What is SEMPRASAFE?

• Joint Venture between EnergySolutions and Studsvik to process US-generated low-level radioactive resin through Studsvik’s THOR® process
• Creates a superior waste form for disposal at Clive
• Based on 10 years of experience safely handling these materials within the existing regulatory environment
Why SEMPRASAFE?

• Addresses resin waste management issues at nuclear power plants
• Offers best practices in processing and disposal to the nuclear power industry
• Addresses issues of NRC Commissioners in Staff Requirements Memo on blending
• Builds on the long-standing business relationship between EnergySolutions & Studsvik
NRC Position on Blending

• NRC has recently stated its new position that “large-scale LLRW blending may be conducted when it can be demonstrated to be safe.”

• Commission recognized significance of
  – Homogeneity
  – Intruder Protection
SEMPRASAFE and the THOR Process
Commercial Nuclear Waste Treatment with the THOR Process in Erwin, TN
THOR Process Overview

Organic Resin
• Polystyrene Beads
• Organics
• Metals
• Water
• Salts

Mineral Former

Pyrolyzed Resin
• Fixed Carbon
• Salts
• Metal Oxides, Spinels, and Aluminates

Heat
Oxygen from Superheated Steam

Reformed Resin
• Metal Oxides, Spinels, and Aluminates
• Salts
• Residual Fixed Carbon
Fluid Bed Process
Operational Features

• Uniform reactions and consistent product due to
  – Complete mixing due to fluid-like behavior
  – Better gas-solid contact than other processes
  – Uniform temperature gradients
• Very high heat transfer coefficients so more efficient
• High efficiency due to continuous operation
• Highly predictable
• Highly reliable
• High degree of control
Waste Receipt

- Waste in high integrity containers (HICs) transferred from cask
- Utilize shielded transfer bell
- Material slurry transferred from HICs to process tanks
Processing Equipment

Waste Receipt Tanks, Process Filters, Steam Superheaters
Reactions in a THOR Reformer

**Main Reaction Inputs**
- Steam
- Coal or Charcoal
- Waste
- Mineral Former

**Main gas phase reactions in fluidized bed reformer**
- \( C_xH_yO_z \leftrightarrow C + CH_4 + CO + H_2 \)
- \( H_2O + C \leftrightarrow H_2 + CO \)
- \( CO + H_2O \leftrightarrow CO_2 + H_2 \)
- \( 2NO_3 + 3C \leftrightarrow N_2 + 3CO_2 \)
- \( 2NO_3 + 6H_2 \leftrightarrow N_2 + 6H_2O \)
- \( C + O_2 \leftrightarrow CO_2 \)
- \( 2CO + O_2 \leftrightarrow 2CO_2 \)
- \( 2H_2 + O_2 \leftrightarrow 2H_2O \)

**Main Reaction Outputs**
- Water Vapor
- Carbon Dioxide
- Nitrogen
- Reformed Residue

- Decomposition of organics
- Water gas reaction
- Water gas shift reaction
- Conversion of nitrates to nitrogen gas
- Conversion of nitrates to nitrogen gas
- Oxidation of carbon
- Oxidation of CO to CO_2
- Oxidation of H_2 to water
## THOR Final Waste Forms

<table>
<thead>
<tr>
<th>Waste Constituent or Characteristic</th>
<th>No Mineral Former (DOE)</th>
<th>Mineral Former (SPFE)</th>
<th>Clay Former (DOE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organics</td>
<td>Destroyed</td>
<td>Destroyed</td>
<td>Destroyed</td>
</tr>
<tr>
<td>Alkali Metals</td>
<td>Carbonate</td>
<td>Aluminate</td>
<td>Alkali Aluminosilicate mineral (NAS)</td>
</tr>
<tr>
<td>Inorganic Metals</td>
<td>Oxides, Spinels</td>
<td>Oxides, Spinels, Aluminates</td>
<td>Spinels and Oxides bound in NAS matrix</td>
</tr>
<tr>
<td>Cl, S, F, P, B</td>
<td>Alkali Salt</td>
<td>Alkali Salts, Aluminum Compounds</td>
<td>Bound in NAS matrix</td>
</tr>
<tr>
<td>Radionuclides</td>
<td>Oxides or Carbonates</td>
<td>Spinels and Oxides, or Carbonates</td>
<td>Spinels and Oxides bound in NAS matrix</td>
</tr>
<tr>
<td>Waste Form</td>
<td>Inorganic and soluble</td>
<td>Inorganic, reduced solubility, non-leachable</td>
<td>Immobilization / non-leachable</td>
</tr>
</tbody>
</table>
Facility and Process Overview

• Shielded facility
• Treats ion exchange resins
• Extremely good radionuclide retention
• >9,900 m³ (>350,000 ft³) processed
• >2,900 incoming LLW shipments
• >4.9 x 10⁹ MBq (133,000 Ci) processed
• Incoming LLW resin contact dose rates up to 10 Sv (1,000 R/hr)
• Over 10 years of LLRW operation
THOR Process Applications

• Studsvik Processing Facility
  – Ion Exchange Resins

• DOE-Idaho Integrated Waste Treatment Facility
  – Nitrate Slurry Waste: Remote Handled TRU (Start-up in 2011)

• DOE-Savannah River Site Tank 48H Treatment Facility
  – Nitrate Waste: High Level Waste (Final Design 2011)

• Qualification testing on-going
  – DOE-Hanford
    • Waste Treatment Plant Secondary Waste and Low Activity Waste (LAW)
    • Nitrate Waste: Intermediate Level Waste
  – Foreign Applications
    • Ion Exchange Resins, Pu Contaminated Wastes, Nitrate Waste, Graphite
Waste Disposal and Clive Safety Analyses
Safety Analysis

• EnergySolutions prepared analysis to demonstrate waste can be safely disposed
  – Site suitability
  – Intruder protection
  – Performance Assessment
Site Suitability

- Arid conditions
- Lack of a source of potable water at the site
- Absence of any conditions that would promote the site as a desirable place to live
- Minimal possibility of a residence being constructed at the site
Intruder Protection

• Prior licensing actions for the Clive facility have evaluated intruder scenarios
• Construction intruder, agriculture intruder, and off-site receptor scenarios found not to be reasonable
• Conducted intruder analysis despite absence of credible intruder scenario
Intruder Protection

• Inherent in Clive CWF Disposal Unit Design
• Acknowledged by NRC in SECY-10-0043
• CWF disposal methodology exceeds the requirements of 10 CFR 61 and the Utah Administrative Code
  – Engineered barrier
  – Stability
  – Depth
Groundwater Analysis

- Assumed all waste disposed at Class A limits for all isotopes
- Groundwater assumed to be potable
- Receptor assumed to reside at the facility for 30 years
- The groundwater protection standard was 4 mrem/yr (0.04 mSv/yr), as opposed to the NRC prescribed 25 mrem/yr (0.25 mSv/yr)
- Groundwater standard (4 mrem/yr) not exceeded after 500 years
Shipment Arrives
Liner removed from cask
Liner placed in caisson
Caisson backfilled
CWF Disposal Layout

CONTAINERNIZED WASTE FACILITY: PLACEMENT CONFIGURATIONS
Summary of Safety Analysis

• The site is suitably located and licensed for the disposal of Class A waste
• Performance assessment demonstrated acceptability of disposal of large quantities of waste at Class A limits
• CWF provides inherent protection of inadvertent intruder
• Protection of an intruder is provided even though there are no credible intrusion scenarios
• Consumption of the groundwater will not result in a dose that exceeds the standard even though the groundwater is not potable
ADDITITIONAL SLIDES SUBMITTED
BY ENERGYSOLUTIONS
Unique Waste Stream

• Blended waste is not intrinsically unique
• NRC defines blended waste as unique when it meets three criteria
  – Large Quantities
  – At or near Class A Limits
  – Disposed in close proximity
Clive Activity Loading

- Class A Limit
- 1.9% of Class A Limit
- Cumulative LLRW Disposal Volume (6.1 million yd³)