Co-operation development project for new treatment of STEAM GENERATORS – Impact on final disposal volumes and recycling in Nortern Europe

(Paper 7130)

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ABSTRACT

This paper describes a real case of cost effective volume reduction of a retired, full size SG removed from the Ringhals Nuclear Power Plant, Sweden. The project is described from the first step of fulfilling the demands from the authorities before treatment to the results of the treatment. The evaluations of the method is also included and compared to the other possibilities and the driving forces that work in favour of our method. The waste owners' strategy is also described in this paper. Finally the method of treatment is described as a principle as well as the results. Technical details as well as detailed results are given in Paper 7131 [ref 1].

BACKGROUND

All pressurized water reactors (PWR´s) are equipped with steam generators (SG) for transfer of heat between reactor tank and steam turbine. In many power reactors the old SG's have been replaced because of increase of input and maintenance problems. The others plants will either exchange SG's during operational lifetime or take them out in connection with decommissioning of the plant.

Retired SG's are considered as waste, which normally is stored intermediately on site waiting for transport for final disposal. The reason for temporary storage often relates to the absence of optimal waste treatment options and/or lack of funds for waste treatment. Also SG's, which are dismantled during decommissioning, will have to be disposed. The final storage of waste is often costly and there is a tendency of cost increase. There is therefore a strong incitement to minimise the volume that has to be disposed of as well as recycling of material resulting in saving natural resources.

A cost effective waste treatment method to solve the SG problem has so far not been widely available.

AUTHORITY ASPECTS

In many countries the competent authorities are demanding plans for relevant waste treatment solutions for retired SG's, or those which will be retired, as well as other waste streams.

The Swedish regulators demand the establishing of "waste treatment plans" for all waste categories arises from exchange of components or for other waste arising from operation of nuclear installations. This "waste treatment plan" shall characterise the waste and explain how the waste will be treated for final disposal.

Many countries have similar problems where SG's have been or will be replaced. Their authorities might not accept temporary site storage of larger components as a final solution.

ALTERNATIVES OF FINAL DISPOSAL IN SWEDEN

Direct storage in SFR in the future

Today's plan for retired SG's is storage on-site until SFR (The **S**wedish **F**inal **R**epository for operational waste) is planned to close. In that final SFR operation period the SG's will be shipped to SFR and be disposed of in the transport tunnels that lead to the repository caverns.

The closure of SFR is planned to take place when the Swedish nuclear programme will end and the operational short-lived radioactive waste is disposed.

Advantages of SFR scenario
In order to place the SG's in the tunnels of SFR, there is no need for expensive technical development and no additional waste treatment. And as a consequence of that there are no direct costs as of today for waste treatment and transport.

Disadvantages of SFR scenario
This alternative requires much volume in the SFR and the inventory for certain nuclides (Fe-55, Ni-63) in SFR is limited and would with the SG's in the tunnels be largely exceeded.

There would be a need for license review for the SFR when using the method to disposal of entire SG's in the tunnels, including new re-evaluation of applications to various authorities as Environmental Court, SSI, SKI, SKB and other interest groups and organisations. Most probably new caves would have to be built with adequate barriers against propagation of activity.

In addition to this an interim storage would have to be constructed at Ringhals-site, for the additional three SG's that are planned for replacement in year 2011.

THE NEW WASTE TREATMENT METHOD

Waste treatment means that an SG could be handled with the goal to obtain a minimum of residual waste and maximum rate of free-release and recycling of material. This has to be achieved within reasonable costs and under the condition that the residual waste from the SG treatment can be accepted by both authorities and by SKB for final disposal at SFR and/or SFL (The **S**wedish **F**inal repository for **L**ong-lived waste).

Advantages
The treatment of an SG would result in less volume at SFR and the future SFL and a major part of the material from the SG will be recyclable.

Things not solved today have to be solved anyhow in a near future as regards nuclide inventory and possibilities for disposal in Sweden's final repositories.

As a result of treatment of already retired SG's at Ringhals there will be no need for an intermediate storage at Ringhals-site for the planned exchange of SG's at unit 4 in year 2011. The existing SG's storage building can be utilized for other purposes.

Regulations for necessary waste treatment will certainly be increasingly more stringent in the future and consequently treatment will be increasingly more expensive. As a consequence the extension of SFR can be postponed. The "environmental liability" for Ringhals will decrease by not storing waste on-site for longer periods.

Significant volume of metals after the free release can be recycled back to the steel industry.

Disadvantages
SG treatment results in radiation exposure to personnel which might be higher as compared to a postponed treatment where it could have been reduced due to the decay of short-live nuclides, especially Co-60.

There is a larger risk exposure in connection with transports of radioactive components, since most of the short-lived nuclides have not decayed.

From an economic point of view, the strategic decision has to be taken that the financing of the SG project will be done today without access to the decommissioning funds.

Since it is the first project of this kind treating the full size SG the uncertainty and technical challenges are considerable.

DRIVING FORCES FOR WASTE TREATMENT OF AN STEAM GENERATOR

The driving forces for waste treatment a foremost:

- Corresponding with Vattenfall environmental policy
- Lower total final repository costs
    - A volume reduction of the order of 85-90 % is possible.
- The space not used for the SG's can be used for other components
- The utilities get rid of their liability for components otherwise being stored on-site for longer times
- Clear signals to the authorities, to the public and to investors that "the Nuclear world" is solving their problems

RINGHALS' STRATEGY

Ringhals has a long-term demand to solve their liability problem as related to the retired components.

There was even a demand in 2005 to present to the Swedish authorities a long-term waste treatment plan comprising the entire site of Ringhals.

Up to recently the primary strategy was to ship the complete SG, untreated, to the tunnels down at SFR-storage, in connection with SFR's closure. The content of the long-lived isotope Ni-63 in the SG tubes is far above design criteria for the SFR repository.

In many countries there is no possibility for disposal of large components in one piece due to the limited space available at final disposals. A Ringhals SG weighs 310 tons and the storage volume would be about 400 m^3. Considering the high costs per m^3 for disposal in existing or planned final repositories, reduced volumes are almost mandatory.

With STUDSVIK's waste treatment method applied to SG's the secondary waste can be reduced down to 20-25 % of the original weight. Most of the material, which is ready for final disposal, is the tube material and parts of the water chambers and tube plate.

COLLABORATION BETWEEN RINGHALS AND STUDSVIK

Ringhals is a nuclear power plant owned by Vattenfall AB, with 3 PWR and 1 BWR unit. Westinghouse delivered the PWR´s.

Two of the PWR´s have replaced their SG's (3 from each unit) in 1989 and 1995 and the replacement at unit 4 is planned for 2011. The removed SG's are presently stored on-site awaiting final disposal.

Studsvik Nuclear AB has for many years developed methods for treatment of large contaminated, components as well as treatment and recycling of metallic scrap both from operation and decommissioning. This experience has now been applied for the treatment of a retired SG.

As will be described below, there are nuclide related problems concerning the disposal of exchanged SG's. This was the driving force to come up with a new technical solution to treat the full size component. The aim with this project was to demonstrate a method that can be applied generally to any SG that is subject to waste conditioning.

Studsvik and NPP Ringhals have successfully conducted a co-financed development project based on the technique mentioned above. The aim was to effectively treat one Ringhals SG under optimal ALARA conditions and to minimise the secondary waste. This project was dubbed “SÅGA” (the acronym of the Swedish title: Studsviks ÅngGenerator Avfallsbehandling = Studsviks SG waste treatment). The treatment of the SG was conducted at Studsvik’s melting facility.

The combination of Ringhals’ SG operational data, which have been extremely valuable for the dose assessments and development of the treatment method to be applied, and Studsvik’s long term experience on treatment and recycling of contaminated components were ideal ingredients for a successful collaboration project.

STUDSVIK’S CONCEPT TO TREAT A SG FOR VOLUME REDUCTION AND MAXIMISING THE RECYCLING OF VALUABLE MATERIAL

The aim of the R&D project SÅGA was to investigate how large/small volumes could actually be obtained for final disposal after treatment of a Ringhals SG.

The assumption for this treatment was that the Inconel tube material was not to be subject to clearance or recycling but to be volume reduced only. Most of the material like the outer shell, the steam dome, the tube plate and water chambers etc was subject to melt and/or free-release and recycle.

The goal was to obtain less than 40 m^3 of residuals waste to be stored at SFR or SFL, respectively. Material that could not be recycled (by clearance) had to be reduced in volume and packaged for final disposal. Furthermore, the SG treatment method should be adjusted to fulfil demands for continuous conditioning of SG’s at Studsvik.

The long-term goal is to treat at least three SG’s per year at Studsvik melting facility.

STUDSVIK’S TECHNICAL CONCEPT

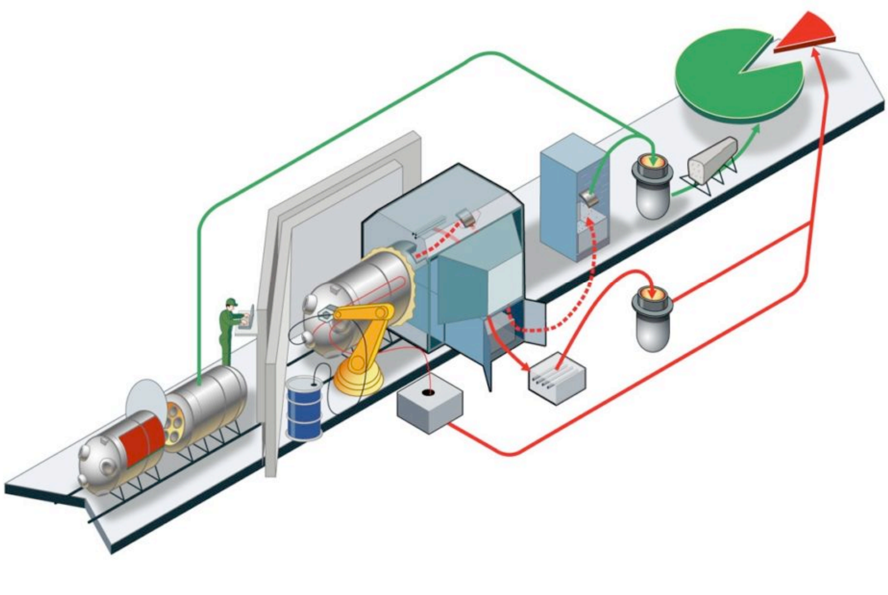

Fig 2.1. Schematic waste treatment of Steam Generators

Some technical items on the waste conditioning of the SÅGA project are summarised below, details are given in paper 7131.

The most important point of the concept is its applicability to SG’s as well as other larger components from NPP´s within and outside Sweden.

- The Ringhals SG was shipped to Studsvik by boat.
- The Steam dome incl. the moisture separator was cut as a first step.
- The tubes were decontaminated using a dry method, i.e. blasting with steel grits, to reach a satisfactory Decontamination Factor (DF) for the further segmentation activities.
- The outer shell, tube plate and water chambers were decontaminated on the inside using grit blasting technique.
- The tube package material was compacted for volume reduction.
- The outer shell, water chamber and tube plate were segmented and melted.
- The main part of the material was possible to free-release either directly after melting, alternatively after decay storage.
- The secondary waste was conditioned in accordance with the waste plan and to meet the criteria for disposal.

Activity inventory
Due to the restrictions concerning nuclide inventory for the existing final repository the characterisation and correct sorting of the waste to be stored is essential.

This is of great importance concerning to the residual waste of the SG’s to come. The long-lived nuclides is mostly concentrated in the tube material and water chambers that can become secondary waste

Today Sweden has a final repository for operational waste (SFR), has acceptance criteria that limits the content in the repository at closure. Restrictions concern many nuclides but are more restricted for long-lived nuclides and alpha emitting nuclides.

This implies that the dominant part of the activity inventory of the Ringhals SG, being Ni-63 and Fe-55, cannot be disposed of in SFR due to these limitations. Such material has to be disposed of in repository for waste containing long-lived nuclides, planned as SFL.

Evaluation of the method
The developed method contributes to fulfil the long-term demands for waste treatment plans. Thus, technical development is requested not only in Sweden but also by other countries around the world in possession of retired SG’s today or in the future.

The Studsvik facilities have advanced methods for managing all working steps necessary for treatment of full size SG’s.

CONCLUSION AND RECOMMENDATIONS

The goal for the project was to develop a method and techniques to achieve minimum waste volumes for final storage from the treatment of a Ringhals SG. Before the treatment the SG had a weight of 310 tons and a storage volume of 400 m^3. The result is less than 40 m^3 to be stored at SFR/SFL.
The conclusion after the conduction of the project is that an effective treatment of a full size SG can technically be achieved resulting in a long-term economical gain and a strong environmental profile due to the low volume of residues.

Recommendations for future projects will be:

- To conduct waste treatment of SG’s and other large reactor components in the new, well adapted facility.
- Continue further development of methods and equipment.

- Focus continuously on ALARA-principle.
- Continue to improve logistics, routines and instructions for the various sub-moments of process.

FUTURE ASPECTS

Focusing on systematic development in the area of waste conditioning of radioactive scrap material Studsvik has established new technique and logistics based around its activity. The investment in method development for SG-treatment has generated great interest from many international utilities, owner of SG's, that has been changed or to be changed in a near future. Within the next 3 – 4 years the remaining five SG's from Ringhals will be treated at Studsvik. Also four SG's from Stade NPP in Germany are foreseen for treatment is Studsvik within the next 3 years.

The modes for waste treatment and the alternatives of needs and requirements vary essentially among the different countries and thus the goal for the different national final repositories regarding amount and characteristics of the waste residuals from an SG being acceptable. But independently of the national needs and possibilities for SG disposal, there is still a demand for volume reduction before storage at those expensive repositories. There have been cases where it turned out to be more economical to do volume reduction of larger components at site in order to save costs for transportation to the repository.

SUMMARY

In many countries waste conditioning of full size SG's is applicable, due to the large volume, the weight as well as the nuclide inventory, before it can be disposed in the final repository.

Studsvik has in this paper described the SÅGA-project that demonstrated the possibility to conduct a complete waste conditioning of an SG with a maximal recycling of steel.

The waste treatment was conducted in a way that respects radiological (ALARA) and environmental conditions.

Economically it is most important to minimise the volumes that are to be disposed of due to the costs per m^3 in today available repositories. In addition it is environmentally important to re-use most of the steel.

Further development may achieve ways to even free-release and recycle tube material. This would allow recycling of a high nickel alloy.

The need for volume reduction is important within the nuclear industry, partly because many NPP´s are under decommissioning, partly because of the need of effective waste treatment in order to allow for upgrading and new installations.

REFERENCES

1 Paper 7131 NEW TREATMENT CONCEPT FOR STEAM GENERATORS- TECHNICAL ASPECTS

New Treatment Concept for STEAM GENERATORS – Technical Aspects

(Paper 7131)

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ABSTRACT

The project that will be described is a co-operation development project (SAGA) between Studsvik and the Ringhals NPP. The objective for this development project was, to show that it is possible to perform effective waste treatment of a Steam Generator (SG), to minimize the volume that in the end will have to be finally disposed of and to recycle as much of the metals as possible. Another objective for the project was to do this in a safe way and without a large dose load to the personnel.

The treatment concept contains the whole chain of activities from loading of the steam generator at Ringhals NPP onto the special vessel M/S Sigyn, and the transportation of the SG from Ringhals NPP on the west coast of Sweden to Studsvik on the east coast, to the recycling of the metals and the packing of waste in final packages suitable for disposal.

The volume for a final repository before treatment was about 400 m^3 for the SG and after treatment the volume for final disposal is < 35 m^3, which gives a volume reduction factor of about 11. The amount of material from the steam generator that has clearance for free release is 75-80 % of the weight.

A project is started to analyse the experience from the project above and to come forward with recommendations for how to lower the dose exposure, minimize the secondary waste for final disposal and to decrease the treatment time.

Some actions are already taken:

- A new larger treatment facility is built at Studsvik, > 1000 m^2, planned to be operational in April 2007.
- Investments in a larger band saw.
- Improvements of the blasting equipment.
- Improvements of the method of segmentation of the tube bundle.
- Improvements of the method of volume reduction for the tube bundle.

INTRODUCTION

The component that should be treated was a steam generator (SG) from the Ringhals 3 NPP. The dimensions of the SG were Length: 21 meter, Diameter: 4.5 meter, the weight: 310 metric tons; the storage volume was approx. 400 m^3.

The estimations of the radiation exposure to the operators were based on measurements. Co-60 was in the range of 0.65 TBq. For the long-lived isotopes, Ni-63 was the dominant in the range of 16 TBq.

The concept for the treatment of the SG was divided into following steps:

- Transportation from Ringhals NPP to the treatment facility in Studsvik with the special vessel M/S Sigyn.
- Separation of the steam dome.
- Decontamination of the tube bundle.
- Segmentation of the tube bundle and the outer shell of the SG.
- Segmentation of the water chambers and tube plate.
- Segmentation of the steam dome.
- Melting of the material from the SG.

TREATMENT

Transportation from Ringhals NPP to Studsvik

Before the transportation of the SG a lot of preparations were done. The paper work that had to be put together were extensive, some examples; transportation permit from Competent Authority (CA), technical description of load-settlement at the ship M/S Sigyn, calculations of the capacity of the roads at Ringhals and Studsvik, all this documents was collected in the Waste Plan written by Ringhals NPP. Technical equipment for the handling with the SG at Ringhals and Studsvik has to be procured.

The transportation of the steam generator started at the temporary storage facility at the Ringhals NPP.

In order to prepare the transport of the SG, a number of shielding walls within the temporary storage facility at Ringhals had to be moved. The next step was to change the beams under the SG, to be able to load the SG onto the special trailer.

After all preparations, the SG was transported on the trailer, from the interim storage to the Ringhals harbour and on board the special vessel M/S Sigyn. M/S Sigyn is a special vessel for transports of radioactive waste from the Swedish nuclear industry.

The SG was then transported from Ringhals NPP on the west coast of Sweden to Studsvik on the east coast, onboard the ship. At Studsvik harbour the SG was unloaded and transported to the treatment facility.

This step worked as planned and the conclusion is that it's possible, without any distortions, to transport a large radioactive component with the dimensions, Length: 21 meter, Diameter: 4.5 meter and a weight of 310 metric tons.

Fig. 1 Transportation of the SG into Studsvik treatment facility.

Separation of the steam dome

Segmentation of the SG started with the separation of the steam dome from the lower section containing the tube bundle. The cutting was preformed with a wire saw. The wire cutting was used as a test to analyse that method for future waste treatment projects. After the segmentation, the steam dome was transported to another location for final treatment.

A special designed shielded cell had been constructed for the treatment of the SG.
The cell is designed as a self-supporting unit equipped with thick steel shielding and an under pressure is maintained in order to avoid spreading of contaminants outside the cell. The cell is equipped with a separate venting system with a cartridge dust collector with automatic rinsing and a HEPA filter as a final filtering step before the air is led to the normal venting system in the building. There is a remote handled segmentation robot installed inside the cell supported by a separate hydraulic system. There are a number of tools for the robot that are used for cutting and handling of the material. The transport of material in and out of the cell is done via a sluice, in order to avoid spreading of contaminants.

The remote handled segmentation robot is operated from a platform outside the cell. For surveillance and control, there is a lead glass window and remote controlled TV cameras inside the cell and monitors on the operator's platform. Most of the work inside the cell was done by camera surveillance.
The cell was moved forwards step by step, as the work progressed, by special hydraulic equipment.

The shielded cell was connected to the SG before the next step.

Fig. 2 The special designed shielded cell.

Decontamination of tube bundle

Decontamination of the tube bundle was performed with using steel grit blasting. Special designed remote controlled blasting equipment was purposely developed.
Used blasting material and oxides from the tube bundle was collected in special containers, designed to be able to send directly for final disposal. The filter bank that was cleaning the air coming from the blasting equipment was also mounted in a container, designed for final disposal.

The dose rate on the surface of the outer shell was 0.5 mSv/h, before the blasting and 0.01 – 0.02 mSv/h, after.

Of the 4674 tubes 4615 were decontaminated, the plugged tubes weren't possible to decontaminate. The result showed that > 85 % of the activity from the tube bundle was removed. The remaining activity was inside the tubes that were not decontaminated and inside the water chambers.

During the time the blasting process took place, improvements were performed. The improvements were both on the blasting equipment to improve the reliability as well as to reduce the radiation exposure to the operators.

The target value for the decontamination of the tube bundle was exceeded. The result from the blasting showed that the tube bundle could be melted combined with compacting for volume reduction, which decreases the volume of the secondary waste to final disposal.

Segmentation of the tube bundle and the outer shell of the SG

Segmentation of the tube bundle and the outer shell of the steam generator were started after the decontamination of the tubes. The segmentation was done in the shielded cell using the remote controlled robot.

The tube bundle was enclosed in an 80 mm thick outer shell and a 9.5 mm wrapping. The tube bundle was made of 4674 U- tubes, fixed longitudinal by 14 baffles, put together with a large plate. In the feed water inlet, there were a number of plates to control the water flow.

The SG was put onto pulley supports, that it could be rotated during the process, in order to increase the efficiency of segmentation.

The segmentation of the tube bundle was divided into several steps, equal to the length of the cell. After each step the cell was moved forward.

Each step was consisting of:

1. Cutting of the outer shell;
2. Cutting of the wrapping;
3. Cutting of the tubes;
4. Cutting of the baffle plate;

The cutting of the outer shell was done by cutting torch into pieces of a size that they could be transported out from the cell through the sluice, for grit blasting and melting. The wrapping was handled the same way.

The tubes and the baffle plates were cut by abrasive grinding machine. The tubes were cut and loaded into storage boxes, before compacting and melting. The volume of the tube bundle was about 45 m^3, and the volume was reduced to < 5 m^3 by compacting and melting.

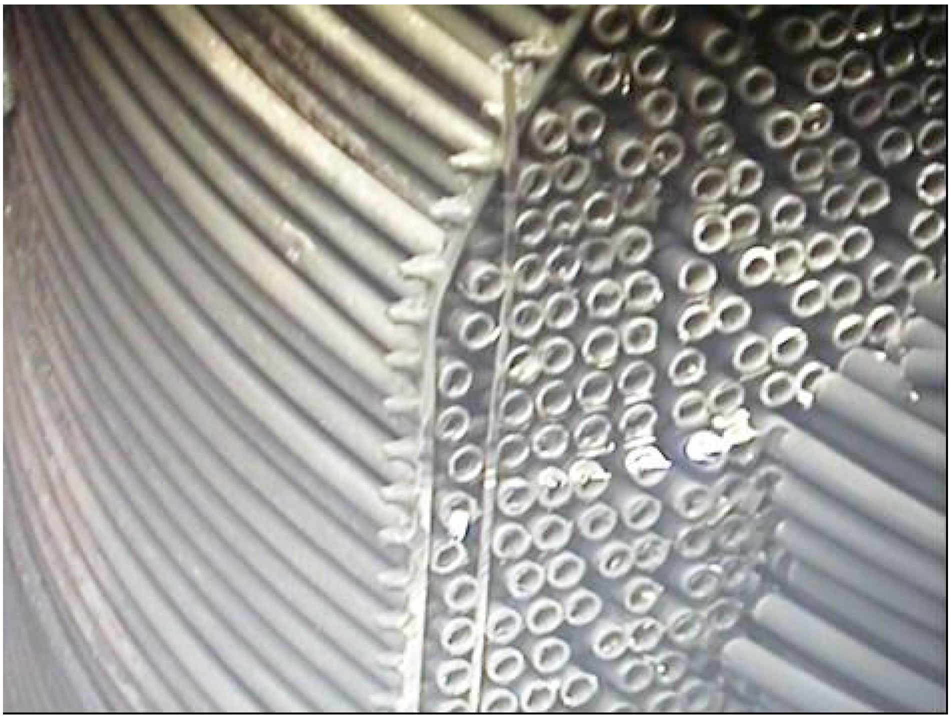

Fig. 3 Tube bundle cut into pieces.

Segmentation of the water chambers and tube plate

The water chambers were cut with a torch into pieces suitable for the band saw. Thereafter the pieces were segmented in the band saw before blasting and melting.

The tube plate was tilted over, after the water chambers were removed. The tube plate was then cut into pieces in the band saw before blasting and melting.

The water chambers and the tube plate were plated by a corrosive resistant layer of SS-steel and Inconel (cladding). In the cladding, there were small (micro) cracks were radioactivity had migrated, during operation. Therefore, the contamination could not be removed by blasting. The remaining activity was too high to enable clearance for free release, after melting, without a special treatment. The solution of the problem was to separate the cladding by cutting and melt it together with the tubes. The rest was possible to melt and clear for free release.

Fig. 4 Water chambers in the band saw.

Segmentation of the steam dome

The internals of the steam dome was cut into pieces for melting. Thereafter the outer shell was cut into approximately 10 pieces, decontaminated and directly cleared for free release.

The aim for this sequence was exceeded as the plan was to melt the outer shell before clearance for unconditional reuse, as it turn out is was possible to clear the material for free release after decontamination and proper testing.

Melting

Melting of the material from the outer shell of the tube bundle, material from the water chambers, tube plate and the internals from the steam dome were done according to normal procedures. The result from the melting was as expected and the material was cleared for free release.

The tube bundle material and the cladding from the water chambers and the tube plate were melted for volume reduction. This metal was not possible to free release because of the amount of rest activity. It was a setback that the cladding couldn't be decontaminated by blasting, but after some investigations it was recognise that the contamination was inside micro cracks in the surface.

The possibility to melt the tube bundle was a big success in the work to reduce the volume of the primary waste. Development is presently focused at the method of melting tubes in order to minimize the radiation exposure and improve the working environment.

Secondary waste

The amount of material from the steam generator that has clearance for free release is 75-80 % of the weight. The rest of the material, not possible to release, are the tubes, cladding from the water chambers and tube plate and the secondary waste from blasting, cutting and melting.

The volume for a final repository before treatment was about 400 m^3 for the SG and after treatment the volume for final disposal is < 35 m^3, which is a volume reduction factor of about 11.

Secondary Waste	Volume (m^3)
Non combustible operation waste	13
Ash from incineration	0.5
Dust from ventilation	2
Used blasting material and oxides	3
Material not possible to free release	8
Slag from melting	3

Table 1 Summery of secondary waste from the development project SAGA

RADIATION EXPOSURE

The goal for the collective dose to the operators during the project was set to 30-40 man-mSv but it became < 70 man-mSv at the end. The cause of the divergence is mainly because of the increase in man-hours that wasn't accounted for.

The largest individual external dose was < 6 mSv. No internal doses were reported.

No accidents were reported.

No significant spreading of contamination occurred during the project.

CONCLUSIONS AND THE FUTURE

The objective for this development project was, to show that it is possible to perform effective waste treatment of a steam generator, to minimize the volume that in the end will have to be finally disposed of and to recycle as much of the metals as possible. Another objective for the project was to do this in a safe way and without a large dose load to the operators.

The goal for volume reduction of the material to final disposal was set to < 40 m^3 and the result becomes < 35 m^3 which is a good result. The amount of material from the steam generator that has clearance for unconditional use is 75-80 % of the weight. The material not possible to recycle has been volume reduced for final disposal.

The dose budget for the project was exceeded, the main reason for that was the increase in man-hour during the project.

A project has been started to analyse the experience from the treatment of the steam generator and to come forward with recommendations for how to lower the radiation exposure to the operators, minimize the secondary waste for final disposal and to decrease the treatment time.

Some actions are already taken:

- A new larger treatment facility is built, > 1000 m^2.

  The new building will give us the opportunity to work in a more effective way and that will give us the possibility to lower the dose load to the personnel. Inside the building there will be flexible walls that can be located depending of the size of the treated object. Another big advantage is that the handling with the secondary waste will be more efficient.

- Investments in a larger band saw.

  The new band saw will make segmentation of the water chambers and the tube plate more efficient. It will also probably give us the possibility to free release more of that material. The new equipment will also have a positive impact on the dose load and treatment time.

- Improvements of the blasting equipment.

  The improvements of the blasting equipment will lower the total time for blasting to a third. It will decrease the need for maintenance, which will lower the dose load to the personnel.

- Improvements of the method of segmentation of the tube bundle.

  The improvements will make it possible to free release more of the material, lower the amount of secondary waste and decrease the treatment time.

- Improvements of the method of volume reduction for the tube bundle.

  There will in the future be possible to choice between two ways of volume reductions for the tube bundle:

  - Compacting for volume reduction before final disposal.
  - Compacting and thereafter melting for volume reduction before final disposal.

ALARA Preparation, Implementation and Some Thoughts With Reference To - Treatment Concept for STEAM GENERATORS

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OUTLINE

The ALARA (Radiation Protection) experience from making the decision to treat a large component as a Steam Generator, to actually collect essential ALARA input data, plan for ALARA activities, implement ALARA in technical solutions, perform volume reduction, follow up and optimize from a Radiation Protection point of view, is probably in many aspects an ideal situation from a Radiation Protection (RP) point of view.

The unique features are that we have got one specific component containing basically one major source contributing to dose exposure, totally limiting and affecting the possibility to decrease the radioactive waste specific volume and release material classified as non-radioactive. The possibility to take advantage from already existing technical solutions and ALARA philosophy at the nuclear power plant and at the waste treatment plant is very important as well as using existing industrial solutions, as long as they meet ALARA requirements.

The experience so far, with treatment of the second Steam Generator in progress, is that the concept is practicable in terms of ALARA. Even though Radiation Protection actions have been implemented continuously; there are still challenges for improvement towards optimal technical and logistic solutions.

This paper gives a rough abstract of the initial analyses [1] carried out to establish the foundation for ALARA and Radiation Protection measures and some thoughts on the outcome.

The treatment concept has been an R&D project in co-operation between Ringhals AB and Studsvik Nuclear AB.

Essential Radiological input data

In order to facilitate planning for all Radiation Protection activities, it was necessary to begin with mapping the radioactive source. We began by comparing old nuclide specific (NS) measurements, from the time of replacement, with new NS measurements and extensive dose rate mapping with GM-detectors and TLD. Other data such as NS measurement on pulled tubes were valuable for comparison.

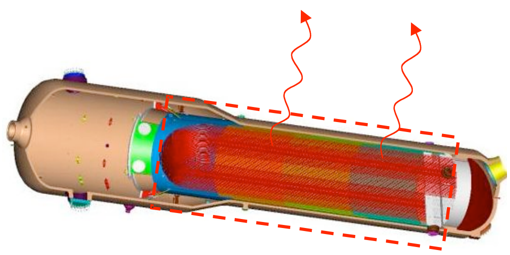

Fig. 1 cross-section Steam Generator

All the gamma activity measurements were in acceptable agreement to make dose rate and shielding calculations for any realistic exposure situation.

Scaling factors for transuranic elements and strontium relative to Co-60 determined for the primary coolant system, were used to calculate the dose contribution compared to Co-60. A postulated intake of activity from a typical Steam Generator tube oxide would be dominated by Co-60, contributing more than 70 % of the effective dose.

Long-lived nuclides, such as Ni-63, having a strong focus in aspects of free release, were initially overestimated. The deposition in the tube bundle oxide is much lower than in the oxide layer of the stainless steel piping. Analyses of the blasting abrasive and dust from the tube oxide showed that the Ni-63 concentration was of the same magnitude (Bq) as Co-60 (13 years after replacement).

Planning for ALARA activities

From the very beginning it was decided that ALARA thinking had to be carefully implemented and maintained throughout the project. It may sound basic, but to actively consider ALARA and Radiation Protection measures, qualified resources and a careful implementation are needed. Typical examples are: Constantly evaluating and balancing technical solutions against ALARA measures and standing ALARA items in meeting agendas and training of personnel. In this type of R&D projects you have to be prepared to stop, think, analyse, react and verify to optimize as the work progresses.

Another driving force to implement ALARA measures has been the alpha-value; it was 4.500 SEK per saved mmanSv, but it has recently been increased to 10.000 SEK/ mmanSv (1000 €/ mmanSv).

Another important driving force has been the dose budget; it was originally set to 30 mmanSv. Actually, it was tricky to establish a realistic target, since it was an R&D-project, proceeding step by step. Since it was a completely new concept, we decided to try a Ringhals average value for dose exposure per produced activity in final waste package (mSv/Bq). Paying regard to this value gave us an estimated dose value of 10 mmanSv. Of course, we had to reject this value, but we believe that it can still be a target level for upcoming treatments. The final dose target was set from using the Studsvik Nuclear AB timetable for all initially planned activities, using calculated radiation levels in a number of work positions and situations with handling of primary and secondary sources (radioactive waste).

Implementing ALARA into technical solutions

Having full control over the initial source and taking advantage of the radiation shielding offered by the component itself, gives a starting point to implement ALARA.

The most important reasons to have full control over the source in all situations are to; minimize dose, avoid spreading of contamination, avoid cross contamination to clean materials, avoid internal contamination, constantly know where activity deposits, optimize radiation shielding around work areas (components) and shields integrated in the equipment, design equipment to minimize deposition and facilitate decontamination, design and use equipment to minimize dose by remote control, control airflows filtration and capacity.

The picture to the right shows examples of ALARA measures, using radiation shields. The areas around radioactive components are shielded with mobile concrete blocks (A), allowing adjustments during the treatment process and reducing radiation levels to some microSv/h outside the shield.
The cutting cell (B) in the rear is heavily shielded with 40 to 80 mm of steel with filtered underpressure ventilation.
The large band saw is encapsulated with filtered underpressure ventilation to avoid spreading of activity into the workshop area.
Main control panels for most operations are positioned behind the shielding walls (D).

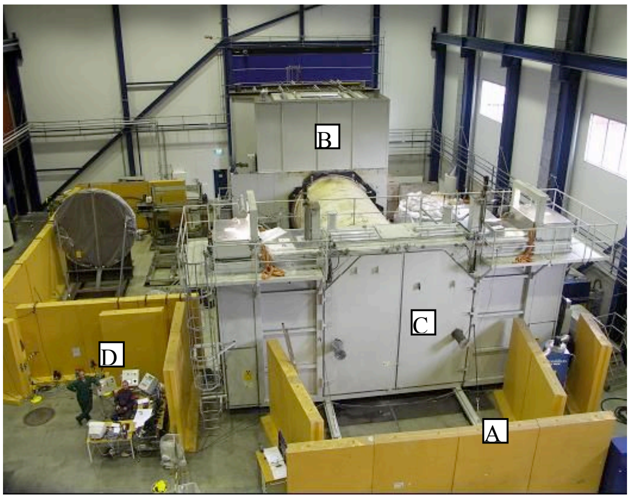

Fig. 2 view treatment area for SG

The main ALARA measure in the process was initially to remove the activity from the tube bundle. The idea is to lower dose to personnel, minimize cross contamination, minimize contamination of equipment used in the process for free release, minimize contamination of clean material and concentrate the tube bundle source into small volume containers for final disposal. The blasting operation has been one of the most dose contributing steps and has gone beyond budget. However, the advantages of the process are still dominating, compared to the dose. It is possible to develop and refine the procedures towards lower doses and to maintain complete control over the removed high activity dry substance.

Follow-up and optimization from a Radiation Protection point of view

An active presence of Radiation Protection personnel is crucial in order to follow-up and to improve radiological conditions. For example, an accurate dose system (EPD), with carefully selected codes for dose registration, is used together with dose rate measurements logged online, as a basis for improvements.

Fig. 3 View tube pulling

One operation that has been changed for treatment of the second Steam Generator is segmentation of the tube bundle. Segmentation starts with the tube bends and then the tubes are pulled out; the tubes are then compacted by a scrap press with melting as an additional option. This showed to be an improved technical solution. Follow-up of the dose load for this operation suggests further ALARA measures. As seen in some other situations, even quite low dose rates and small doses for single operations will result in a significant collective dose for the total work. In this case, the dose per pulled tube was 2,5 μSv. It seems quite low, but note that there were some 9400 tubes resulting in roughly 25 mmanSv.

Final point

Performing ALARA with high standards is in principle a matter of accepting ALARA and implementing it in a way that already is established in purchaser and vendor routines. Corporate cultures may differ to some extent, but in an R&D project it is just an opportunity to join forces.

As you see, the treatment concept is a completely tailor made, based on special equipment as well as industrial standard equipment; this makes it an ALARA challenge. From the purchaser view, the treatment concept has expressly developed with a number of ALARA implementations, but ALARA reviews must continue and result in still more improvements, ALARA never sleeps!

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