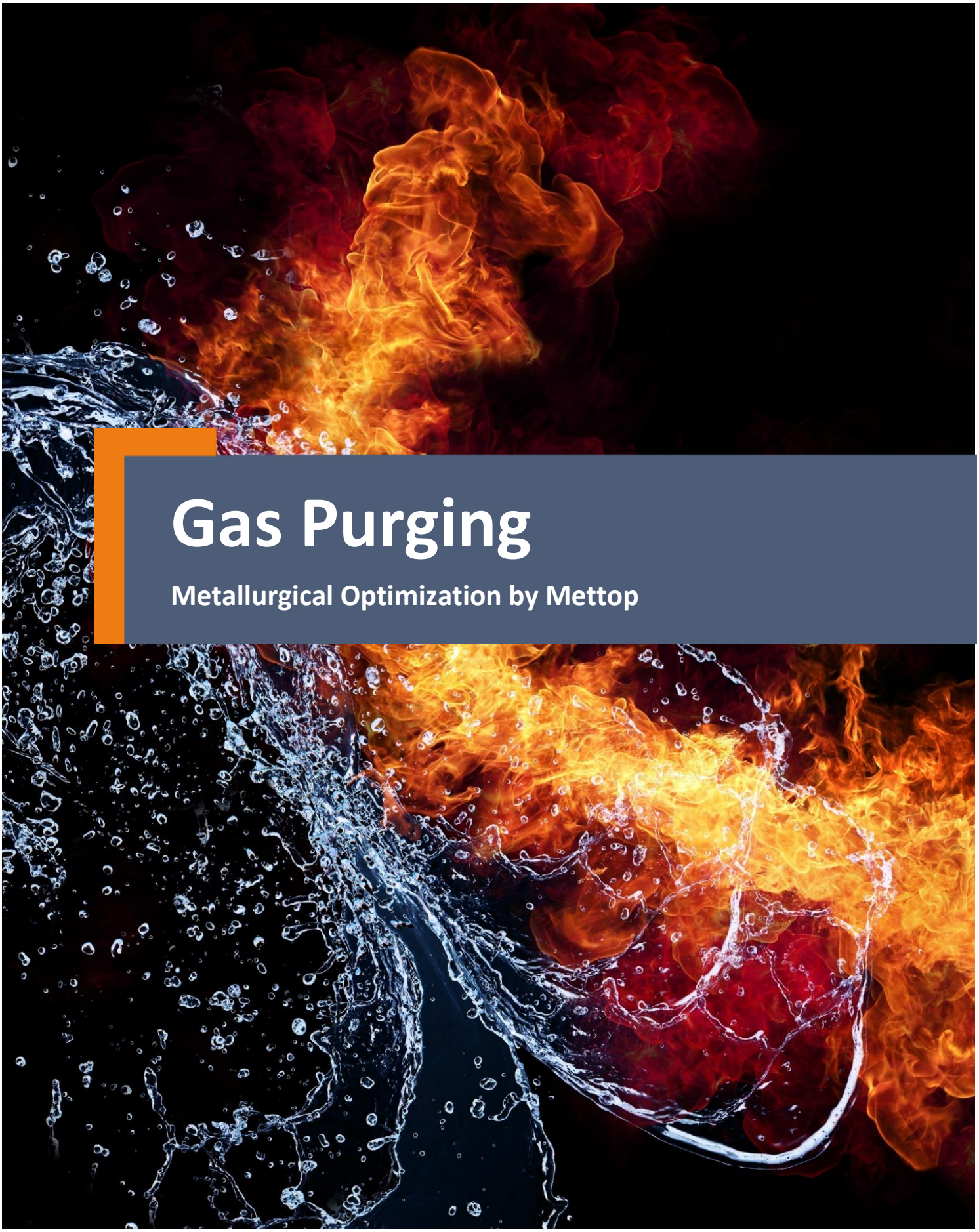

Gas Purging

Metallurgical Optimization by Mettop

mettop

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1 EXECUTIVE SUMMARY

With the implementation of gas purging in new applications or an upgrade of existing furnaces can lead to a wide range of improvements:

- Homogenization of the temperature and bath chemistry in the molten bath
- Better kinetics due to increased bath movement and turbulence
- Decrease of slag overheating
- Easier deslagging when installing purging plugs at certain positions
- Decrease of slag coatings and accretions
- Lower sulphur and oxygen contents due to lowering the partial pressure when introducing nitrogen or noble gases
- Extended refractory lifetime

Especially in copper industry, the following advantages within different aggregates can be emphasized:

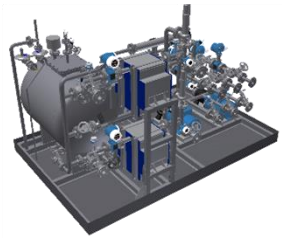
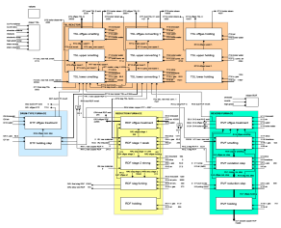
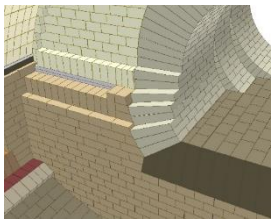
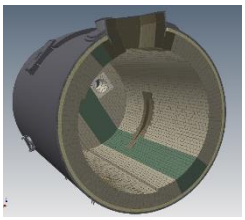
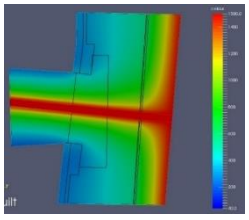
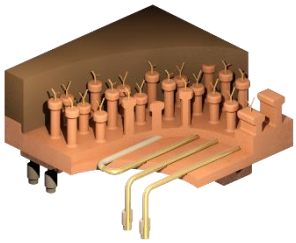
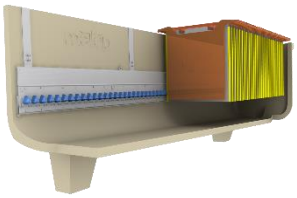
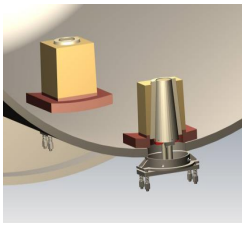
- Anode furnace: Gas purging in the anode furnace results in 30 % shorter oxidation, 50 % shorter deslagging, less reductant consumption, less refractory wear, time savings and finally cost savings
- Peirce Smith converter: Gas purging can also be applied in the converter to achieve lower sulphur content, lower oxygen content, decreased process time and decreased deslagging time. Furthermore purging in the converter may change the process in the subsequently anode furnace.

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 METALLURGICAL OPTIMIZATION VIA GAS PURGING IN ANODE FURNACE

Gas purging improves metallurgical work and can result in a significant reduction of process time. The introduction of inert gas bubbles into the liquid melt influences both, the kinetics and the thermo-dynamical processes.

The advantages of gas purging systems can be summarized:

Thermal and analytical homogenization of the molten bath

- Reduction of fuel and auxiliary material consumption
- Decreased slag overheating and refractory wear
- Uniform chemical purity

Increased surface layer between slag and metal bath

- Decreased boundary layer
- Increased diffusion controlled reaction
- Increased metal recovery
- Decreased highly oxidized slag

Inert gas bubbles in the molten bath

- Decreased partial pressure for SO_2, H_2O and CO
- System reaches equilibrium more quickly

The principle of the sulphur and oxygen removal in the anode furnace is shown in the left diagram in Figure 1 and can be described a follows. During the anode furnace process, two sequential process steps are conducted, at first the desulphurization followed by the desoxidation step, as marked in the figure with red lines. Within the first step (1), oxygen is introduced and hence, the sulphur is decreased to the final desired level of < 50 ppm (whereas the oxygen level is increased). And the second reduction period (2) the oxygen is removed to the desired final extent of < 1,500 ppm.

In Figure 1 the equilibrium lines (black lines) for the solubility product of SO_2 between the liquid copper melt and the gas phase are given, depending on the partial pressure of SO_2 (p_{SO2}). It can be seen that with decreasing partial pressure (as a result from the gas bubbles, partial pressure of SO_2 within the nitrogen bubbles is zero), lower overall levels of oxygen and sulphur in the melt can be achieved.

On the right side of Figure 1 the difference caused by decreasing partial pressure is obvious. For realizing comparable sulphur contents, the oxidation level of the melt is significantly decreased, exemplary given in the figure from 6000 ppm to 4000 ppm. The process time decrease for the oxidation process is around 30 %.

Consequently the second step, the reduction period, can be reduced too.

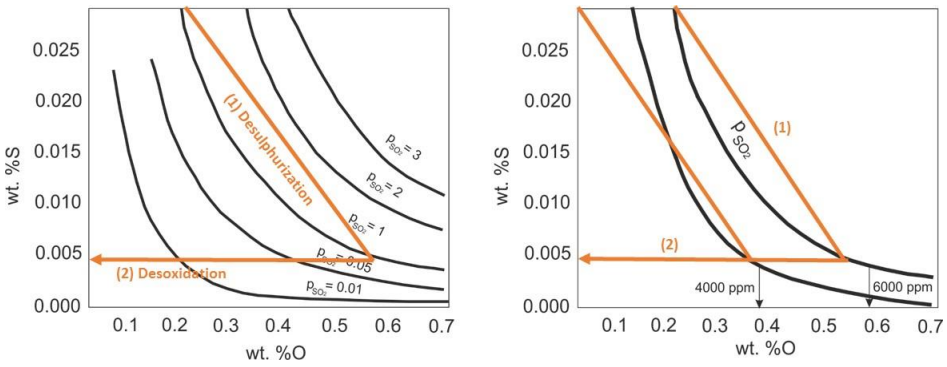


Figure 1 – Fundamental principal of the two process periods during the anode furnace process (left) and fundamental principle of gas purging, decrease of partial pressure (and shifting the lines of the solubility product of SO_2 towards lower levels) because of introduction of nitrogen or noble gases.

In Figure 2 a drawing of an anode furnace with altogether eight purging plugs is shown. However, the number and the position of the gas purging plugs influences the metallurgical performance of a reactor and have to be considered for an optimized process and output.

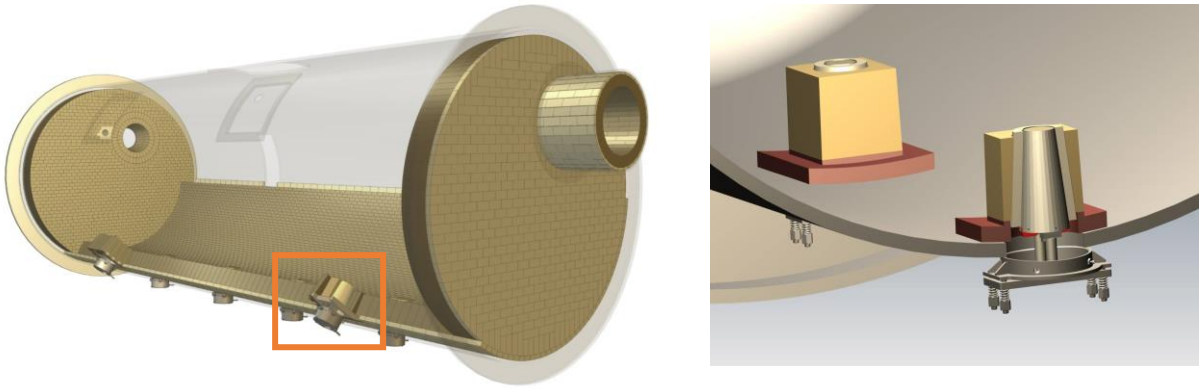


Figure 2 – Installation situation of purging plugs in an anode furnace

As an example, the experience with the N_2-gas purging system from industrial partners is as follows (data from the 1st year of installation):

- Oxidation time needed: reduced oxidation time: Installation of the porous plugs reduces oxidation time for 70 minutes
- Time for slag skimming: reduced deslagging time: 5 to 10 minutes are saved per batch
- Time for poling: reduced reduction time: 12 minutes are saved per batch
- LPG Savings: reduced LPG consumption: 0.3 kg/t-anode LPG is saved with the porous plugs
- Longer tuyere lifetime: tuyere lifetime is extended accordingly

4 GAS PURGING IN PEIRCE SMITH CONVERTER

Caused by the improved kinetics but especially by the thermodynamical changes via the decreased partial pressure of SO_2 within the inert gas bubbles, gas purging in the converter process can result in an optimized process. However, while it is already commonly used in anode furnaces, there are only a few converters, which are equipped with a purging system.

The Figure 3 shows a Peirce Smith converter equipped with altogether eight purging plugs. A detailed picture of the complete purging plug unit (well block, inset layer and porous plug) is given on the right side.

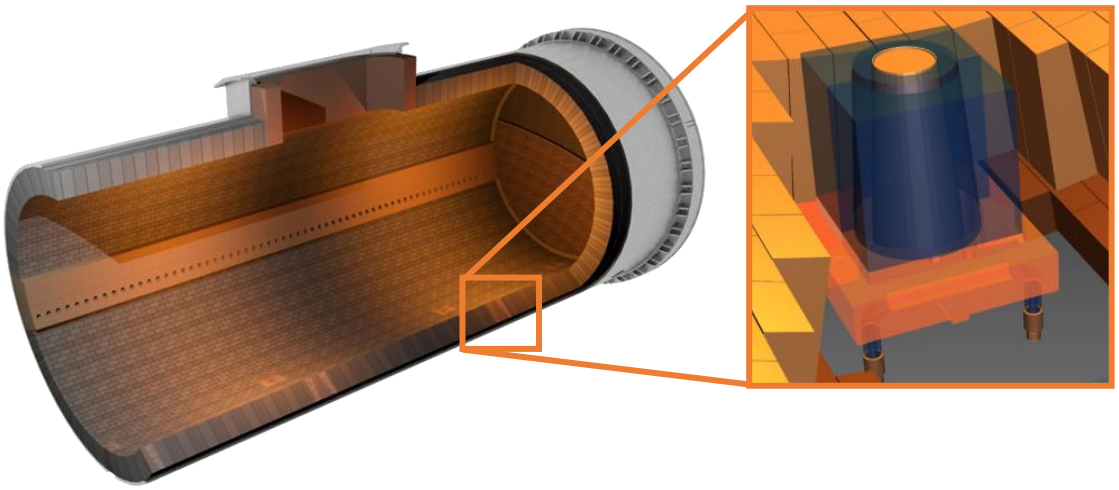


Figure 3 – Peirce Smith converter equipped with purging plugs and detailed picture of the purging plug unit

Whereas during the charging, the iron blow, the copper blow and the tapping step only minor influence can be realized, there are severe process improvements achievable during the marked process steps:

(1) Slag skimming: By pushing the slag more towards the converter month, an optimization of the slag skimming process can be realized. This will result in 50 % less time for deslagging and further avoid that fayalithic slag will remain in the converter vessel. This prevents that magnetite is formed from the iron within the fayalithic slag and no fuming can occur.

(2) Purging step prior to tapping: With a waiting step after copper blowing and prior to the tapping and between the tapping steps, a notably decreasing of the sulphur and oxygen content can be realized. Due to the introduction of inert gas bubbles, the partial pressure of sulfur and oxygen is decreased.

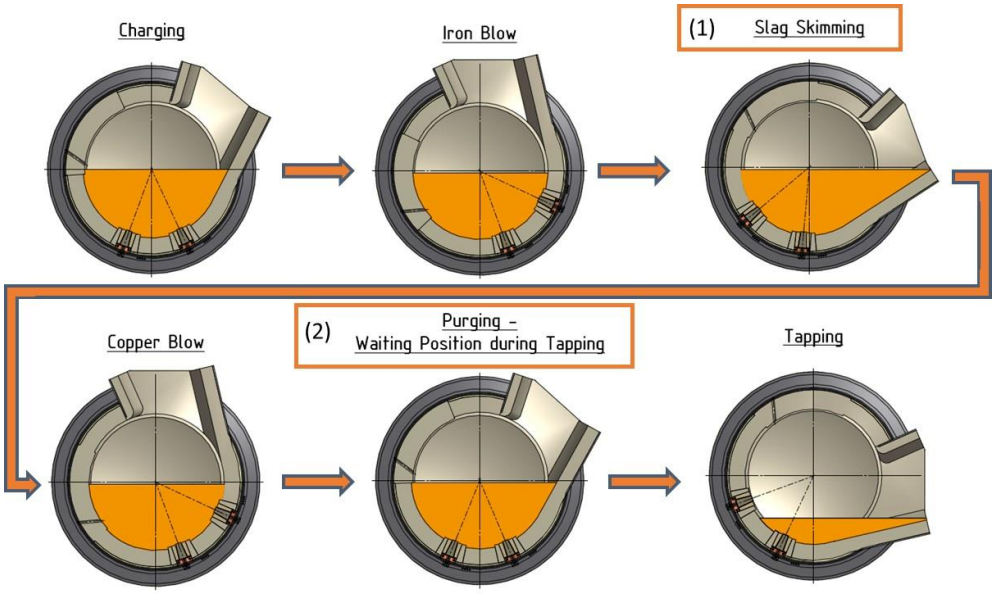


Figure 4 – Sequence of process steps within the converting process and marked steps where purging leads to significant changes in productivity and product quality

It can be seen from Figure 5 that the decreased partial pressure because of nitrogen introduction lead to significant decrease in both, oxygen and sulphur content of the copper melt. Especially the decreased sulphur content below < 100 ppm enables a skipping of the oxidation step within the anode furnace.

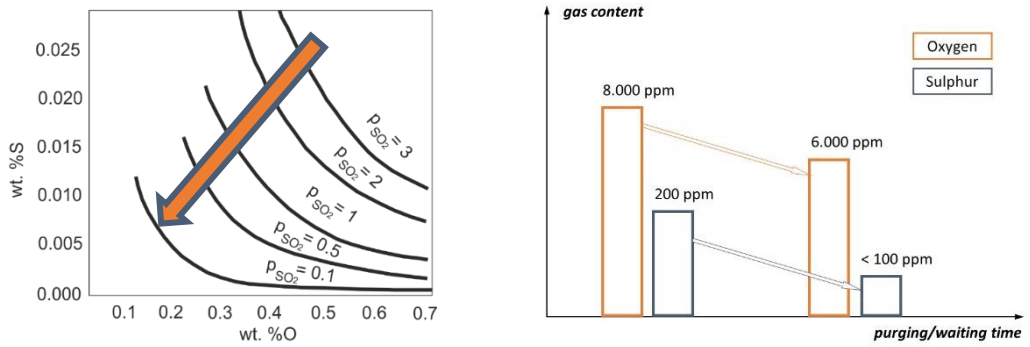


Figure 5 - Achievable lowering of oxygen and sulphur levels because of the decreased partial pressure

Beside the possibility of adapting the installation situation for a tailor made and optimized process, generally there can be distinguished between two different procedural cases, depending on the overall situation on site:

- Change of process control: As a result of the lower partial pressure resulting from the gas bubbles and the enhanced kinetics, the process time for reaching the desired oxygen and sulphur contents is decreased. Especially of the converting process is the “bottle neck” this

fact can help to increase the entire output of the process chain because the process time is shortened.

- Change of anode furnace process: If the time needed for the converting process is not the limiting factor, an additional purging and waiting step can completely change the process within the anode furnace. Since the sulphur level can be lowered below < 100 ppm the oxidation step within the anode furnace can be skipped. This leads to a significant lowering in process time in anode furnace and in addition, because of the lack of change of atmosphere between oxidizing and reducing, to a significant increase in furnace lifetime.

5 SCOPE OF SERVICE BY METTOP

The scope of service of Mettop comprise of the following:

- Purging Plugs:

The delivered and installed purging plugs comprise of the inner porous plug, the ceramic inlay and the well block.

- Gas control unit:

The technical realization of the gas control unit for every application is shown in Figure 6. On the left side the gas control unit as constructed, built and delivered by Mettop can be seen, in this case there are 8 supply lines for the nitrogen purging of every plug. On the right side an example of the visualization (HMI – human machine interface) is shown.

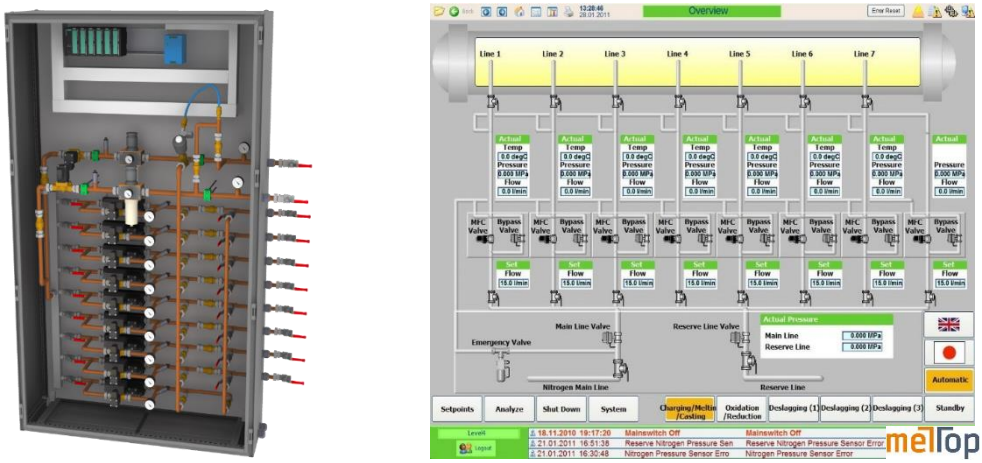


Figure 6: Gas control unit and user interface (HMI) for operation

- Installation on site:

The entire installation on site will be supervised by Mettop personal.

- After Sales service:

In case either any unlikely event or planned maintenance, Mettop provides after sales service.

- Training courses

For optimized profiting from the benefits and using the entire metallurgical potential of gas purging it is of interest to fully understand the metallurgical background of the processes. Therefore Mettop provides detailed and comprehensive training courses on site for teaching the operators metallurgical knowhow combined with operational instructions.

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