Treatment of LLW Components for Waste Minimization and Recycling – 16258

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ABSTRACT

The Studsvik Melting Facility has been in operation for almost 30 years. Many turbines, heat exchangers and other retired components, pipes, structures have been treated in the facility during those years.

The ambition of all projects is to minimize the waste volumes for final disposal and to maximize the amount of material that can be recycled. Another objective, respecting ALARA, is to keep dose exposition to the personnel at very low levels. The overall concept comprises the whole sequence of preparations from road and sea transports, the management of the metallic LLW by segmentation, decontamination and sorting using specially devised tools and shielded treatment cell, to the decision criteria for recycling of the metals, radiological analyses and conditioning of the residual waste into a final form suitable for customer-related disposal.

The records show that the amount of material possible for conditional clearance to open market after treatment is between 95 – 97 % on weight for falling metallic scrap. For large components there is a larger span and especially for heat exchangers.

This paper describes the Studsvik technical concept and experience related to treatment of metals from the program for modernization and power upgrade of the Swedish nuclear power plants.

INTRODUCTION

When the metal treatment operations at the Studsvik site started in 1987 most objects were fairly limited in size, with low dose rates and low levels of contamination. The production capacity was low due to facility limitations as well as limited experience. As early as in 1988 the first large components (i.e. objects that do not fit into an ISO freight container) from abroad arrived at Studsvik for treatment. This first shipment consisted of low pressure pre-heater and moisture separators, in total 300 Mg. In these early days the selection of segmentation tools was not as wide as is currently available. Those early projects gave considerable experience in lifting, transportation and treatment of large size material.

Due to accumulated experience and a facility extensions, in the 1990’s Studsvik became able to treat “large components” such as larger heat exchangers and turbine casings from BWR's as routine operations.

Today, Studsvik has developed and is an international supplier of waste processing services for most types of contaminated metals including large components with relatively high radioactivity concentrations and/or complex geometries such as PWR steam generators, BWR re-heaters and Magnox boilers.

Fig. 1. Induction furnace at Studsvik after completed casting process.

Over the years, several retired components from domestic and international customers such as BWR turbines, heat exchangers including PWR steam generators and Magnox boilers have been treated. The purpose of the waste processing projects is to minimize the waste volumes for final disposal, mainly by metals recycling to open market.

THE SWEDISH MODERNISATION AND POWER UPGRADE PROGRAM

The Swedish nuclear power industry has the last decade performed a large program aiming to extend the life time as well as increase the power.

Since the closure of the Barsebäck NPP (twin BWR plant) Sweden has in total ten power reactors in operation. Seven BWRs and three PWRs, all designed by what today is Westinghouse. The NPPs are located on three sites along the along the Swedish coast. The size of the BWRs are from 492 to 1450 MWe and the PWRs have a rating of 865-1107 MWe.

In a radioactive waste management perspective those modernizations and power upgrades resulted in a large volume of retired objects. For some components only the internals, like tube bundles in heat exchanger were replaced while other components were entirely replaced. The main objective of the licensees was to arrange the waste management in a way that did not disturb the activities with installing the new equipment at the NPPs. Every day without power production is very costly. Other important objectives were to perform the waste management shortly after the replacement, not to put burden on future generations, as well as to perform treatment and clearance by internal resources when beneficial.

All the licensees turned to Studsvik for technical support and cooperation in the waste management as well as for treatment of the components not decided to make clearance of locally.

In total a significant tonnage of metals from the turbine island of the BWRs as well as steam generators and other components from the PWRs has been sent for treatment and there is still material to come.

MATERIAL SUITABLE FOR CLEARANCE THROUGH METAL MELTING

As this paper is focused on the material from modernization of the Swedish NPPs during the period 2004-2014, this section will entirely focus on BWRs and PWRs. Even though a lot is very similar between the two types of reactors there are significant differences not at least when it comes to the management of retired components.

Boiling Water Reactors

Boiling Water Reactors, as per the principal design, contain significantly more metal that is or could be contaminated above clearance levels. In a modernization program like the ones performed in Sweden most material that will have to be taken care of comes from the turbine island, i.e. the area of the plant in which the power in the steam is converted to electric power. Examples of components within the turbine island are the turbines, heat exchangers, valves, pumps and a lot of piping and structures.

The nuclide inventory is from a metal clearance perspective dominated by Co-60. For the residues other nuclides as the actinides and cesium has to be considered as they are transferred to the secondary waste.

Typical components which by decisions of the licensees have been sent to Studsvik for treatment are:

- High pressure turbines
- Low pressure turbines
- Low pressure feed water heaters
- High pressure feed water heaters
- Steam re-heater (heat exchanger for steam heating before entering the low pressure turbine)
- condenser (steam side)
- Steam valves

- Pumps

The reason for the decision to send for off-site treatment is, in most cases, the cost benefit but could also be of or combined with sustainability or technical reasons.

Fig. 2. Forsmark NPP turbine rotor to Studsvik for treatment.

Fig. 3. BWR re-heater during transport to Studsvik for treatment.

Depending on the properties of the objects it may be possible to decontaminate the objects.

More than 6000 tonnes of material from turbines, heat exchangers etc. from the modernisation program of the Swedish BWRs has been treated in the period 2004-2014.

Pressure Water Reactors

Pressure Water Reactors are in in the normal case only contaminated within the primary systems which means that for example all material within the turbine island can be considered as non-contaminated.

The main components from a PWR that are typical objects for waste treatment are the steam generators and other heat exchangers, the pressurizer as well as other equipment and installations within the reactor building.

Fig. 4. One out of in total nine steam generators from NPP Ringhals to Studsvik.

The steam generators, as an example are contaminated on the tube side while the steam side should be free from contamination unless there has been leakages. Out of the total volume of a steam generator only a low percentage of the material is expected to be contaminated or at least not contaminated above clearance levels.

The nuclide inventory is also here dominated by Co-60 in a metal clearance perspective. For the residues other nuclides as the actinides and cesium has to be considered as they are transferred to the secondary waste. Long lived beta emitters like C-14, Ni-59/63 may also be of importance.

In total approximately 2800 tonnes of steam generators from the modernisation program of the Swedish PWRs has been treated in the period 2004-2014.

WASTE ACCEPTANCE CRITERIA FOR TREATMENT IN STUDSVIK MELTING FACILITY

Studsvik treats low level radioactive contaminated metallic scrap, slightly activated metallic scrap and large components from power reactors. Also material from other facilities like research facilities and fuel fabrication plants can in most cases be accepted as long as the Waste Acceptance Criteria [1] are fulfilled or a special approval is granted.

Metals subject to treatment

The following metals can be melted in the facility:

- Carbon steel
- Stainless steel
- Aluminium
- Cupper
- Brass
- Lead

A few other metals, like titanium, can be decontaminated by mechanical means followed by general clearance without melting. Mixed metals, like electric motors, cannot be treated.

Radiological characteristics

Surface dose rates should in general be below 0.2 mSv/h even though "hot spots" up to 0.5 mSv/h in most cases can be accepted. The dose rate at one meter distance should be below 0.1 mSv/h. The total activity of beta and gamma emitting nuclides should be below 50 Bq/g and alpha emitting nuclides below 100 Bq/g.

Fissile material must not have an U-235 enrichment < 5 %.

For large components with higher specific activity levels as well as for other more contaminated material, a special review is required before a potential acceptance as a special specific case.

THE STUDSVIK TREATMENT CONCEPT

The overall concept applied to metal scrap and especially large components sent 'as is' to treatment in Studsvik comprises a whole sequence of planning and preparation arrangements. The handling of the objects including the road and sea transports may need significant attention, expertise and in some cases also physical arrangements. The experience built up by Studsvik and partners is extensive, somewhat unique as well as well proven.

The activities after arrival to the Studsvik facility covers several pre-treatment steps including segmentation, decontamination and material segregation. Specially devised tools for both segmentation and decontamination have been developed and implemented in the operations to secure a sound radiological environment for the workers. A shielded treatment cell is available in case of heavily contaminated parts inside components. The latter is typical for certain heat exchangers like steam generators. The importance of a strong safety culture throughout all activities is crucial.

Before the metal is charged to the melting furnace it will be inspected to make sure the material not contains any liquids or closed cavities. When the metal is melted the slag will be removed, representative samples taken and the metal is casted to ingots. All ingots and samples are marked to achieve full traceability.

The samples are analysed and the result of which will form the basis for whether the material is subject to clearance for recycling to open market as per license conditions or has to be disposed as waste along with the secondary waste generated (cutting residues, slag and dust).

SUMMARY OF MATERIALS TREATED AND ASSOCIATED RESULTS

As mentioned above in total approximately 9000 tonnes of metals from the modernization program of the Swedish NPPs has been treated in the period 2004-2014.

Most metals have been subject to clearance either directly or after certain decay storage. A significant percentage has due its activity content been melted or compacted for volume reduction only. The table below gives a summary of the volumes for metals treated for clearance or volume reduction.

TABLE I.Total tonnage of metals from NPP modernization programs treated in Studsvik, Sweden.

NPP	**Tonnage (Mg)**
Forsmark (3xBWR)	3064
Oskarshamn (3xBWR)	2356
Ringhals (1xBWR + 3xPWR)	3544
TOTAL	8964

The global amount of secondary waste from all these campaigns, including significant amounts of heat exchanger internals treated for volume reduction only, is 12.8% on weight.

Considering only material treated for clearance the amount of secondary waste generated during treatment of large components is in the range of 5% on weight.

In a volume perspective, since most components contains a lot of voids, the impact of the treatment is even higher. The savings in disposal volume can be as high as 96 to 98%.

CONCLUSIONS

The results from the metal treatment campaigns from the Swedish modernisation program shows the benefit applying metal melting and clearance for recycling to open market. It is obvious that the same concept can be applied on the decommissioning projects taking full benefit of the experience built up.

Melting of metals from nuclear facilities for clearance and recycling is sustainable as well as attractive from a cost perspective.

To secure success we have within Studsvik identified the following success factors:

- Experience, competence and understanding
- Structure and logistics, do things in the right order
- Safe, effective and robust processes
- Stakeholder involvement

REFERENCES

1. B WIRENDAL, A STENMARK, G KRAUSE; STUDSVIK/N-09/041, Metallic scrap Acceptance Criteria – melting services, Studsvik, 2009