Sustainable Copper Smelting

Jukka Tuominen
Vice President – Smelting
Outotec
Outotec – a process technology company

- Outotec provides leading technologies and services for the sustainable use of Earth’s natural resources.

- As the global leader in minerals and metals processing technology, we have developed many breakthrough technologies over the decades for our customers in mining and metals industries.

- We also provide innovative solutions for industrial water treatment, the utilization of alternative energy sources and the chemical industry.

- Outotec shares are listed on NASDAQ Helsinki.
Local operations, global presence

Wide supplier network with established long-term relationships

Experts of over 60 nationalities

Deliveries to more than 80 countries

R&D, sales and service centers in 34 countries

Over 4,200 employees

Sales EUR 1,058 million in 2016

Services 42% of sales

Environmental goods and services 90% of orders

Listed on Nasdaq Helsinki since 2006

10/28/2017  Sustainable Outotec, Tehran, 2017
Strategic intent and focus in the value chain

The leading provider of sustainable minerals and metals processing solutions... ... and an innovative provider of sustainable energy and water processing solutions

<table>
<thead>
<tr>
<th>Leadership in sustainable technology</th>
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</thead>
<tbody>
<tr>
<td>Minerals processing for all ore types</td>
</tr>
<tr>
<td>Metals refining of all ore/concentrate types</td>
</tr>
<tr>
<td>Industrial water treatment</td>
</tr>
<tr>
<td>Energy</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Life-cycle services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable end-to-end solutions from feasibility studies to complete plants and life cycle services for virtually all ore types</td>
</tr>
<tr>
<td>Extensive range of sustainable process solutions for virtually all types of ores and concentrates and sulfuric acid, turn-key delivery and life-cycle services</td>
</tr>
<tr>
<td>Solutions to produce water that meets environmental discharge standards, maximize water recycling and reduce water and energy consumption</td>
</tr>
<tr>
<td>Innovative solutions for biomass, agricultural and municipal waste, and industrial byproducts; sludge incineration</td>
</tr>
</tbody>
</table>
A century of accumulated expertise

1910
Outokumpu Oy founded in Finland to benefit from the large copper deposit found in eastern Finland.

1940-1960
- Flash smelting process revolutionizes the world’s copper smelting and leads to the formation of a technology division.
- 1949: metallurgical research center established in Pori, Finland.
- 1954: technology sales begin when Japanese company Furukawa buys a flash smelting license.

1965
Department established for the licensing of technology and selling of knowledge for copper, zinc, nickel, and ferrochrome processing.

1975
Internationalization through establishment of sales offices in North and South America.

1980-2000
Growth through acquisitions:
- Rammer (hydraulic hammers)
- Roxon (belt conveyors)
- Candor (galvanizing)
- Asco Systems (aluminum smelter equipment)
- Supaflo (thickeners)
- Wennberg (cathode stripping machines)
- Indepco (engineers)
- Carpio and Inprosys (physical separation)
- Eberhard Hoesch & Söhne (filters)

2001
Merger of two major players:
- Outokumpu Technology acquires Lurgi Metallurgie.
- Other acquisitions:
  - Royal Pannevis (filters)
  - KHD Aluminium Technology (aluminum smelter technology)
  - Norberg Mills’ grinding technology

OUTOKUMPU

CONTINUED...

LURGI METALLURGIE

1881
Metallgesellschaft established for metal trading and activities expanded to mining and metallurgical plants.

1990
Lurgi Chemie, Metallurgie und Industrieaainlagenbau established, focusing on metallurgy, sulfuric acid plants, and general engineering.

1995
Lurgi Metallurgie focuses solely on metallurgy and sulfuric acid plants.
A century of accumulated expertise

2001
Merger of two major players
Outokumpu Technology acquires Lung Metallurgie
Other acquisitions:
- Royal Pannevis (filters)
- KDH Aluminium Technology (aluminium smelter technology)
- Nordberg Mills’ grinding technology

2003
Boliden Contech (engineering, precious metals technology) merges with Outokumpu Technology as part of industry restructuring

2004
Filter businesses (Ceramec, Hoesch, and Pannevis) sold to Larox

2006
More out of ore
Outokumpu Technology Oy listed on the Helsinki Stock Exchange and launched as an independent company; name changed to Outotec Oyj in 2007

2008
Acquisition:
- Auburn Group (maintenance and shutdown services)

2010
Sustainable use of Earth’s natural resources
Acquisitions:
- Larox (complementing the ore-to-metal value chain with filters)
- Millteam (grinding mill services)
- Ausmelt (smelting and recycling)
- Edmeaton (special steel structures for acid plants)

2011
Acquisitions:
- Klin Services Australia
- Energy Products of Idaho
- ASH DEC (phosphorus recycling business)
- Vertical Pressure Filter technology

2012
Acquisitions:
- Backfill Specialists [mine backfilling]
- TME Group [services]
- Demit Manutenção [services]
- Numcore [3D imaging]

2013
Acquisition:
- Scanalyse [measurement software]

2015
Acquisitions:
- Kempe Engineering
- Kovit Engineering [tailings management solutions]
- Biomin South Africa’s BIOX® bio-oxidation technology
- Sinter Plant Services
Global operating model

Outotec Customers

Market areas and customer centers

Minerals Processing
Metals, Energy & Water
Services

Executive Board and corporate functions

President and CEO
Minerals Processing

• Sustainable solutions from pre-feasibility studies to complete plants and life-cycle services
• Our comprehensive offering makes the efficient and profitable treatment of virtually all ore types possible
• With more than a century of experience, we have the established R&D resources to continuously develop sustainable technologies

Solutions for

<table>
<thead>
<tr>
<th>Concentrators</th>
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<tbody>
<tr>
<td>Comminution</td>
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<tr>
<td>Flotation</td>
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<tr>
<td>Dewatering</td>
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<tr>
<td>Automation</td>
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<tr>
<td>Services incl. operation &amp; maintenance</td>
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</table>
Metals, Energy & Water

• Solutions for processing virtually all types of ores and concentrates to refined metals, incl. sulfuric acid production
• Innovative waste-to-energy solutions for biomass, sludge, agricultural and industrial by-products as well as sorted waste
• Solutions for oil winning from oil shale and phosphorus recycling from sewage sludge ashes
• Our solutions produce water that meets environmental discharge standards, maximize water recycling and reduce water and energy consumption

**Solutions for**

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<table>
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<tbody>
<tr>
<td>Non-ferrous metals</td>
<td></td>
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<tr>
<td>Ferrous metals and ferroalloys</td>
<td></td>
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<tr>
<td>Light metals</td>
<td></td>
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<tr>
<td>Waste-to-energy solutions</td>
<td></td>
</tr>
<tr>
<td>Industrial water treatment</td>
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<td>Services incl. operation &amp; maintenance</td>
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Services

- Our services range from supplying an individual spare part to comprehensive solutions covering maintenance and operations.
- We focus on creating unique solutions to enhance the performance and productivity of our customers' plants and equipment.

Comprehensive service portfolio

- Advisory Services
- Maintenance Services
- Operations Services
- Remote Services
- Spare and Wear Parts
- Training Services
- Upgrades
Proven track record with thousands of references globally

**Equipment**

- 1,100 grinding mills
- 10,000 flotation units
- 1,800 thickeners
- 3,500 filters
- 60,000 coated titanium anodes
- 500 reactors
- 80 full deposit stripping machines

**Processes and plants**

- 130 non-ferrous smelters
- 650 sulfuric acid plants
- 45 solvent extraction plants
- 20 ferroalloys pelletizing and sintering plants and 9 smelters
- 400 iron ore sintering plants
- 67 iron ore pelletizing plants
- 290 fluidized bed roasting plants
- 50 alumina calcination plants
- 120 fluidized bed energy systems for biomass
- 10 bioleaching processes for refractory gold
Our commitment to sustainability

• Outotec has been included in the Global 100 Most Sustainable Corporations Index for 5 consecutive years (Corporate Knights).
• Sustainability is integrated into everything we do.
• 90% of order intake in 2014-2016 was classified as environmental goods and services (OECD criteria).
• We are committed to the principles of The United Nations Global Compact regarding human rights, environment, labor and anti-corruption.
• Our reporting is based on GRI G4 guidelines and third-party assured.
Sustainable Offering for Our Customers

- Resource-efficient solutions based on deep technological know-how
  - Keep the share of environmental goods and services (EGS under OECD definitions) in our order intake permanently above 90%
  - Reduce CO$_2$ emissions in metals processing
  - Improve water management of the mining industry
  - Achieve reduction in the use of fossil fuels through Outotec waste-to-energy solutions

- Mitigating negative impacts of the minerals and metals industry
Our environmental performance

- The bulk of Outotec’s operations involve engineering and business management in offices. The environmental impact of the office work is relatively small.
- New office premises fulfill LEED® Gold requirements.
- GHG emissions from air travel are the biggest single source of Outotec’s emissions.
- We monitor our impact on the environment and report energy consumption, emissions, materials used, waste and water consumption.

<table>
<thead>
<tr>
<th>GHG emissions, tonnes CO₂-e</th>
<th>2016</th>
<th>2015</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outotec’s own emissions/1 M€ sales</td>
<td>24.7</td>
<td>28.2</td>
<td>24.8</td>
</tr>
<tr>
<td>Our supply chain’s emissions</td>
<td>360,000</td>
<td>345,000</td>
<td>386,000</td>
</tr>
<tr>
<td>Emissions avoided through use of 7 Outotec technologies</td>
<td>5,870,000</td>
<td>5,469,000</td>
<td>5,067,000</td>
</tr>
</tbody>
</table>
Outotec’s Copper Smelting Solutions
Copper Value Chain

• Outotec is a leading technology provider in:
  • Ore grinding
  • Flotation
  • Concentrate smelting and converting
  • Anode casting
  • Solvent extraction
  • Electrowinning and Electrorefining
Proven track record with thousands of references globally

- Half of the world’s pyrometallurgical primary copper is produced with Outotec® Flash Smelting
- One third of the world’s hydrometallurgical copper is produced with Outotec® SX-EW
- Over a third of the world’s sulfuric acid capacity runs on Outotec technology
Outotec Copper Smelters
Outotec Flash Smelting
Different types of copper flash furnaces

**Flash Smelting Furnace (FSF)**
- Regular copper concentrate is smelted to produce copper matte
- Typical oxygen coefficient 160 Nm³/t
- Most common copper production method in the world
- Concentrate (~20-35% Cu)

**Flash Converting Furnace (FCF)**
- Ground copper matte is re-smelted (converted) to produce blister copper
- Typical oxygen coefficient 200 Nm³/t
- At the moment there are four plants in operation
- Matte (~60-70% Cu)

**Direct Blister Furnace (DBF)**
- High grade copper concentrate is directly smelted to blister copper without a separate converting phase
- Typical oxygen coefficient 240 Nm³/t
- At the moment three plants in operation
- Concentrate (~30-60% Cu)

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Outotec Has Delivered 54 New Flash Installations and Hundreds of Modernizations

Cumulative # of New Flash Furnaces Commissioned
<table>
<thead>
<tr>
<th>Client</th>
<th>Scope</th>
<th>Start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMMC Svyatogor, Russia</td>
<td>Ausmelt smelting technology, lance system, launders, electric slag cleaning furnace</td>
<td>(2018)</td>
</tr>
<tr>
<td>NICICO Khatoonabad, Iran</td>
<td>Steam drier, complete flash furnace</td>
<td>(2018)</td>
</tr>
<tr>
<td>Nyrstar Australia</td>
<td>Ausmelt furnace, lance system, laundering system</td>
<td>(Nov 2017)</td>
</tr>
<tr>
<td>NICICO Sarcheshmeh, Iran</td>
<td>Complete new flash furnace with feeding system, concentrate burner, cooling system, structures and refractory lining</td>
<td>Sep 2017</td>
</tr>
<tr>
<td>Boliden Harjavalta</td>
<td>Flash furnace cooling system and feeding system</td>
<td>Jun 2017</td>
</tr>
<tr>
<td>Birla Copper, India</td>
<td>Flash furnace cooling system</td>
<td>Nov. 2016</td>
</tr>
<tr>
<td>KGHM, Glogow 1, Poland</td>
<td>Flash furnace concentrate burner, feeding system</td>
<td>Oct. 2016</td>
</tr>
<tr>
<td>ETI Bakir, Turkey</td>
<td>Flash furnace cooling system, concentrate burner, feeding system, PS converters with hoods and punching machines, Anode casting shop</td>
<td>Sep. 2016</td>
</tr>
<tr>
<td>Codelco Chuqui, Chile</td>
<td>Converter hoods</td>
<td>Jul 2016</td>
</tr>
<tr>
<td>Aurubis Bulgaria</td>
<td>Flash furnace cooling system</td>
<td>Jun. 2016</td>
</tr>
<tr>
<td>Norilsk Nickel, Russia</td>
<td>Complete flash furnace with feeding system, concentrate burner, cooling system, structures and refractory lining</td>
<td>Dec. 2015</td>
</tr>
<tr>
<td>BCL, Botswana</td>
<td>Flash furnace cooling system</td>
<td>Aug. 2015</td>
</tr>
<tr>
<td>PASAR, Philippines</td>
<td>Flash furnace control system, concentrate burner, feeding system, Anode casting shop</td>
<td>Jul. 2015</td>
</tr>
<tr>
<td>RTB-Bor, Serbia</td>
<td>Complete flash smelting line installed (EPC)</td>
<td>Mar. 2015</td>
</tr>
</tbody>
</table>
Future Development in Smelting
Development Trends in Smelting

• Shift to Flash Smelting and other autogenous processes
A Shift to Autogenous Smelting Processes

(1000 t p.a. of copper concentrate)

Source: Wood-Mackenzie

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Development Trends in Smelting

- Shift to Flash Smelting and other autogenous processes
- Decrease in environmental emissions
SO$_2$ emissions in 1995 – 2015 from major primary copper smelters

Source. Brook Hunt data base
Development Trends in Smelting

• Shift to Flash Smelting and other autogenous processes
• Decrease in environmental emissions
• Continuous increase in unit size (economy-of-scale)
Capacities Are Getting Bigger and Bigger
Development Trends in Smelting

- Shift to Flash Smelting and other autogenous processes
- Decrease in environmental emissions
- Continuous increase in unit size (economy-of-scale)
- Furnace campaign lives of 10+ years
Maximizing Furnace Campaign Life

- Completely water-cooled furnaces reaching campaign lives of over 10 years
Development Trends in Smelting

- Shift to Flash Smelting and other autogenous processes
- Decrease in environmental emissions
- Continuous increase in unit size (economy-of-scale)
- Furnace campaign lives of 10+ years
- Automation and digitalization
Intelligent Furnace Monitoring – Outotec Sentinel

1. Date and time
2. Notification banner
3. Help
4. Settings
5. Tools
6. Past notifications
7. Variable selection
8. Variable data
9. Align view buttons
10. Arrow buttons
11. Zoom control
12. Furnace model
13. Trend panel
Outotec Direct-to Blister Smelting
– and Flash Converting
Brief History of Flash Converting

- Outotec has developed Direct Blister Flash Smelting since the late 1960’s with the first commercial installation in 1978.

- Joint development of Flash Converting by Kennecott Utah Copper Co. and Outotec since 1983.

- Four Flash Converting Furnaces in operation:
  - Kennecott Utah Copper
  - Yanggu Xiangguang
  - Tongling
  - Jinchuan Fangchenggang

- Also four DB Furnaces in operation
  - KGHM Glogow 2
  - BHP Billiton Olympic Dam
  - Konkola Copper Mines
  - KGHM Glogow 1
Development of Flash Furnace Blister Output
(1000’s tons)
Outotec Flash Technology Benefits

- Lowest emissions
  => best in environmental performance
- Best in energy efficiency
- Lowest overall investment cost
- Largest capacity range
- Longest furnace campaign life
- Highest on-line availability
- Able to treat even the most complex and impure raw materials.
- The most proven and most reliable copper smelting technology
Outotec is not only about Flash Smelting Technology
Outotec Ausmelt TSL
Outotec Ausmelt Technology – unparalleled in versatility
Kaldo for the Most Challenging Feeds

- Kaldo top blown rotary converter is the smelting technology of choice for the most challenging feed materials.
- Kaldo is the most proven smelting technology for electronic scrap.
- Kaldo is the most widely used technology for smelting anode slimes.
Peirce-Smith Converting
Peirce-Smith Converter Hoods

The converter aisle does not have to look like this.
Peirce-Smith Converter Hoods

Modern, well-designed hoods make a world of difference.
Copper Recovery from Slags

Electric Furnaces for slag cleaning

Slag Concentrators for slag cleaning
Outotec Anode Casting

Control room with automation systems
Easy operation, smooth and logical controls
Complete Outotec Modernization Solutions

Outotec’s extensive expertise and excellent track record in smelting technology combined with Outotec’s Shut-down Services guarantees the best outcome for a smelter modernization.