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1 EXECUTIVE SUMMARY

With Mettop’s new and revolutionary cooling technology ILTEC it is possible to realize 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 – 200 °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. But not only the properties if IL-B2001 makes ILTEC unique, the combination with special cooler designs for high intensity cooling enables new application fields.

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

- **Substitution of water – More safe operation mode**
  Whenever cooled with water-cooled components are prevailing, the closed loop water system 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, for 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. A study has to be done case by case but in general the outlet temperature up to 250 °C can be perfectly used for heat recovery with various different systems.

- **New areas – Higher furnace availability**
  This revolutionary new approach allows cooling of areas where no water cooling was imaginable so far and creates new solution paths. Cooling beneath bath level within side walls and cooling of tap holes and parts underneath reaction vessels can be realized. Combined with a new design of coolers and the concept of high intensity coolers for creation of a freeze line, this technology allows novel and innovative cooling solutions.

The following pages will give an overview about 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 outline. For giving an idea about the limitless possibilities for the ILTEC Technology, the references and upcoming projects are described in short.
2 METTOP AT A GLANCE

Mettop GmbH is an independent Austrian engineering company, which was founded in 2005. Mettop is specialized in process design, process optimization, and process engineering with the focus on:

- Feasibility studies on metallurgical processes
- Basic and detail engineering of metallurgical processes
- Technical process optimization
- New tankhouse technology, the METTOP-BRX-Technology
- New cooling technology, the Ionic Liquid Cooling Technology (ILTEC)
- Cooler design, integrated solution for cooler, refractory and process conditions
- Delivery of coolers
- Refractory engineering
- Delivery of refractory
- Staff-training for realization of the provided technical innovations
- Trading technical devices and equipment in the frame of the above described company subjects
- According to the specific customer and project, the above-mentioned products and services are provided as either complete package or single parts

Mettop’s activities include the field of the pyro- and hydrometallurgy of non-ferrous metals as well as the iron and steel industry. The scope of service comprise optimization work in the area of furnace construction (furnace integrity), like refractory linings, gas purging systems, and cooling systems. In the field of hydrometallurgy, a new electrolysis technology - the Mettop-BRX-Technology - was developed, which is already used commercially. For all metallurgical aggregates and equipment, Mettop developed a new cooling technology ILTEC, which uses an ionic liquids as cooling medium instead of water.
3 NEW COOLING SOLUTIONS

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

However, water has some disadvantageous characteristics. Since water is restricted to maximum temperatures of 60 °C and the possibility of exploding both due to volume expansion and possible hydrogen explosion, the cooling medium water causes severe dangers.

On taking a closer look at the security risk, it has be noted that due to water damage - 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 why finally the innovation “cooling with ionic liquids” was developed.

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

3.1 ILTEC Technology

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

The ILTEC Technology is characterized by the following:

- Instead of water the ionic liquid IL-B2001 is used as cooling medium
- IL-B2001 is an ionic liquid which is liquid at room temperature and can be used up to 250 °C operating temperature
- If there is a leak in the cooling system, the IL-B2001 decomposes into its components without sudden increase in volume and without the formation of hydrogen. If it comes in contact with liquid metal there will be no explosions and work safety can be guaranteed
- No corrosion problems, since the IL-B2001 can be used as a cooling medium at higher temperatures (above the dew point of the exhaust gases)
- Due to the higher temperature (up to 250 °C), the dissipated heat can also be recovered again. This advantage will play a particularly important role in the future

The ILTEC Technology is generally secured through several patents. The patent no. 508292 secures the cooling in metallurgy, the patent WO2013113461A1 the ionic liquid IL-B2001 and patents WO2008052863A2, WO05021484A2, WO2008052860A1 WO2010122150A1 the method of preparation of the ionic liquid.

These facts have been tested and proved by performing tests where 35 l/min of ionic liquid were introduced into an anode furnace at Montanwerke Brixlegg AG, Austria 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 results was perfectly the same: no explosion at all, only a slight bubbling of the melt could be seen.

An exemplary design of an ILTEC facility is given in Figure 1, the main components thereof can be summarized as follows:

- 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 for removing 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

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 construction with a low maintenance operation mode and a perfect reliability and safety in terms of cooling are only some of the features of the ILTEC Technology. After a delivery period of around 16 weeks the easy assembly, installation and start up on site is conducted within a few days by Mettop.
3.2 Patented Cooling Medium IL-B2001

In general, ionic liquids are salts which means consisting 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, caused by their badly 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 for perfectly meeting the requirements within this application field.

Chemically seen 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 because of 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 the higher operation temperatures of 250 °C.

IL-B2001 has a variety of properties which gives it a unique character and makes 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>50 – 200</td>
<td>°C</td>
<td></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>( c_p )</td>
<td>1.38 – 1.70</td>
<td>J/gK</td>
<td>50 – 200 °C</td>
</tr>
<tr>
<td>Density</td>
<td>( \rho )</td>
<td>1.25 – 1.14</td>
<td>kg/dm(^3)</td>
<td>50 – 200 °C</td>
</tr>
<tr>
<td>Dynamic viscosity</td>
<td>( \eta )</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>
3.2.1 Physical Properties

The superior physical properties of IL-B2001 make it the perfect cooling medium for a broad range of applications:

- Crystallization temperature is below 15 °C
- Comparable values for dynamic viscosity compared to water, this makes it possible of exchanging water in existing systems regarding capacity of pumps and piping
- Decomposition temperature 450 °C results in total vanishing and no residues
- Long term stability between 50 °C – 200 °C, short term stability of 250 °C
- IL-B2001 is not a consumable
- No vapour pressure below decomposition temperature and no explosion at temperatures above decomposition temperature
- Not 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”) and hence no problems in case of shutdown

3.2.2 Legal Requirements

Since the liquid is not harmful either no environment or 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)
- For more details contact Mettop at cu@mettop.com

Figure 2: Impressions of the cooling medium IL-B2001
3.3 Composite Furnace Modules (CFM) for high intensity cooling

Mettop provides full engineering service for the perfect tailor-made cooling device. After the installing and start-up of the facility there is provided supporting after-sales for ensuring a perfect functionality. The proven and practice applied technology of high intensity cooling is best possible realized via composite furnace module cooling elements.

The advantages are:

- Effective and adjustable cooling
- Homogeneous hot face temperature
- Steep temperature gradient
- Accretion layer/freeze lining for protection of the refractory
- Extended refractory lifetime and furnace campaigns
- Increased furnace capacity because of less thick refractory lining

The design can be describes as a compound of a copper cooling element and the refractory material, a visualization is given in Figure 3. The casted copper coolers consist of a copper back plate with copper fingers at the surface. Within the copper plate, the cooling pipes (made of either copper or Monel alloy) are casted for an optimized flow of the cooling medium. The cooling medium might be water; for a further improve a cooling with ionic liquid (ILTEC) can be realized.

The copper fingers are covered with refractory mass. The height of the copper fingers as well as the thickness of the castable refractory can be adjusted for each case. Due to the increased remove of the heat because of the better cooling, an accretion layer of frozen metal or slag is supposed to form onto the refractory, which acts as a protection and hence can increase the lifetime of the refractory.

The basic concept of the CFM cooling elements in conjunction with the cooling medium IL-B2001 is a freeze lining concept. This freeze lining concept is attributed to the fact that the removed amount of heat is high enough for creating a frozen slag/metal layer upon the castable refractory. The slag/metal bath is locally (at the contact face melt and castable refractory) cooled to such an extent that the temperature of the liquid falls below the liquidus temperature. Consequently, a solid slag/metal layer is formed.

Once this slag/metal layer is created there is no further wear and, thus, consumption of the refractory material since an equilibrium between melting of the frozen layer and freezing of a new layer is formed.
Before design and construction of the CFM elements, the industrial application situation of each case has to be considered closely. In order to do so, models of the installation situation are created and with CFD modelling the temperature distribution is calculated. In Figure 4 it can be seen that although the layer of refractory is thin, the temperature is decreasing within a short length and the removal of the heat is high.

![Figure 3: Basic design and components of a CFM cooling element](image1)

![Figure 4: CFD modelling of the temperature distribution within the refractory castable at a melt temperature of 1600°C](image2)

![Figure 5: Side wall panels for cooling the whole side wall of a copper slag cleaning furnace](image3)
4 REFERENCES AND UPCOMING PROJECTS

The possibilities and uses 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. Beside standard applications for cooling Mettop provides tailor made solutions even at areas where so far no cooling was imaginable because of safety concerns.

4.1 List of References

Mettop has references of the ILTEC Technology in operation and in final planning until now at the following locations.

4.1.1 ArcelorMittal – Bremen, Germany

Blast furnace tap hole cooling, in operation since October 2015.

At ArcelorMittal Bremen, the demand for a more safe possibility of tapping at a blast furnace tap hole made Mettop implementing the new cooling medium IL-B2001 at tap hole number 3 on site.

The existing water cooling system was replaced by an ILTEC system. Since the start up in October 2015 the system is running without any problems and to the satisfaction of the customer.

4.1.2 Nyrstar – Hoyanger, Norway

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

For the company Nyrstar, located in Norway, the request from the customer was to prevent severe corrosion on the inside of the furnace side walls of a zinc oxide shaft furnace.
Due to change in the burden material, high amounts of sulphur was charged with leaching residues, \( \text{SO}_2 \) was created and because of low temperature at the side wall, the corrosive attack led to a breakdown of the furnace walls within a week.

The new approach from Mettop 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 an increase of the inside wall temperature of above 200 °C and hence above the dew point of the sulfuric acid.

Since the start-up of the ILTEC system in beginning 2015 no corrosion happened and the zinc oxide furnace runs at full operation.

4.1.3 voestalpine Stahl Donawitz GmbH – Leoben, Austria

Cooling of the flanges of a RH vessel, start up in autumn 2016.

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

4.2 Projects to be realized

Since the ILTEC Technology opens up a huge new field of application, either for increasing safety, for energy savings because of heat recovery or for totally new cooling applications. The following projects are in detail engineering phase and are about to be realized within the near future with different customers. This is for giving an idea about the possible applications and opportunities ILTEC can offer.

4.2.1 Substitution of water for cooling tap holes and side walls – Increasing safety

Within the slag cleaning process of a producer for platinum group metals (PGMs) the temperatures in the electric arc furnace are high and the furnace suffers from severe wear. Especially the tap holes (slag as well as matte tapholes) are areas of extreme wear and are therefore water cooled by now. Also the slag lining suffers from enhanced refractory consumption and is cooled by water.

Since water always causes danger, Mettop is planning to substitute the entire water cooling within side walls of the bottom vessel for the DC-type EAF furnace by using IL-B2001 as cooling medium instead. The areas are marked in the construction drawing in Figure 7, the cooling comprises of slag and matte tapholes and the entire side wall of the rectangular furnace.
4.2.2 Cooling of tuyere zone of Peirce Smith converter – Increasing furnace lifetime

When thinking about the Peirce Smith converter for converting copper concentrate, the tuyere zone is an area of severe wear, even further it can be said that the lifetime of the tuyeres is the limiting factor for the lifetime of the entire vessel. Since the tuyere level is beneath bath level at most of the time during the furnace operation, there is no cooling implemented at all because of safety concerns in case of any malfunction or leakage of the cooling circuits.

![Figure 7: Cooled areas of a DC-type EAF for slag cleaning](image)

![Figure 8: Cooling panels for cooling the tuyere zone of a Peirce Smith converter](image)
With the new and perfectly safe ILTEC Technology, this new field of cooling application can be realized, the design of the cooled area is given in Figure 8. Every panel comprises of an upper and lower casted steel part which is flown through the cooling medium IL-B2001.

### 4.2.3 Off gas shaft cooling – energy saving via heat recovery

Every aggregate needs to remove the off gas, which still is of high temperature and needs to be cooled for the subsequent cleaning process. Cooling of these off gas shafts with IL-B2001 and combining it with a suitable heat recovery system would result in energy savings.

The higher outlet temperature of 200 °C of the cooling medium IL-B2001 is the perfect base for efficient and economical heat recovery.

![Figure 9: Example of a cooled off gas duct of an electric arc furnace](image)

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