Efficient and environmentally sound treatment of radioactive waste streams from maintenance, upgrade and decommissioning

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Abstract

Power generation of today struggle with many challenges and as the effects of global warming become obvious many countries seek alternatives to fossil fuel. The increasing interest in nuclear technology is based on its many advantages but the technology also offers challenges in how to cope with prolonged lifetime support and sustainable waste routes.

Studsvik have been processing Low Level Waste (LLW) at its licensed facility in Studsvik, Sweden since the mid-1970s. The facility has historically processed metallic and combustible waste and can today demonstrate a well defined, cost effective and robust waste volume reduction route for both the Swedish and the international nuclear industry.

Introduction

Significant volumes of Low Level Waste are today generated by the nuclear industry. Some waste has well defined routes for disposal using economically and technically efficient solutions. Other waste is temporarily stored on power plant sites waiting to be conditioned before final storage at dedicated repositories. The reasons for intermediate storage of waste may be several, such as radiological or physical complexity. Therefore on site conditioning for final repository may be technically challenging or time consuming and as such expensive.

Various technical options are available in the industry to handle LLW where one suitable route for waste includes external treatment by specialists. This helps the industry to minimize the cost for volume reduction and conditioning of waste before final repository. One such route includes Studsvik Nuclear AB in Sweden. With more than 60 years of experience in the nuclear industry in Sweden, Studsvik has since the 1970's treated combustible LLW and since the 1980's treated metallic LLW for the national and the international market. Today Studsvik is a leading specialist on waste volume reduction of Low Level Waste to help save cost at final repository.

Waste treatment is also logistics and transportation. Studsvik has over the years developed a good understanding of the complexity in national and international transportation of radioactive waste. Such transports always require close cooperation with the customer as well as with regulatory authorities in both Sweden and the country of origin for non-Swedish waste.

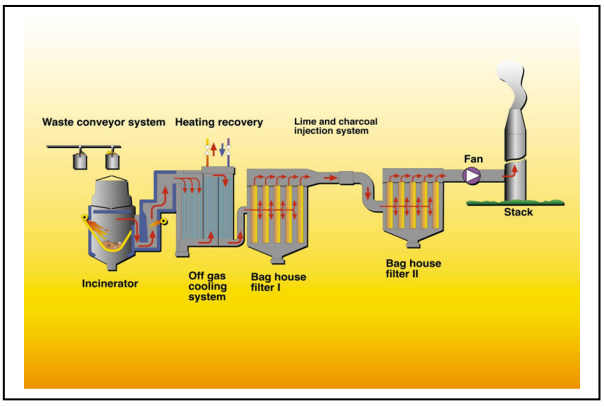
Waste Categories and Methods

Studsvik focuses on treating two typical waste streams generated by the industry.

- Low level combustible waste suitable for incineration
- Low level contaminated metallic scrap

Combustibles are treated in a high temperature incinerator for maximum destruction, resulting in minimized volume and a very stable residue suitable for final repository.

Typical combustible waste is protective clothing, wood, paper, plastics, etc. Studsvik has in recent time also developed methods for incineration of liquid oil and is currently developing a method for incineration of active granulated char coal used in gas filters etc. This service is expected to be available during 2011.
According to Studsvik acceptance criteria waste is typically pre-packed by the owner into transparent plastic bags, < 25 kg to allow some limited manual handling, sorting and inspection. The waste is typically shipped in 20-foot IP-2 containers and well characterized for physical properties as well as radiological content (maximum dose rate and nuclide inventory).
After processing, the remaining ash and fly-ash accumulated in the bag house filters is collected in drums. This secondary waste is conditioned according to customer specifications and subsequently returned to the owner together with a detailed production report.



Schematic overview of incinerator

Typical combustible waste

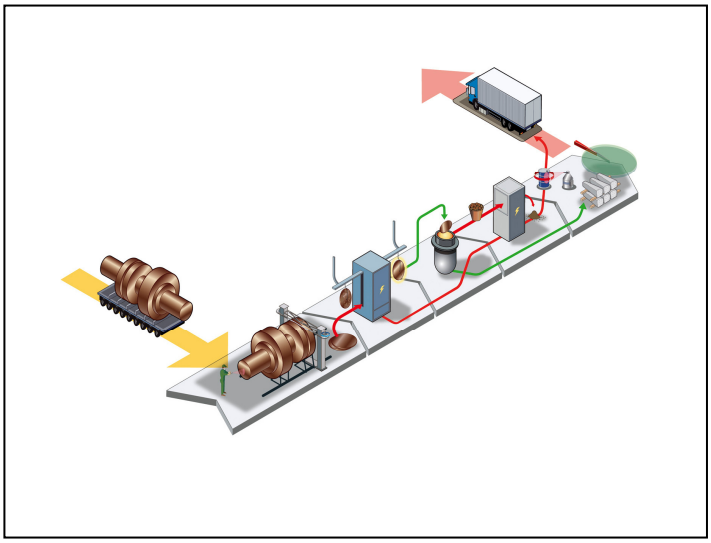
Treating combustible waste typically consists of:

- Close dialogue with customer to identify suitable waste streams and to verify match against Studsvik Criteria For Acceptance (CFA)
- Arrival inspection and verification of transport documentation, including radiological data
- Safety inspection of all waste and an assessment of the scope of work required

- Loading waste on the conveyor system for registering, weighing and transport into the incinerator
- Collection of residues such as ashes and fly-ash resulting from the treatment, forming secondary waste
- The secondary waste, including the radioactive contamination, is analysed to verify that the activity content matches the original declaration by the customer to ensure proper return back to its rightful owner
- All secondary waste is conditioned, packed and shipped back with a detailed production report declaring the result of the processing

Environmental aspects is an important part of Studsvik operations and off gas filtering is enhanced by using lime and activated char coal to minimize emissions. To further reduce the environmental impact Studsvik is recovering energy (~1,5MW) by reusing it within the site to heat facilities and thus saves significant expense and environmental impact.

Metal scrap is comprised of a wide variety of components such as pumps, pipes, duct work and other small waste fitting into a container, but also processing large components is today common practice at Studsvik. This includes heat exchangers and turbine components such as housing and turbine axel, with a typical weight of 150 - 250 tonnes. Large PWR steam generators, weighing 300 tonnes or more, are also successfully treated on a regular basis.



Schematic process flow for metal scrap

Typical metal scrap recycled by Studsvik consists of carbon steel, iron alloys, aluminium, lead, copper, brass, etc. Waste is delivered in transport packages such as 20-foot IP-2 containers and large components are transported under alternative arrangements according to international transport regulations. The acceptance criteria are well defined for physical properties as well as radiological content (maximum dose rate and nuclide inventory).

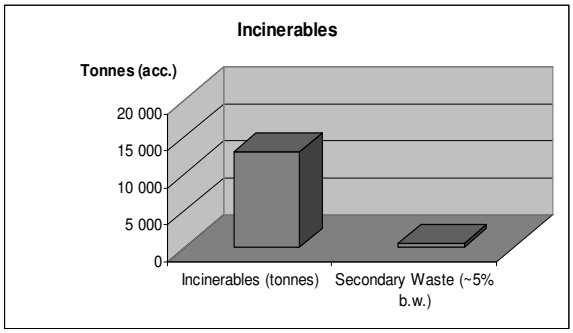
The treatment of metal waste is shown in the schematic illustration above and can be described as follows:

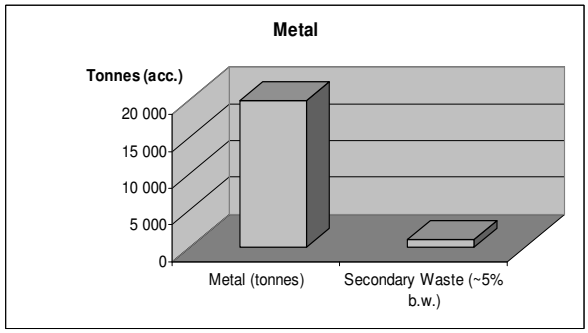
- Close dialogue with customer to verify suitable waste streams and verify match against Studsvik CFA
- Arrival inspection and verification of transport documentation including radiological data
- Safety inspection of all scrap and an assessment of the scope of work required
- Segmentation as needed to suitable size and weight. Surface contamination removed and collected in customer isolated campaigns
- Decontaminated scrap metal is melted into ingots and analytically sampled to verify successful processing
- To ensure all radioactive nuclides are returned back to the rightful owner after the residual secondary waste from the process is analysed. All residual secondary waste is conditioned and shipped back with a detailed production report declaring the result of the processing
- Metal ingots analytically verified to be in compliance with free release regulation is declared exempt by Studsvik, and after exchange of ownership from customer to Studsvik, the metal can be recycled as valuable raw material and routed back into the metal industry through internationally accepted procedures

Typical scrap metal processed at Studsvik, Sweden

Results

Studsvik has in total treated an excess of 10’000 tonnes of combustible material and 20’000 tonnes of metal at its site in Sweden since start of operation. Today the annual processing rate is approximately 500 tonnes of combustibles and 3500 tonnes of metal with a very high rate of volume reduction, shown below in the two graphs as the average over the historical production. Specific details depend however on waste character and may vary some from one case to other.





All final packages are analyzed and labelled, the results of which is reported in the final production report. The resulting secondary waste is prepared according to customer specifications before it is returned. The conditioning typically includes packaging in a 200 litre drums and subsequent return back to the owner where the package undergoes final preparations before storage in a repository in the country of origin.
Other forms of packaging may be required and will be arranged according to individual requirement by each customer and their standards.
After a completed campaign all secondary waste is returned to customer in country of origin to ensure volume reduced waste (containing the radioactive inventory) is brought back to its rightful owner for final storage.

Gamma-scanning

Exempt metal ready for recycling

Metal samples from each melting batch is analyzed to document data and to allow recycling as exempt metal. Metal ingots meeting regulated requirements will be recycled after transfer of ownership from customer to Studsvik.

Transportation

Transport of radioactive waste is well regulated at both national and international level. In order to safely and compliantly transport waste for treatment a variety of regulations must be understood and applied. Studsvik has many years of experience in this field and has a detailed understanding of the regulations for land (ADR - Accord européen relatif au transport international des marchandises Dangereuses par Route), sea (IMO – International Maritime Organization) and air (Dangerous Goods Regulations) transport. (Radioactive waste is, however, not transported by air freight due to several reasons, the main one being cost.)

To perform a shipment of radioactive waste not only the relevant transport regulation must be complied to fulfil safety concerns but also a special transport authorization must be granted. This authorization must be given according to directive Euratom 2006/117 and approved by the competent authority in both countries. The approval operates on a system of prior notification and approval where-by the applicant (consignee) must apply to the competent authority in the country of export for consent to ship the waste internationally. They in turn seek approval from the competent authority in the country of import (and any countries transited across) prior to approving, or otherwise, the shipment. The Euratom 2006/117 system also enables the competent authorities to place conditions on the shipment such as a requirement to return the secondary waste (ash, dust, slag, etc.) to the country of origin, or to give advance notice of when the consignment will ship.

Studsvik regularly performs, in close cooperation with customers, their competent authorities, and Swedish authorities, many international transports from, and back to, countries within EU as well as other international countries. A mandatory condition in all cases is that any individual campaign must in normal cases be concluded within 24 months and all generated secondary waste (any and all waste not possible to classify as exempt and free releasable) must be returned to country of origin.

Efficient planning with NPP and customer to create added value

The historical and most common scenario is that Low Level Waste generated on NPP sites is handled locally and packed/stored for future fate. Many examples can be seen where dedicated storage facilities at great expense has been built locally on NPP site to temporary hold waste for future treatment.

By experience Studsvik has seen possibilities of large savings to be made by detailed planning before the waste is generated to determine how LLW should be dealt with as it is arising.

- Waste categorisation into metallic waste, combustible waste and other waste suitable for high force compaction, etc. will allow first steps for optimum and final treatment of waste for final repository.
- By understanding the options available how to deal with different waste streams the best economical solution can be picked. Waste needing direct storage at final repository can be isolated from other waste streams subject for pre-treatment by efficient volume reduction to help save space in repositories.
- Some waste streams can be arranged to never reside on NPP site as they can directly be removed for external processing and volume reduction before final repository.

This strategy can successfully be applied for both regular production wastes as well as during exchange of components and decommissioning projects.
Studsvik has long experience being part of such planning, both in Sweden and in other European countries, and it has proven to allow large saving in time, effort and expense for the NPP management.

- Forsmark upgraded 2004 the low pressure turbines and Studsvik participated in the planning already during the summer of 2003 to present the concept how to fully help with packaging, transport, heavy lifting etc. as the metal was dismantled and removed from the facility.
    - Scope of work was to fully take responsibility of the transport, waste volume reduction, conditioning, final packaging and return transport of the radioactive residues as well as free release and recycle the bulk metal according to stipulated procedures mandated within the frame of Studsvik permits.

- GNS/STADE dismantled four steam generators in 2007 during decommissioning and Studsvik again participated early together with the customer in the project to offer turn key solution.
    - Scope was including documentation preparation, authority correspondence in Sweden as well as in Germany
    - Packaging, transport to Studsvik, waste volume reduction, conditioning and final packaging of radioactive residues as well as free release and recycle the bulk metal according to stipulated procedures mandated within the frame of Studsvik permits.

- OKG made a major upgrade during 2009 (PULS-project). Studsvik was again involved in early identification and preparation of how to handle metallic waste suitable for treatment by volume reduction at the in Studsvik. Philosophy was again same, as previous campaigns such as Forsmark and GNS/STADE, to find optimum solution to minimize burden on NPP's waste management.

- TVO, Finland was running into storage limitations and had to make a decision whether to create more space by building additional temporary storage facilities on site or find external alternatives to free space.
    - Studsvik presented an alternative other than extending the facilities in 2009 including prevention of additional cost by presenting improved waste management through alternative priorities including a review of the current waste inventory on site and the upcoming need of further storage space.
    - By sending eight heat exchangers to Studsvik for volume reduction considerable space was freed at an already existing temporary storage facility at TVO, reducing cost by eliminating need to extend temporary storage building. This space will now be used for other need whilst eliminating cost for additional facilities otherwise being built.

During several years Studsvik has promoted this strategy also in United Kingdom and it has been widely accepted by industry and authorities. Today Studsvik has a dedicated waste management facility in Workington, Cumbria dedicated for the UK nuclear industry.

Conclusions

As nuclear power industry experiences a revival many questions on waste treatment must be answered. Prolonged lifetime and worldwide discussions of new power plant constructions highlights the obvious demand of modern, effective and safe waste treatment. Cost for storage at repositories is often volume driven and as such large savings can be obtained by volume reduction before disposal, which enables economically feasible management of waste. The process not only ensures that the volume of waste volume is significantly reduced but also produces a stable residue suitable for final disposal in a highly cost effective manner. This route offers clear benefits with less demand of space in final repository with prolonged life time at reduced over all cost.

Effective waste treatment is also about a responsible engagement in environmental aspects. Recycling of valuable raw material and energy helps to further reduce the carbon footprint from the energy industry.
By using the heat generated during incineration of combustible waste, Studsvik saves at the site in Sweden approximately 1,5MW when heating site facilities. As a result the carbon foot print is reduced by utilising combustible waste as recyclable energy. Metal meeting exempt criteria after treatment at Studsvik, will be circulated back into the metal industry as a valuable raw material. Reusing high quality metal saves on the environmental impact from our industry and uses our limited natural sources more efficiently.

Studsvik has long experience of waste volume reduction and a clear vision of how waste management can be improved within the nuclear industry. It requires a close cooperation not only between the power plants and the service providers but also with the authorities and the final repositories to keep a clear focus to develop what will be the most environmentally friendly and cost efficient strategy for the future.

Is this good enough also for the future?

The largest waste volumes generated are in the LLW category and these can in most cases be further reduced before placed in a final repository. Studsvik is today handling waste with a variety of activity and dose rate. Today all waste transports to Studsvik is according to the transport regulation ADR and therefore maximised to a surface dose rate of D_0<2ms/h, D_1<0,1mS/h. This is typically applied to all transport to and from Studsvik and as such limiting the scope of work possible to offer.

We at Studsvik see this as a limitation to what today can be offered to the nuclear industry. There is possibility to improve the service if waste with higher dose rates can be managed in a safe and economical way.

In the industry waste must be dealt with also within the definition ILW and volume reduction is an obvious solution to storage issues also in this category.
Studsvik see this question worth a debate within the industry as there are room to improve.

- Can we improve the cost efficiency of waste treatment in the segment of ILW?
- Similar with LLW, is there better solutions also in the ILW area where today limited alternative of waste treatment is available?

- Should the industry develop and optimise the treatment of this waste on each site for direct disposal, or can a central facility be better suited?
- Is it possible to save operational cost for the industry with a central facility?
- Would such central facility reduce the clean up liability in the future?
- Can this reduce down time at upgrades and new build?
- Will it help speed up decommissioning work?

A processing facility suitable for this work must be adapted for much higher dose rates than typical LLW and should comprise of a remote controlled receiving area, remote controlled treatment cell connected with a specialised area for conditioning of ILW waste and also package conditioning suited for final repository. All safety measures must be adapted to ILW for personnel protection and general safety.

As part of the facilities available on site at Studsvik one is dedicated to Swedish legacy waste. Today the facility is part of SVAFO and since this unit is very limited in size and capacity it is not suited for the work needed to be done.
A large benefit is however that the operational experience is available on Studsvik site and an up-sized service can be an important contribution to a better waste management solution in Sweden.
Studsvik has long experience in waste volume reduction and believe that together with SKB and the power plants it is important to investigate new technologies and how further capabilities can save over all cost. It is clear that repository space is limited and Studsvik sees cost savings to be significant in a central treatment unit compared with divided efforts on each power plant.

What may the future requirement be?

- Close cooperation between industry and authorities
- A common understanding of needs in the industry and safety standards to apply for this kind of operation
- Transportation should be made possible directly from NPP to Studsvik to Repository
- Transportation by ship is likely to be the most suitable solution
- Dedicated universal transport container with proper shielding capabilities is required. As a suggestion such universal transportation container should be able to hold waste up to approximate size 6x6x6 meters with adequate shielding capabilities
- Transport container to Studsvik will most likely require a dedicated transport vessel
- Dedicated facilities at Studsvik must be developed as complement to existing LLW facilities

Studsvik see this as a good and important topic to debate and would like to invite the industry as a whole with this statement.