Rectangular Furnace Design and Revolutionary DC-Slag Cleaning Technology for the PGM Industry

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Non-Ferrous Applications:

Submerged arc furnaces are frequently applied in the non-ferrous industry and other special operations, as described below.

Slag cleaning: SMS Demag has supplied more than 25 slag cleaning units in the last 40 years. Depending on the process, the slag is either liquid-charged via launders into the furnace or cold-charged in solid form via conventional feeding systems. The application range is very wide and units are operating in copper, nickel, cobalt, lead, tin, zinc and precious metals (platinum/palladium) production.

Copper: Slag cleaning furnaces are commonly connected to copper smelting units such as Teniente and Noranda converter, Outokumpu flash smelter. The main function of the furnace is the reduction of the copper level in the slag. SMS Demag's furnaces are designed for a reduction of the copper level from 1-8% down to 0.6-0.9%.

There is a trend towards semi-continuous operating practice of the primary smelters (such as ISASMELT or Ausmelt) as well as of the slag cleaning furnaces. The rectangular SAF is more suitable for this task due to better geometrical conditions.

We expect that for continuous operation, the recovery rate of a rectangular furnace can be (depending on the specific parameters) 0.1-0.4% higher in comparison to the conventional round type SAF's. This fact persuaded a customer in Zambia to install a SMS Demag rectangular slag cleaning furnace downstream a continuously operating ISASMELT furnace. The plant is currently under construction and incorporates latest mechanical design aspects.

It is intended by the client to commission the furnace in the 3Q of 2006.

For batch operating practice, state-of-the-art round type furnaces is still the preferable choice.

PGM: Platinum Group Metals (PGM) are mainly produced from sulphide nickel and copper minerals. After flotation and concentrate drying, raw material is smelted in large SAF's for separating the gangue and generating a base-metal-matte phase as a collector for noble metals. The matte is further treated in converting steps.

PGM smelting can be compared to the smelting of nickel matte by SAF, with SMS Demag's rectangular furnace being the ideal equipment for this technology.

The rectangular layout leads to a uniform bath and allows a good separation of the matte from the slag phase. For increasing the specific power input sidewall cooling systems and thyristor control systems are required for such furnaces.

Optimized charging systems for concentrate and fluxes can be individually developed by SMS Demag's 3-D fluidodynamic modelling.
3-D Fluidodynamic Modelling:

With the application of SMS Demag modelling tools, the understanding of up-scaled new processes is becoming more transparent. One example is the 3-D-modeling of large-scale submerged arc furnaces. This model was first successfully applied for two large-scale submerged arc furnaces in Chile. The modelling provides important data for proper furnace sizing and correct dimensioning for the cooling system. Furthermore, it gives realistic indications of operational conditions.

![Figure 7: Example of temperature distribution in a rectangular furnace](image)

Major factors which are considered in the model:

- Joule's heat generation in ohmic resistors: slag, metal, arc and electrodes;
- Heat consumption in the bank and bank/slag interfaces due to endothermic reactions of reduction and melting;
- Heat transfer by conduction and convection in the slag and metal/matte;
- Heat transfer by conduction in refractory, shell and electrodes;
- Heat transfer by convection through furnace shell/water, shell/air interfaces;
- Heat transfer by convection and radiation at slag/gas, bank/gas, electrodes/gas and refractory/gas interfaces;
- Slag and metal/matte motion induced by buoyancy forces (natural convection);

The advanced modelling tool of SMS Demag therefore contributes:

- To get a better understanding of new process approaches
- To have more orientation points for furnace design
- To match long-term experiences with new advanced modelling tools
- To support customers and suppliers in their decisions for new process procedures
- To get a better understanding for sidewall cooling concepts
- To considerably lower up-scaling risks

Secondary DC based intensive slag cleaning step ("washing machine"):

SMS Demag offers an innovative intensive slag cleaning step which is arranged downstream conventional slag cleaning furnaces. This new development overcomes the hitherto unsolved problem of fine dispersed smaller precious metal droplets not gravitationally settling into the matte/metal phase of the furnace (see figure 8).

This has always led to a significant portion of precious metals remaining in the slag zone.

The new invention is a very interesting solution especially for the copper and PGM industry.

In the case of copper slag cleaning, the copper content of the slag can be further reduced by 0.2-0.5 percentage points.

The recovery of copper inclusion had been demonstrated successfully. Currently numerous talks are held with the platinum and palladium producing industry especially in Southern Africa. SMS Demag sees great potential of this technology in this field. A recovery of 50% of the lost PGM containing matte as inclusions at a unitary electric energy consumption of 50 70 kWh/t of slag is according to the test work feasible.

The principles of the cannel type furnace are simple.

The small channel-type unit has a permanent DC electric field in combination with a magnetic field.

![Figure 8: Principles of the new slag cleaning unit for the recovery of precious metals](image)
electrolytic effects increase the metal recovery rate. The unit/process is patented for all metals.

The principles of the new slag cleaning step were jointly developed by SMS Demag and the University of Chile in Santiago/Chile. In the initial stage numerous fundament test had been carried out.

Due to the ability to further reduce the precious metal content, the unit has internally the nick name “washing machine”.

During the comprehensive test program, numerous slags from various applications of SAF technology had been investigated such as:

- Copper slag
- Lead and zinc slag
- Waste material
- PGM slag
- FeCr slag
- FeMn slag
- FeNi slag
- Others

**Figure 9** illustrates a cross section of three possible test set ups for the laboratory tests. The small test rig allowed to run the process in conventional AC-, conventional AC with coke layer- and in DC-mode.

Especially for all the copper slags, results looked very promising. In UDC carried out numerous fundamental tests in the field of settling phenomenon of copper slags.

![Figure 9: Laboratory test AC-DC comparison](image)

![Figure 10: Copper content over the time under AC and DC conditions](image)

The test demonstrated that (especially for copper slags) settling conditions could be significantly enhanced. Looking at the graph trend for copper slag in **figure 10**, it is obvious that the slag cleaning effect was more progressive with applying a DC-field. Beside other effects the reason for the acceleration of copper slag cleaning could be explained with the so-called Electro capillarity Motion Phenomena, which is in principle shown in the next picture as well as overlapping electrolytic effects (see **figure 11**).

![Figure 11: Principles of Electro capillarity Motion Phenomena](image)

When the liquid metal droplet is exposed to an electrical DC-field, it start to develop a certain internal “flow pattern” as shown in the above picture. The droplet movement at the exterior area in combination of the friction between droplet and the slag forces the droplet to move. The drop “eats itself through the slag (in the shown case downwards).

It is well known that coagulation of the copper droplets will also promote settling conditions in a slag cleaning furnace. Additional stirring/agitation of the slag enhance the chance that matte droplet hit each other. The liquid drops will coagulate to larger droplets, which has better descending conditions.

The new slag cleaning channel type furnace incorporated both principles of enhancing coagulation and enforcement of matte setting into the matte phase. A picture of the pilot plant is shown in **figure 12**.

The first pilot set up at UDC had a capacity of 0,5 tph of slag processing. In a first furnace, slag was molten in a chamber by means of a natural gas burner. Then the slag was tapped continuously into the DC-channel type slag cleaning unit.

The first results exceeded SMS Demag’s and UDC expectations. Occasionally the copper content in the slag could be reduced down to < 0,4% (depending on the original slag copper content).
It was demonstrated that a significant fraction of the remaining copper droplets could be transferred in the matte phase. Looking at the cross section of the slag before and after the slag cleaning step, it can be seen that the further cleaned slag is almost free of copper droplets (see figure 13).

The first pilot set up was especially designed for testing slags from the copper producing industry. In order to test a larger variety different slag with a higher melting point, it had been decided to install a new pilot plant at UDC. The primary gas fired slag melting furnace was replaced with an electrically powered smelter (see figure 14).

This modification of the pilot plant was done jointly done with Europe's leading copper producer. The first test results are very promising showing a copper reduction in the slag from 0.9% down to 0.4%.

One major drawback of both pilot test facilities is the limitation in melting capacity. In addition the pilot plant does not 100% reflect the identical slag characteristics as tapped on industrial site, because the fact that it needs to be re-molten.

For this reason SMS Demag is currently designing a mobile test facility. The unit will have a capacity of approx. 1 - 2 tph slag treatment. The necessary instrumentation for receiving immediate results of the tests is included in the test rig.

SMS Demag is planning to carry out test especially in the southern countries of Africa, Europe and in Chile. The mobile DC-slag cleaning step pilot facility will give our clients the immediate evidence that the slag cleaning principles will also work for their specific process. First tests on sites are planned for 2007.

The economics of this unit are for some applications outstanding. Taking the example of conventional plant utilizing submerged arc furnace for copper slag cleaning and taking the current copper price of approx. 8000 USD per ton of copper and a copper production of approx. 200,000 tpy, such a unit will have an amortization period of less than 6 month.

Additionally SMS Demag is in talks with numerous other companies in the copper and PGM industry to install the first industrial scale plant. The R.O.I. of less than half a year is very promising for some companies that they consider an immediate installation of the unit. Figure 15 shows the cross section of a 75 tph unit.
The advantages of the unit are obvious:

- High recovery of precious metals
- Extremely low investment due to simple principle
- No control of the electrode necessary => easy operation
- Minimum of graphite anode consumption due to coke layer principle
- Possibility of bypass option will not effect daily operation and minimizes project risks
- Small compact unit will fit almost in all downstream location of primary smelting unit
- Amortization of less than half a year possible

**Conclusions and Outlook:**

The first SAF was commissioned 100 years ago in Germany. Since then a tremendous development of this smelting tool was recognized all over the world and submerged arc furnaces are now operating in at least 20 different main industrial fields.

SMS Demag as a leader in large scale electrical smelters proudly looks back at the significant role of the company in the history of this unique and highly efficient unit.

Especially in the field of rectangular furnace technology, SMS Demag could enhance its market position. The last orders in rectangular furnaces demonstrate our clients trust in our intelligent solution (such as side wall cooling system, furnace integrity).

Our recent innovations also focus on the additional recovery of precious metals out of liquid slag. The developed “washing machine” will become a very attractive solution especially for the PGM and copper industry in Africa.