ILTEC Technology
Ionic Liquid Cooling Technology – Description and Application
# TABLE OF CONTENT

1 EXECUTIVE SUMMARY ............................................................................................................................. 3

2 METTOP AT A GLANCE ............................................................................................................................. 4

3 WATER FREE COOLING SOLUTION ........................................................................................................... 5

  3.1 DESCRIPTION OF THE ILTEC TECHNOLOGY .................................................................................. 5

  3.2 HARDWARE OF ILTEC ....................................................................................................................... 6

  3.3 PATENTED COOLING MEDIUM IL-B2001 ...................................................................................... 7

4 REFERENCES ............................................................................................................................................... 9

  4.1 ARCELORMITTAL BREMEN – GERMANY ....................................................................................... 9

  4.2 NYRSTAR – HOYANGAR, NORWAY ................................................................................................. 9

  4.3 VOESTALPINE STAHL DONAWITZ GMBH – LEOBEN, AUSTRIA .................................................... 10

5 SCOPE OF SERVICES ............................................................................................................................... 11

6 CONTACT .................................................................................................................................................. 12
1 EXECUTIVE SUMMARY

With Mettop’s new and revolutionary cooling technology ILTEC it is possible to realise a water free cooling solution. The new cooling medium IL-B2001 enables a substitution of water as the state of the art cooling medium in an easy way and creates a perfectly safe operation mode for all application fields. This special ionic salt IL-B2001 with its superior characteristics regarding operation temperature (50 – 250 °C), the physical properties and of course the total lack of reaction when getting in contact with liquid metal or slag, opens up a total new way of cooling metallurgical plants.

When talking about the ILTEC Technology and the cooling medium IL-B2001 the following aspects and opportunities can be highlighted:

- **Substitution of water – a safer operation mode**

Whenever water-cooled components are prevailing, the closed water system loop can be substituted by IL-B2001. The same amount of heat can be removed, the same existing piping and instrumentation system can be used. Hence, with the same cooling effect, a perfectly safe operation mode can be achieved.

- **Heat recovery – energy saving**

Higher temperatures and larger temperature ranges allow a more efficient heat recovery. Even if individual studies need to be done on a case-to-case basis, the outlet temperature up to 250 °C (on a short term basis, 200 °C on long term) can still be perfectly used for heat recovery with various different systems.

- **New areas – higher furnace availability**

This revolutionary new approach allows cooling of areas where water cooling was difficult to imagine so far, creating new solution paths. Cooling beneath bath level, within side walls and cooling of tap holes and parts underneath reaction vessels can now be realised. Combined with a new design of coolers and the concept of high intensity coolers producing a freeze line, this technology allows novel and innovative cooling solutions.

The following pages will give an overview of what the ILTEC Technology is capable of. A description of the technology combined with the description of the characteristics of the ionic liquid IL-B2001 and the high intensity cooling technology will help getting an overview. In order to get an idea about the limitless possibilities of the ILTEC Technology, the references and upcoming projects are described in short.
2 METTOP AT A GLANCE

Mettop GmbH, founded in 2005, 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 pyrometallurgy as well as hydrometallurgy of non-ferrous metals and recently also started with innovative cooling systems for the iron and steel industry. Special topics can be highlighted:

- Feasibility studies on metallurgical processes
- Basic and detail engineering of metallurgical processes
- Technical and metallurgical process optimisation
- New tankhouse technology, i.e. the METTOP-BRX Technology
- Water-free and safe cooling technology, i.e. the Ionic Liquid Cooling Technology (ILTEC)
- Cooler design and integrated solutions for cooler, refractory and process conditions
- Gas purging systems
- Refractory management comprising of refractory engineering, delivery and supervision during lining on site
- Project management, monitoring and risk analysis
- Staff-training to implement the provided technical innovations

The scope of services comprises optimisation solutions in the area of furnace integrity, combining refractory selection and layout, gas purging systems and cooling elements. In the field of hydrometallurgy, a new electrolysis technology - the METTOP-BRX Technology - was developed and is in operation to allow an acceleration of the electrolytic refining of up to 50 percent. For all metallurgical aggregates and equipment, Mettop developed the new and water-free cooling technology ILTEC, which uses an ionic liquid as cooling medium, for creating new pathways towards safe and efficient cooling for the entire metallurgical industry.

In addition, Mettop is internationally active in terms of technical consulting (process optimisation) and operator training for customers in the non-ferrous metals industry, and also assists in the optimisation of risk management in metallurgical plants.
3 WATER FREE COOLING SOLUTION

There are many different melting and refinery aggregates used in the area of metallurgy. All these have in common that they need a sufficient cooling system, since high temperatures from 800 to 2000 °C are needed for the production, depending on the metal. Worldwide, these cooling systems mainly operate with water. This is mainly due to the high thermal conductivity and the cheap availability of water, making it broadly used and favourable.

However, water also has several disadvantageous characteristics. Since it is restricted to a maximum temperature of 60 °C and the possibility of exploding - both due to volume expansion and possible hydrogen explosion - is given, the cooling medium water can cause severe dangers.

On taking a closer look at the safety risk, it has to be noted that due to water damages - especially in the field of taps – several fatal accidents happen every year worldwide. This was the main motivation to rethink the existing cooling systems in metallurgy and to finally develop the innovative “cooling with ionic liquids” concept.

This resulted in the patented ILTEC Technology with the patented cooling medium IL-B2001.

3.1 Description of the ILTEC Technology

After several years of research activities, the technology was enhanced and finally brought to industrial scale. The special designed ionic liquid IL-B2001 combines several superior properties and together with Mettop’s know-how regarding cooling technology and cooler designs, a tailor made cooling solution can be provided for every customer.

The ILTEC Technology is characterised by the following:

- Instead of water the ionic liquid IL-B2001 is being used as cooling medium
- IL-B2001 is liquid at room temperature and can be used at an operating temperature of up to 250 °C (for short term, 200 °C on a long term basis)
- In case of a leak in the cooling system, the IL-B2001 will disintegrate into its components without a sudden increase in volume and without the formation of hydrogen. There will be no explosion when getting in contact with liquid metal, so work safety can be guaranteed
- No cooler corrosion problems will occur, as the IL-B2001 can be used at higher temperatures (above the dew point of the exhaust gases)
- Due to the higher temperature (up to 250 °C), the dissipated heat can be recovered again. This advantage will play a particularly important role in the future


These facts have been tested and proved by tests that were carried out at Montanwerke Brixlegg AG, Austria, where 35 l/min of ionic liquid were introduced into an anode furnace at a liquid copper
temperature of 1200 °C. In another test, the ionic liquid was pumped beneath bath level of a ladle filled with stainless steel at 1600 °C and the both results were perfectly the same: no explosion occurred, only a slight bubbling of the melt could be seen.

3.2 Hardware of ILTEC

An exemplary design of an ILTEC facility is shown below, the main components can be summarised as follows:

- Storage 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) guarantee the flow of the ionic liquid through the entire pipe system
- Two heat exchangers for removing the heat to the secondary cooling circuit
- Numerous measuring devices for temperature, flow, pressure and differential pressure throughout the entire system guarantee a fast leak detection
- Variety of valves, adjusting wheels and shut-off devices for all different operation modes

The exact dimensioning of the facility as well as the design and capacity of the single components are tailor-made for each application.

The compact design together with low maintenance component parts, a perfect reliability and safety in terms of cooling are only some of the features of the ILTEC Technology. Assembly, installation and start-up on site is conducted by Mettop personal within a few days.
3.3 Patented Cooling Medium IL-B2001

Basically, ionic liquids are salts, meaning that they consist solely of anions and cations. Per definition, ionic liquids show a melting point below 100 °C; many of them are liquid even at room temperature, due to their poorly coordinated ions. Dislocated charging and one ion based on an organic molecule avoid the formation of a stable crystal lattice, so that only a minor amount of thermal energy is required to conquer the lattice energy and break the crystal lattice. Varying the cations and anions allows designing ILs with different properties (e.g. melting point, viscosity and solubility).

For the special application of cooling, the ionic liquid IL-B2001 was designed as a cooling medium to perfectly meet the requirements within this application field.

Chemically IL-B2001 consists of 97 % 1-Ethyl-3-methylimidazoliumTetrafluoroborate, 1.5 % 1-Ethyl-3-methylimidazoliumfluoride and 0.5 % water. What makes it special is the patented production procedure, making the product perfectly free of chlorine. The usual way of producing ionic liquids with chlorine as an ion exchanger is circumvented and hence the liquid is absolutely non-corrosive due to the absence of chlorine. In order to proof this, different investigations and tests have been performed. The results indicate that the corrosion rate is below 0.8 mm per year for all commonly used piping materials as copper, steel or Monel, even at higher operation temperatures of 250 °C.

IL-B2001 has a variety of properties giving it a unique character and making it perfectly suitable for the use as a cooling medium:

<table>
<thead>
<tr>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation temperature</td>
<td></td>
<td>50 – 200</td>
<td>°C</td>
<td>ΔT = 150 °C</td>
</tr>
<tr>
<td>Short term stability</td>
<td></td>
<td>250</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Decomposition temperature</td>
<td></td>
<td>450</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Crystallization temperature</td>
<td></td>
<td>&lt; 15</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Specific heat capacity</td>
<td>cₚ</td>
<td>1.38 – 1.70</td>
<td>J/gK</td>
<td>50 – 200 °C</td>
</tr>
<tr>
<td>Density</td>
<td>ρ</td>
<td>1.25 – 1.14</td>
<td>kg/dm³</td>
<td>50 – 200 °C</td>
</tr>
<tr>
<td>Dynamic viscosity</td>
<td>η</td>
<td>20 – 5</td>
<td>mPa·s</td>
<td>50 – 200 °C</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>K</td>
<td>30 – 130</td>
<td>mS/cm</td>
<td></td>
</tr>
</tbody>
</table>
The superior physical properties and characteristics of IL-B2001 make it the perfect cooling medium for a broad range of applications:

- Crystallisation temperature is below 15 °C
- Equivalent values of the dynamic viscosity in comparison with water, allowing the exchange of water in existing systems, also with regard to the capacity of pumps and piping
- Decomposition temperature of 450 °C resulting in total disintegration with no residues
- Long term stability between 50 °C – 200 °C, short term stability of 250 °C
- IL-B2001 is not a consumable good
- No vapour pressure below decomposition temperature and no explosion at temperatures above decomposition temperature
- Non-flammable below decomposition temperature
- Non-toxic which guarantees perfect safety for employees and environment
- Non-corrosive and hence no decreased system availability
- No increase in volume at lower temperatures ("freezing") preventing problems in case of shutdown

Legal Requirements

As the liquid is not harmful to neither environment nor any organisms, there is no problem regarding legal specifications or requirements:

- Not classified as dangerous good
- Can be transported and stored
- REACH certified
- Classification according to regulation (EC) No 1272/2008 (CLP)
4 REFERENCES

The possibilities and applications of the ILTEC Technology are still in their infancy. Together with our customer we can achieve highly efficient cooling solutions for a variety of scenarios. In addition to standard applications for cooling, Mettop provides tailor made solutions even at areas where no cooling was imaginable so far because of safety concerns.

The following sections show references in industrial scale application in use, on-site of our perfectly satisfied customers.

4.1 ArcelorMittal Bremen – Germany

Tap hole cooling of a blast furnace, in operation since October 2015.

At ArcelorMittal Bremen, the demand for safer tap hole cooling at the blast furnace made Mettop apply the new cooling medium IL-B2001 at the tap hole 3. The existing water cooling system was replaced by an ILTEC system. Since the start-up in October 2015, the system is running without problems and to the full satisfaction of the customer.

![Figure 4 – ILTEC System as installed and in operation within the existing computational system at ArcelorMittal Bremen](image)

4.2 Nyrstar – Hoyanger, Norway

Side wall cooling of a zinc oxide furnace, in operation since January 2015.

At the company Nyrstar, located in Norway, the customer`s request was to prevent severe corrosion on the inside of the furnace side walls of a zinc-oxide shaft furnace.

Due to a change in the burden material, caused by the charging of sulphur-containing leaching residues, SO₂ was created and combined with the low temperature at the cooled side wall, acidic condensate was formed, resulting in a rapid corrosion of the furnace wall.

Mettop`s new approach was to cool the side wall to a lower extent. The inlet temperature of the ionic liquid within the cooling panels was increased to 150 °C. This lead to a rise in the inside wall temperature to more than 200 °C and thus above the dew point of the sulphuric acid.
Since the start-up of the ILTEC system in the beginning of 2015 no corrosion occurred and the zinc-oxide furnace runs at full operation.

4.3 voestalpine Stahl Donawitz GmbH – Leoben, Austria

Cooling of the flanges of a RH degassing vessel, start-up in winter 2017/18.

For the customer voestalpine Stahl, an ILTEC system is designed to cool the flanges, i.e. the connection of the nozzles with the lower part and the connection between the lower part and the upper part. The main reason for cooling in general is the form stability of these connections (no warping caused by temperature fluctuation), the decision to substitute water by IL-B2001 is due to the increased safety for employees and equipment.

For this special application of cooling the flanges of the RH degassing facility, the technology is even more sophisticated. Due to the regularly changes of the nozzles and the lower vessel part respectively, a nitrogen purging for flushing the cooled parts is implemented. This guarantees a perfectly safe operation mode with ILTEC and at the same time allows a loss-free change of vessel parts.

Figure 5 – 3D engineering drawing of the ILTEC facility at voestalpine
5 SCOPE OF SERVICES

Creating an optimised solution for our customers, the scope of services not only includes the layout and manufacturing of an ILTEC facility, but also takes economic impact and metallurgical feasibility into account. Moreover, Mettop provides comprehensive after-sales service in order to maintain and ensure perfect functionality.

The comprehensive package of services provided by Mettop consists of:

Case verification on site

As a first step, detailed feasibility and economical studies have to be conducted in order to define the best possible tailor-made solution. By collecting and illustrating technical fact, this tool will show the economic impact of the implementation of ILTEC.

Basic and detail engineering

The completion of the conceptual design first leads to basic engineering. Definitions of requisition for scope of delivery and services for all disciplines with regard to process, location, estimation of total investment and final lay-out of the system are carried out.

As a next step, final design solutions are prepared during the detail engineering phase. The complete ILTEC design as well as requirements resulting from the authorisation process are implemented into the engineering documents. Deadlines for activities are accurately timed on the basis of a project time schedule.

Delivery, Installation and Start-up

Mettop personnel will be on-site to ensure and guarantee a perfect installation and start-up procedure.

After Sales Service

A service and maintenance contract with Mettop will be established, securing an annual complete equipment inspection and operator training comprising of the following:

- Visual inspection of system components
- Verification of the function of all single components
- Identification and analysis of the error log report
- Checking of alert system
- Calibration of all measuring devices
- Control of physical properties of the ionic liquid IL-B2001
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