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

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Abstract After a short summary of the historical milestones of the submerged arc furnace, the paper will highlight different applications and their specific smelting furnace requirements in the non-ferrous area. Additionally aspects of rectangular furnace design and the features of the copper cooling system for the side wall will be emphasized. Finally a state of the art design tool as well as a new invention to improve slag cleaning technology will be featured, which shows great potentials especially for the PGM and copper related industry.

History of the submerged arc furnace:

100 years of submerged arc furnace technology (SAF), a remarkable achievement by SMS Demag! We are proud of looking back at our involvement in this technology in which SMS Demag played a significant role in the development of this smelter.

During the last century, the submerged arc furnace has been one of metallurgy’s most amazing diversified melting units which has found many applications in over 20 different industrial areas, including ferro-alloys, iron, silicon metal, copper, lead, zinc, refractory, titanium oxide, calcium carbide, phosphorus and materials recycling, etc. SMS Demag has been developing this technology for more than 100 years and has supplied a diverse market with about 700 furnaces and major furnace components. Numerous applications were constantly developed serving various users.

Such an evolution was only possible because of tremendous efforts in research and development and due to the large range of design solutions. The increasing demand for ferroalloys and desoxidation agents in steelmaking at the beginning of the 20th century led to the development of the first few furnaces.

DEMAG, for the last two centuries a major supplier for the iron and steel industry, started with the construction of the first submerged arc furnace in 1906. The 1.5 MVA unit was installed in Horst, Ruhr/Germany, for the production of calcium carbide and was successfully commissioned in 1906.

The “evolution” and the major milestones of the technology are shown below:

1906 : Reduction furnace (bottom + top electrode)
1913 : 6-electrode rectangular reduction furnace
1935 : 15 MVA furnace
1951 : SAF with rotating gear for Si-metal production
1953 : 40 MVA large capacity furnace
1956 : Compensated low-inductive high currency line
1957 : Copper slag cleaning furnace
1958 : Hydraulically controlled electrode column
1959 : Large-capacity 60 MVA furnace
1966 : Encapsulated electrode column
1967 : Large-capacity ferro-, silicon-chromium
1974 : Large-capacity silicon metal furnace
1975 : Hollow electrode charging system
1982 : High capacity FeNi rectangular furnaces
1993 : FeNb furnace
1995 : Slag wool furnace
2001 : DC furnace for ilmenite smelting
2004 : Rectangular copper slag cleaning furnace
2004 : High capacity FeNi rectangular SAF with thyristor + copper cooling system
2006 : DC slag cleaning unit for precious metals (PGM, Cu, Co, etc.)
Figure 1 shows a typical submerged arc furnace from the 1950’s, as it was promoted at that time. It should be pointed out that the principles of the furnace technology have not changed significantly.

The development of large electrode systems, advanced transformer and thyristor technology and new furnace construction principles nowadays allows the design of large-capacity rectangular SAF’s with dimensions of up to 40 m in length and 18 meters in width and circular furnaces with 22 m in diameter. From a design point of view even bigger units are possible but their technological and economical feasibility has to be carefully checked.

The furnace control systems also underwent a significant evolution during the last decades. The first few furnaces were completely manually controlled. Since the end of the 1950’s, SMS Demag SAF’s have been equipped with electrode controllers. Today’s advanced submerged arc furnaces make use of modern software controllers. SMS Demag’s key competence is the mid size and large scale rectangular furnaces. An example of a two rectangular furnace in-line layout is illustrated in figure 2.

The shown unit illustrates the world largest submerged arc furnace which had been sold to a Brazilian client for the production of FeNi.

Figure 3: Electrode arrangement of a rectangular furnace

The design of high-power smelting units for ferro-nickel also led to the development of various sidewall cooling concepts as well as to the development of AC thyristor controls, which allow better operational control, higher and more efficient power input and less overall maintenance. Sidewall cooling and a thyristor control system are currently successfully in operation at a newly installed smelter for Eramet in New Caledonia. It represents the world best available large scale FeNi-smelter.

The furnace is designed as a 6-electrode rectangular SAF with a transformer rating of 99 MVA and an operating load of 75 MW. The furnace has been placed on the original foundations in an existing building. With the a.m. modifications, the target to double the power input/capacity while keeping the original dimensions has been exceeded. Figure 4 shows the sidewall cooling system of this furnace.

The advantages of large-capacity rectangular furnaces of SMS Demag vs. other suppliers can be summarized as follows:

- Moderate electrode sizing for higher availability and easier operation
- Easier charging/tapping arrangement and charging/tapping philosophy
- Simple and mechanically robust shell and roof design (no expensive down-holding system required)
- Higher possible production rate by even power and burden distribution
- Intelligent refractory and sidewall cooling system
- Less complex building construction due to less span
- Proven technology in large scale
- Extreme short commissioning period
  ⇐ Satisfied customers
For safety reasons the water cooling channels remain outside the furnace shell.

In certain applications such as PGM, pig iron and several ferroalloys and non ferrous processes, a sufficient heat removal rate will create a layer of frozen slag, the so-called freeze line, which protects the remaining sidewall lining. In this case a high thermal conductivity of the lining is of capital importance.

The main features of the cooling concept are:
- Safe system with water passages outside the shell
- Mechanically stable, embedded in furnace design
- Uniform - not point-wise - cooling of the slag zone
- Formation of “freeze line” guaranteed all over the refractory wall in the slag zone - chemical and mechanical attack of slag is safely avoided
- Cooling of slag and hot metal level possible
- Spacing of the copper stripes and their thickness can be varied over a wide range and thus be adapted to all heat loads to be expected; this way the cost-optimized solution for each application can be selected
- Cooling elements are easy and cheap to fabricate
- Thickness of plates allows thermal expansion of the lining
- Bricks are ensured to remain in full contact with the copper elements

Furthermore the two world largest rectangular furnace will be equipped with the same cooling concept. Onca Puma, a daughter company of CVRD place the order to SMS Demag for supplying two of the world largest submerged arc furnaces. The two 120 MVA furnaces with a hearth dimension of 36.4 x 13.4 meter will be commissioned in 2008. This demonstrates a full trust of our customers in this concept.

(Article to be cont. in next issue)