pipe systems, the refuelling machine, heat exchangers (steam generators) with pumps and the blow down tanks are contained in a rock cavern approximately 60×45×26 m in dimensions, see Fig. 1.

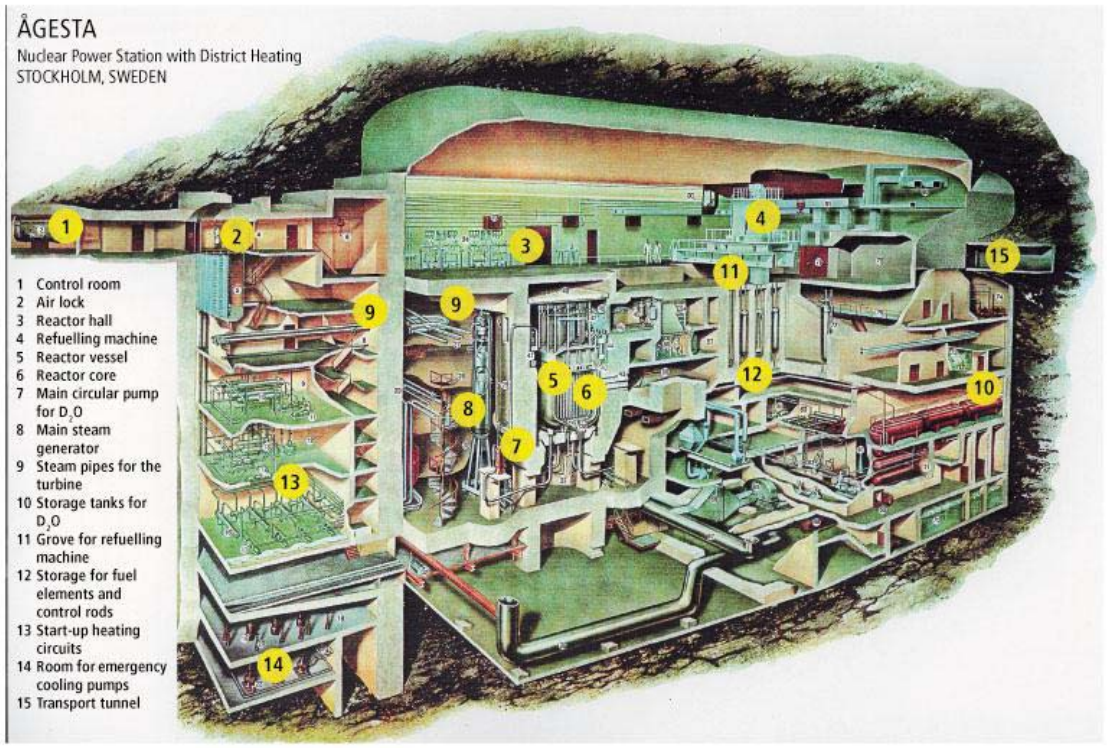

Fig. 1 Ågesta Nuclear Power Station with district heating

The minimum thickness of rock above the reactor vessel is 15-20 m. The entire rock cavern, Fig. 2, is clad on the inside with a gas-tight, pressure-tight (up to 2 bar over-pressure) steel lining, with all penetrations like pipes, etc., carefully sealed and tested. Pipes that penetrate the lining are fitted with automatic double valves and other similar arrangements.

Fig. 2 View of the reactor hall. To the left is the refuelling machine and at the far end is the reactor hidden by a thick concrete cylinder

Personnel and material can enter the cavern only though air tight locks. The plant has been without on-site personnel since 1975 and has been inspected and checked at least twice a month by staff. A security company carries out regular rounds to check the integrity of the entrance and that the water level does not go above prescribed levels.

The reactor was of the Pressurised Heavy Water Reactor (PHWR) type, with heavy water both as moderator and primary coolant. This design allowed the use of natural uranium as fuel, which was termed as the Swedish line. Uranium could be mined in Sweden, which made it independent on other countries.

THE REACTOR

Reactor Power

- 65 MW thermal in total (later increased to 80 MW). 10 MW of this was fed into the electricity grid. The rest went into the district heating system.

Reactor data

- Type PHWR
- Reactor vessel 4.7 m diameter, wall thickness in barrel 75 mm
- Reactor vessel inside height at centre 5.6 m
- 140 fuel elements, totally 18 t slightly enriched fuel

- 67 t D_2O (Heavy water)
- Operational pressure: 34 bar (Design pressure: 41 bar)
- Temperatures at 100 % power:
  - Inlet: 205^o C,
  - Outlet: 220^o C,
- 4 heat exchangers (steam generators), see Fig. 3.

Fig. 3 Biological shield for the reactor surrounded by the four steam generators

Personnel

A total of 70 persons worked within the facility. Of the total staff 16 persons worked with the operation of the reactor divided into 4 shifts. The 4 persons on each shift were responsible for the operation and checking of the reactor and surroundings. The rest of the personnel were technical support, administration and maintenance. A specification of the different personnel categories is not available.

NOTEWORTHY EVENTS DURING OPERATION

1962 Test operation with light water.

1963 Test operation with heavy water. Criticality achieved.

1964 Start of operations with supply of heat and electricity.

1968 Accident due to vibration induced damage on fuel elements. Some fuel rods and sleeves were broken. Special tools were manufactured for retrieval of these objects. The reactor was re-started with new fuel elements after 6 months.

1969 When a pump was started on the light water (secondary) side, a pressure wave destroyed parts of a non-return valve, resulting in the out-flow of 400 m3 water over equipment including electrical components. The reactor was scrammed after which followed clean-up and repair.

1974 The reactor was finally shut down on 2 June. The fuel was taken out of the reactor and transported off site. At first it was stored at the interim storage at Studsvik. It was later moved to the central interim storage for spent fuel in Sweden, The CLAB The heavy water was also shipped off site, i.e. sold for reuse at the facilities in Canada. The reactor vessel and pipe systems were dried as thoroughly as possible.

At shut down, the reactor had completed 52 000 operational hours. A "shut down" agreement was signed, dividing the ownership between Vattenfall AB, AB Atomenergi and the Stockholm Electric Power Company.

The operating personnel, who had received a good training in reactor operation and technology, applied for positions at other reactor stations that were then being built and taken into operation. These persons were much sought after at these new plants.

EVENTS AFTER SHUT DOWN

1975-1992 Forsmark Kraftgrupp AB was responsible for inspection and maintenance at Ågesta according to radiation protection permit given by the Swedish Radiation Protection Authority, SSI.

1992 2 steam generators were removed and transported to Studsvik for a demonstration of decontamination of the inner surfaces that had been in contact with the reactor's heavy water. After decontamination, the steam generators was segmented and melted at the Studsvik Melting Facility into ingots (about 750 kg each). Today 72 % of the material has been cleared for unconditional reuse, the rest will be cleared in 2008 and 2017. The late release dates are melts containing the tube plates, channel heads and some un-contaminated tubes that was plugged for sampling.

1993 Vattenfall AB took over stewardship, with Studsvik RadWaste AB responsible for inspection including responsibility for radiation protection. The company AB SVAFO took over Studsvik AB's share of ownership of the plant. The company AB SVAFO was owned by the Swedish NPPs, Sydkraft, VAttenfall, Forsmark and Oskarshamn. Since 2003 AB SVAFO belong to the Studsvik group.

1995 Inventory of eventual remaining fissile material in the reactor vessel and pipe systems.

1997-1998 Decontamination of the water clean-up building, which was thereafter free released by the SSI.

1999-2000 Investigations of the areas outside the reactor containment showed that the surfaces were not contaminated. The areas had not been in the "controlled" zone.
Inventory inside the containment, covering even all storage positions. The inventory was carried out regarding components and the radioactive status. The storage positions still contained the reactor control rods (30), radiation protection and sealing plugs as well as measurement devices.
The fire brigade inspected the plant and asked for complementary new fire alarms as well as the division of the plant into fire "cells" with automatic doors closing if smoke was detected.

2000 Agreement between Vattenfall AB and AB SVAFO, whereby AB SVAFO took over stewardship for Ågesta. A dismantling plan for the reactor and systems was submitted to the SSI.
New pumps were installed in the rock drainage tank and the pump cavity in the transport tunnel. At the same time, high water level alarm indicators were also installed.

2002-2003 Removal of remaining tools used at the fuel accident as well as transport off site of contaminated water from tanks on the lower floor.

2003 Studsvik AB took over ownership of AB SVAFO. In connection with this, preparations were made for transfer of the nuclear licence to AB SVAFO (from Vattenfall AB). The water clean-up building was modified and taken over by the fire brigade.

INSPECTION AND SAFETY

Security at the plant is regulated according to radiation protection rules from the SSI. The rules ask for inspection of the buildings and approach roads with associated signs, locks and alarms regarding damage, to be carried out twice a week.

If damage that can affect the security is discovered it should be reported to the SSI. If a crime is suspected in connection with such damage, it should also be reported to the police.

The rules also include the taking of samples and analysis of water from the rock drainage, which is pumped out via a channel to a lake near by.

CONDITIONS FOR SAFESTORE

According to one (UK) definition, Safestore is:

- Removal of buildings where there is no radioactivity
- Secure buildings where there are radioactivity, which can include a new building. This is to provide a robust shell capable of resisting accidental or intentional damages or unauthorised access.

The WNS (World Nuclear Society) also calls the Safe storage period for "Care and maintenance" period.

Both these definitions are applicable to the situation in Ågesta. The non radioactive buildings have been cleared and the radioactive building is located in a mountain cave and is cared for and maintained in good condition.

Apart from the above there are conditions given that must be followed in order to keep the plant without personnel at site.

The current rules date from 1999 with a change during 2002, but the same principle has been applied as long as the plant has been without personnel.. The rules assume that "no work, other than minor repair or maintenance, is carried out in the shut down nuclear plant". The rules refer to a number of SSI regulatory documents regarding working with ionising radiation, including:

- SSI FS 1998:3
  Rules regarding Categories of workers and Workplaces when Working with Ionising Radiation.

- SSI FS 1998:4
  Rules regarding Dose Limits when Working with Ionising Radiation.

- SSI FS 1998:5
  Rules regarding Measurement and Reporting of Personnel Doses.

- SSI FS 1998:6
  Rules on Medical Inspection for Working with Ionising Radiation.

Further conditions are:

- Storage of reactor components and other radioactive material shall take place according to special instructions from the SSI.

- Permit holder shall keep the SSI continuously informed about work with dismantling which can have influence on radiation protection.

- The containment liner and components shall be inspected once every six months, specially for rust damage and presence of moisture and water. If water is found, a sample shall be taken for analysis of radioactivity.

- The activity in the rock drainage water shall be measured in its cavity every six months.

- The above analyses shall be nuclide specific and the tritium contents shall be determined.

- No release of contaminated water is expected from equipment in the reactor building. On the other hand, the rock drainage water will be collected and pumped out into the channel to the lake Orlången. Samples of such water shall be analysed nuclide specifically as above. Water from sources in the reactor building may be pumped out only with a special permit from the SSI.

- Water and bottom sediment tests shall be performed in the Orlången channel twice a year, during spring and autumn. The samples shall be analysed by gamma spectroscopy and the tritium contents shall be determined.

- All approach roads to the reactor building shall be locked and fitted with alarms.

- Doors to such roads shall have signs showing the storage of radioactive material and banning entry.

- A report regarding inspections carried out and environmental inspections should be prepared for the SSI once a year.

FUNCTIONAL CONTROL AND MAINTENANCE

The functions of the systems shall be checked periodically and maintenance shall be carried out as necessary:

- Alarm devices (Service agreement with security company)

- Rock drainage pumps (suitable frequency of inspection is at least once a week).

FULFILMENT OF CONDITIONS

In order to fulfil the conditions for Safestore the facility at Ågesta is inspected twice a year. The water is sampled as requested and sent for analysis. During 2002 the sampling of water and sediments took place in April and in October, as they do every year. The containment liner and rock drainage is inspected and if any corrosion is detected it will be repaired as a pert of the maintenance work.

All the inspections and analyses are documented and reported to the SSI once a year.

Apart from the formal inspections the plant at Ågesta is visited by Studsvik personnel at least once a month.

RADIATION PROTECTION INSPECTOR

There shall be a radiation protection inspector at Ågesta, who should be deemed as qualified by the SSI. The inspector shall keep the SSI informed about the conditions at the shut down plant and pass on observations of significance for radiation protection at the Ågesta plant. The inspector shall be responsible for suitable instructions to be given to workers participating in the work and shall see to it that work is carried out in a manner acceptable from the radiation protection point of view and that the test results are reported to the SSI.

RADIATION PROTECTION INSTRUCTIONS

Radiation protection instructions shall be prepared for the owner's personnel, contractors and visitors to the Ågesta plant. The SSI shall be kept informed of the contents of these instructions.

COST FOR INSPECTION AND MAINTENANCE

The shut down of the plant cost 3 200 kSEK (350 k€) in 1974, corresponding to about 20 000 kSEK (2 200 k€) in current money.

During the last few years, the total costs each year (both fixed and variable) have been just under 3 000 kSEK (330 k€).

GENERAL

It can be stated generally that the plant is in a good condition. It is necessary to carry out maintenance work on the electric systems, the hoisting devices and pumps. The heating and ventilation systems are shut down. Only some electric heating fans are placed in certain strategic locations, such as the control room, the offices and the changing rooms.
Until the repository for decommissioning and dismantling waste in Sweden is built the Ågesta plant will be maintained to such extent that the present status is kept intact. Thereafter will the plant be decommissioned and dismantled.

THE FUTURE

Apart from the shut down reactor Ågesta, there are 12 commercial power reactors in the Swedish power reactor programme. Out of these, 11 are in operation and one has been shut down for political reasons. In addition, there are a number of plants with other kinds of nuclear activity.

According to Swedish Law, the organisation that gives rise to radioactive waste is responsible for its being managed in a safe manner. A great part of the final management of radioactive waste is carried out by the Swedish Nuclear Fuel and Waste Management Co, SKB. SKB plans, builds and owns the plants necessary for conditioning and disposing nuclear material and radioactive waste. Today the system covers an interim storage for spent fuel, a final repository for low and intermediate level, short-lived operation waste as well as a transport system. A system is being developed for encapsulating and disposing spent fuel, the aim being to start disposal of fuel about the year 2020. The existing final repository for operation waste, Fig. 4, is judged to have a capacity to accommodate continued operation of the reactors up to the middle of the twenty-twenties. The facility must thereafter be expanded.

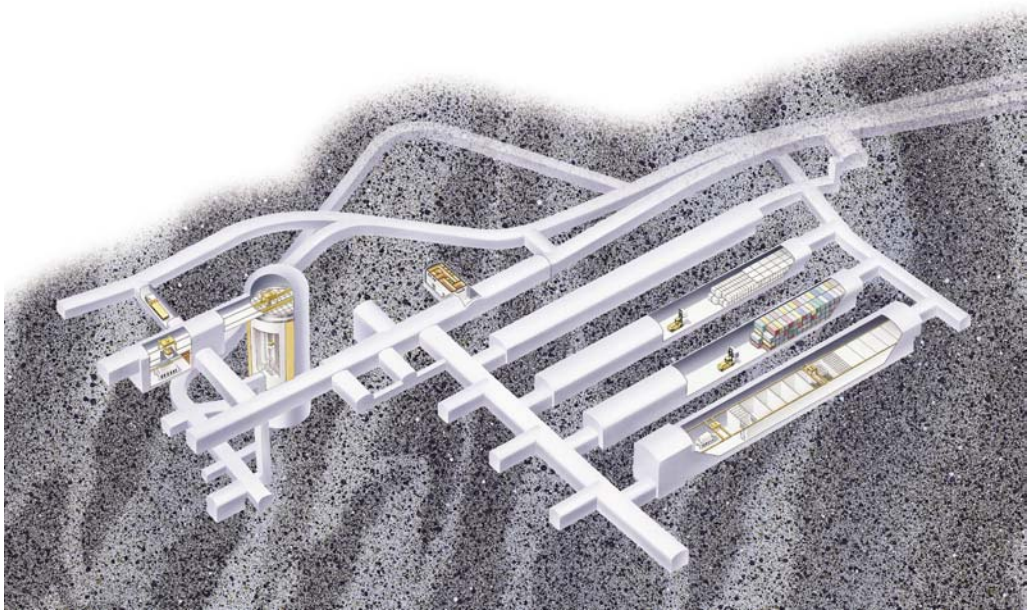

Fig 4 The existing final repository for low and intermediate level waste

A final repository for short-lived, low and intermediate level decommissioning waste must be available before dismantling of nuclear plants can be carried out on a large scale. Current plans envisage an expansion of the current final repository. It should also be possible to store low and intermediate level (decommissioning) wastes on an interim basis. A final repository for long-lived wastes cannot be expected to be available before 2045. The exact point in time dismantling of the plants shall start will be decided by the owners of the plants, if safety and radiation protection concerns don't cause the authorities to take special action. Assuming that the nuclear power plants are in operation for 40 years and then dismantled immediately, the first commercial plants will start being dismantled early in the twenty-twenties. The dismantling of the Ågesta reactor will be part of this national programme of decommissioning. Therefore it can be expected that the current scope of service and maintenance will continue for at least another twenty years.

DISMANTLING COSTS

The costs for the final decommissioning and dismantling of the Ågesta nuclear plant have been estimated (in the year 2001) to about 200 MSEK (22 M€). This figure accommodates the decontamination and dismantling of as much of the plant as will be necessary for the site to be free released radiologically and will not any longer have to satisfy the requirements of the Act on Nuclear Activities. Process equipment and activated/contaminated concrete will be removed from the plant. The non-radioactive concrete constructions will remain. It is estimated that 1 750 t of waste will be removed from the plant. 650 t of this will have to go to the final repository for radioactive waste while the rest can go to a conventional tip or be re-used. The actual costs for dismantling are ca 100 MSEK. The remaining 100 MSEK consists mainly of administrative costs as well as those for packing, handling and disposal of the dismantling wastes.

SUMMARY

- The Ågesta NPP was built in 1957-1962 and operated 1964-1974 during 52 000 hours
- In 1974, after shut down, the fuel and the heavy water were transported off site

- During 1975-1995 the Ågesta plant was maintained by different Nuclear Licence Holders in Sweden

- In 1992 two steam generators were removed and decontaminated and the material cleared for reuse

- During the period 1995-2003 the remaining radioactive inventory, such as remaining fissile material from the damaged fuel elements, 30 control rods and contaminated water from the tanks, were removed

- Studsvik AB took over ownership of SVAFO in 2003 and with that the Ågesta plant

- The cost for decommissioning of the Ågesta plant has been estimated to 22M€ in the year 2001. Of this about 50% is for the dismantling and 50% for administrative, packaging, handling and disposal costs

- After 30 years of safestore the Ågesta plant is still in good condition although it is clearly seen that the plant was built in the 1960'ies.