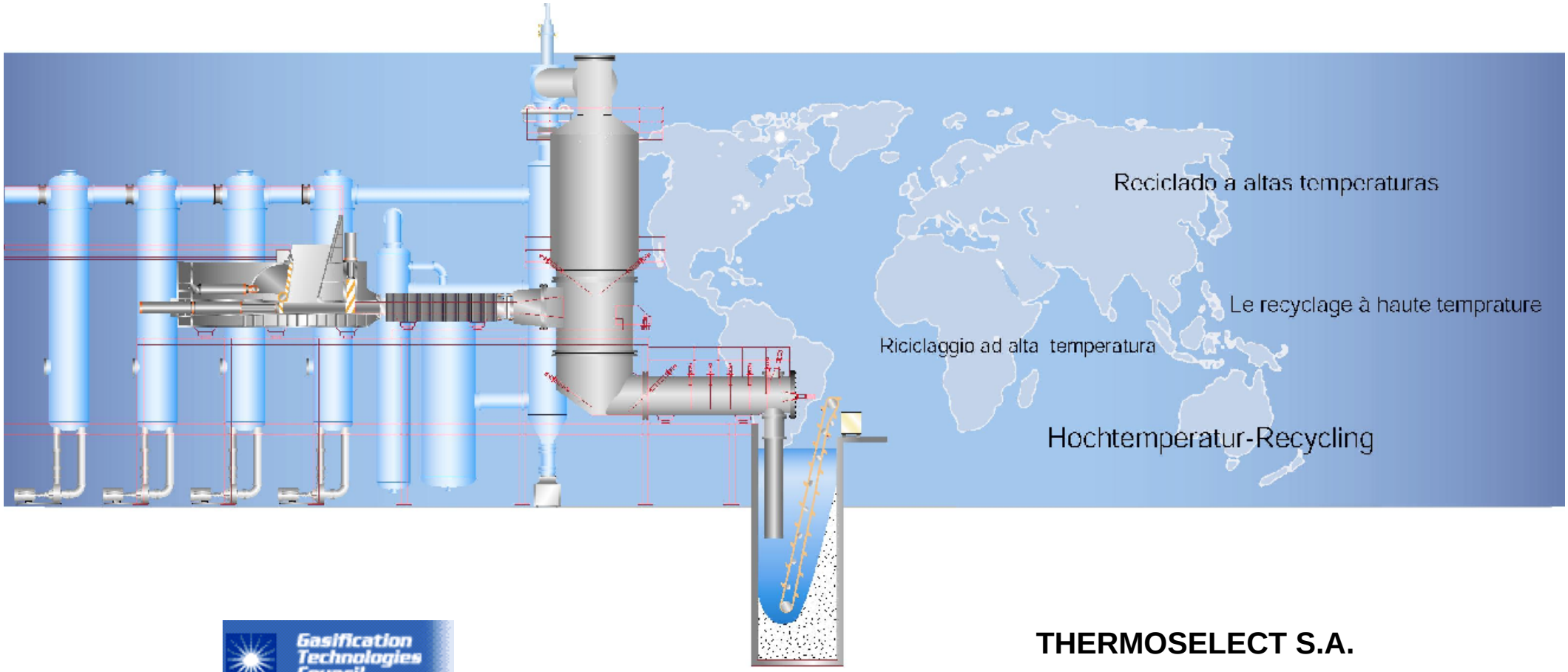
# THERMOSELECT – An Advanced Field Proven High Temperature Recycling Process




Gasification Technologies Council

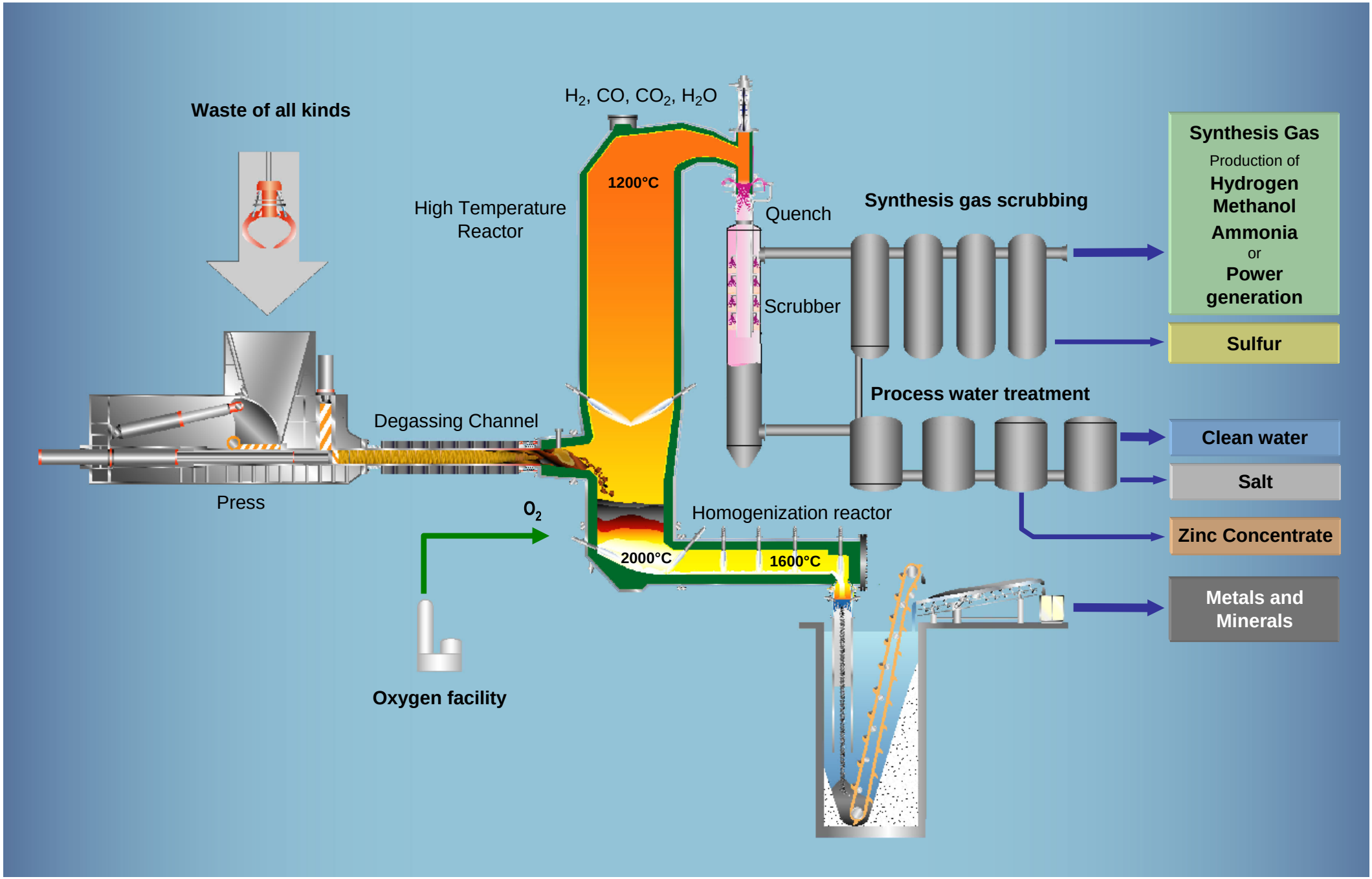
**October 12-15, 2003**

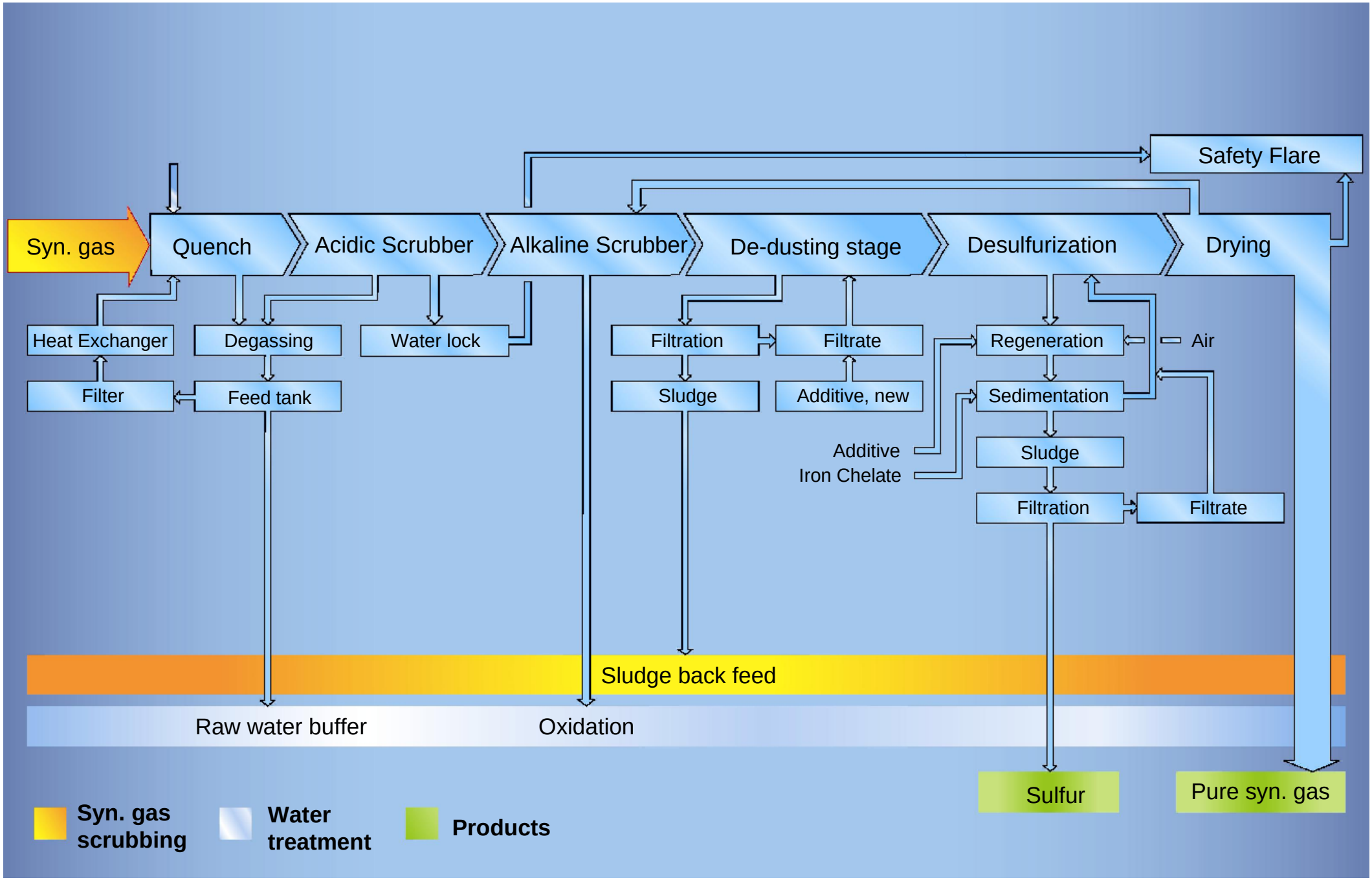
**THERMOSELECT S.A.**

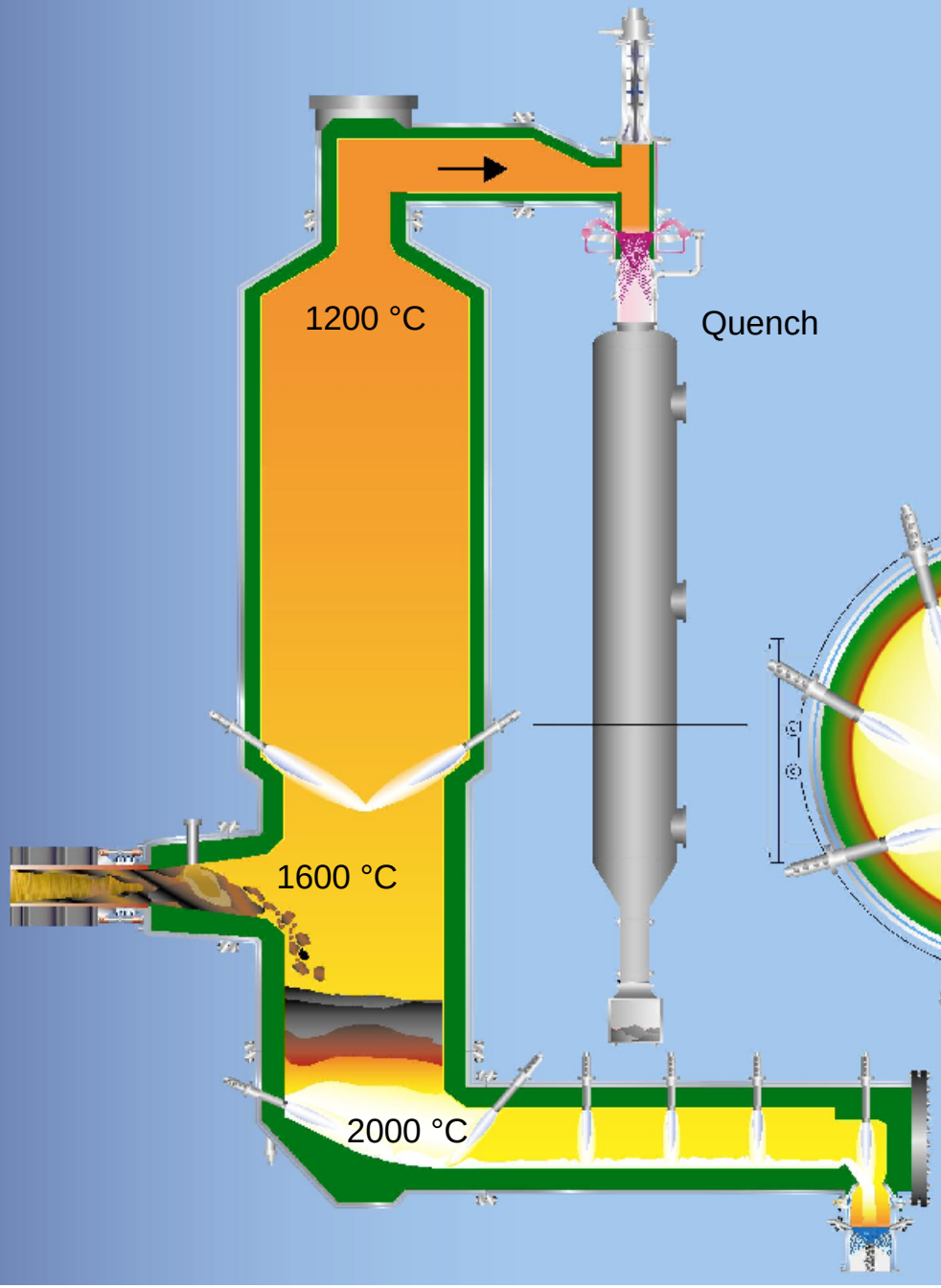
**Via Naviglio Vecchio 4**
**6600 Locarno**
**Switzerland**

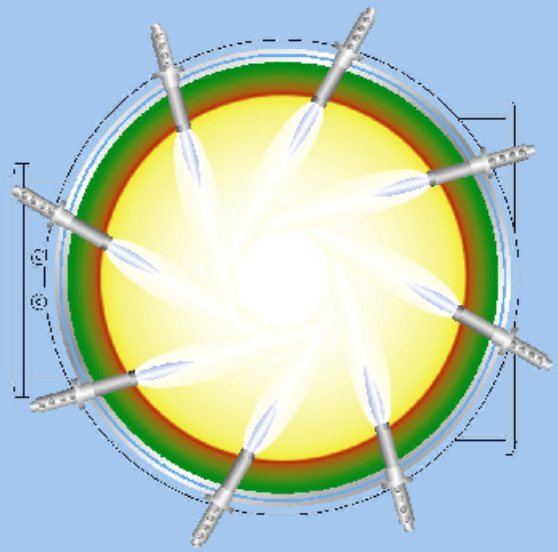
- Company Information
- Technology
- Karlsruhe Plant / Germany
- ASR Processing (Automotive Shredder Residue)
- Chiba + Mutsu Plant / Japan

- 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
- 1992 – 1998: Fondotoce plant operation, process optimization and technology demonstration
- 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


Waste of all kinds
$H_2$, CO, $CO_2$, $H_2O$
1200°C
High Temperature Reactor
Quench
Synthesis gas scrubbing
Synthesis Gas
Production of
Hydrogen
Methanol
Ammonia
or
Power generation
Scrubber
Sulfur
Process water treatment
Degassing Channel
Clean water
Salt
Press
$O_2$
Homogenization reactor
Zinc Concentrate
2000°C
1600°C
Metals and Minerals
Oxygen facility


Safety Flare
Syn. gas
Quench
Acidic Scrubber
Alkaline Scrubber
De-dusting stage
Desulfurization
Drying
Heat Exchanger
Degassing
Water lock
Filtration
Filtrate
Regeneration
Air
Filter
Feed tank
Sludge
Additive, new
Sedimentation
Additive
Iron Chelate
Sludge
Filtration
Filtrate
Sludge back feed
Raw water buffer
Oxidation
Sulfur
Pure syn. gas
Syn. gas scrubbing
Water treatment
Products



Burner / oxygen lances

## Exothermic Reactions

$C + O_2 \rightarrow CO_2$

$C + 1/2\,O_2 \rightarrow CO$

$2\,C_nH_m + (2n + m/2)\,O_2 \rightarrow 2nCO_2 + mH_2O$

## Endothermic Reactions

$C + H_2O \rightarrow CO + H_2$

$CO + H_2O \rightarrow CO_2 + H_2$

$C + CO_2 \rightarrow 2\,CO$ (Boudouard)

$C_nH_m + nH_2O \rightarrow nCO + (n + m/2)H_2$

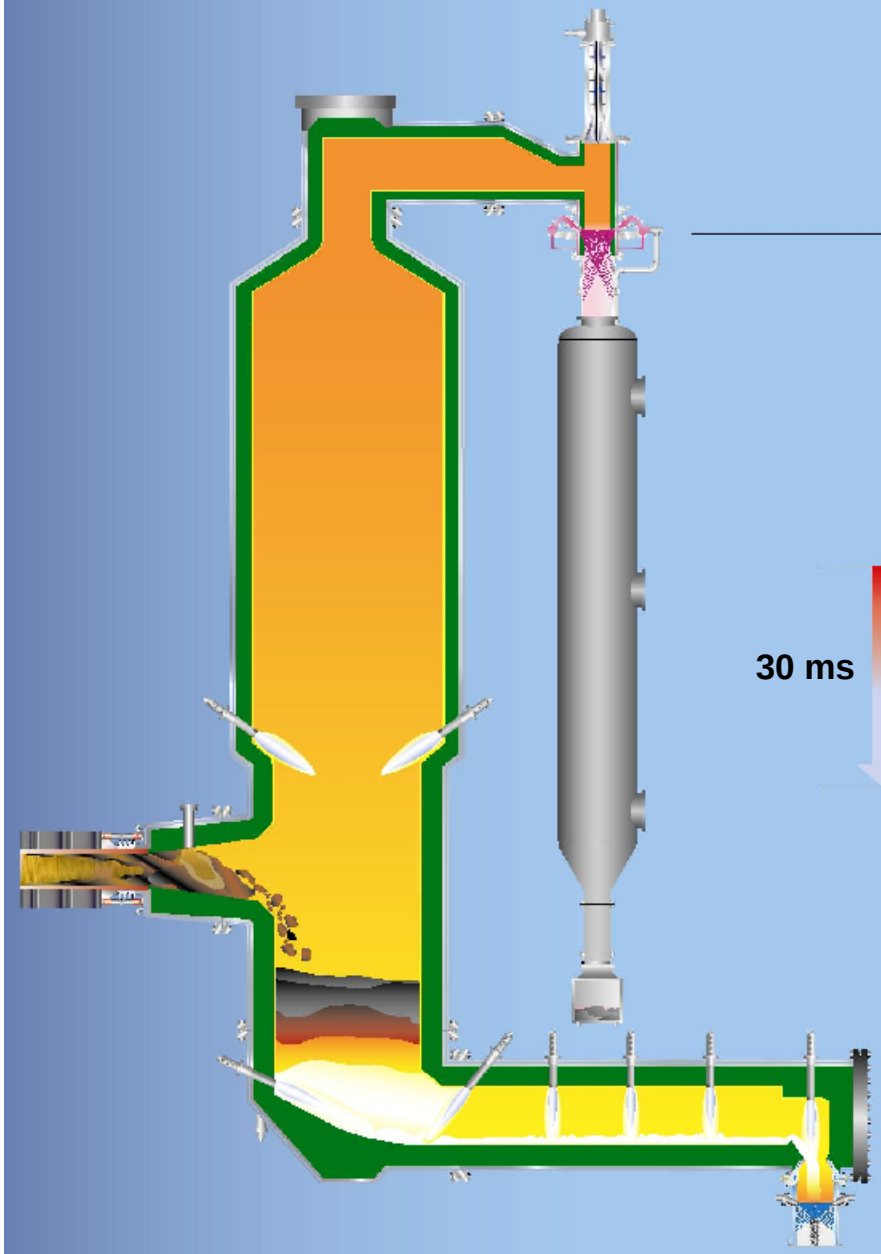
Controlled injection of oxygen is used to gasify organic components at temperatures up to 2000°C.

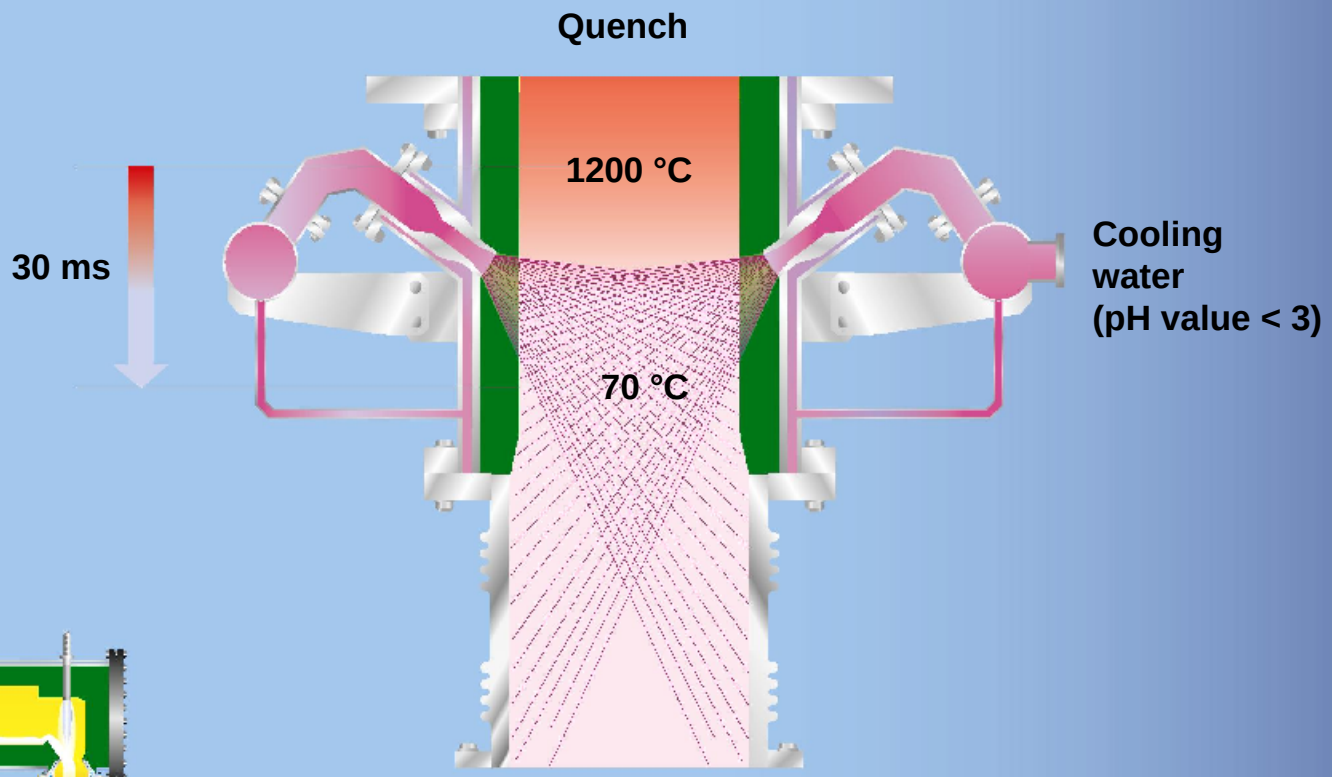
The produced synthesis gas is primarily composed of $H_2$, CO, $CO_2$

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.

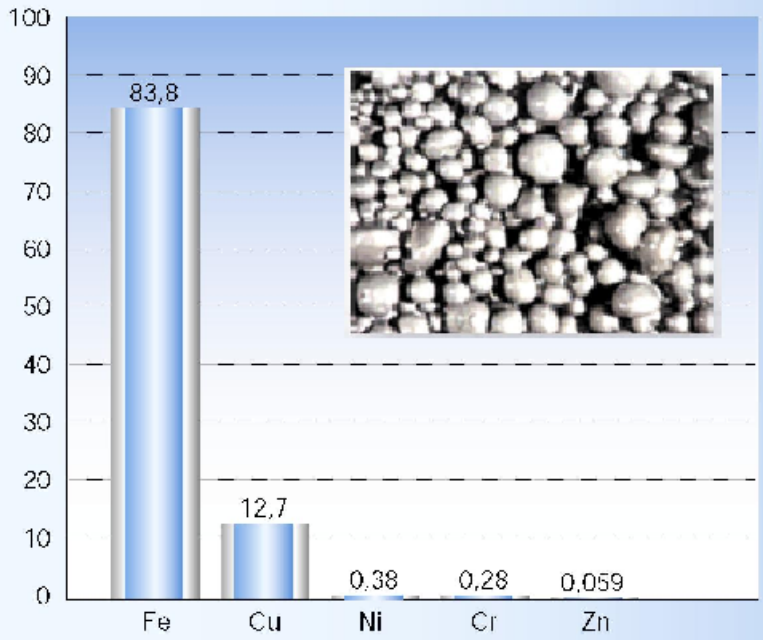




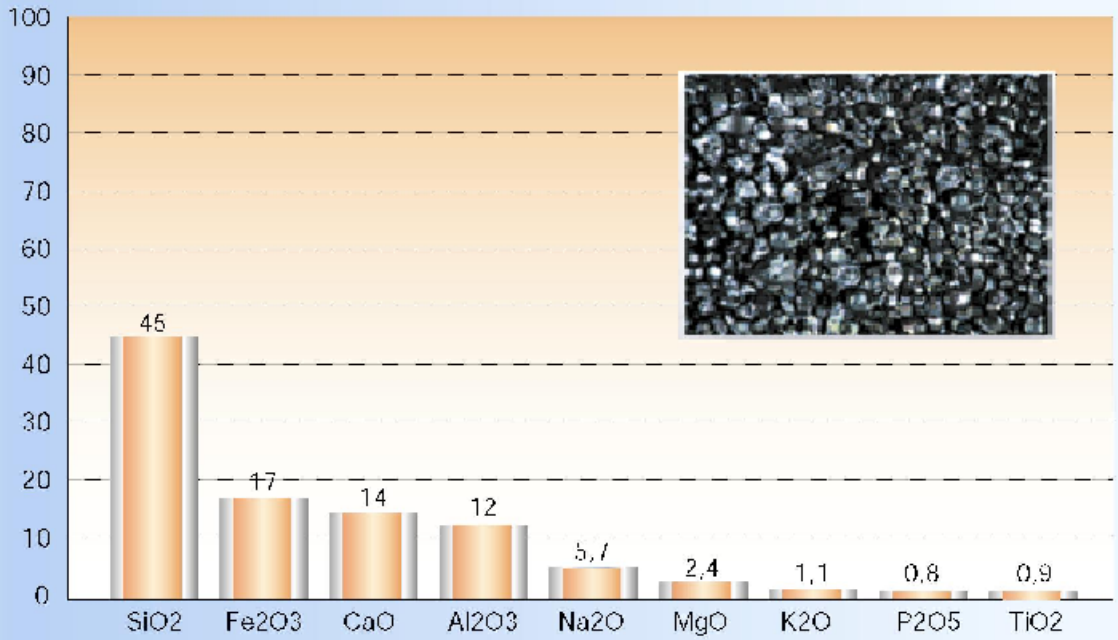
Metal and mineral granulate is ready for reuse.

The vitreous mineral granulate leachability complies with strictest regulations.

**Typical metal granulate (wt%)**



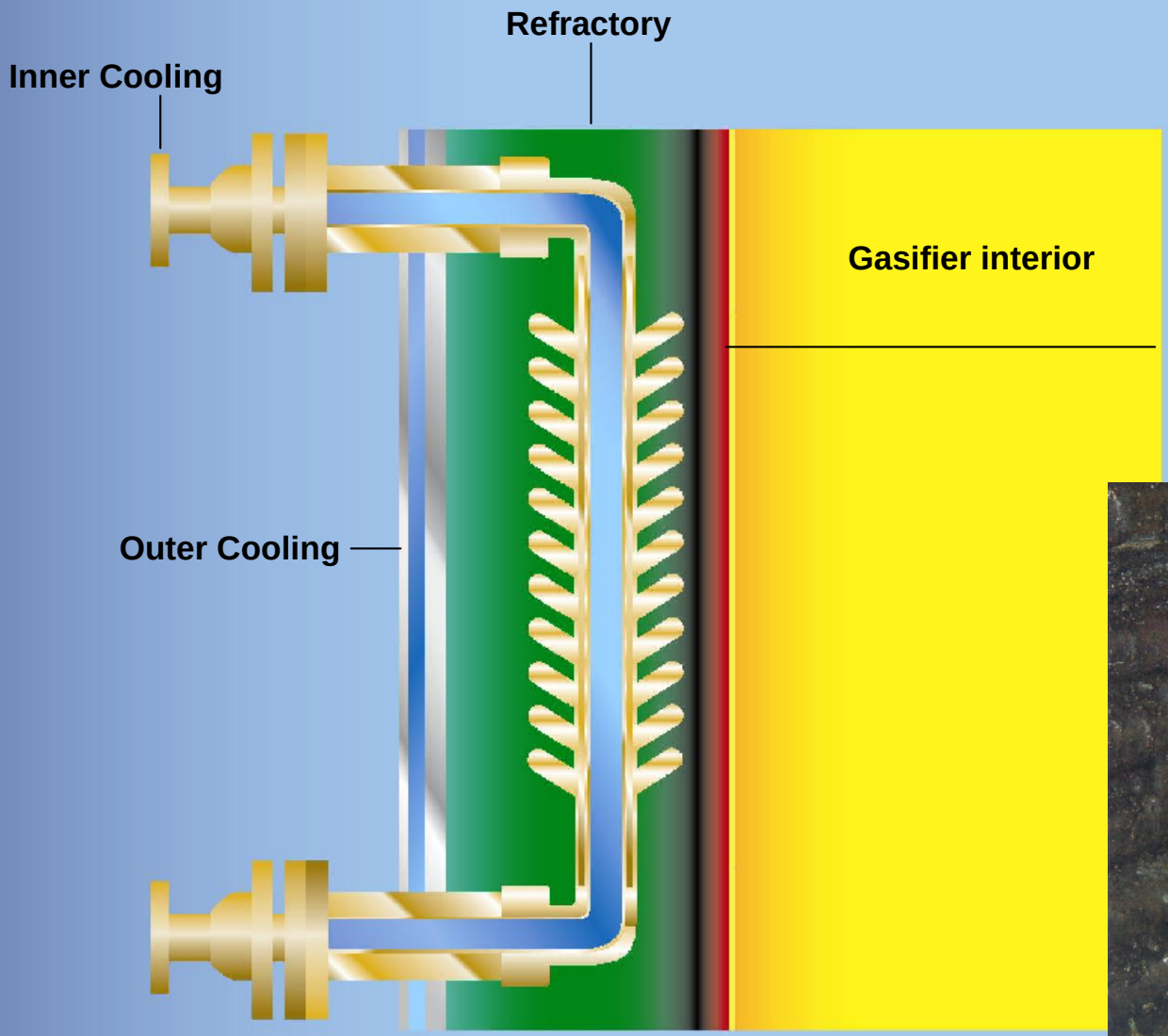

**Typical mineral granulate (wt%)**

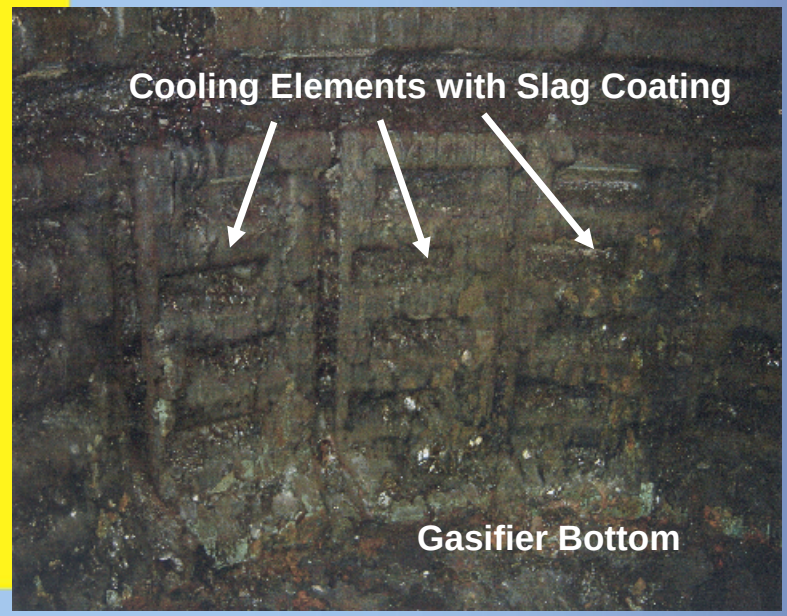


The reactor wall consists of a thermally-insulating refractory lining.

The highly stable refractory material is protected by a slag coating of vitrified mineral melt.

Liquid mineral melt runs off the slag coating.



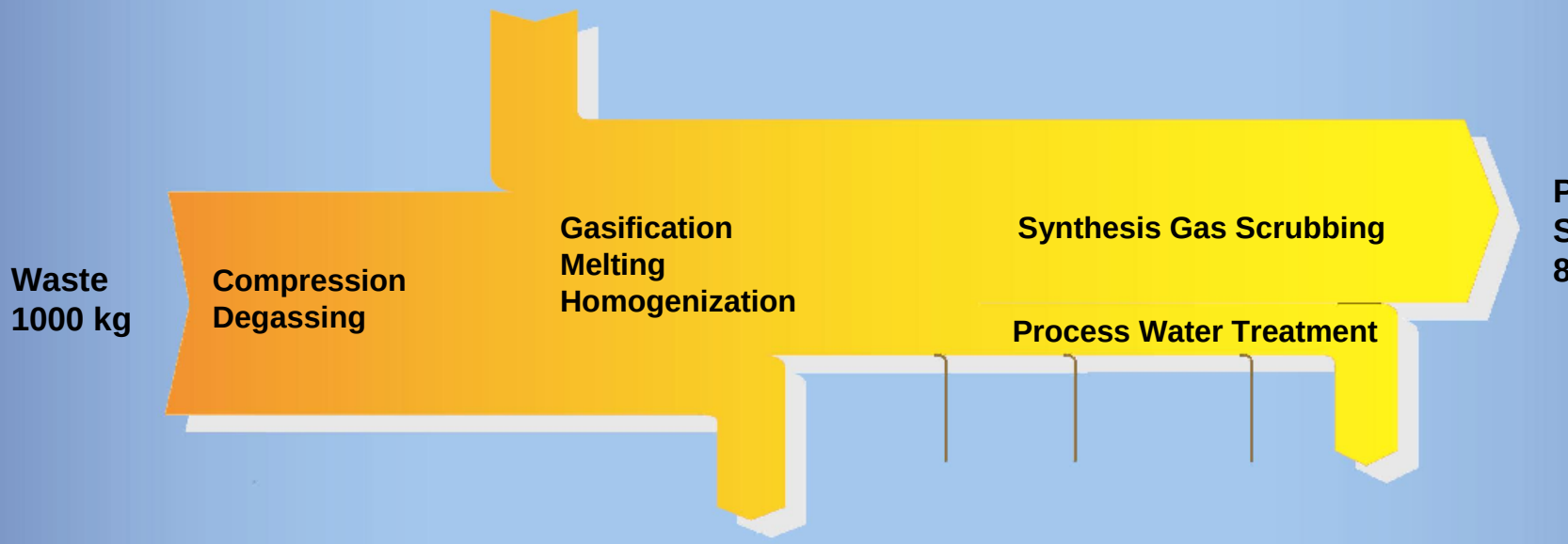



- ✓ **High Temperature Recycling (> 99.5% Material Recovery)**
- ✓ **Lowest Emissions (Dioxin Destroyer, Total << 1 µg/Mg)**
- ✓ **Synthesis gas for flexible utilisation (Power, Hydrogen ...) on site or over-fence**
- ✓ **Broad range of wastes can be processed, EC directive:**

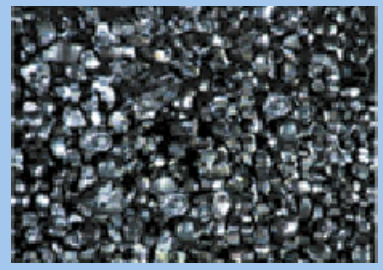
  **"If hazardous wastes with a content of more than 1% of halogenated organic substances, expressed as chlorine, are incinerated, the temperature has to be raised to 1'100 °C for at least two seconds"**

- ✓ **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)

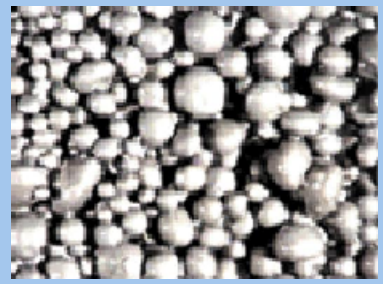


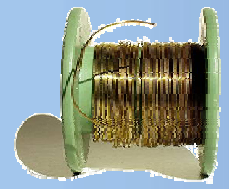
**Vitreous Mineral Granulate**
**approx. 20-25 % of Input**



**Concrete**
**Sand-Blasting**
**Road Construction**

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





**Metallurgy**

**Salt**
**approx. 1 % of Input**

**Chemical Industry, Additive for Metallurgy**

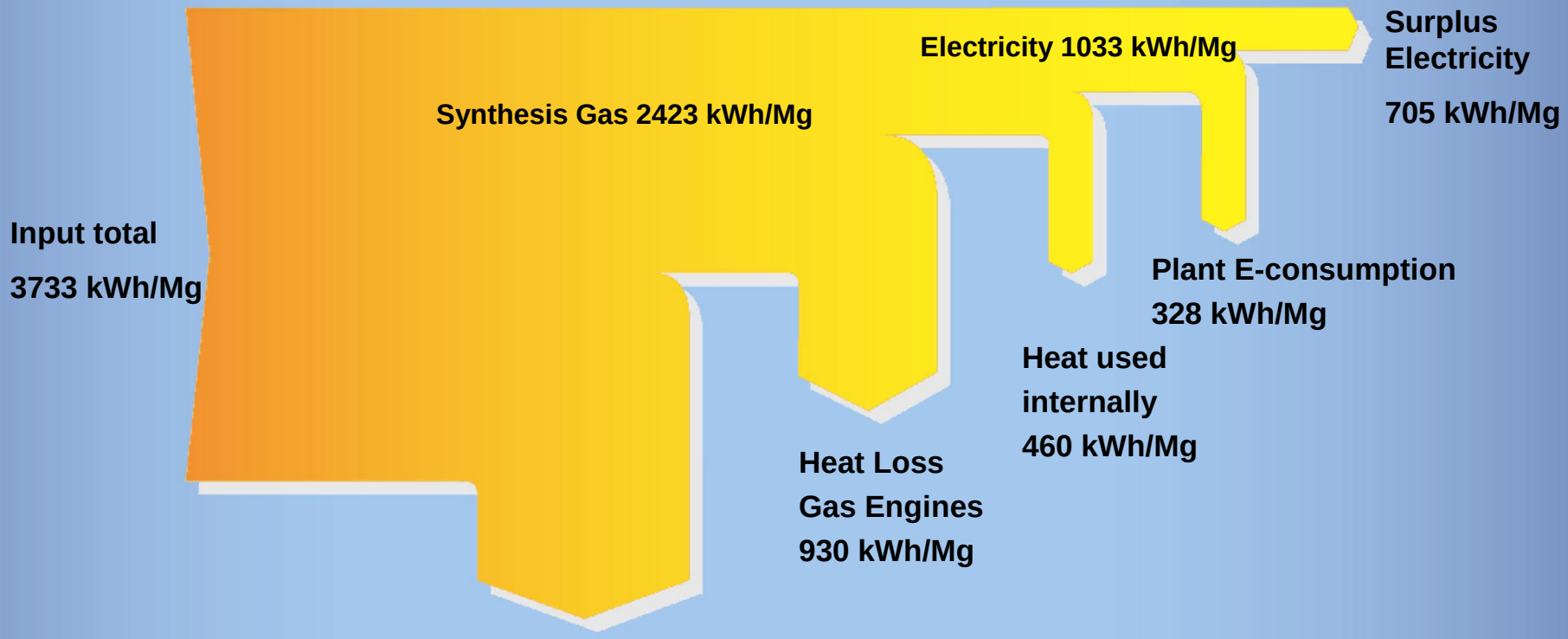
**Sulfur**
**approx. 0.2 - 0.3 % of Input**

**Chemical Industry,**
**i.e. Sulfuric Acid Production**

**Zinc-Concentrate**
**approx. 0.2 - 0.3 % of Input**

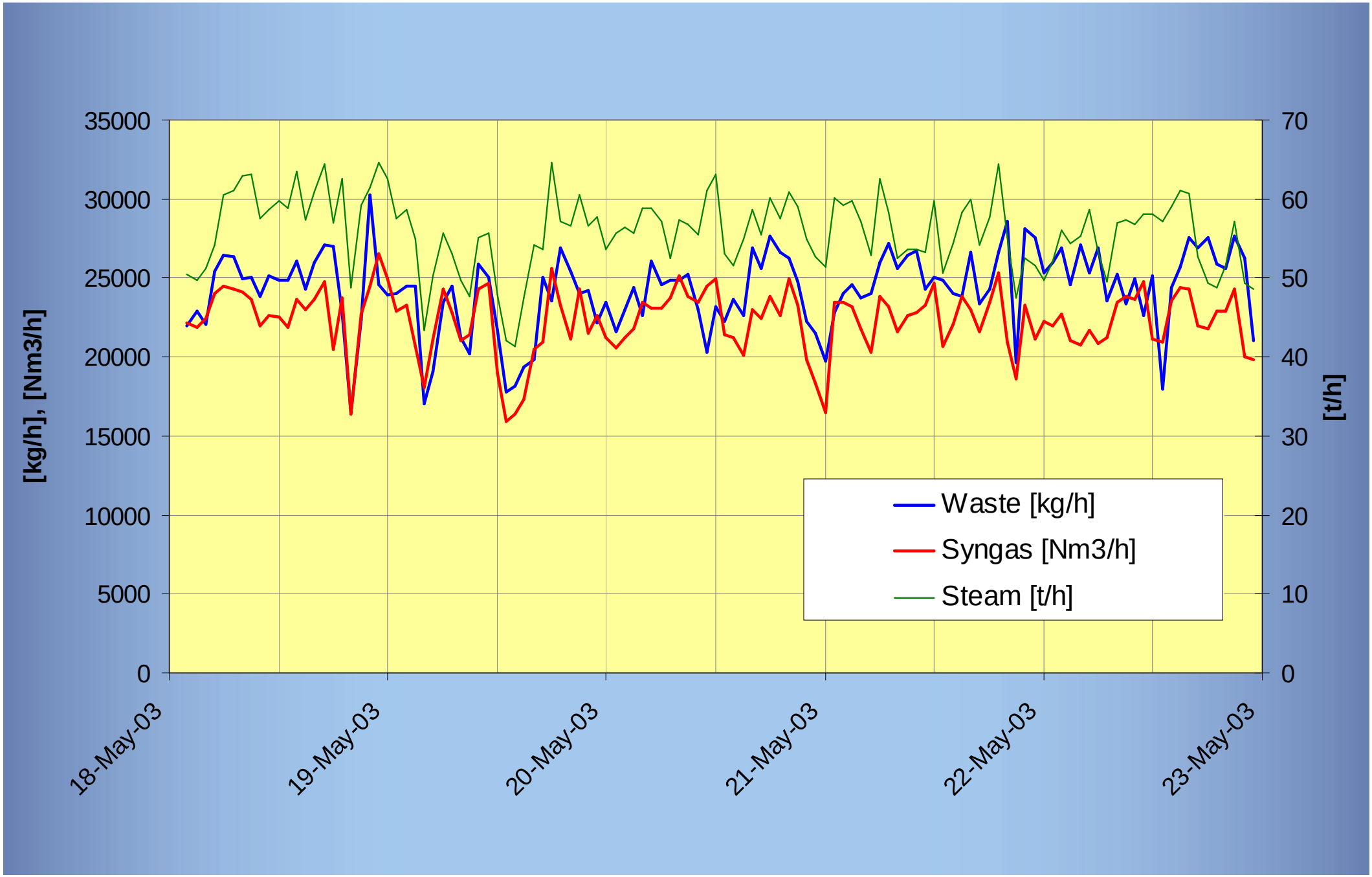
**Zinc-Recovery**

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



## 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** | |


35000
30000
25000
20000
15000
10000
5000
0
[kg/h], [Nm3/h]
70
60
50
40
30
20
10
0
[t/h]
18-May-03
19-May-03
20-May-03
21-May-03
22-May-03
23-May-03
Waste [kg/h]
Syngas [Nm3/h]
Steam [t/h]

| | Overall | Train 1 | Train 2 | Train 3 |
|---|---|---|---|---|
| Product not required | 1% | 1% | 1% | 1% |
| Planned Outages | 23% | 26% | 31% | 27% |
| Outage Power unit (part of planned outage) | 0% | 1% | 1% | 1% |
| Unplanned Outages | 0% | 7% | 7% | 7% |
| | | | | |
| Onstream | 76% | 66% | 62% | 65% |
| | | | | |
| Yearly Throughput (metric tons) | 100,100 | 35,009 | 30,691 | 34,400 |
| (mmscf) | 3,535 | 1,236 | 1,084 | 1,215 |
| | | | | |
| Forced Outage Rate | 0% | 9% | 10% | 10% |
| | | | | |
| Availability | 77% | 67% | 63% | 66% |
| | | | | |
| Rated Capacity (mmscf) | 9,308 | 3,103 | 3,103 | 3,103 |
| | | | | |
| Annual Loading Factor | 38% | 40% | 35% | 39% |

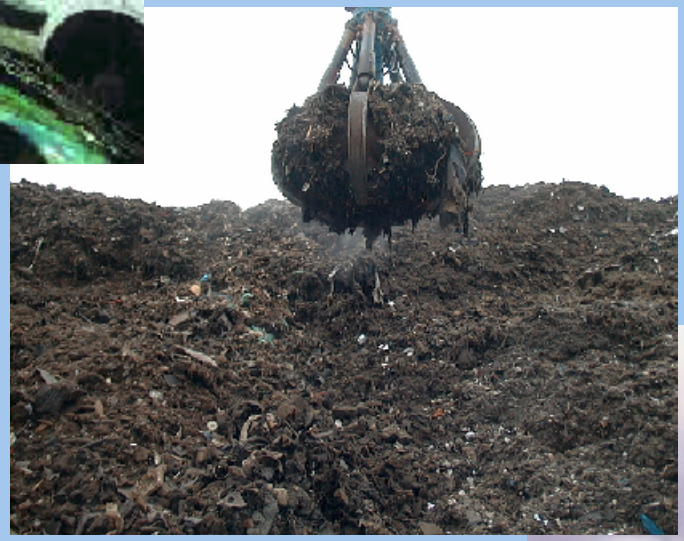
## Kawasaki Steel Chiba Plant - Japan


| | | |
|---|---|---|
| **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** | |

| | Overall | Train 1 | Train 2 |
|---|---|---|---|
| Product not required | 0% | 0% | 0% |
| Planned Outages | 6% | 6% | 9% |
| Unplanned Outages | 1% | 6% | 4% |
| | | | |
| Onstream | 94% | 88% | 88% |
| | | | |
| Yearly Throughput (metric tons | 75,552 | 37,563 | 37,989 |
| (mmscf) | 2,668 | 1,327 | 1,342 |
| | | | |
| Forced Outage Rate | 1% | 6% | 4% |
| | | | |
| Availability | 94% | 88% | 88% |
| | | | |
| Rated Capacity (mmscf) | 4,125 | 2,062 | 2,062 |
| | | | |
| Annual Loading Factor | 65% | 64% | 65% |

End-of-life vehicles

ASR / Shredder-dust



THERMOSELECT

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

- 2006 – 85%
- 2015 – 95%

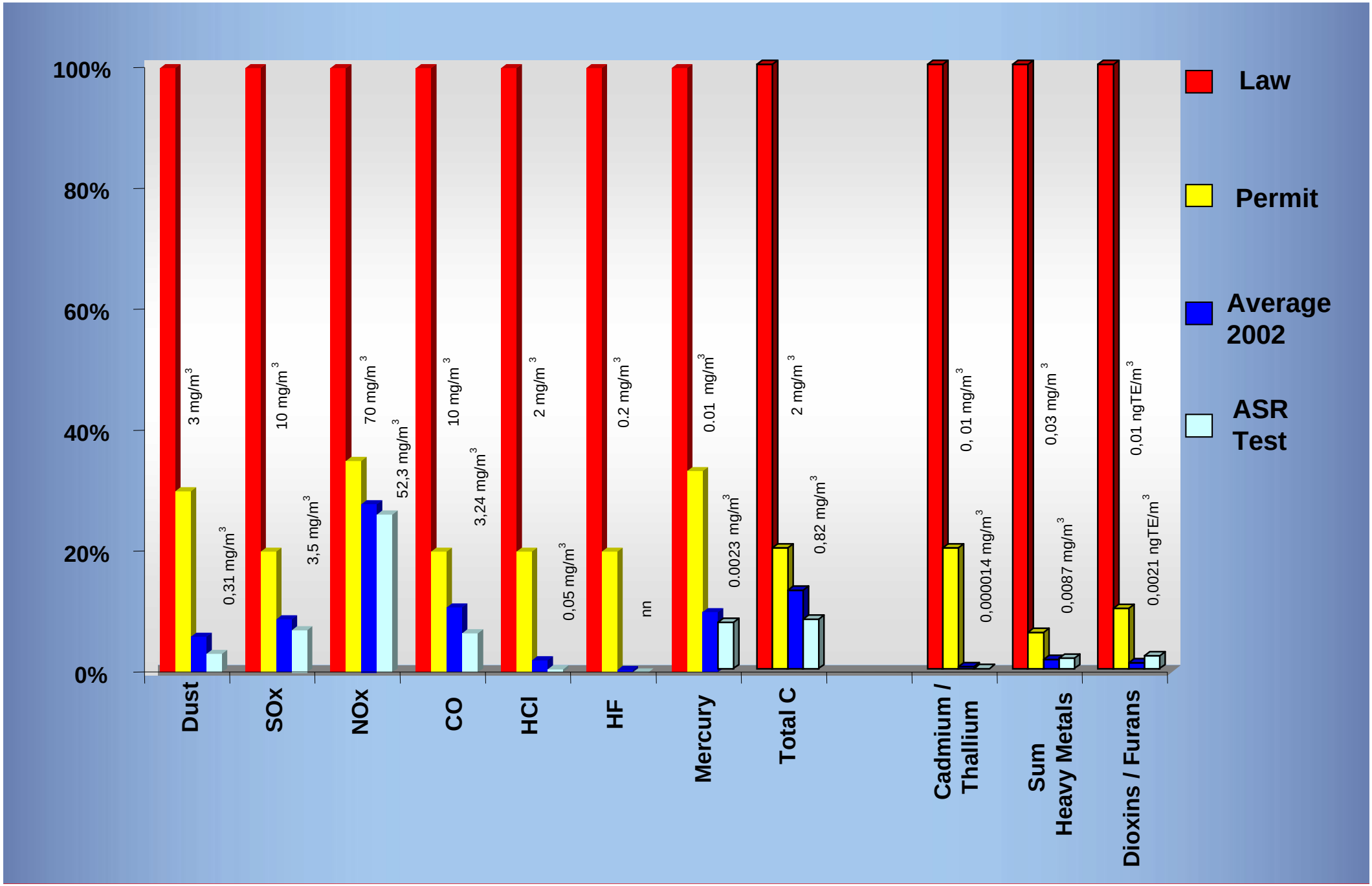
**Test Procedure:**

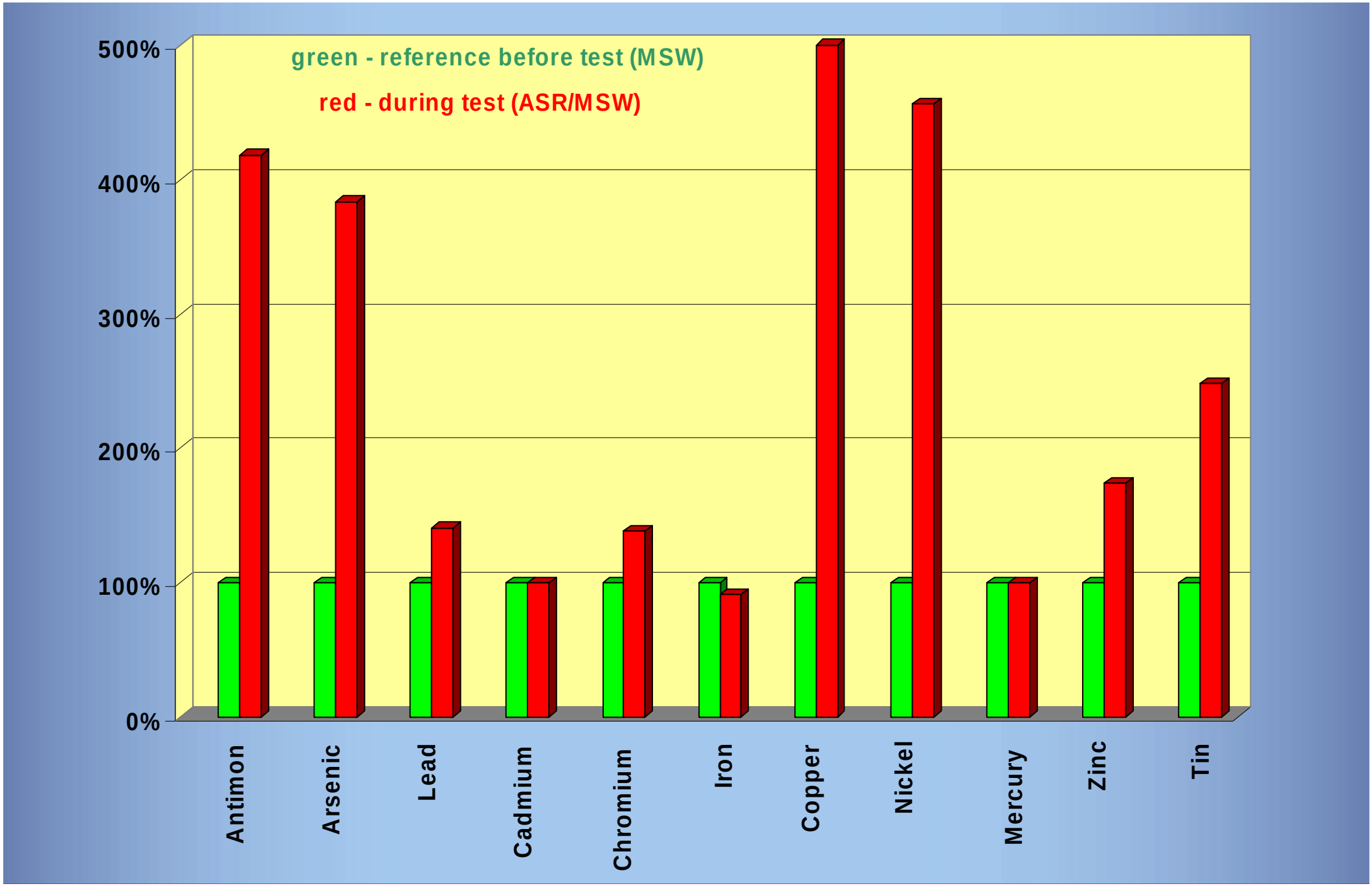
- Throughput: 428 t ASR
- Time period: 66 h, ca. 3 days from 27.-29. of November 2002
- Mixture: 40 - 55 Gew.-% ASR, mixed with MSW
- Throughput per line: approx. 7.8 t/h (up to 4.3 t/h ASR)

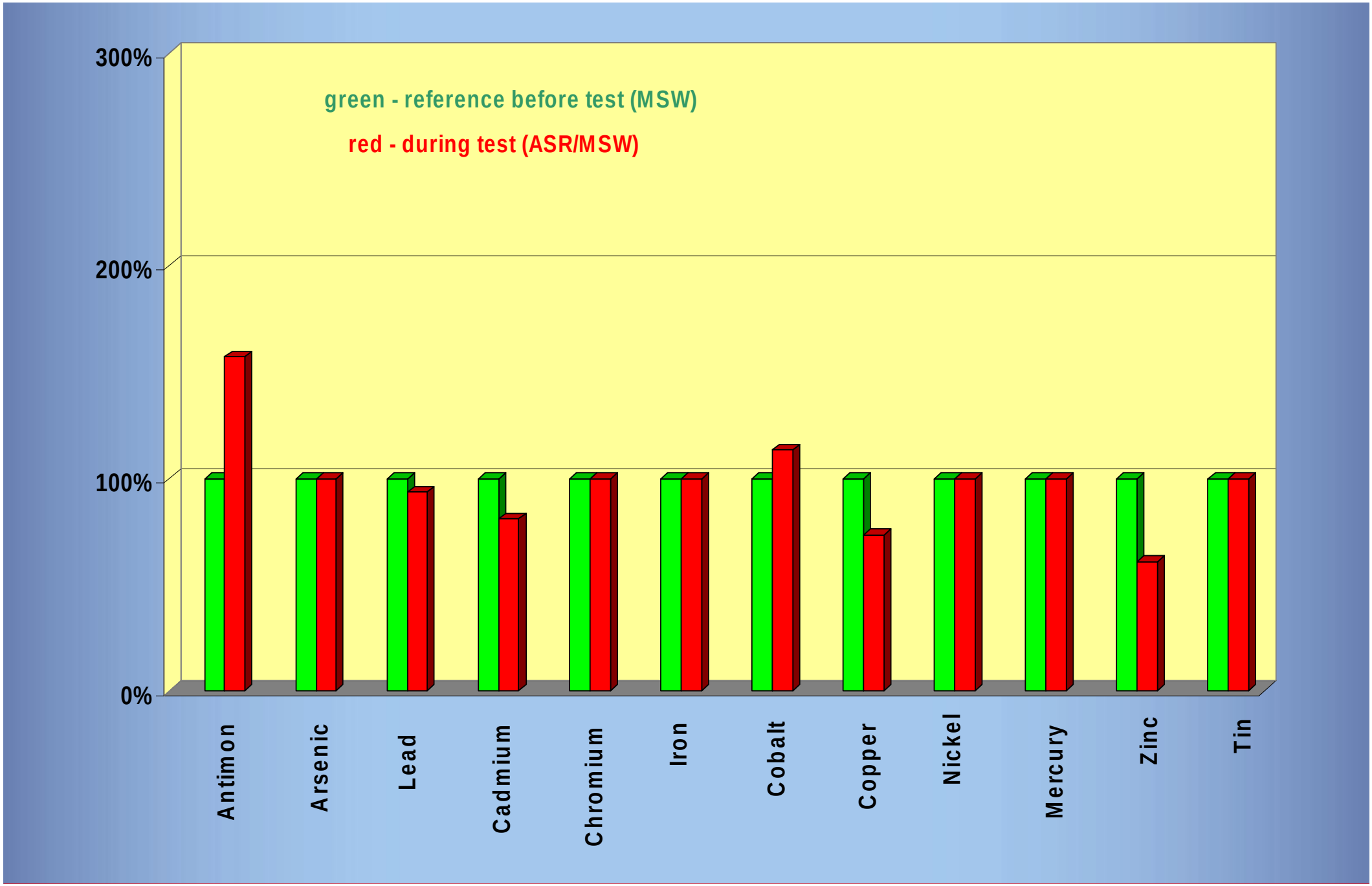
**Sampling /Analysis:**

- Air emissions
- Granulate
- Sulfur
- Zink concentrate
- mixed salt

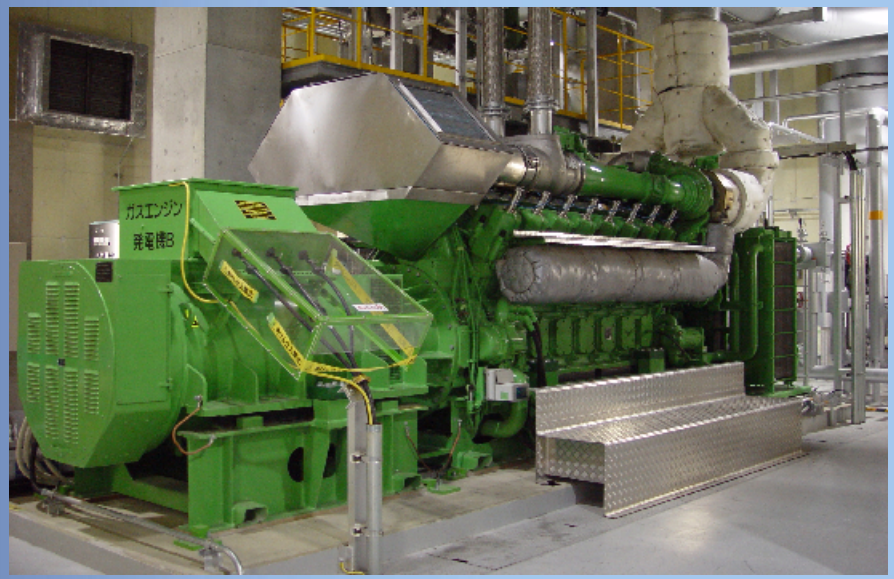
| Parameter | | MSW Literature | Trial operation 11/2002 Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|---|---|
| **Heating value, LCV** | kJ/kg | **7,000 - 10,000** | **16,940** | **10,280** | **11,350** | **14,920** |
| Ignition residue 550°C | weight-% | | 79.3 | 79.6 | 79.6 | 78.8 |
| Water | weight-% | 25 - 35 | 11.8 | 20.5 | 23.9 | 16.4 |
| Hydrocarbons | mg/kg DS | - | 10,500 | | | |
| **Iron** | weight-% DS | **2 - 5** | **12.0** | **10.7** | **26.6** | **13.36** |
| **Chloride** | weight-% DS | **0.1 - 1** | **1.8** | **1.72** | **3.18** | **3.52** |
| Fluoride | weight-% DS | 0.01 - 0.02 | 0.01 | 0.02 | 0.01 | 0.01 |
| Sulfur | weight-% DS | 0.05 - 0.5 | 0.2 | 0.3 | 0.2 | 0.2 |
| **Copper** | g/kg DS | **0.1 - 2** | **8.4** | **3.6** | **25.6** | **5.3** |
| **Zinc** | g/kg DS | **0.4 - 4** | **14.0** | **9.9** | **13.5** | **15.0** |
| Chromium | g/kg DS | 0.2 - 2 | 0.6 | 0.3 | 0.5 | 0.4 |
| Tin | g/kg DS | 0.05 - 0.5 | 0.03 | 0.003 | 0.01 | 0.05 |
| Barium | g/kg DS | 0.1 - 1 | 0.31 | 0.202 | 0.42 | 0.56 |
| **Lead** | g/kg DS | **0.2 - 2** | **4.4** | **2.7** | **2.4** | **4.7** |
| Antimon | mg/kg DS | o.A.** | 94 | 72 | 226 | 512 |
| Arsenic | mg/kg DS | 1 - 8 | 11.6 | 10.0 | 16.5 | 13.1 |
| Cadmium | mg/kg DS | 3 - 30 | 21.8 | 25.1 | 31.3 | 37.3 |
| Mercury | mg/kg DS | 0.3 - 10 | 2.1 | 4.1 | 2.6 | 1.6 |


100%
80%
60%
40%
20%
0%
Law
Permit
Average 2002
ASR Test
3 mg/m3
0,31 mg/m3
10 mg/m3
3,5 mg/m3
70 mg/m3
52,3 mg/m3
10 mg/m3
3,24 mg/m3
2 mg/m3
0,05 mg/m3
0.2 mg/m3
nn
0.01 mg/m3
0.0023 mg/m3
2 mg/m3
0,82 mg/m3
0, 01 mg/m3
0,000014 mg/m3
0,03 mg/m3
0,0087 mg/m3
0,01 ngTE/m3
0,0021 ngTE/m3
Dust
SOx
NOx
CO
HCl
HF
Mercury
Total C
Cadmium / Thallium
Sum Heavy Metals
Dioxins / Furans


green - reference before test (MSW)
red - during test (ASR/MSW)
500%
400%
300%
200%
100%
0%
Antimon
Arsenic
Lead
Cadmium
Chromium
Iron
Copper
Nickel
Mercury
Zinc
Tin


300%
200%
100%
0%
green - reference before test (MSW)
red - during test (ASR/MSW)
Antimon
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**