THERMOSELECT – An Advanced Field Proven High Temperature Recycling Process

October 12-15, 2003

THERMOSELECT S.A.
Via Naviglio Vecchio 4
6600 Locarno
Switzerland
• 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
THERMOSELECT PROCESS OVERVIEW

Zinc Concentrate
Salt
Clean water
Sulfur
Synthesis Gas
Production of Hydrogen Methanol Ammonia or Power generation
Sulfur
Clean water
Salt
Zinc Concentrate
Metals and Minerals

Oxygen facility
Press
Degassing Channel
High Temperature Reactor
Homogenization reactor

1600°C
2000°C
1200°C

O2

Synthesis gas scrubbing
Process water treatment

H2, CO, CO2, H2O

Waste of all kinds

1600°C
2000°C

1200°C

Scrubber
Quench

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
- Mineral Material: 230 kg
- Metals: 29 kg
- Sulfur: 2 kg
- Zinc Concentrate: 3 kg
- Salt: 10 kg
- Clean Water (cooling tower): 350 kg

Processes:
- Compression
- Degassing
- Gasification
- Melting
- Homogenization
- Synthesis Gas Scrubbing
- Process Water Treatment
- Purified Synthesis Gas: 890 kg
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
THERMOSELECT ENERGY BALANCE

Input total: 3733 kWh/Mg

1310 kWh/Mg Rejected Heat and Plant Requirement (Evap.)

Synthesis Gas: 2423 kWh/Mg

Surplus Electricity: 705 kWh/Mg

Heat used internally: 460 kWh/Mg

Plant E-consumption: 328 kWh/Mg

Heat Loss Gas Engines: 930 kWh/Mg

Electricity: 1033 kWh/Mg

4 line plant gas engine power generation: 12 MJ/kg Waste

1310 kWh/Mg Rejected Heat and Plant Requirement (Evap.)
Karlsruhe - Germany

- Company: TESS (Thermoselect Südwest)
- Status: in service
- Start-up: Feb. 1999
- Capacity: 225,000 Mg/a
- No. of lines: 3 lines, 10 Mg/h each
- Heating value: 12,000 kJ/kg
- Syn. gas utilization: steam vessel & steam turbine, district heating
<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>
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<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</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(metric tons)</td>
<td>100,100</td>
<td>35,009</td>
<td>30,691</td>
<td>34,400</td>
</tr>
<tr>
<td>(mmscf)</td>
<td>3,535</td>
<td>1,236</td>
<td>1,084</td>
<td>1,215</td>
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<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>
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<tr>
<td>Rated Capacity (mmscf)</td>
<td>9,308</td>
<td>3,103</td>
<td>3,103</td>
<td>3,103</td>
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<tr>
<td>Annual Loading Factor</td>
<td>38%</td>
<td>40%</td>
<td>35%</td>
<td>39%</td>
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**Kawasaki Steel Chiba Plant - Japan**

- **Company:** Kawasaki Steel Corporation
- **Status:** In service
- **Start-up:** Sept. 1999
- **Capacity:** 100,000 Mg/a
- **No. of lines:** 2 lines, 6.25 Mg/h each
- **Heating value:** 8,500 kJ/kg
- **Syn. gas utilization:** One Jenbacher Gas Engine and in CC power plant
<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Train 1</th>
<th>Train 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product not required</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>Planned Outages</td>
<td>6%</td>
<td>6%</td>
<td>9%</td>
</tr>
<tr>
<td>Unplanned Outages</td>
<td>1%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Onstream</td>
<td>94%</td>
<td>88%</td>
<td>88%</td>
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<tr>
<td>Yearly Throughput</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(metric tons)</td>
<td>75,552</td>
<td>37,563</td>
<td>37,989</td>
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<tr>
<td>(mmscf)</td>
<td>2,668</td>
<td>1,327</td>
<td>1,342</td>
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<tr>
<td>Forced Outage Rate</td>
<td>1%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Availability</td>
<td>94%</td>
<td>88%</td>
<td>88%</td>
</tr>
<tr>
<td>Rated Capacity (mmscf)</td>
<td>4,125</td>
<td>2,062</td>
<td>2,062</td>
</tr>
<tr>
<td>Annual Loading Factor</td>
<td>65%</td>
<td>64%</td>
<td>65%</td>
</tr>
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</table>
End-of-life vehicles

ASR / Shredder-dust

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>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sample 1</td>
</tr>
<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></td>
</tr>
<tr>
<td>Water</td>
<td>weight-%</td>
<td>25 - 35</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>mg/kg DS</td>
<td>-</td>
</tr>
<tr>
<td>Iron</td>
<td>weight-% DS</td>
<td>2 - 5</td>
</tr>
<tr>
<td>Chloride</td>
<td>weight-% DS</td>
<td>0.1 - 1</td>
</tr>
<tr>
<td>Fluoride</td>
<td>weight-% DS</td>
<td>0.01 - 0.02</td>
</tr>
<tr>
<td>Sulfur</td>
<td>weight-% DS</td>
<td>0.05 - 0.5</td>
</tr>
<tr>
<td>Copper</td>
<td>g/kg DS</td>
<td>0.1 - 2</td>
</tr>
<tr>
<td>Zinc</td>
<td>g/kg DS</td>
<td>0.4 - 4</td>
</tr>
<tr>
<td>Chromium</td>
<td>g/kg DS</td>
<td>0.2 - 2</td>
</tr>
<tr>
<td>Tin</td>
<td>g/kg DS</td>
<td>0.05 - 0.5</td>
</tr>
<tr>
<td>Barium</td>
<td>g/kg DS</td>
<td>0.1 - 1</td>
</tr>
<tr>
<td>Lead</td>
<td>g/kg DS</td>
<td>0.2 - 2</td>
</tr>
<tr>
<td>Antimon</td>
<td>mg/kg DS</td>
<td>o.A.**</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/kg DS</td>
<td>1 - 8</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/kg DS</td>
<td>3 - 30</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/kg DS</td>
<td>0.3 - 10</td>
</tr>
</tbody>
</table>
ASR TEST – EMISSIONS (average per day)

Current emissions are displayed at www.thermoselect-karlsruhe.de
ASR TEST – MINERAL GRANULATE COMPOSITION

THERMOSELECT

![Graph showing mineral granulate composition with bars for Antimon, Arsenic, Lead, Cadmium, Chromium, Iron, Copper, Nickel, Mercury, Zinc, and Tin. The graph compares reference before test (MSW) in green and during test (ASR/MSW) in red.](image-url)
ASR TEST – MINERAL GRANULATE LEACHABILITY

**THERMoselect**

Green - reference before test (MSW)

Red - during test (ASR/MSW)

- Antimony
- Arsenic
- Lead
- Cadmium
- Chromium
- Iron
- Cobalt
- Copper
- Nickel
- Mercury
- Zinc
- Tin
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.