Mettop GmbH

Summary of the ILTEC Technology
Introducing Mettop

Mettop GmbH, founded in 2005 by Dr. Iris & Dr. Andreas Filzwieser, is an independent Austrian engineering company, specialised in the design, optimisation, and engineering of technologies for metallurgical processes.

It is active in the field of pyro- as well as hydrometallurgy of non-ferrous metals and recently also started with innovative cooling systems for the iron and steel industry. With it´s headquarter in Leoben, Austria but customers all over the world, Mettop is a global player for creating new pathways for the entire metallurgical industry.
Key to Mettop’s position as an expert partner is the open-minded, creative spirit of our team. We develop innovations in cooperation with renowned institutes and universities and especially with YOU! This interaction with third parties constantly provides new dynamics and fresh inspiration.
Mettop at a Glance
Meet customers’ problems – tailor-made process optimization

Tankhouse Engineering
- METTOP-BRX Technology
- Basic Engineering
- Detail Engineering
- Feasibility Studies
- Consulting decreasing OPEX
- Consulting increasing Current Efficiency

Furnace Integrity
- Process Modelling
- CFD Simulation
- Gas Purging Systems
- 3D Refractory Engineering

Cooling Technology
- Cooling Solutions
- ILTEC Technology
- Feasibility Studies
Furnace Cooling
Special cooler design for optimized cooling performance
Why Cooling?
Advantages of an optimized cooling solution

• Cooling of refractory is inevitable for smelting operations to **intensify their performance**

• Better cooling of the refractory leads to a more **steep temperature gradient** within the lining

• Steeper temperature gradient means **less area** for possible **infiltration** of liquid slag or metal

• Less infiltration leads to **better wear performance** of the refractory material

• Better performance of refractory leads to increase in lifetime, increase in campaign lifetime and to a **more cost saving and economical production**
Different Cooling Solutions

Standard coolers

**Stave Coolers**

Copper cooler (stave) for a blast furnace shaft cooling solution.

**Plate Coolers**

Different solutions for side wall cooling of an electric arc furnace
- Plate coolers at the outer wall, behind the brickwork
- Plate coolers in between the layers of the brick-lining for an even better cooling performance
- Different copper cooling panels
Different Cooling Solutions
Variety of different approaches to cooling

**Plate Coolers**
Copper plates cooled with water, positioned between the bricks or at the back side of the brick lining.

**Waffle Type Coolers**
Refractory filled and dovetailed grooves on the element hot face and copper fins inbetween.

**CFM Coolers**
Casted copper fingers combined with castable refractory.

Source: M.W. Kennedy, J. Nos, M. Bratt and M. Weaver: Alternative coolants and cooling system designs for safer furnace lined furnace operation.
Composite Furnace Module CFM

CFM – best example for high intensity cooling

- Optimum compound of copper cooling element and refractory material
- Effective and adjustable cooling
- Homogeneous hot face temperature
- Steep temperature gradient
- Accretion layer/freeze lining concept (self protective lining)
- Extended refractory lifetime and furnace campaigns – no consumption of refractory
Freeze Lining Concept

Principal mechanism of the self-protective accretion layer

- Removed amount of heat is high enough to create a frozen slag/metal layer upon the castable refractory.
- Once a slag/metal layer is formed there is no further consumption of the refractory material.
- Equilibrium between melting of the frozen layer and freezing of a new layer.
- Steeper temperature gradient caused by cooled copper cooler means less area for possible infiltration of liquid slag or metal.
Removed Heat and Limitations

Heat transfer limitation

- Limiting factor is neither heat transfer coefficient between copper and cooling medium nor the thermal conductivity of the cooling medium.

- The limiting factors for the heat transfer are the thermal conductivity of the accretion layer and the refractory as well as the heat transfer coefficient between accretion layer and refractory (marked red in the picture).
CFM - Examples of Use
Composite Furnace Module Cooling

Anode Furnace – Off gas junction

Electric Arc Furnace – Off gas opening

Tilting Furnace – Charging mouth
Cooling Technology
Revolutionary new: Ionic Liquid Cooling Technology (ILTEC)
ILTEC Technology
Why rethink cooling solutions?

Fatal accidents caused by water coming into contact with liquid metal happen every year. Water + liquid metal = 1700 times volume expansion plus potential oxyhydrogen reaction.
Some conventional water-cooled areas in metallurgical vessels show potentials for explosions with dramatic consequences for the equipment as well as for the safety and health of the personnel. SMS group offers an innovative non-explosive cooling liquid – the ionic liquid IL-B2001. The ILTEC (ionic liquid cooling technology) eliminates these risks and improves the plant safety significantly. It also prolongs the vessel lifetime in specific zones and allows a complete new view on the principals of metallurgical processes. The technology is fully proven and already applied in references for the iron, steel and non-ferrous industry.

Non-explosive ILTEC – makes you sleep better
Water as a danger

Severe danger from water in iron and steel industry

<table>
<thead>
<tr>
<th>YEAR</th>
<th>COUNTRY</th>
<th>FACILITY</th>
<th>INJURIES</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Germany</td>
<td>Steel mill</td>
<td>7 injured</td>
<td>EAF explosion caused by water leak from sidewall cooling system</td>
</tr>
<tr>
<td>1995</td>
<td>Germany</td>
<td>Steel mill</td>
<td>1 killed, 1 seriously injured</td>
<td>EAF explosion caused by water leak in cooling system</td>
</tr>
<tr>
<td>2003</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>2 seriously injured</td>
<td>Half-ton EAF explosion caused severe burns</td>
</tr>
<tr>
<td>2004</td>
<td>U.S.</td>
<td>Construction prod.</td>
<td>1 hospitalized injury</td>
<td>Explosion occurred as technician was trying to stop EAF water leak</td>
</tr>
<tr>
<td>2004</td>
<td>U.S.</td>
<td>Smelting plant</td>
<td>1 killed</td>
<td>Worker burned by 3000 F steam when EAF exploded</td>
</tr>
<tr>
<td>2007</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>1 killed, 2 injured</td>
<td>Stray electrical arc created an internal leak on a water-cooled shell panel</td>
</tr>
<tr>
<td>2008</td>
<td>Germany</td>
<td>Steel mill</td>
<td>none</td>
<td>Water leak in the EAF caused six-figure damage but no injuries</td>
</tr>
<tr>
<td>2010</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>1 killed, 4 injured</td>
<td>Leak in EAF caused water to mix with molten slag</td>
</tr>
<tr>
<td>2010</td>
<td>U.S.</td>
<td>Steel pipe mfg</td>
<td>1 killed, 2 injured</td>
<td>Workers exposed to 2000 F molten metal and steam in EAF explosion</td>
</tr>
<tr>
<td>2011</td>
<td>U.S.</td>
<td>Carbide mfg</td>
<td>2 killed, 2 injured</td>
<td>Water leak in EAF caused over-pressure event ejecting 3800 F furnace contents</td>
</tr>
<tr>
<td>2011</td>
<td>Australia</td>
<td>Steel mill</td>
<td>4 injured, 1 seriously</td>
<td>Water accidentally entered EAF as workers were removing partly melted scrap</td>
</tr>
<tr>
<td>2012</td>
<td>Canada</td>
<td>Steel mill</td>
<td>1 injured</td>
<td>Injury occurred from a small steam explosion in the melt shop EAF</td>
</tr>
<tr>
<td>2012</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>2 injured</td>
<td>EAF steam explosion injured two workers</td>
</tr>
<tr>
<td>2013</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>1 killed</td>
<td>EAF explosion fatally injured one worker</td>
</tr>
<tr>
<td>2013</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>3 injured, 2 critically</td>
<td>Water leak into 3000 F EAF caused severe explosion</td>
</tr>
<tr>
<td>2013</td>
<td>Mexico</td>
<td>Steel mill</td>
<td>4 killed, 10 injured</td>
<td>Explosion occurred during routine maintenance at DRI intake of EAF</td>
</tr>
<tr>
<td>2014</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>2 killed, 17 injured</td>
<td>Deaths and injuries resulted from violent EAF explosion</td>
</tr>
<tr>
<td>2014</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>1 killed, 5 injured</td>
<td>Leak caused 1000 gallons of water to pour into EAF, creating a hydrogen explosion</td>
</tr>
<tr>
<td>2014</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>1 killed</td>
<td>Pipe exploded in a BOF furnace, fatally injuring one worker</td>
</tr>
<tr>
<td>2016</td>
<td>U.S.</td>
<td>Steel mill</td>
<td>2 injured</td>
<td>Reaction in a 175-ton EAF triggered an explosion. Cause is under investigation.</td>
</tr>
</tbody>
</table>

Quelle:
- Electric Arc Furnace (EAF) Explosions: A Deadly but Preventable Problem By Scott Ferguson and Nick Zsamboky, Systems Spray-Cooled™
Weshalb das Überdenken von Kühllösungen wichtig ist?

Source: Harmen Oterdoom, FURNACE EXPLOSIONS WITH A FOCUS ON WATER
Ionic Liquid IL-B2001

- Almost no vapour pressure below decomposition temperature
- Not flammable below decomposition temperature
- Non toxic
- Non corrosive
## Ionic Liquid IL-B2001

### Characteristic properties

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation temperature</td>
<td>50-200</td>
<td>°C</td>
<td>ΔT = 150 °C</td>
</tr>
<tr>
<td>Short term stability</td>
<td>250</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Decomposition temperature</td>
<td>450</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Minimum operation temperature</td>
<td>-10</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Crystallization temperature</td>
<td>-30 – -40</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>ρ</td>
<td>1.25 – 1.14</td>
<td>kg/dm³</td>
</tr>
<tr>
<td>Specific heat capacity</td>
<td>c_p</td>
<td>1.38 – 1.70</td>
<td>J/gK</td>
</tr>
<tr>
<td>Dynamic viscosity</td>
<td>η</td>
<td>20 – 5</td>
<td>mPa·s</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>κ</td>
<td>30 – 130</td>
<td>mS/cm</td>
</tr>
</tbody>
</table>

\[
Q \ [W] = \dot{m} \ [m/s] \cdot c_p \ [J/gK] \cdot \Delta T \ [K]
\]

Lower specific heat capacity can be compensated due to a higher temperature range and enables a heat transfer comparable to water \((c_p = 4.19 \ [J/gK])\).
Ionic Liquid IL-B2001

Optimized properties – intensive research activities

- **Non-corrosive** because of chlorine free chemical composition and production procedure – production route patented by proionic

- Absolutely **no explosive reaction** at contact with liquid metal – tests carried out at University of Leoben, Montanwerke Brixlegg AG and Böhler Edelstahl GmbH

- **Sufficient cooling** due to sufficient heat removal – heat transfer and heat capacity of IL-B2001 are not limiting factors; proven at FH Wels and at our reference plants

- **No harmful decompositions products** in case of decomposition – tested at proionic and at University of Leoben

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Range</th>
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<td>Operation temperature</td>
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<td>ºC</td>
<td>ΔT = 150 ºC</td>
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<tr>
<td>Short term stability</td>
<td>250</td>
<td>ºC</td>
<td></td>
</tr>
<tr>
<td>Decomposition temperature</td>
<td>450</td>
<td>ºC</td>
<td></td>
</tr>
<tr>
<td>Crystallization temperature</td>
<td>&lt; -15</td>
<td>ºC</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>ρ</td>
<td>1.25 – 1.14</td>
<td>[kg/dm³]</td>
</tr>
<tr>
<td>Specific heat capacity</td>
<td>c₂</td>
<td>1.38 – 1.70</td>
<td>[J/gK]</td>
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<tr>
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<td>η</td>
<td>20 – 5</td>
<td>[mPa-s]</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>κ</td>
<td>30 – 130</td>
<td>[mS/cm]</td>
</tr>
</tbody>
</table>

Registration number (REACH) 01-2120086816-43-0000
Ionic Liquid IL-B2001

Optimized safety

Industrial scale tests with IL-B2001 introduced into liquid steel melt

No reaction when liquid steel melt gets in contact with IL-B2001

Improved safety standards
ILTEC Technology
Possible applications of ILTEC-Technology with IL-B2001

**Substitution of water in existing systems**
Blast furnace taphole, formerly cooled with water

**New cooling applications**
Tuyere zone of Peirce Smith Converter or EAF shell - no cooling so far because of danger

**Possibility of heat recovery**
Sufficient heat transfer and higher outlet temperature of up to 200 °C enable heat recovery
ILTEC Technology
Re-defining the term safety and becoming **Best Available Technology (BAT)**

- Accidents happen from time to time
- When exchanging water by IL-B2001 -> **explosion free** environment that allows cooling in a safe and sound manner
- Probability remains at the same level BUT the extent of consequences can be tremendously shifted towards a decreased impact
- The diagram shows the path of becoming **best available technology**
Main components:

- **Tank** filled with IL-B2001, the freeboard volume above the liquid level is purged with nitrogen to prevent hydration of the liquid through moisture in the air
- Two identical **pumps** (one for redundancy in case of breakage or malfunction) guarantee the flow of the IL through the entire pipe system
- Two **heat exchangers** to remove the heat to the secondary cooling circuit, again one in operation, one for redundancy
- Numerous **measuring devices** (digital as well as analogue) throughout the entire system to measure temperature, flow, pressure and differential pressure
- Variety of **valves**, adjusting **wheels** and shut-off devices for all different operation modes
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Hardware at WECO
ILTEC Technology
Scope of Service by Mettop

Basic and detailed Engineering

Manufacturing and Assembly of ILTEC including IL-B2001

Installation and Start up on Site
ILTEC Technology – PI-Diagram

Example of a facility with 4 individual supply lines
Ionic Liquid IL-B2001
Heat transfer and cooling efficiency

Lab scale tests with IL-B2001: re-melting (ESR) of steel:

Simulation of cooling efficiency of IL-B2001 in use at a BF taphole

Sufficient cooling efficiency both during standard operation and tapping
Corrosion resistance:
insertion of various materials in IL-B2001 at 200 and 250 °C for 30 days:

- No corrosion of any metal tested at both temperatures
- In general: No altering of ionic liquid during use in closed circuits (absence of oxygen and water)

Corrosion rates of all materials are less than 0.8 mm/a
ILTEC Technology
References of industrial scale use
# ILTEC Technology

## References of industrial scale use

<table>
<thead>
<tr>
<th>Application</th>
<th>Benefit</th>
<th>Supply lines</th>
<th>Overall flow capacity</th>
<th>Country</th>
<th>Start Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling of shaft part of plasma furnace</td>
<td>Guaranteeing higher temperature inside the furnace for preventing corrosion from sulfuric acid</td>
<td>3</td>
<td>30 m³/h</td>
<td>Norway</td>
<td>January 2015</td>
</tr>
<tr>
<td>Blast furnace tap hole</td>
<td>Increasing safety</td>
<td>2</td>
<td>20 m³/h</td>
<td>Germany</td>
<td>October 2015</td>
</tr>
<tr>
<td>Test for cooling EAF bottom shell</td>
<td>Increasing the lifetime of refractory beneath bath level</td>
<td>2</td>
<td>20 m³/h</td>
<td>Germany</td>
<td>Tests performed in Summer 2017</td>
</tr>
<tr>
<td>Cooling of pipes of copper coolers during the casting process</td>
<td>Increasing process safety and improve copper cooler quality</td>
<td>4</td>
<td>50 m³/h</td>
<td>Spain</td>
<td>January 2018</td>
</tr>
<tr>
<td>Cooling of connection flanges at the RH degassing vessel</td>
<td>Increasing process safety and prevent warping</td>
<td>2</td>
<td>15 m³/h</td>
<td>Austria</td>
<td>June 2018</td>
</tr>
<tr>
<td>Cooling of a permanent charging lance and camera at TBRC converter</td>
<td>Increasing process safety and allowing a permanently remaining lance in TBRC</td>
<td>2</td>
<td>10 m³/h</td>
<td>Germany</td>
<td>postponed</td>
</tr>
</tbody>
</table>
Blast Furnace Taphole
Substitution of water in existing taphole

Taphole cooling
Blast Furnace
ArcheflorMittal, Bremen (Germany)
since October 2015
ILTEC Technology

ArcelorMittal Bremen: taphole, initially water cooled

- IL-Inlet
- IL-Outlet
- Refractory mass TP-9BM
- Cu-Stave
- Mass ZBU 155-25SiC
- Steel shell
- Carbon NDK BC8-SR
- Ucar NMD
- Coranit Al
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Industrial scale application at Blast Furnaces – CFM Modelling

Temperature distribution during tapping and during normal operation

Temperature distribution during tapping and during normal operation

with wear

as built

as built

as built

with wear

with wear

with wear
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Industrial scale application at Blast Furnace at ArcelorMittal Bremen – Hardware
ILTEC-Technology

Industrial scale application at a zinc oxide furnace (Høyanger, Norway)
Zinc Oxide Furnace
Industrial scale application for side wall cooling at higher temperatures

Cooling of furnace walls
For preventing temperatures below the dew point, installed at Nyrstrar (Norway) and in operation since January 2015

- **No corrosion** of the steel structure due to selective cooling to temperatures of 180 °C and hence preventing of condensation of sulfuric acid

- **Increase in lifetime** of entire vessel
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Hardware as installed in Hoyanger
RH Degassing

Industrial scale application at a steel vacuum degassing system

Cooling of all flanges

as the connection parts between nozzle and lower part and lower and upper part for increased operating safety at voestalpine Donawitz GmbH, Austria.
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Impressions of the hardware at voestalpine Stahl Donawitz GmbH

During Installation (without isolation)

3D Modell
ILTEC Technology
For cooling the copper piping during casting of copper coolers, Spain

<table>
<thead>
<tr>
<th>Start-up date</th>
<th>Jan 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Application</td>
<td>Cooling of copper pipes during casting</td>
</tr>
<tr>
<td>Former applications</td>
<td></td>
</tr>
<tr>
<td>Outer dimensions (l x b x h)</td>
<td>2,5 x 1,6 x 2,5 m 2,5 x 1,6 x 2,5 m 4 DN40</td>
</tr>
<tr>
<td>Number supply lines</td>
<td></td>
</tr>
<tr>
<td>Piping dimension supply lines</td>
<td></td>
</tr>
<tr>
<td>Number supply lines</td>
<td></td>
</tr>
<tr>
<td>Piping dimension facility</td>
<td>DN80</td>
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<tr>
<td>Capacity pumps</td>
<td>20 m³/h + 30 m³/h</td>
</tr>
<tr>
<td>Maximum Flow</td>
<td>50 m³/h</td>
</tr>
<tr>
<td>Maximum heat removal</td>
<td>2x 2,500 kW</td>
</tr>
<tr>
<td>Heizkabel</td>
<td>---</td>
</tr>
<tr>
<td>Capacity instantanuous heater</td>
<td>7,5 kW + 30 kW</td>
</tr>
<tr>
<td>Maximum heat removal</td>
<td></td>
</tr>
<tr>
<td>Water Supply</td>
<td>400 dm³</td>
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<tr>
<td>Piping dimension water supply</td>
<td>max. 100 m³/h</td>
</tr>
<tr>
<td>Tank volume</td>
<td>DN100</td>
</tr>
<tr>
<td>Water Supply</td>
<td></td>
</tr>
<tr>
<td>Piping dimension water supply</td>
<td></td>
</tr>
<tr>
<td>Current/Frequency</td>
<td>3x 400/230 50 Hz</td>
</tr>
<tr>
<td>Power Supply</td>
<td>45 kW</td>
</tr>
<tr>
<td>Full load current</td>
<td>65 A</td>
</tr>
</tbody>
</table>
ILTEC Technology

Tests at bottom shell of EAF for steelmaking

Copper cooler behind the brick lining of an EAF could reveal significant decrease of brick wear, even in the hot spot area installed.

Test performed in summer 2017
ILTEC Technology
For charging lance cooling in a TBRC converter – Start up in June 2018

ILTEC facility with two individual supply lines for cooling of the permanent charging lance and the camera installed in the TBRC converter.

Start up in June 2018
Summary

• ILTEC Technology is a proven technology
• ILTEC increases lifetime of refractory and reduced down time
• ILTEC allows to recover heat at temperatures @ 200°C
• ILTEC increases safety for employees and systems
Let’s think out of the box!