

## **STUDSVIK PROCESSING FACILITY PYROLYSIS/STEAM REFORMING TECHNOLOGY FOR VOLUME AND WEIGHT REDUCTION AND STABILIZATION OF LLRW AND MIXED WASTES**

J. Bradley Mason, Thomas W. Oliver, Marty P. Carson, G. Mike Hill  
Studsvik, Inc.  
Columbia, SC

### **ABSTRACT**

Studsvik has completed construction, start-up testing, and has commenced commercial operation of a Low-Level Radioactive Waste (LLRW) processing facility in Erwin, TN. The Studsvik Processing Facility (SPF) has the capability to safely and efficiently receive and process a wide variety of solid and liquid LLRW streams including: ion exchange resins (IER), charcoal, graphite, sludge, oils, solvents, and cleaning solutions with contact radiation levels of up to 100 R/hr. The licensed and heavily shielded SPF can receive and process liquid and solid LLRWs with high water and/or organic content.

The SPF employs the THERMAL Organic Reduction (THOR<sup>sm</sup>) process, developed by Studsvik, which utilizes pyrolysis/steam reforming technology. THOR<sup>sm</sup> reliably and safely processes a wide variety of LLRWs in a unique, moderate temperature, dual-stage, pyrolysis/reforming, fluidized bed treatment system. The THOR<sup>sm</sup> technology is suitable for processing hazardous, mixed and dry active LLRW (DAW) with appropriate licensing and waste feed modifications.

Operations have demonstrated consistent, reliable, robust operating characteristics with volume reductions up to 30:1 and weight reductions up to 50:1 when processing depleted, mixed bed, ion exchange resins with over 99% of all radionuclides in the waste feed incorporated in the final solid residue product. Final reformed residue comprises a non-dispersible, granular solid suitable for long-term storage or direct burial in a qualified container. THOR<sup>sm</sup> effectively converts hexavalent chromium to non-hazardous trivalent chromium and can destroy nitrates with over 99 percent efficiency in a single pass.

### **PROCESS OVERVIEW**

Studsvik Inc., with offices in Columbia, SC and Erwin, TN, is a subsidiary of Studsvik Holding AB located near Stockholm, Sweden. 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.

A five phase test program was implemented to develop a process that could effectively volume reduce and stabilize a wide variety of liquid and solid LLRWs that could not be processed by the Studsvik incinerator. The successful test program culminated in the decision to proceed with the licensing, design, and construction of a commercial LLRW processing facility that utilizes the patented THOR<sup>sm</sup> process. The Studsvik Processing Facility (SPF) has completed construction,

startup testing, and will commence commercial operations with processing of radioactive IER from nuclear power stations in March 1999.

The THOR<sup>sm</sup> process utilizes two fluid bed contactors to process a wide variety of solid and liquid LLRWs. Figure 1 provides an overview flow diagram of the THOR<sup>sm</sup> 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. 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, sludges, oils, antifreeze, solvents, cleaning solutions, etc are metered into the Pyrolyzer by a pump.

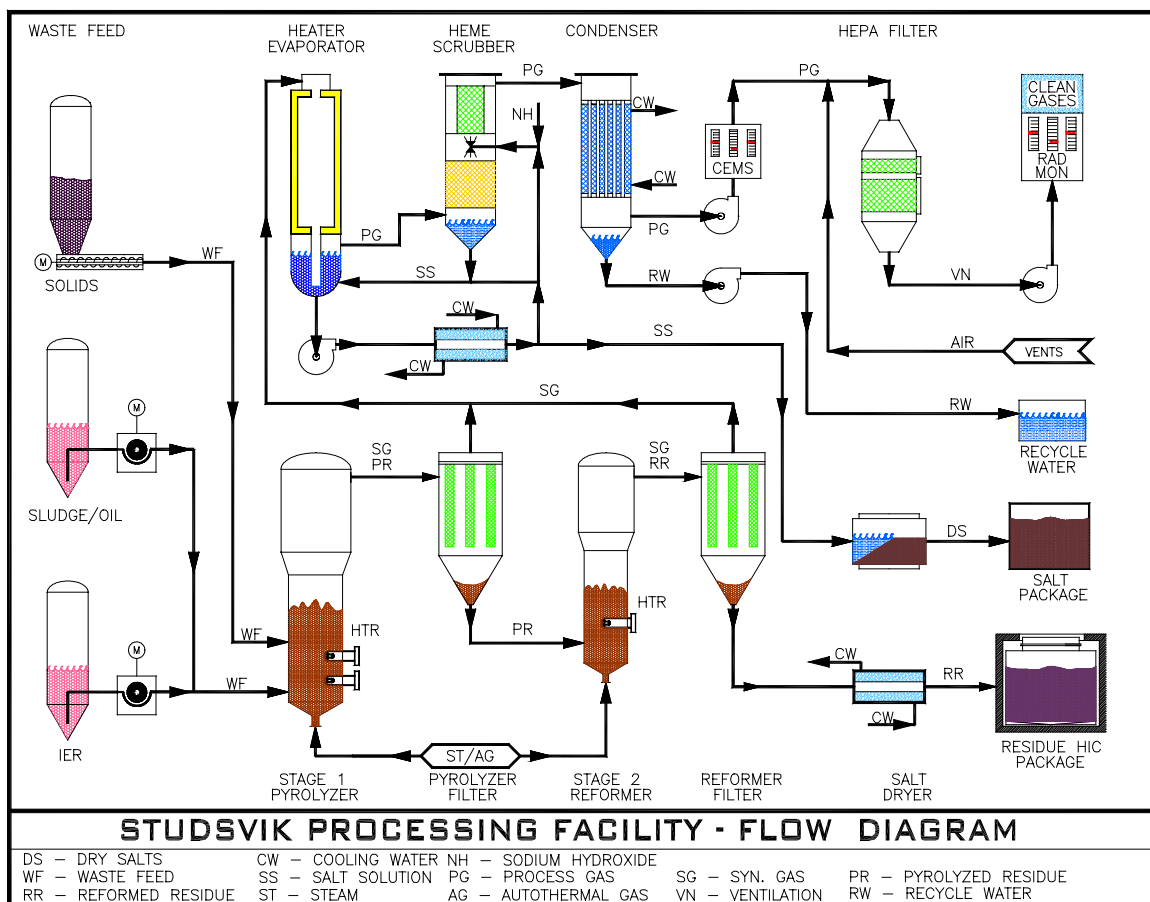


Figure 1 - THOR<sup>sm</sup> Process Flow Diagram

The Pyrolyzer fluid bed serves to evaporate all water from the IER slurry and liquid waste feeds, and pyrolyze 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 ceramic filters and to the gas handling system. The high-carbon, metal oxide-rich residue removed by the ceramic filter is then processed in the second stage steam reformer.

Carbon is gasified in the Reformer leaving a metal oxide-rich, inorganic residue as the final waste. The radioactive, volume reduced residue is packaged in qualified high integrity containers for burial at licensed burial sites or return to the generator. For average, depleted, mixed-bed IER it is possible to achieve a volume reduction (VR) of 15-80 with a corresponding weight reduction (WR) of 12-85.

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 on the IER. It is possible to reach near theoretical mass reductions with the THOR<sup>sm</sup> process. Another significant improvement realized by the THOR<sup>sm</sup> 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 IERs have all been successfully processed by the THOR<sup>sm</sup> process.

### **STUDSVIK PROCESSING FACILITY**

Studsvik has completed construction and start-up testing of a Low-Level Radioactive Waste (LLRW) processing facility in Erwin, TN. The SPF has all applicable licenses and permits for operation including a radioactive materials license from the State of Tennessee. Commercial operation of the Studsvik Processing Facility (SPF) will begin in March 1999. The SPF and THOR<sup>sm</sup> 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 Fig. 2.



*Figure 2 - SPF Overview*

The SPF is designed to meet the following criteria:

Facility Curie Inventory:	up to 2,000 Ci
LLRW Input Curies:	up to 2.0 Ci/cu.ft. (Contact dose of up to 100 R/hr)
LLRW Inputs:	Ion Exchange Resins, Charcoal, Organic Solvents and Oils, Aqueous Decon and Cleaning Solutions, Slurries, and Sludge

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.

### **Process Building**

The Process Building contains all radioactive processing, handling, and packaging systems for volume and weight reduction of incoming LLRW. Major areas include Truckbays, LLRW Input Holding Tank Vault, Pyrolysis/Reforming Vault, Gas Handling Vault, Salt Dryer Room, Final Residue Packaging Vault, and Auxiliary Equipment Rooms.

### **Truckbays**

LLRW is shipped to the SPF in DOT or NRC qualified non-shielded containers and/or shielded casks. Most LLRW is received in the Truckbay where containers and casks are surveyed, opened and the waste transferred to shielded Waste Input Holding Tanks located in shielded vaults. Cask maintenance activities are performed in the Truckbay where an overhead bridge crane provides lifting capability. Figure 3 is a photograph of the dual station truckbay.

### **Waste Input Holding Tanks**

Three large stainless steel Slurry Holding tanks are provided for receipt and holdup of incoming liquid and slurry wastes. A separate Liquid Waste tank is used to receive more volatile organic solvents, cleaning solutions, and oils. A Lockhopper Feeder is used to receive and feed granular and powdered LLRW, such as charcoal. A separate Waste Feed tank with Injection Pumps is used to meter slurry and liquid wastes from the Slurry Holding tanks into the stage one Pyrolysis vessel. Figure 4 is a photograph of the Process Area.



*Figure 3 – Truckbay*



*Figure 4 – Process Area*

### **Pyrolysis/Reforming System**

The Pyrolysis/Reforming THOR<sup>sm</sup> 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 800 °C. LLRW is injected into the electrically heated, 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, hydrogen, 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 Ceramic Filter vessel. The Pyrolyzer is fluidized with superheated steam and additive gas.

The stage two Reforming contactor is a vertical, cylindrical fluid bed designed to operate at up to 800 °C. Pyrolyzed solid residues from the stage one filters are transferred to the Reformer which is an electrically heated, fluidized bed where the fixed carbon is gasified to carbon monoxide and carbon dioxide by contact with the superheated fluidizing gases. The reformed, low-carbon, final residue is collected in the stage two Ceramic Filter vessel. The Reformer is fluidized with superheated steam and additive gas.

### **Gas Handling System**

The Gas Handling system comprises an Energy Recovery Heater, Submerged Bed Evaporator, Scrubber/Mist Eliminator, Condenser, CEMS, Process Blower, HEPA filter, Vent Blower and Radiation Monitor. The purpose of the Gas Handling system is to convert synthesis gas constituents to carbon dioxide and water, recover energy from the synthesis gas, convert acid gases to stable salts, control water content of exiting process gas, and control negative pressure levels throughout the THOR<sup>sm</sup> pyrolysis/reformer system.

Synthesis gases from the Pyrolyzer and Reformer are filtered and then oxidized in the Energy Recovery Heater to carbon dioxide and water. The Heater recovers energy from the synthesis gas and provides heat to the Submerged Bed Evaporator where excess water is evaporated from the scrubber water. The Heater is a vertical, refractory lined vessel that operates at up to 1200 °C.

The Submerged Bed Evaporator is an energy recovery system that channels the hot Heater outlet gases through a volume of scrubber water, thereby evaporating excess water. The Evaporator concentrates scrubber solution to 10 to 20 percent salts. The wet evaporator gases pass through the rotary atomizer Scrubber where sulfur and halogen gases are efficiently converted to salts. Sodium hydroxide is metered into the Scrubber to neutralize sulfur and halogen gases that are absorbed by the scrubber solution. The outlet of the Scrubber is fitted with a high efficiency Mist Eliminator that removes particulates and mists from the Scrubber outlet.

The clean, moisture-laden gases exit the scrubber and excess moisture is condensed for recycle/reuse in the process. The Condenser serves as the process heat sink and serves to control water balance in the SPF. The cool gases are then compressed to atmospheric pressure by the Process Blower. A Continuous Emissions Monitoring system (CEMs) is provided on the Process Blower outlet to monitor and record the release of any traces of carbon monoxide, acid gases, total hydrocarbons, and NOx.

The clean, cool process gases commingle with the building ventilation airflow. The combined gases flow through a HEPA filter bank, Vent Blower and are then released through a monitored vent stack. A complete Radiation Monitor system measures and documents any trace radionuclides that may pass through the stack. The Radiation Monitor system includes gamma, beta, alpha, iodine, carbon<sup>14</sup>, and tritium samplers and detectors.

### **Salt Handling System**

The salts that are formed in the scrubber and concentrated in the evaporator are transferred to the Salt Handling system, which comprises a filter, an ion exchange system and Salt Dryer. The concentrated salt solution is filtered to remove any trace particulates that may pass through the Pyrolyzer and Reformer filters. Any trace radioactive species are removed from the scrubber solution by a high-efficiency, metals selective ion exchange medium. The Salt Dryer dries the purified salt solution to form a salt cake suitable for direct disposal at a licensed landfill.

### **Residue Handling System**

The reformed, low-carbon residue from the Reformer is transferred to the High Integrity Container (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 either the licensed Barnwell or Hanford LLRW burial sites. The packaged residue is also suitable for long-term storage due to its solid, inert, all inorganic nature. The packaged residue is not subject to common problems with long-term storage of wet wastes including bacterial activity and radiolysis of organic compounds.

It is possible to package the low-volume residue in any of the following forms:

- stabilized in High Integrity Containers (HIC);
- compacted, cold-sintered, high-density, metal oxide monolith;
- solidified monolith using polymer sulfur cement, portland cement, thermoplastics, or polymers;
- vitrified monolith using borosilicate or phosphate glass; or
- melted metal monolith.

### **Spill Protection and Contamination Control**

All interior surfaces of the SPF are provided with durable, easy-to-decon coatings. The interior wall and roof panels are of interlocking and sealed construction to eliminate leakage paths from the inside of the SPF to the outdoors. Interior concrete and steel surfaces have a special multi-layer coating to prevent migration of spills or contaminants from the SPF to the environment. The HVAC system also maintains the inside of the SPF at a slight negative pressure relative to the ambient outdoors, effectively eliminating potential airborne releases. Dikes, berms and sumps are located so as to prevent tank leaks and even large firewater events from escaping to the outdoor environment.

### **Auxiliary Equipment and Utility Services**

The Process Building contains all auxiliary and utility subsystems required to support SPF operations and THOR<sup>sm</sup> operations including:

Steam Supply	Sluice Water	Nitrogen Supply
Steam Superheaters	Demineralized Water	Service Air
Steam Condensate	Potable Water	Instrument Air
HVAC and Ductwork	Dryer Condensate	Breathing Air
Natural Gas Supply	Cooling Water	Additive Gas
Motor Control Center	Hot Laboratory	DAW Compactor

### **ANCILLARY BUILDING**

The Ancillary Building is designed for storage of spare parts, empty waste shipping containers and equipment for use at customers' locations. Full salt containers are accumulated for shipment for disposal. Low activity LLRW can also be received and offloaded in the Ancillary Building. Maintenance of plant equipment is also performed in a controlled area. A modular, skid-mounted, pilot-scale THOR<sup>sm</sup> system can be located in the Ancillary or Process Building to perform testing on surrogate and low activity wastes.

### **ADMINISTRATION BUILDING**

The Administration Building has: offices for plant staff and management, control room, switchgear and UPS, health physics and personnel contamination monitoring areas, and count room. The THOR<sup>sm</sup> control room provides remote readout of all process parameters. Trained operations personnel utilize the fully automated SCADA system to monitor and control all system operations. The SCADA provides a comprehensive human-machine-interface that monitors the PLC panels, instruments, and equipment located in the Process Building. Automated safety systems, alarms, and interlocks are provided together with real-time data acquisition and trending. The SCADA provides the operators automated flow diagram windows to monitor and control the process through graphical interfaces.

### **CONCLUSION**

The THOR<sup>sm</sup> process, as implemented in the SPF, has the following features and provides the following significant advantages over other current LLRW processing technologies. Figure 5 is a block flow diagram that demonstrates the overall capabilities of the THOR<sup>sm</sup> process technology for a wide variety of mixed and LLRW.

- VR of 15 to 80 for IER wastes;
- WR of 12 to 85 for IER wastes;
- Atom-for-atom processing mode is possible;
- Inert, inorganic, homogeneous, final waste form;
- Direct disposal in qualified HICs;
- Accept IER with contact dose rates up to 100 R/hr;
- Accept LLRW including: IER, charcoal, SGOG solvents, antifreeze, oils, sludge, high-water content wastes, and high-organic content wastes;
- 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 reprocessable to alternative waste forms including vitrification, solidification, encapsulation, cold-sintering, and melting.

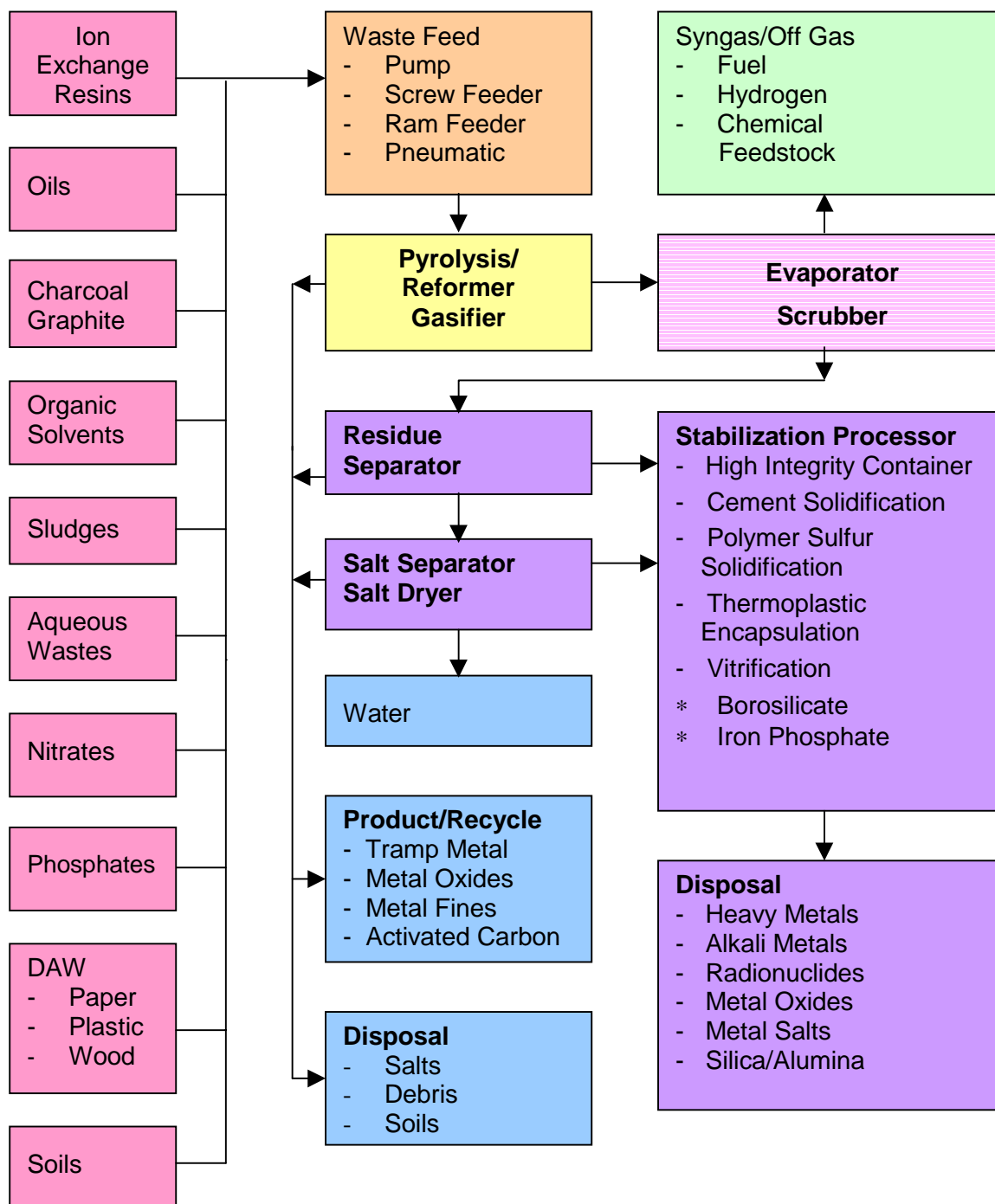


Figure 5 - Block Flow Diagram