THERMOSELECT – An Advanced Field Proven High Temperature Recycling Process

THERMOSELECT S.A.
Via Naviglio Vecchio 4
6600 Locarno
Switzerland

October 12-15, 2003
• Company Information
• Technology
• Karlsruhe Plant / Germany
• ASR Processing (Automotive Shredder Residue)
• Chiba + Mutsu Plant / Japan
Company founded in 1989

1989 – 1991: Laboratory scale studies of waste degasification, carbonization and gasification

1991 – 1992: Development and erection of an industrial scale pilot plant in Fondotoce / Italy


1998 – 1999: Erection of commercial plants in Karlsruhe / Germany and in Chiba / Japan

150 employees, headquarter in Locarno / Switzerland, manufacturing subsidiary in Dottikon / Switzerland

Licensees:
- JFE Engineering, Japan (Kawasaki Steel + NKK)
- Daewoo Engineering, Korea
**PROCESS OVERVIEW**

**THERMOSELECT**

- **Waste of all kinds**
- **Degassing Channel**
- **High Temperature Reactor**
- **Press**
- **Oxygen facility**
- **Homogenization reactor**
- **Synthesis gas scrubbing**
- **Process water treatment**
- **Synthesis Gas**
  - Production of Hydrogen
  - Methanol
  - Ammonia
  - or Power generation
- **Sulfur**
- **Clean water**
- **Salt**
- **Zinc Concentrate**
- **Metals and Minerals**

**Reagents and Products:**
- Zinc Concentrate
- Salt
- Clean water
- Sulfur
- H₂, CO, CO₂, H₂O
- Synthesis Gas
- Process water treatment
- Waste of all kinds
SYNTHESIS GAS SCRUBBING

Syn. gas → Quench → Acidic Scrubber → Alkaline Scrubber → De-dusting stage → Desulfurization → Drying

- Heat Exchanger
- Degassing
- Water lock
- Feed tank
- Filter
- Sludge back feed
- Raw water buffer
- Oxidation

- Filtration
- Filtrate
- Additive, new
- Regeneration
- Sedimentation
- Additive Iron Chelate
- Sludge
- Air
- Filtration
- Filtrate

- Safety Flare
- Sulfur
- Pure syn. gas
Controlled injection of oxygen is used to gasify organic components at temperatures up to 2000°C.

The produced synthesis gas is primarily composed of H₂, CO, CO₂

Metal and mineral constituents are molten
The synthesis gas produced in the gasifier is shock-cooled in the quench immediately downstream.

Cooling takes place in less than 30 ms.
Metal and mineral granulate is ready for reuse.

The vitreous mineral granulate leachability complies with strictest regulations.
The reactor wall consists of a thermally-insulating refractory lining. The highly stable refractory material is protected by a slag coating of vitrified mineral melt. Liquid mineral melt runs off the slag coating.
High Temperature Recycling (> 99.5% Material Recovery)

Lowest Emissions (Dioxin Destroyer, Total << 1 µg/Mg)

Synthesis gas for flexible utilisation (Power, Hydrogen ...) on site or over-fence

Broad range of wastes can be processed, EC directive:

“If hazardous wastes with a content of more than 1% of halogenated organic substances, expressed as chlorine, are incinerated, the temperature has to be raised to 1’100°C for at least two seconds“

Current plants are operated on:

- MSW Japan, low inerts, high moisture (Chiba & Mutsu)
- MSW Germany, high inerts (Karlsruhe)
- Industrial waste Japan (Chiba)
- ASR, high Chlorine, high LCV (Karlsruhe & Chiba)
- RDF, high LCV (Karlsruhe)
Typical mass balance for Municipal Solid Waste (MSW)

Waste 1000 kg

Oxygen, Natural Gas, Additives 514 kg

Compression Degassing

Gasification Melting Homogenization

Mineral Material 230 kg

Metals 29 kg

Sulfur 2 kg

Zinc Concentrate 3 kg

Salt 10 kg

Clean Water (cooling tower) 350 kg

Synthesis Gas Scrubbing

Process Water Treatment

Purified Synthesis Gas 890 kg
DIVERSION FROM LANDFILL

Vitreous Mineral Granulate
approx. 20-25 % of Input

Iron-Copper Alloy
approx. 1-3 % of Input

Salt
approx. 1 % of Input

Sulfur
approx. 0.2 - 0.3 % of Input

Zinc-Concentrate
approx. 0.2 - 0.3 % of Input

Concrete Sand-Blasting Road Construction

Metallurgy

Chemical Industry, Additive for Metallurgy

Chemical Industry, i.e. Sulfuric Acid Production

Zinc-Recovery
**ENERGY BALANCE**

Input total 3733 kWh/Mg

- **Synthesis Gas** 2423 kWh/Mg
- **Heat used internally** 460 kWh/Mg
- **Heat Loss Gas Engines** 930 kWh/Mg
- **1310 kWh/Mg Rejected Heat and Plant Requirement (Evap.)**

- **Plant E-consumption** 328 kWh/Mg

**Electricity** 1033 kWh/Mg

- **Surplus Electricity** 705 kWh/Mg

**4 line plant gas engine power generation**

**12 MJ/kg Waste**
<table>
<thead>
<tr>
<th>Company:</th>
<th>TESS (Thermoselect Südwest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status:</td>
<td>in service</td>
</tr>
<tr>
<td>Start-up:</td>
<td>Feb. 1999</td>
</tr>
<tr>
<td>Capacity:</td>
<td>225‘000 Mg/a</td>
</tr>
<tr>
<td>No. of lines:</td>
<td>3 lines 10 Mg/h each</td>
</tr>
<tr>
<td>Heating value:</td>
<td>12‘000 kJ/kg</td>
</tr>
<tr>
<td>Syn. gas utilization:</td>
<td>steam vessel &amp; steam turbine, district heating</td>
</tr>
</tbody>
</table>
KARLSRUHE – MSW OPERATION DATA

Waste [kg/h]
Syngas [Nm3/h]
Steam [t/h]
<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Train 1</th>
<th>Train 2</th>
<th>Train 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product not required</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Planned Outages</td>
<td>23%</td>
<td>26%</td>
<td>31%</td>
<td>27%</td>
</tr>
<tr>
<td>Outage Power unit (part of planned outage)</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Unplanned Outages</td>
<td>0%</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Onstream</td>
<td>76%</td>
<td>66%</td>
<td>62%</td>
<td>65%</td>
</tr>
<tr>
<td>Yearly Throughput (metric tons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100,100</td>
<td>35,009</td>
<td>30,691</td>
<td>34,400</td>
</tr>
<tr>
<td></td>
<td>3,535</td>
<td>1,236</td>
<td>1,084</td>
<td>1,215</td>
</tr>
<tr>
<td>Forced Outage Rate</td>
<td>0%</td>
<td>9%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Availability</td>
<td>77%</td>
<td>67%</td>
<td>63%</td>
<td>66%</td>
</tr>
<tr>
<td>Rated Capacity (mmscf)</td>
<td>9,308</td>
<td>3,103</td>
<td>3,103</td>
<td>3,103</td>
</tr>
<tr>
<td>Annual Loading Factor</td>
<td>38%</td>
<td>40%</td>
<td>35%</td>
<td>39%</td>
</tr>
<tr>
<td>Company:</td>
<td>Kawasaki Steel Corporation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status:</td>
<td>In service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start-up:</td>
<td>Sept. 1999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity:</td>
<td>100,000 Mg/a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of lines:</td>
<td>2 lines 6.25 Mg/h each</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating value:</td>
<td>8,500 kJ/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syn. gas utilization:</td>
<td>One Jenbacher Gas Engine and in CC power plant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>Train 1</td>
<td>Train 2</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Product not required</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Planned Outages</td>
<td>6%</td>
<td>6%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Unplanned Outages</td>
<td>1%</td>
<td>6%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Onstream</td>
<td>94%</td>
<td>88%</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>Yearly Throughput (metric tons)</td>
<td>75,552</td>
<td>37,563</td>
<td>37,989</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(mmscf)</td>
<td>2,668</td>
<td>1,327</td>
<td>1,342</td>
</tr>
<tr>
<td>Forced Outage Rate</td>
<td>1%</td>
<td>6%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td>94%</td>
<td>88%</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>Rated Capacity (mmscf)</td>
<td>4,125</td>
<td>2,062</td>
<td>2,062</td>
<td></td>
</tr>
<tr>
<td>Annual Loading Factor</td>
<td>65%</td>
<td>64%</td>
<td>65%</td>
<td></td>
</tr>
</tbody>
</table>
End-of-life vehicles

EU end-of-life directive for vehicles, recycling rates:

- 2006 – 85%
- 2015 – 95%
Test Procedure:

- Throughput: 428 t ASR
- Time period: 66 h, ca. 3 days from 27.-29. of November 2002
- Mixture: 40 - 55 Gew.-% ASR, mixed with MSW
- Throughput per line: approx. 7.8 t/h (up to 4.3 t/h ASR)

Sampling /Analysis:

- Air emissions
- Granulate
- Sulfur
- Zink concentrate
- mixed salt
### KARLSRUHE PLANT – SHREDDER DUST COMPOSITION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MSW Literature</th>
<th>Trial operation 11/2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating value, LCV</td>
<td>kJ/kg</td>
<td>7,000 - 10,000</td>
</tr>
<tr>
<td>Ignition residue 550°C</td>
<td>weight-%</td>
<td>79.3 79.6 79.6 78.8</td>
</tr>
<tr>
<td>Water</td>
<td>weight-%</td>
<td>25 - 35</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>mg/kg DS</td>
<td>- 10,500</td>
</tr>
<tr>
<td>Iron</td>
<td>weight-% DS</td>
<td>2 - 5 12.0 10.7 26.6 13.36</td>
</tr>
<tr>
<td>Chloride</td>
<td>weight-% DS</td>
<td>0.1 - 1 1.8 1.72 3.18 3.52</td>
</tr>
<tr>
<td>Fluoride</td>
<td>weight-% DS</td>
<td>0.01 - 0.02 0.01 0.02 0.01 0.01</td>
</tr>
<tr>
<td>Sulfur</td>
<td>weight-% DS</td>
<td>0.05 - 0.5 0.2 0.3 0.2 0.2</td>
</tr>
<tr>
<td>Copper</td>
<td>g/kg DS</td>
<td>0.1 - 2 8.4 3.6 25.6 5.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>g/kg DS</td>
<td>0.4 - 4 14.0 9.9 13.5 15.0</td>
</tr>
<tr>
<td>Chromium</td>
<td>g/kg DS</td>
<td>0.2 - 2 0.6 0.3 0.5 0.4</td>
</tr>
<tr>
<td>Tin</td>
<td>g/kg DS</td>
<td>0.05 - 0.5 0.03 0.003 0.01 0.05</td>
</tr>
<tr>
<td>Barium</td>
<td>g/kg DS</td>
<td>0.1 - 1 0.31 0.202 0.42 0.56</td>
</tr>
<tr>
<td>Lead</td>
<td>g/kg DS</td>
<td>0.2 - 2 4.4 2.7 2.4 4.7</td>
</tr>
<tr>
<td>Antimon</td>
<td>mg/kg DS</td>
<td>0.A.** 94 72 226 512</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/kg DS</td>
<td>1 - 8 11.6 10.0 16.5 13.1</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/kg DS</td>
<td>3 - 30 21.8 25.1 31.3 37.3</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/kg DS</td>
<td>0.3 - 10 2.1 4.1 2.6 1.6</td>
</tr>
</tbody>
</table>

Parameter MSW Literature: 7,000 - 10,000
Current emissions are displayed at www.thermoselect-karlsruhe.de
ASR TEST – MINERAL GRANULATE COMPOSITION

green - reference before test (MSW)
red - during test (ASR/MSW)
ASR TEST – MINERAL GRANULATE LEACHABILITY

green - reference before test (MSW)
red - during test (ASR/MSW)
Mitsubishi Materials Mutsu Plant - Japan

Company: Mitsubishi Materials Corporation
Status: In service
Commercial op.: April 1st, 2003
Capacity: 140 Mg/d
No. of lines: 2 lines 2.9 Mg/h each
Heating value: 7.1 – 9.3 MJ/kg
Syn. gas utilization: Two Jenbacher Gas Engines
1.2 MW each
Thermoselect plants are extremely environmental friendly in terms of emissions and resource recovery.

The Thermoselect process has a multipurpose capability, various types of wastes with a broad range of heating values and compositions can be processed in a single plant.

With three commercial plants in operation, Thermoselect technology is now proven.

Currently, four further plants are under construction in Japan.