Studsvik's Comments on the Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement (DOE/EIS-0287D)

Studsvik is requesting that the subject EIS provide recognition of newly commercialized "non-separation" technologies, such as Studsvik's patented TTHOR™ pyrolysis/steam reforming fluid bed system, which is presently operational on a large-scale basis in the commercial nuclear power market.

Steam Reforming Technology as deployed by Studsvik in a fluid bed can offer:

- Non-Incineration Thermal Treatment
- Thermal treatment of SBW without the problems encountered with typical incinerators or the presently operated calciner.
  - Direct conversion of nitrates to nitrogen in the fluid bed without the resultant NOx emission problems.
  - Reduced operating temperatures, eliminating the need for bulky additives to prevent molten alkali metal salt agglomerations.
  - Elutriating operation to prevent the build up of waste salts in the fluid bed.
  - Low gas flow processing for simplified off-gas control.
Reduced Overall Waste Processing Cost and Schedule

- Duplication of existing full-scale, commercialized equipment already active in the nuclear marketplace.
- Flexible Processing System
  - Input of liquid, slurry, solid, or gaseous nitrate and organic wastes.
  - Applicable to processing SIBW, Low-Level Mixed Waste, gaseous NOx emissions and others.
- Inert, easy to handle final product that can be packaged for shipment to a final waste depository, or stored at INEEL.
- Potential for replacement of the incinerator systems originally considered for the AMWTP

Studsvik recognizes that the EIS process has been very thorough and we do not desire to inject any new processing approaches that would delay the accomplishment of the INEEL waste cleanup mission. However, we feel that it should recognize technologies that have been commercialized in the private sector since the technical review activities for this EIS were completed. We regret that we have not brought this technology to your attention before this date, however, our total focus has been on the construction and operation of our processing facility in Erwin, TN. The Erwin facility focuses on the processing of high activity (up to 100 R/hr, beta/gamma activity) ion exchange resins produced by the commercial nuclear power stations. With this effort in full operation, we are now turning our attention to the needs of the DOE community. Attachment One provides a description of our technology and its deployment at the Studsvik Processing Facility.

Overview

Studsvik’s patented THOR™ pyrolysis/steam reforming technology is presently deployed for the destruction of water slurries of high specific activity ion exchange resins (up to 100 R/hr beta/gamma). The THOR™ steam reformer in operation in Erwin, TN can continuously process over 500 kg/hr of slurry waste feed. The technology has been proven to be able to process nitrate bearing wastes by converting the nitrates directly to nitrogen without the associated NOx off-gas emissions typically present with other thermal conversion processes. The system can input either a wet, sodium bearing (high nitrate) waste slurry or solids.

Other adaptations of the technology can be utilized for processing of high NOx off-gas streams. By utilization of the THOR™ technology, expensive NOx off-gas conditioning units can be avoided. Additionally, and of significant importance, is the fact that the primary THOR™ technology, steam reforming, exhibits none of the attributes of an incinerator and in fact has been classified by DOE as an "alternative to incineration".

The EIS (EIS Page No. F-2) indicates that the it has been developed in part to facilitate negotiations required by the Settlement Agreement.

"Because of technology developments and changes needed in existing treatment facilities to properly manage sodium-bearing waste, Idaho agreed with DOE that an EIS could facilitate negotiations required by the Settlement Agreement."

It is within the scope of "technology developments", as referenced above, that these comments are submitted. We feel that the patented THOR™ technology is directly applicable to the processing of many of the waste streams at INEEL and is in fact superior in some aspects to the technologies specifically mentioned in the EIS. Comments to the EIS would have been made at an earlier date, however, full-scale commercial deployment of the THOR™ process did not commence until July 1999. Routine operations were established in December 1999 and over 8,000 ft³ of radioactive waste was processed through March 2000. This fully demonstrates the large-scale application of the technology.

Alternative to Incineration

In 1997, the Mixed Waste Focus Group, completed an evaluation of Nonflame technologies to be utilized for an alternative to incineration for mixed waste processing. The final report from that effort, Evaluation of Alternative Nonflame Technologies for Destruction of Hazardous Organic Waste, INEL/EXT-97-00123 of April 1997 specifically listed the advantages of steam reforming for processing organic mixed wastes. In fact, steam reforming was listed as the recommended process. Studsvik’s unique pyrolysis/steam reforming fluid bed system can not only process organic wastes, but has proven to be highly effective at processing liquid and solid nitrate waste streams. The unique operating modes for nitrate conversion using the THOR™ steam reformer are subjects of pending patents.

Comparison to Existing Calciner Technology

Studsvik is requesting that the subject EIS provide recognition of newly commercialized "non-separation" technologies, such as Studsvik’s patented THOR™ pyrolysis/steam reforming fluid bed system. This technology ład its genesis in fluid bed technology for biomass gasification utilizing auto-thermal steam reforming, but is truly a next generation design which offers the following advantages over the existing INTEC calciner:

1. Reformer has significantly reduced off-gas volume of 1/8th to 1/20th of the off-gas volume of the current calciner.
2. Reformer has gaseous NOx emissions that meet MACT standard without addition of gaseous de-NOx unit. Nitrites are fully converted to N₂ in the reformer fluid bed. Reformer has estimated NOx emissions at 1/1,000th of those emitted from current calciner.
3. Reformer minimizes use of additives to prevent agglomerations. Low temperature operation minimizes or eliminates the need for additives to prevent alkali metal compounds from melting in the bed. This also significantly reduces the final volume of the end product.
4. Reformer provides high conversion of nitrates to nitrogen and minimizes or eliminates the presence of nitrates in the high sodium end product.
5. Reformer has lower Ca volatility than high temperature units operating over 600 °C.
6. Efficient mercury recovery unit can be easily utilized in the off-gas from the reformer.
7. Construction labor to build new plant is estimated to be 2 times that required for performing continued current operations modifications of adding a de-NOx unit to existing calciner off-gas system. The new reformer plant could be designed and built to meet the same schedule as estimated to modify the existing calciner.

In addition to improvements directly related to utilization of the existing calciner, the fluid bed reformer has other significant advantages:

1. Potentially eliminate the use of the INTEC evaporator, as reformer can process large percentage waste from SBW and newly generated liquid waste.
2. Can process tank heels as SBW and newly generated liquid waste.
3. Can safely and efficiently process destroy spent organic solvents from Separations
4. Alternatives operations in a "non-incineration" process.
5. Operations staff for new reformer facility is estimated to be 60 to 70 full-time personnel for operations, maintenance and plant management.

We have also reviewed the safety and accident aspects of a reformer facility compared to modifications of the current calciner to meet MAC (as referenced in the EIS). The reformer provides a higher level of safety than the current calciner.

**Accident Analysis:**

**ABN 01**
No liquid or gaseous fuel is used in the Reformer, therefore, no fuel spills or fire scenarios apply.

**ABN 02**
See above.

**ABN 15**
No ammonia additive is needed to promote NOx conversion in off-gas. Therefore, no ammonia spill scenarios apply.

**DBE 01**
The existing calciner uses kerosene injection that could cause explosive mixtures to form. An explosion could cause subsequent failure of HEPA filtration. This scenario is impossible as the reformer is of explosion-proof design and it will contain any postulated explosion condition. The THOR™ reformer does not use gaseous or liquid fuels that could cause such an explosion due to operator error or equipment or control failures.
### Table 1 - THOR™ Pyrolysis/Steam Reformer Capabilities (Single Step Fluid Bed)

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Description</th>
<th>Slurry/Solid® Denitrator Reformer</th>
<th>Integral® Evaporator</th>
<th>Off-gas® NOx Reduction</th>
<th>Off-gas® Organics Destruction</th>
<th>Liquid® Organics Destruction</th>
<th>Mercury Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1A</td>
<td>Calcine SBW Including New Waste Calciner Facility Upgrades</td>
<td>Yes</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>P1B</td>
<td>Newly Generated Liquid Waste and Tank Farm Heel Waste Management</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NR</td>
<td>Yes</td>
</tr>
<tr>
<td>P91</td>
<td>HAW Denitrification, Packaging, and Canal Loading Facility</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NR</td>
<td>Yes</td>
</tr>
<tr>
<td>PSC, P2SC</td>
<td>Class A Great Plant</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NR</td>
<td>Yes</td>
</tr>
<tr>
<td>P49C</td>
<td>Class C Great Plant</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>NR</td>
<td>Yes</td>
</tr>
<tr>
<td>P88</td>
<td>Early Verification Facility with MACT</td>
<td>NR</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
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<td>P118</td>
<td>Separations Organic Incinerator</td>
<td>NR</td>
<td>NR</td>
<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
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<td>P333</td>
<td>Waste Treatment Pilot Plant</td>
<td>NR</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>P111</td>
<td>SBW and Newly Generated Liquid Waste Treatment with Cs Ion Exchange of CH-TRU and LLW granules</td>
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<td>Yes®</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

**Notes:**

1. THOR™ steam reformer converts gaseous NOx to nitrogen and oxides of carbon to CO2 and water. THOR™ process utilizes less energy than “Noxidizer” as the reformer operates at only 400 to 700°C. THOR™ process is much more efficient at converting NOx to nitrogen than “Noxidizer.” The outlet of reformer will contain less than 100 ppm NOx. THOR™ reformer does not utilize ammonia injection or expensive catalysts.

2. THOR™ steam reformer will fully oxidize liquid organics to CO2 and water. Steam reforming is a non-incineration thermal treatment process.

3. THOR™ steam reformer fluid bed has high water evaporation capacity that could eliminate need for separate liquid waste evaporator.

4. THOR™ steam reformer can convert nitrates directly to nitrogen. Reformer can process direct injection of acidic or basic nitrate wastes. Little to no additions needed to prevent formation of alkaline metal agglomerates. No liquid or gaseous fuels are used.

5. Use of THOR™ reformer could replace evaporator and eliminate need to add CaO to neutralize liquid wastes.

*NR = Not Required*
The THOR™ gaseous NOx conversion reformer far surpasses the ability of any other commercial scale technology for converting high NOx input streams directly to nitrogen.

**Material Handling and Final Waste Form**

Material handling of input waste and output residue are generally the most critical components of a processing system with the most potential for operational failures. Studsvik’s fluid bed/steam reforming system can input waste in either a liquid slurry, solid (powder or small particle) or gaseous form. In working with radioactive waste, the wet slurry form is generally preferred because it provides for ease of handling, it provides a level of contamination control should a system require breaching, and it accommodates a wide variety of waste streams.

The output residue from the system is an inert dry granular material that can be pneumatically transferred to remotely filled and handled output packages or can be directly input to a greater facility. The output package would be designed specifically for criticality concerns and to meet the requirements of the final depository or interim storage location.

**Criticality and Other Safety Considerations**

A fluid bed system operating in a continuous feed, elutriating mode has a unique advantage over batch processing technologies in the area of criticality issues. Conventional waste processing fluid bed systems retain the waste residue in the fluid bed which is periodically drained. This build up of residue provides the potential for a criticality concern.

With the THOR™ system operating in an elutriating mode, there is little to no “build up” of fissionable or other materials in the fluid bed. The process residue is continually carried with the gas stream out of the bed and captured downstream where it can be closely monitored and controlled. Controlled input and continuous removal of debris help to alleviate criticality concerns.

Studsvik, through one of its sister companies SCANDPOWER (formerly Studvik USA, Inc.), has the capability to provide a complete criticality analysis of the system design. SCANDPOWER is one of the world leaders in the area of power reactor core reload analysis and other nuclear physics reaction calculations.

Another unique property of our continuously feed/elutriating system is that only a very small amount of material is actually “in process” at a given time. Should an upset condition occur, simply by securing feed, the chemical conversion processes and resultant off-gas ceases in a matter of seconds. This represents an important safety advantage for the system.

Additionally, the Studsvik system is design as an “explosion proof” system. The materials of construction and design is such that the maximum credible upset that can be postulated will be retained by the system without the requirement for a complicated relief and expansion gas capture system. This feature substantially reduces the overall complexity of the system and contributes to the innate safety of the system design.

The operational experience that we have gained at our commercial processing facility has demonstrated the inherent safety and the ease of operator control of the reformer. “Lessons learned” through present operations would translate directly to an improved design for any systems that may be provided for use at INEEL.

**AMWTP**

With the recent termination of the incinerator system originally incorporated into the AMWTP, there is the potential that improved technology, not available when the AMWTP was contracted for, such as pyrolysis/steam reforming could be incorporated into the revised facility design. If this were to be the case, then it could prove beneficial to include an evaluation of steam reforming for processing of SBW at the AMWTP in the final EIS. The steam reformer technology could be utilized to process low-level mixed TRU waste originally planned for the incinerator and to destroy the nitrate in the SBW. The resultant nitrate free, alkali compounds could then be efficiently packaged as TRU waste.

Modifications could be made to the AMWTP to enable the processing of SBW that would have no impact on the overall schedule for the AMWTP and would not jeopardize compliance with the Settlement Agreement/Consent Order.

**Other Considerations**

The Draft EIS provided a summary description of Project Number P9J, HAW Denitrification, Packaging and Cask Loading Facility (listed in Table C.6.1-1 and more fully described in section C.6.2.10, page C.6-73). Project P9J discussed utilization of an elutriating fluid bed of a similar nature to Studvik steam reforming system, to process high-activity wastes with a nitrate component.

Due to the many advantages listed throughout this document, we feel that it is imperative that provisions be made for the evaluation of fully deployed technologies, such as steam reforming, prior to issuance of the final EIS. The advantages to be realized far outweigh the effort that would be required to perform the revision.

Again, we are asking that the fluid bed pyrolysis/steam reforming approach be evaluated in the EIS as a non-separation alternative for the various waste streams discussed in this letter. Additionally, we invite the DOE to visit our operating facility and view first-hand the Reformer technology application in commercial radioactive operation.
Mr. T.L. Wichmann / Ms. Ann Dold
April 12, 2000
Draft EIS Comments, Page 10

We thank you for your time and consideration in this matter and look forward to having the
opportunity to directly discuss the issues addressed in this letter. If you have any questions on
this information, please call me directly at (803) 731-8220.

Sincerely,

Thomas W. Oliver, P.E.
Vice President

Attachments: 1. THOR™ Technology and Processing Facility, Erwin TN

Attachment One
THOR™ Technology and Processing Facility, Erwin TN
STUDSVIK PROCESSING FACILITY
PYROLYSIS/STEAM REFORMING TECHNOLOGY FOR VOLUME AND WEIGHT REDUCTION AND STABILIZATION OF LLRW AND MIXED WASTES

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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 1.5 Sv/h (150 mR). The licensed and heavily shielded SPF can receive and process liquid and solid LLRWs with high waste and/or organic content.

The SPF employs the Thermal Organic Reduction (THOR™) process, developed and patented by Studsvik, which utilizes pyrolysis/steam reforming technology. THOR™ safely processes a wide variety of LLRWs in a unique, moderate temperature, pyrolysis/refracting, fluidized bed treatment system. The THOR™ process is suitable for processing hazardous, mixed and dry active LLRW (DAW) with appropriate licensing and waste fee modifications.

Operations have demonstrated consistent, reliable, robust operating characteristics with consistent volume reductions of up to 70:1 and weight reductions of up to 30:1 when processing depleted, mixed bed, ion exchange resins with over 94.6% of all radionuclides in the waste feed incorporated in the final solid residue product. Final processed residue comprises non-dispersible, granular solid suitable for long-term storage or direct burial in a qualified container. THOR™ effectively converts environmental chromium to non-hazardous trivalent chromium and can convert nitrates to nitrogen with over 99 percent efficiency in a single pass.

The paper provides an overview of the first 6 months of commercial operations processing radioactive ion exchange resins from commercial nuclear power plants. Process improvements and lessons learned will be discussed. Plans for new mixed waste and graphite steam reforming processing will be presented.

PROCESS OVERVIEW

Since 1947 Studsvik has been actively involved in 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 steel 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 develop a new, licensed, and construction of a commercial LLRW processing facility that utilizes the patented THOR™ process. The Studsvik Processing Facility (SPF) has completed construction, start-up testing, and commenced commercial operations with processing of radioactive IER from nuclear power stations in July 1999.

The THOR™ process utilizes two fluid bed reactors to process a wide variety of solid and liquid LLRWs. Figure 1 provides an overview flow diagram of the THOR™ 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, sludges, oils, antifreeze, solvents, cleaning solutions, etc. are metered into the pyrolyzer by a pump.

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 to the gas handling system. The low-carbon, metal oxide-rich residue removed by the ceramic filter 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 2 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 for burial at licensed burial sites or return to the generator. The final reforming residue volume is readily only 1 to 4 percent of the incoming residue volume. For depleted, mixed-fed IER it is possible to achieve a volume reduction (VR) of 20-100 times with a corresponding weight reduction (WR) of 12-85 times.

Through selection of appropriate thermal waste reforming operating conditions it is possible to produce an inert, inorganic final waste that consists of only the radioactive elements, metal oxides and insoluble calcium and silica compounds initially absorbed on the IER. It is possible to reach near theoretical waste reductions with the THOR™ process. Another significant improvement realized by the THOR™ process is the ability to process wastes with high water content. Aquous 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 slurries, oils, activated carbon, antifreeze solution, steam generator cleaning solvents and several types of IERs have all been successfully processed by the THOR™ 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...
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.

The SPF is designed to meet the following criteria:

- **Facility Caris Inventory**: up to 2,000 Ci (74 TBq)
- **LLRW Input Caris**: up to 2.0 Ci/cm² (2.6 TBq/m²)
- **LLRW Inputs**: Uranium, Plutonium, Thorium, and Actinides
- **Oils, Aqueous Decon, and Cleaning Solutions**, Solvents, and Sludge

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

**Process Building**

The Process Building contains all radioactive processing, handling, and packaging systems for volume reduction and weight reduction of incoming LLRW. Major areas include truckbays, LLRW input holding tank vault, pyrolysis/refining 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. Tank maintenance activities are performed in the truckbay where an overhead crane provides lifting capability. Figure 3 is a photograph of the dual station truckbay.

**Pyrolysis/Reforming System**

The Pyrolysis/Reforming THOR system comprises: stage one pyrolysis reactor (pyrolyzer), stage two reformer reactor, 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 destructed 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 inorganic and debris present in the LLRW feed) are removed from the pyrolyzer and collected in the stage one ceramic filter vessels. The pyrolyzer is fluidized with superheated steam and additive gas. Figure 5 is a photograph of the reformer process area.

**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 organics, cleaning solutions, and oils. A lockiepper feeder is used to receive and feed granular and powdered LLRW, such as charcoal. A separate slurry 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 slurry holding tank vault.

**Gas Handling System**

The gas handling system comprises an energy recovery heat exchanger, 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 components to carbon dioxide and water, recover energy from the synthesis gas, convert acid gases to stable salts, control water content of exiting process gases, and control negative pressure levels throughout the THOR™ 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...