STUDSVIK PROCESSING FACILITY UPDATE

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ABSTRACT

Studsvik has completed over 4 years of operation at its Erwin, TN facility. During this time period Studsvik processed over 6.0 million pounds of radioactive ion exchange bead resin, powdered filter media, and activated carbon, which comprised a cumulative total activity of 27,000 Ci. To date, the highest radiation level for an incoming resin container has been 395 R/hr.

The Studsvik Processing Facility (SPF) has the capability to safely and efficiently receive and process a wide variety of solid and liquid Low Level Radioactive Waste (LLRW) streams including: Ion Exchange Resins (IER), activated carbon (charcoal), organic solids, graphite, oils, solvents, and cleaning solutions with contact radiation levels of up to 400 R/hr. The heavily shielded SPF can receive and process liquid and solid LLRW with high water and/or organic content. The most recent addition to the facility's capabilities is the cost and volume efficient processing of many types and radiation levels of filters, including the emerging family of OREX filters and consumable contamination control apparel.

This paper provides an overview of the last several years of commercial operations processing radioactive LLRW from commercial nuclear power plants. Process improvements, expanded incoming waste form acceptance, and risk management of waste disposition will be reviewed.

PROCESS OVERVIEW

Since 1947 Studsvik has been actively involved as a research center for nuclear power in Sweden. Studsvik operates a research test reactor and hot cell facility for production of medical isotopes, commercial nuclear fuel testing, and materials irradiation. Studsvik operates a Dry Active Waste (DAW) incinerator, which has been in commercial operation since the early 1970s. Full metal melting and recycling capabilities for carbon and stainless steels, and aluminum have been in use for several years.

The SPF employs the THermal Organic Reduction (THOR^{sm}) process, developed and patented by Studsvik, which utilizes pyrolysis/steam reforming technology. THOR^{sm} reliably and safely processes a wide variety of waste in a unique, moderate temperature, pyrolysis/reforming, fluidized bed treatment system. The THOR^{sm} technology is suitable for processing hazardous, mixed, and dry active waste with appropriate licensing and waste feed modifications.

The SPF has proven to be an experienced and reliable source for volume reduction and cost efficient management of IER and other filtration media. The THOR^{sm} process employed by the SPF results in a superior final disposal waste form. The disposal form and reduced processing requirements, at the point of generation, reduces the immediate and long-term risks related to the management of IER and other filter media.

Operations have demonstrated consistent, reliable, robust operating characteristics. The process has consistently demonstrated the capability to meet Client demands by processing adverse spectrum of wastes. Input waste has varied in total inorganic content (the determining factor for volume reduction) from <1% to >90%. A substantial element of this variability has been the soluble inorganic "predominately salt" content of the input waste streams, which has been found to vary from <1% to 83% of the input waste material.

Final reformed residue comprises a non-dispersible, granular solid suitable for long-term storage or direct burial in a qualified container. THOR^{sm} effectively converts hexavalent chromium to non-hazardous trivalent chromium and can convert nitrates, if present, to nitrogen with over 99% efficiency in a single pass.

The THOR^{sm} process utilizes two fluid bed contactors to process a wide variety of solid and liquid LLRW. Figure 1 provides an overview flow diagram of the THOR^{sm} process. Radioactive waste feeds are received at the SPF and stored in holdup tanks. As waste is needed in the process, waste is transferred to the waste feed tanks for metering and injection into the first stage fluid bed pyrolyzer/reformer. Solid, dry, granular wastes such as charcoal, graphite, soil, etc are metered into the pyrolyzer by the solids feeder. Liquids and slurry wastes such as IER, oils, antifreeze, solvents, cleaning solutions, etc are metered into the pyrolyzer by a pump.

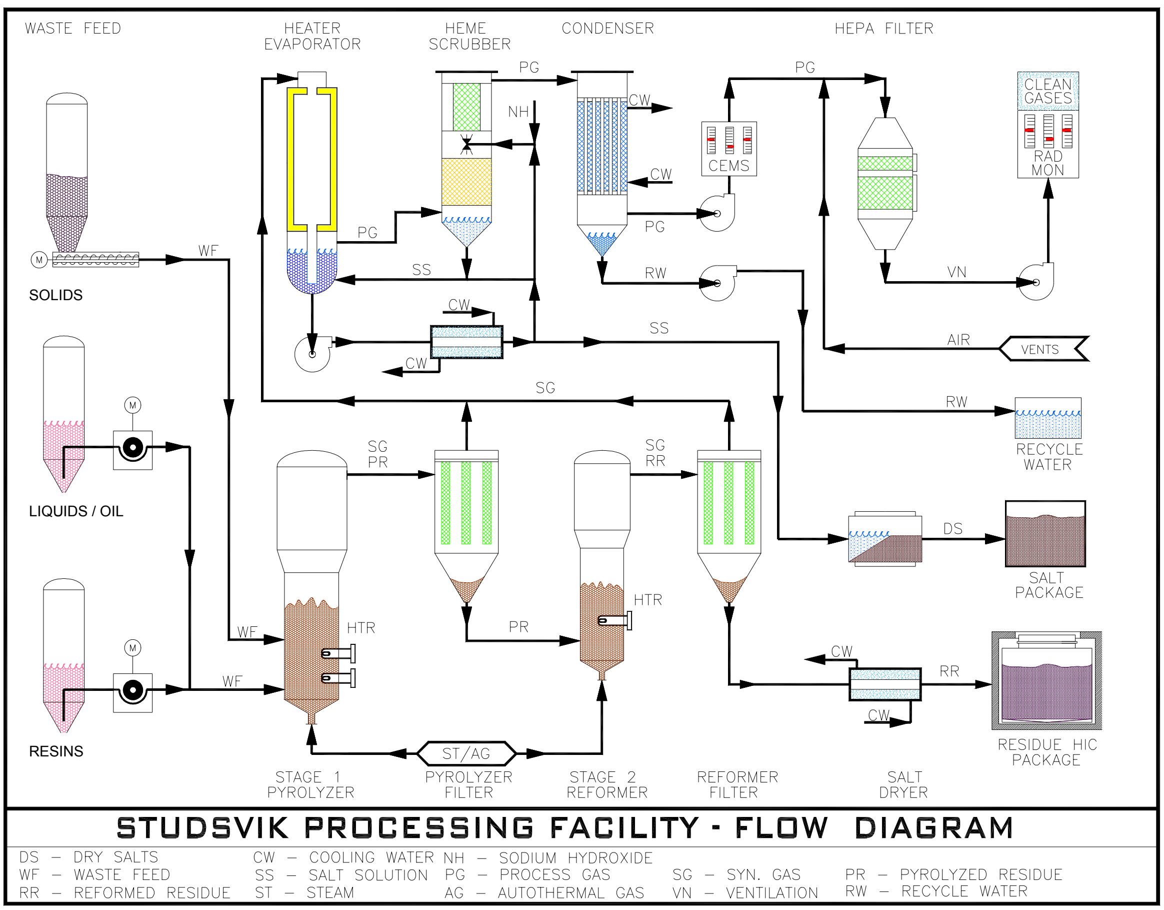

Fig. 1 THOR^{sm} Process Flow Diagram

The pyrolyzer fluid bed serves to evaporate all water from the IER slurry and liquid waste feeds, and pyrolyzes the organic components through destructive distillation. Fluidizing gases, volatile organic vapors, and steam released in the pyrolyzer fluid bed comprise a synthesis gas, which passes through the high temperature filters and to the gas handling system. The low-carbon, metal oxide-rich residue removed by the high temperature filters can be further processed in the second stage steam reformer to remove any final carbon or to convert the oxidation state of selected metals. The stage-two Reformer can also be used as a primary waste processing unit by the direct injection of liquid wastes. The radioactive, volume reduced residue is packaged in qualified High Integrity Containers (HICs) for burial at licensed burial sites or return to the generator for storage.

Through selection of autothermal steam reforming operating conditions it is possible to produce an inert, inorganic final waste that consists of only the radioactive elements, metal oxides and inorganic calcium and silica compounds initially absorbed/trapped on the LLRW. Another significant improvement realized by the THOR^{sm} process is the ability to process wastes with high water content. Aqueous wastes do not need to be dried prior to processing, but can be injected directly into the fluid bed using reliable slurry pumping equipment. Sodium nitrate slurry, oils, activated carbon, antifreeze solution, steam generator cleaning solvent, and several types of IER have all been successfully processed by the THOR^{sm} process.

STUDSVIK PROCESSING FACILITY

Studsvik has completed four years of full commercial operation. Commercial operation of the Studsvik Processing Facility (SPF) began in July 1999 with limited operations as the plant was brought up to capacity. The SPF and THOR^{sm} process systems are described below. The SPF is designed to meet all laws, codes, and standards related to processing LLRW. A photograph of the SPF is shown in Figure 2.

Fig. 2 SPF Overview

The SPF is designed to meet the following criteria:

Facility Curie Inventory: up to 3,000 Ci (111 TBq)
LLRW Input Activity: up to 4.0 Ci/ft^3 (5.2 TBq/m^3) Contact dose of up to 400 R/h (4.0 Sv/h)
LLRW Inputs: Ion Exchange Resins (IER), Activated Carbon (Charcoal), Powdered Filter Medias, Graphite, Cartridge Filters and other discrete plastics, Oils, Steam Generator Owner's Group (SGOG) Solvents, Decon Solvents and Cleaning Solutions

The SPF consists of a heavily shielded Process Building, unshielded Ancillary Building, and an Administration Building. The Process and Ancillary Buildings are licensed for receipt, handling, processing, and packaging of LLRW.

Pyrolysis/Reforming System

The Pyrolysis/Reforming THOR^{sm} system comprises: stage one pyrolysis contactor (pyrolyzer); stage two reformer contactor and associated filters. The pyrolyzer is a vertical, cylindrical fluid bed gasifier designed to operate at up to 1472^{o}F (800^{o}C). LLRW is injected into the fluidized pyrolyzer where: 1) water is instantly vaporized and superheated, and 2) organic compounds are destroyed as organic bonds are broken and resulting synthesis gas (principally carbon dioxide, carbon monoxide, and steam) exits the Pyrolyzer. Residual solids from the pyrolysis of the LLRW (including fixed carbon, >99.8 percent of the incoming radionuclides, metal oxides, and other inorganics and debris present in the LLRW feed) are removed from the pyrolyzer and collected in the stage one high temperature filter vessels. The pyrolyzer is fluidized with superheated steam and additive gas. Figure 3 is a photograph of the reformer process area.

Fig. 3 Process Area - Reformer

The stage two reforming contactor is a vertical, cylindrical fluid bed designed to operate at up to 1472^{o}F (800^{o}C). Pyrolyzed solid residues from the stage one filters or additional LLRW feed can be transferred to the reformer, which is an electrically heated, fluidized bed. The reformed, low-carbon, final residue is collected in the stage two high temperature filter vessel. The reformer is fluidized with superheated steam and additive gas.

Residue Handling System

The reformed, low-carbon residue from the pyrolyzer and reformer is transferred to the HIC packaging vault. Qualified HICs are filled with the solid, inert residue. Filled HICs are transferred from the packaging vault to a shipping cask by means of a shielded transfer bell. Dual containment and seals are provided on residue handling components. The packaging vault is provided with separate HEPA filtered ventilation system and water washdown capability.

The HIC packaged residue is suitable for direct burial at any of the Class A, B, and C LLRW burial sites currently licensed (e.g., Barnwell, Envirocare, or Hanford). The packaged residue is also suitable for long-term storage due to its solid, inert, all inorganic nature.

Waste Form Improvement

Thermal processing alleviates many of the concerns associated with the long-term storage or shallow land disposal of IER:

- Organic materials are destroyed thus eliminating the generation of flammable gases from biological attack and/or radiolysis.

- "Foreign chemicals" have been destroyed that could react with packaged waste and generate undesirable reactions. Thus the potential for damage to waste packages, which could promote radionuclide migration, is removed.

- Volume is reduced yielding a small sized source term for storage, disposal and/or long-term monitoring and the overall waste form is improved to enhance environmental protection.

An additional benefit of the thermal processing of the IER is that the long half-life radionuclides (Tritium and Carbon-14), which are two major concerns for shallow land disposal because of radionuclide migration, is alleviated.

LESSONS LEARNED

The Studsvik Processing Facility commenced limited commercial operations in summer of 1999; however, many of the facility's balance of plant systems designed by the facility's design/build contractor were not capable of achieving their design capacities. This resulted in an extensive ramp-up period. Over the past three years, Studsvik has conducted an extensive program to bring the facility to its original specifications. The following is a partial list of "lessons learned" during the three years of facility operation. It is presented to provide the reader with an understanding of the importance of the support systems for a radioactive waste processing facility.

Agglomerations/Eutectics

As with any thermal treatment process, strict controls and thorough screening of the incoming waste streams are required to ensure long-term operating reliability. This is especially true when utilizing thermal fluid bed technology such as that used in the patented THOR^{sm} process. Incoming waste streams can contain a wide variety of soluble inorganics (e.g., salts). Each can have individual melting points that are non-problematic, but when combined in a unique thermal environment can form new compounds (via eutectics), which are problematic. These problematic "eutectics" can promote "agglomerations" within the fluid bed. Studsvik has developed a simple approach to the treating of incoming wastes to prevent the formation of agglomerations.

Reusable Containers

Many generators have switched to "Studsvik Approved" reusable containers that use back-flushable stainless steel filters for their resin processing needs. The reusable container program has proven to offer the users substantial ALARA and monetary cost savings annually, while virtually eliminating the potential empty container bottleneck at the SPF.

Non-Studsvik High-Rad Empty Containers

The ability to disposition incoming non-Studsvik containers, once the waste is removed, has continued to be a serious challenge when the incoming radiation levels are in excess of 5 R/h (0.05 Sv/h). The consumable (use once) dewatering filters remain impregnated with radioactivity and continue to have radiation levels >0.4 R/h (0.004 Sv/h). Off-site vendors, that offer services for empty container processing, have proven to be unreliable in their consistency and timeliness in taking these high-rad empty containers. This has forced Studsvik into processing the empty containers in-house, greatly diminishing the need for out-sourcing and vastly reducing disposal cycle time. This further supports the importance of utilizing "Studsvik Approved" reusable containers that use back-flushable stainless steel filters. History has proven that reusable containers reduce personnel exposure and save the generator thousands of dollars annually.

Resin Transfer Lines

Efficient transfer of resins requires a substantial amount of water to prevent line plugging. When resins are transferred with a vacuum assist, the potential exists for significant line blockage. All resin transfer systems must be equipped with numerous backflush and blowdown connections at all points where line plugging can occur.

Resin Filtration

When transferring resins, it is necessary to filter large quantities of sluice water utilized for the transfers. Resin slurry contains fractured resin particles, high concentrations of ion oxide, and other "filter blanking" particulate. The sluice water filter systems must be designed with appropriate particle filtration capability and at the same time these systems must have sufficient filter surface area to ensure that the filters don't require excessive backwashing.

Waste Resin Storage

The IER is transferred to the slurry holdup tanks where the resin/water mixture is allowed to settle and excess water is then decanted off the top of the settled resin. Resins of different types have slightly different densities and without adequate storage tank mixing ability, resins will "layer" in a tank. This reduces the ability to efficiently achieve the optimum blend of input waste for processing.

Resin Feed Systems

For efficient thermal processing it is necessary to maintain a constant, low water content feed system to the process. Metering of constant resin/water input is a difficult task and specific attention must be paid to design and equipment considerations to ensure efficient operations with both bead and powdered resins and mixtures of both.

Off Gas System

The facility utilizes a pool type quencher system for quenching and final scrubbing of the hot off gas from the process system. Impurities, mostly sulfur salts from the cation resins, concentrate in the scrubber solution. The concentrated solution is transferred to a drying system. Care should be given in equipment design, specification, and checkout to ensure that systems are operable at design throughput with the actual solution to be dried. Pilot scale test programs on "similar" solutions have proven to be inadequate.

Materials of Construction

With any chemical process system, the materials of construction play a large role in the long-term reliability of the systems. We have encountered instances where carbon steel utilized in a high salt environment lead to material failures that have required component replacements.

WHAT'S NEW

The Studsvik Processing Facility has recently added two solid LLRW waste streams to its service capabilities: 1) Empty Container Processing and 2) Cartridge Filters (to include UF/RO membranes).

Empty Container Processing

As mentioned previously in the LESSONS LEARNED, empty containers have caused considerable attention over the last years. Studsvik and its Clients quickly learned that it could no longer rely on out-sourcing to accommodate the unique empty container processing demands. As a result, beginning October 2002, Studsvik began processing empty containers in-house. Many factors determine which processing avenue can be utilized for each empty container component: waste class, radiation level, physical dimensions, chemical make-up and type of material utilized in dewatering filter and supporting pipe construction, etc. Studsvik presently has the following processing avenues for empty container components.

- Dewatering Internals - Dewatering internals are removed and are either repackaged for disposal with other facility waste and/or processed utilizing the patented THOR^{sm} technology with the outgoing Reformed Residue (RR) commingled with the resins.

- Poly HIC Shells - With the dewatering internals removed, poly shells are sectioned and are either repackaged for disposal with other facility waste and/or processed utilizing the patented THOR^{sm} technology with the outgoing Reformed Residue (RR) commingled with the resins.

- Metal Shells - With the dewatering internals removed, metal shells are presently sent off site for processing by a metal processor. Studsvik is presently evaluating the need to begin processing metal shells in-house.

Filter Cartridges

Studsvik has begun to receive and process a variety of Class-A, -B, and -C filter cartridges (to include UF/RO membranes). Filter Cartridges will arrive in many types of containers from drums, boxes, and dewatering containers. The first Filter HIC was received in May 2003 and the SPF has received many liners/containers since then

Many factors determine which processing avenue can be utilized: waste class, radiation level, physical dimensions, chemical make-up and type of material utilized in filter/cartridge construction, etc. Studsvik presently has the following processing avenues for filter cartridges.

- Pyrolysis - The filter is processed utilizing the patented THOR^{sm} technology and the outgoing RR commingled with the resins.

- Repackaging with RR - The filter is repackaged in outgoing RR containers where RR is used to fill remaining container void spaces.

- Repackaging with Bulk Waste - The filter is repackaged for disposal with other outgoing facility bulk waste.

OPERATIONS SUMMARY

The facility has operated near its design throughput and was "available for processing" over 80% for 2002/2003. Multiple "record runs" have been achieved. Studsvik will continue to improve its THOR^{sm} process utilizing the knowledge acquired from four years of "real life" experience processing a wide variety of LLRW streams generated by nuclear facilities.

RISK MANAGEMENT

The SPF has created a waste management service that helps to mitigate the risks involved with the disposition of Ion Exchange Resin other filter media and some liquid waste streams by:

- Volume reduction of IER to meet the ever-declining disposal space for Class B/C wastes. Through an innovative agreement between several Utilities, the SPF and the State of South Carolina, we were able to accommodate the limited disposal space at Barnwell and the B/C waste disposal needs of several utilities.

- The use of the SPF by IER generators reduces in plant costs, meets ALARA needs and reduces the requirements by the generators to meet the stringent requirements for disposal. The SPF process control program meets those stringent requirements.

- The expanding waste stream processing capabilities of the SPF allow the generator to process and VR filters and other media both conserving Class B/C volume and meeting the disposal requirement.

- Creating a superior waste form that does not have organics and will not degrade in the storage or disposal mode, thus mitigating future risk for generators and disposal site operators.

CONCLUSION

The Studsvik Processing Facility has demonstrated long-term operation in meeting the waste processing needs of the commercial utilities. We have processed a wide variety of LLRW with widely varying chemical composition and activities. Efforts are in progress to enhance our operational capabilities and to provide more cost-effective waste services in the future.

The THOR^{sm} process, as implemented at the SPF, has the following significant advantages:

- Near Atom-for-atom processing mode is possible;

- Inert, inorganic, homogeneous, final waste form;

- Direct disposal in qualified HICs;

- Accept LLRW including: Ion Exchange Resins (IER), Activated Carbon (Charcoal), Powdered Filter Medias, Graphite, Cartridge Filters and other discrete plastics, Oils, Steam Generator Owner's Group (SGOG) Solvents, Decon Solvents and Cleaning Solutions;

- Accept LLRW with contact dose rates up to 400 R/h (4.0 Sv/h);

- Packaged final waste form suitable for long-term storage with no risk of gas generation due to bacterial or radiolysis action (residue has no organic content);

- Final waste form is re-processable to alternative waste forms including vitrification, solidification, encapsulation, cold-sintering, and melting.

- Risk Management mitigation for disposal.