

# Application potential of SMS DC smelter technology for the pyrometallurgical industry in South Africa

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**Abstract** – In 1906, the first submerged-arc furnace was supplied by SMS Siemag. Since then, the division has become established in various industries such as ferro-alloys and non-ferrous metals, and in numerous other special applications. During the evolution of this technology, more efficient units with longer lifetimes were developed. Today, especially the potential of DC-based smelters, raises worldwide attention, with some projects having already started to implement this kind of technology. This paper evaluates SMS Siemag's general viewpoint regarding the potential application of DC smelter technology and possible options for the ferro-alloy and non-ferrous industry. SMS Siemag is currently executing a FeCr project in Kazakhstan, where four of the world's largest closed-type DC smelting furnaces, with a power input of 72 MW, will be installed. These furnaces include the latest technological features of modern DC smelters, which are described in this paper. SMS Siemag has started a long-term research and development project allowing a direct comparison of AC versus DC technology on a large scale, using a recently installed 1 MVA test furnace at the IME at the University of Aachen, in Germany. For open-type ferro-alloy and Si-metal furnaces, SMS Siemag has developed an energy recovery system, which is presented in this paper.

## SMS SIEMAG'S HISTORY IN SMELTER TECHNOLOGY

The increasing demand for ferro-alloy and de-oxidation agents in steel-making at the beginning of the 20th century led to the development of the first electric furnaces. Demag, for the past century, a major supplier to the iron and steel industry, started with the construction of the first submerged-arc furnace in 1905<sup>1</sup>. This 1.5 MVA unit was installed in Horst Ruhr, Essen, Germany, for the production of calcium carbide, and was successfully commissioned in 1906, based on DC technology. Since then, SMS SIEMAG has been developing various DC- and AC-based smelter types for more than 100 years, and has supplied a diverse market with about 700 smelting furnaces and major furnace components<sup>2,3</sup>. Today, the majority of metal-producing smelting furnaces (excluding steel-making furnaces) are represented by AC-based concepts. Numerous applications have been constantly developed, serving various users. The customers are distributed all over the world, predominantly in countries with large raw material reserves and/or low energy costs. The major SMS Siemag milestones of electric smelting technology are shown in Table 1.

**Table 1:** SMS Siemag milestones in AC and DC technology<sup>2</sup>

1906	First reduction furnace – DC single electrode principle (1.5 MVA)
1911	First reduction furnace – AC 3-electrode principle
1913	6-electrode reduction furnace
1935	15 MVA furnace with circular shell
1953	40 MVA large-capacity furnace
1956	Compensated low-inductive high current line
1958	Hydraulically controlled electrode column
1959	Large-capacity 60 MVA furnace
1966	Encapsulated electrode column
1969	Large-capacity ferro-, silico-chromium furnaces
1971	Large-capacity silicon metal furnace
1975	First large-scale DC furnace for steel production
1980	84 MVA rectangular furnace
1982	108 MVA circular closed-type furnace
1992	First conductive hearth for ilmenite smelting
1992	Largest 102 MVA SiMn/FeMn furnace
2001	DC furnace for ilmenite smelting
2002	Continuous operating circular copper slag-cleaning furnace
2003	Side-wall copper-cooling system for large-capacity rectangular furnace
2004	Continuous operating rectangular copper slag-cleaning furnace
2004	High-capacity 120 MVA rectangular furnaces with thyristor and copper-cooling system
2006	Pilot plant DC slag-cleaning unit for precious metals (PGM, Cu, Co, etc.)
2009	Development of largest DC furnace for FeCr (70 MW)

The vast majority of furnaces supplied to the ferro-alloy and non-ferrous industry are based on AC concepts. Furthermore, the SMS Siemag steel-making department has supplied around 400 furnaces, of which approximately 15 % are DC-based EAFs.

### **TECHNOLOGICAL FEATURES OF AC AND DC FURNACES**

The chemical process dictates the primary requirements for the technological design features of a smelter. The following summary describes the various types of furnace features with regard to power characteristics, process, roof, charging system, shell, and electrode system. The combination of such basic features allows the design of tailor-made furnaces to suit the specific process requirements.

**Table 2:** Furnace features related to specific process types

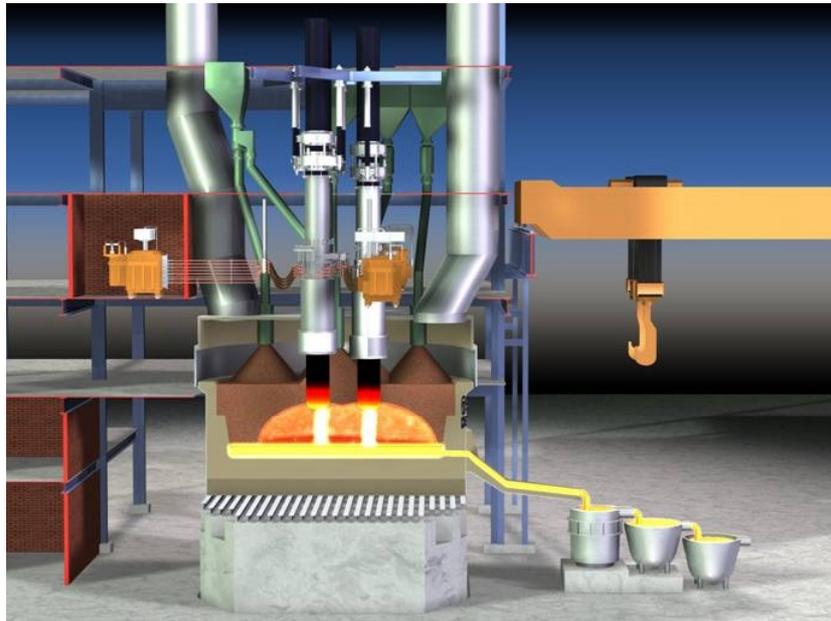
<p><b>Basic system</b></p> <ul style="list-style-type: none"> <li>■ AC based rectangular (3 or 6 electrodes in-line)</li> <li>■ AC based circular furnaces</li> <li>■ DC based circular furnaces (single or twin electrode)</li> </ul>	<p><b>Process type</b></p> <ul style="list-style-type: none"> <li>■ Open design</li> <li>■ Semi-closed design</li> <li>■ Closed design</li> </ul>	<p><b>Furnace roof types</b></p> <ul style="list-style-type: none"> <li>■ Water cooled multi-sectional roofs</li> <li>■ Water cooled roof (spray cooling)</li> <li>■ Suspended brick roof/cast roof</li> <li>■ Flat/arched shape</li> </ul>
<p><b>Charging systems</b></p> <ul style="list-style-type: none"> <li>■ Hot/cold charging</li> <li>■ Hollow electrode charging system (HES)</li> <li>■ Liquid charging (launder system)</li> <li>■ Choke/batch feeding principle</li> <li>■ Automatic/manual feeding</li> </ul>	<p><b>Furnace shell types</b></p> <ul style="list-style-type: none"> <li>■ Flat/dished bottom</li> <li>■ Cylindrical/conical</li> <li>■ Stationary/rotating</li> <li>■ Changeable/tiltable</li> <li>■ Various sidewall cooling systems</li> </ul>	<p><b>Pre-baked/graphite electrodes</b></p> <ul style="list-style-type: none"> <li>■ Self baking electrodes</li> <li>■ Extrusion electrodes</li> <li>■ Hollow electrode system for pre-baked or self-baking electrodes</li> <li>■ Suspended/supported E-column design</li> <li>■ Prebaked electrode</li> </ul>

## CONVENTIONAL AC FURNACES

The principle of a conventional submerged arc furnace is electric resistance heating. Electrical energy is converted into thermal and reduction energy by using the resistance  $R$  of the burden, or the molten slag; sometimes, *e.g.* in the case of FeNi production, this is supplemented by the electrical resistance of an arc between the electrode and the slag. The energy is transmitted to the furnace hearth by carbon electrodes<sup>4,5</sup>. The power of the furnace is the product of the resistance and the square of the electrode current. Therefore, a limited increase in electrode current may result in a relatively large increase in load. A typical furnace with slag operation comprises a circular- or rectangular-shaped furnace shell with separate tap-holes for slag and metal. For some processes, the slag and metal is tapped through one tap-hole and separated downstream via cascade casting or skimmers. The furnace shell is refractory-lined and – if additional shell-cooling is required by the process – water-cooled by a special side-wall cooling system. The shell bottom is usually cooled by forced air ventilation. The electrode is consumed by the furnace bath. The self-baking electrodes, with casings or pre-baked electrodes, are periodically extended by new pieces<sup>6</sup>. The electrode is semi-automatically slipped into the bath, with the furnace at full electrical load and with no interruptions of the furnace operation. The electrode column assemblies contain all the required facilities to hold, slip, and regulate the penetration into the bath. All electrode operations are performed hydraulically. A cross-section of a typical AC smelter is illustrated in Figure 1.

The electric power is normally supplied from the furnace transformer via high-current lines, water-cooled flexibles, and bus tubes at the electrodes and at the contact clamps to the electrodes. If the process generates off-gas which contains a certain amount of CO, the furnace can be designed as a closed-type furnace,

and the CO can be utilized for further applications, such as power generation, heating, pumping, steam generation, *etc.*



**Figure 1:** Cross-section of a conventional SAF

The major features of SMS Siemag's AC-based furnaces have:

- Patented, low-maintenance electrode columns for various electrode types
- Fail-safe, robust-designed electrode holding and slipping device
- Robust vessel design that does not allow bulging/movement
- Proven hollow-electrode charging system
- Gas-tight water-cooled roof design that provides high-quality CO-rich gas
- Possibility of application of energy recovery system

The choice of the raw materials, obtained by the customer, has the biggest impact on the process. On the one hand, it affects the slag composition, and, on the other hand the smelting pattern inside the furnace (based on the physical properties and the amount of energy input)<sup>7</sup>.

The physical properties determine whether the smelter can run in:

- conventional resistance mode using the electrical resistance of slag,
- shielded arc mode using the electrical resistance of the slag and arc, or
- using the electrical resistance of the feeding mix.

### **CONVENTIONAL DC FURNACES**

The DC furnaces built by SMS Siemag are generally of circular type and the electrical energy is converted into thermal energy (in most of the processes) mainly by the arc, which is established between the electrode tip and the slag bath. The top of the electrode is connected as the cathode, and the conductive

bottom system is connected as the anode. It should be noted that SMS Siemag holds patents for most DC bottom-anode systems, *i.e.* conductive hearth (Concast), billet-type (DEMAG), and pin-type (GHH). In this way, the company was, and still is, involved in almost all DC-based projects all over the world.

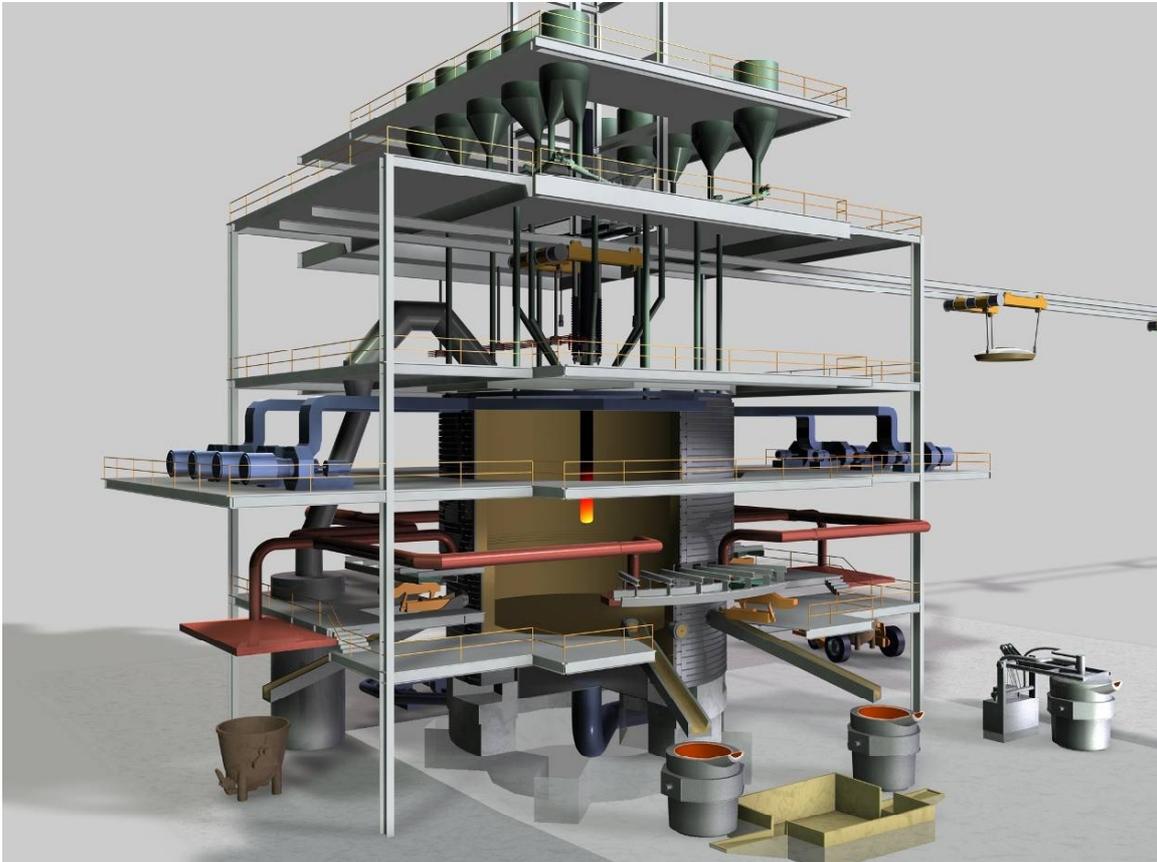
A typical furnace with open slag-bath operation usually comprises 1 to 3 slag tap holes, and 1 to 2 metal tap-holes at a lower elevation. The furnace requires advanced cooling arrangements in the roof and side-wall area, to counteract the effects of the hot liquid slag in direct contact with the refractory material, and the increased thermal radiation. The refractory concept must be designed carefully to adapt to these harsher conditions. The electrode is consumed by the furnace process. The pre-baked electrodes are periodically extended by new pieces<sup>4</sup>. Electrode arms are used to regulate the electrode. SMS Siemag has developed an innovative E-column specially designed for DC furnaces<sup>5,6</sup>. The mechanical functions and the electrical power-transfer principles are similar to the conventional AC-based electrode columns.

DC furnaces can also be designed as a closed-type furnace, and the CO can be collected. The SMS Siemag strength in DC technology can be summarized as follows<sup>4,9</sup>:

- Patented, reliable, long-life electrode column system allows slipping and nipping under full power (providing maximized power-on time)
- Less power-off time improves furnace lifetime and operation of the off-gas system
- Minimization of energy losses with innovative cooling/refractory concept
- Optimized energy consumption due to combined electrode movement regulator with thyristor ignition controller and high electrode speed
- Quick-changeable centre-piece device essential for maximum operating time
- Unique in-house knowledge to minimize arc deflection (bus bar routing and E-column)
- Intelligent feeding arrangement to maximize throughput and refractory lifetime
- Joint competence with RHI for conductive hearth with long lifetime and even power distribution
- Robust vessel design does not allow bulging/movement
- Large product portfolio of roof and side-wall cooling systems for sufficient protection at moderate energy consumption level
- Gas-tight roof design provides high-quality CO-rich gas
- Application of energy recovery system possible
- Leading supplier for DC furnaces in the metals industry

Details of a DC unit are illustrated in Figure 2. The DC furnace is usually operated with an open arc, which smelts the material within a very short time. The material can be charged via a hollow-electrode system (HES) directly into the arc. Investigations show that the arc is dancing at the tip of the electrode.

Therefore, it is also practicable to charge the material directly around the electrode tip.



**Figure 2:** Illustration of a modern DC smelter with conductive hearth

In some furnaces, it is possible to pile up a side-wall protection layer with the charged material (as applied at the Co/Cu smelter at Chambishi Metals in Zambia). Most processes where the slag is overheated do not allow this kind of side-wall protection. Generally speaking, the overall energy consumption of DC furnaces can be higher in comparison to AC smelters due to:

- the higher radiant-energy load in the furnace freeboard
- additional furnace cooling requirement due to higher process temperatures
- high degree of metal fuming, which consumes additional energy

Perhaps the greatest benefit of DC technology is the direct use of fine run-of-mine material, eliminating the necessity for investment-intensive agglomeration steps required upstream of the furnace. The lower price level for fine material is beneficial for the overall operating costs.

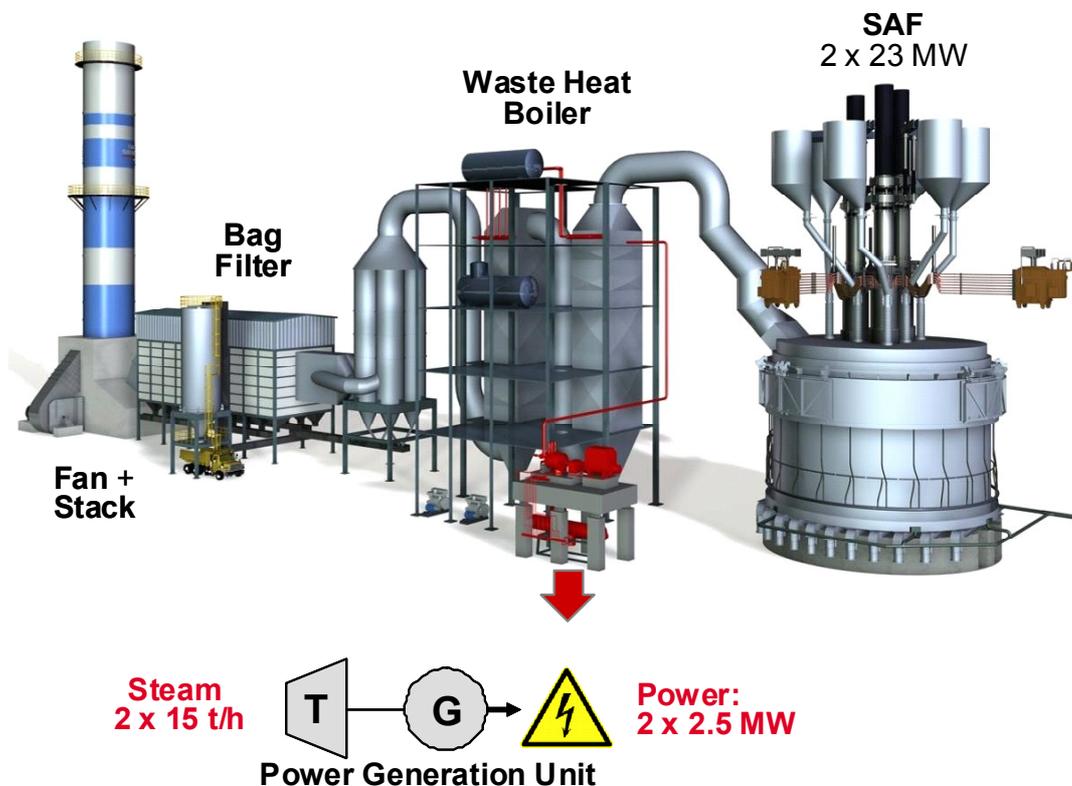
### **General aspects application**

More than 90% of today's ferro-alloy and  $\text{TiO}_2$  production is carried out in AC furnaces. A partial substitution of AC furnaces by DC furnaces has been

considered by a few customers (mainly for application to FeCr, FeNi, TiO<sub>2</sub>, and PGMs), as will be further described in the following sections<sup>9</sup>.

### Ferrochrome

Ferrochrome production is carried out in either a DC arc furnace or an AC-based submerged-arc furnace. Currently, the majority of FeCr is produced in conventional AC furnaces that are charged with cold lumpy material. At the beginning of 2008, SMS Siemag received an order from ETI- Krom in Elaziğ, Eastern Turkey, for the revamp of two AC-based FeCr furnaces. The engineering work has commenced, and the customer plans to commission the new furnaces during 2011. The furnace power of 30 MVA will remain unchanged, as well as major parts of the feeding system<sup>10</sup> (see Figure 3).



**Figure 3:** Energy recovery system as designed for ETI- Krom in Elaziğ/Turkey

The two new furnaces are connected to an energy recovery system. The unit consists mainly of a waste-heat boiler, a bag station, a fan, and a stack. It is assumed that 2 x 15 t of steam can be produced, which will generate approx. 2 x 2.5 MW electrical power. According to ETI- Krom in Elaziğ, the energy recovery system reduces the overall CO<sub>2</sub> emission by 25 000 tons per annum, and the amortization period was calculated to be less than 3.5 years.

This kind of energy recovery system is economically feasible, especially for larger-scale, open-type, submerged-arc furnaces, as supplied to the ferro-alloy and Si-metal industries. It is possible to recover up to 20% of the electrical

power of a Si-metal furnace, as also carried out in the Bjoelevossen plant in Norway.

One option for saving operating costs is to pre-heat the ore, which can be done in a rotary kiln, a rotary hearth furnace (RHF), or a pre-heating shaft. The use of a pre-heated stage (especially shaft furnaces) has proven to be beneficial for achieving low electrical energy consumption in an AC submerged-arc furnace. It is used mainly in South Africa. The major drawback of such technologies is the higher investment cost as well as lower overall plant availability for the complete process line.

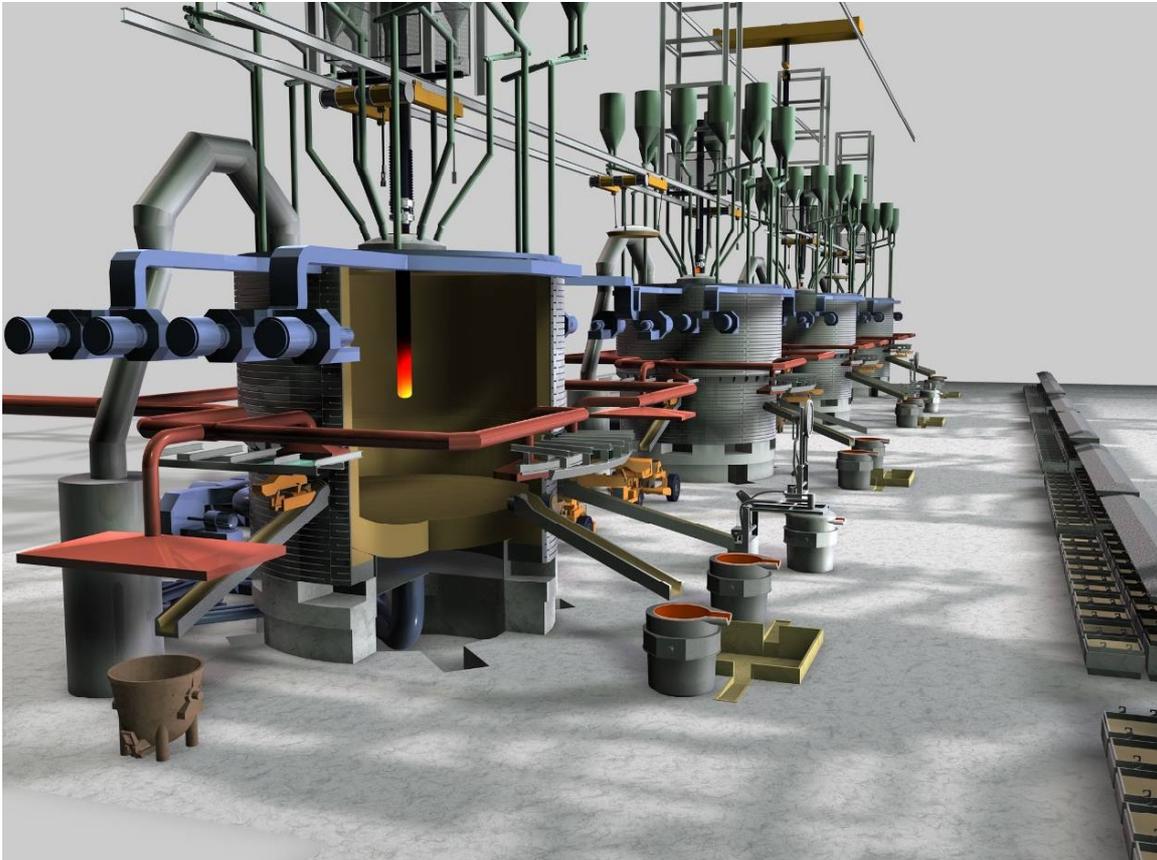


**Figure 4:** RHF-SAF combination for ferro alloy production

An illustration of a large-scale RHF-SAF combination is shown in Figure 4. The technical feasibility was demonstrated in the 1980s by SMS Siemag at pilot scale. Until today, there has been no large-scale unit operating based on this process route.

The increasing proportion of available fine ore has driven some ferrochrome producers to decide to process the material directly as fines. The application of DC furnaces was investigated in the 1970s in South Africa, due to the accumulation of huge stockpiles of FeCr ore fines. A first pilot 16 MVA furnace was operated at Palmiet Ferrochrome in Krugersdorp in South Africa in 1983, and five years later a 62 MVA furnace was commissioned at Middelburg Ferrochrome. Currently, there are two DC arc furnaces in operation at Samancor Chrome (40 MW and 60 MW), and two smaller units at Mogale Alloys in Mogale City / Krugersdorp. SMS Siemag is currently installing 4 x 72 MW

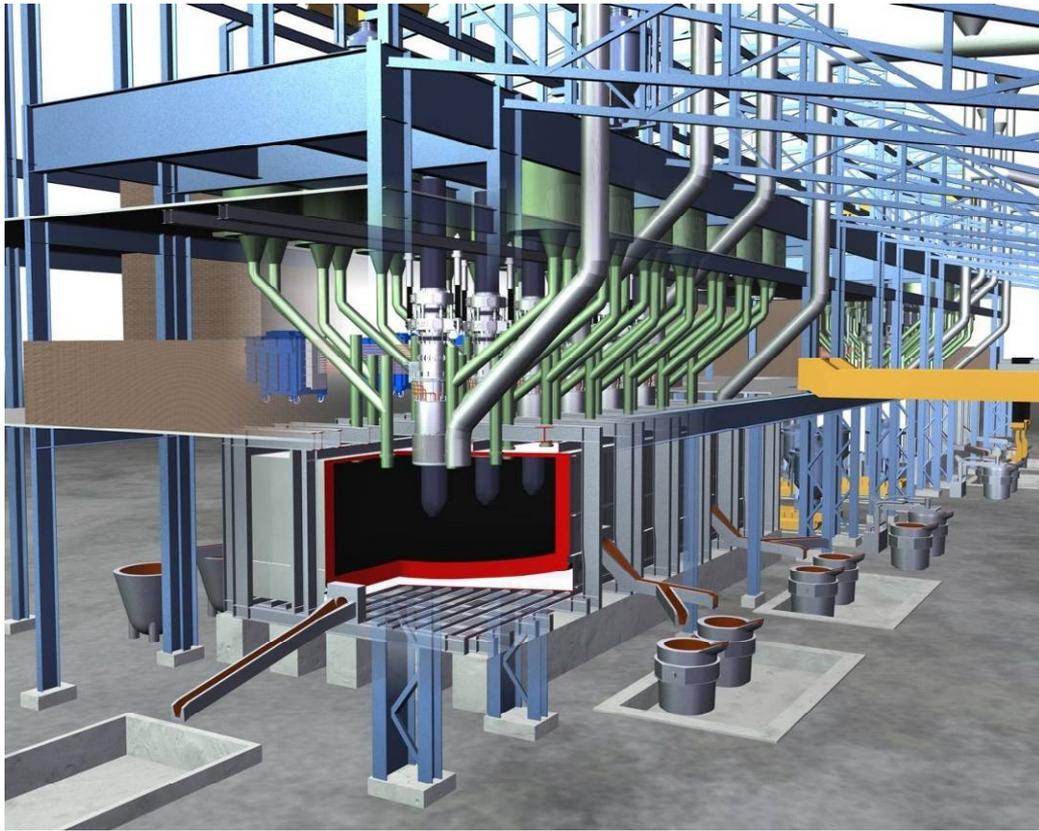
furnaces for Kazchrome in Kazakhstan. The units will produce approx. 440 000 tons per year of liquid ferrochrome<sup>4</sup>. The plant will also operate a converter shop with a capacity of 50 000 tons per year of medium-carbon ferrochrome. A preliminary layout of the plant is shown in Figure 5.



**Figure 5:** 3D illustration of a modern DC-based FeCr plant

### **Ferronickel**

Currently, the majority of the pyrometallurgical FeNi is produced in conventional AC-based arc furnaces<sup>8</sup>. The strong competitiveness of submerged-arc furnaces for ferro-alloys has been achieved mainly by the installation of advanced high-power smelting units. During the past decade, numerous improvements have been developed, providing efficient and safe operation with large-scale FeNi-furnaces. Today, modern ferro-nickel SAFs are characterized by high efficiency. In general, depending on the requested capacity, these may be round or rectangular-shaped furnaces<sup>11</sup> (see Figure 6). The choice is based mainly on the anticipated power input. SMS Siemag has found that where more than 60–70 MW of nominal furnace load is required, a rectangular furnace is the best solution from the technical, economical, and operational point of view. Below this capacity, the circular furnaces are the preferred solution<sup>12,13</sup>.



**Figure 6:** 3D Illustration of a modern rectangular FeNi plant

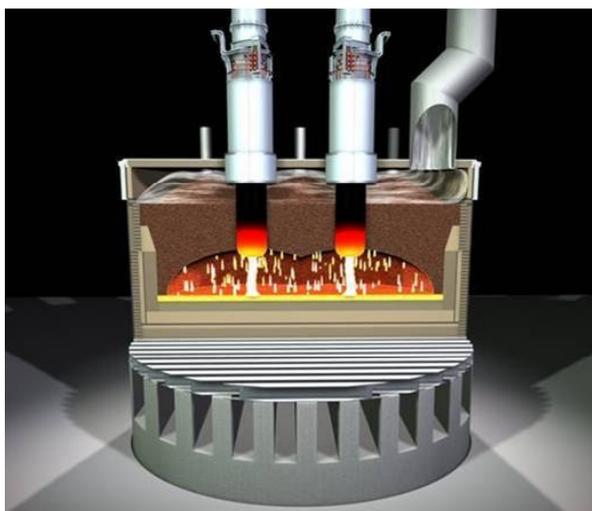
This new demand led to the development of various side-wall cooling concepts, as well as to the development of AC thyristor controls, which allow better operational control, higher and more efficient power input and less overall maintenance. Side-wall cooling and a thyristor control system are currently successfully in operation at a newly installed smelter for Eramet in New Caledonia, and are under construction for Anglo American and Vale in Brazil.

Several industries are also evaluating the potential for applying DC technology for the production of ferronickel. One project in New Caledonia has caused attention by using various sequences of fluidized beds in combination with a twin-electrode DC smelter. SMS Siemag does not see any benefit in comparison with the conventional approach. It is the opinion of SMS Siemag that the majority of submerged arc furnaces for FeNi production are, and will continue to be, AC technology based.

SMS Siemag follows this technological approach critically. The proposed DC process combines a calcination and smelting step, which are not proven on an industrial scale. Furthermore, SMS Siemag has concerns regarding the higher energy consumption due to lower thermal efficiency and lower lifetime of such a technological approach. The start-up and ramp-up of such technology is expected to be another challenging factor. Other companies are following up the development of twin-electrode DC furnaces for FeNi smelting. This technology might provide additional challenges in terms of roof integrity and process control. It will be interesting to follow this technology when it enters the commissioning stage.

## Ferromanganese

Over recent decades, SMS Siemag has designed and supplied several ferromanganese / silico-manganese SAFs around the world. In France, the world's largest FeMn-SiMn furnace is operating very successfully, processing alumina-rich Carajas ore from Brazil. The major part of the ore is charged as sinter into the furnace, which is nearly 20 metres in diameter, and has a 102 MVA transformer capacity<sup>14</sup>. An illustration of a typical FeMn furnace is shown in Figure 7.



**Figure 7:** Cross-section of an AC-based closed-type FeMn furnace

Today's ferro-alloy furnaces are designed with a compact high-current supply system, which minimizes the reactance of the furnace and maximizes the electrical efficiency.

SMS Siemag received an order for the supply of one semi-closed type 39 MVA AC FeMn furnace and one AOD converter, including raw material handling system, de-dusting unit, E-column, furnace proper, power supply, high-current system, and automation system. The plant will be commissioned during 2012.

The application of open-slag-bath DC technology for FeMn production is, from an economical point of view, not recommended. The Mn recovery of such a process is, due to excessive Mn-vaporization, fairly poor.

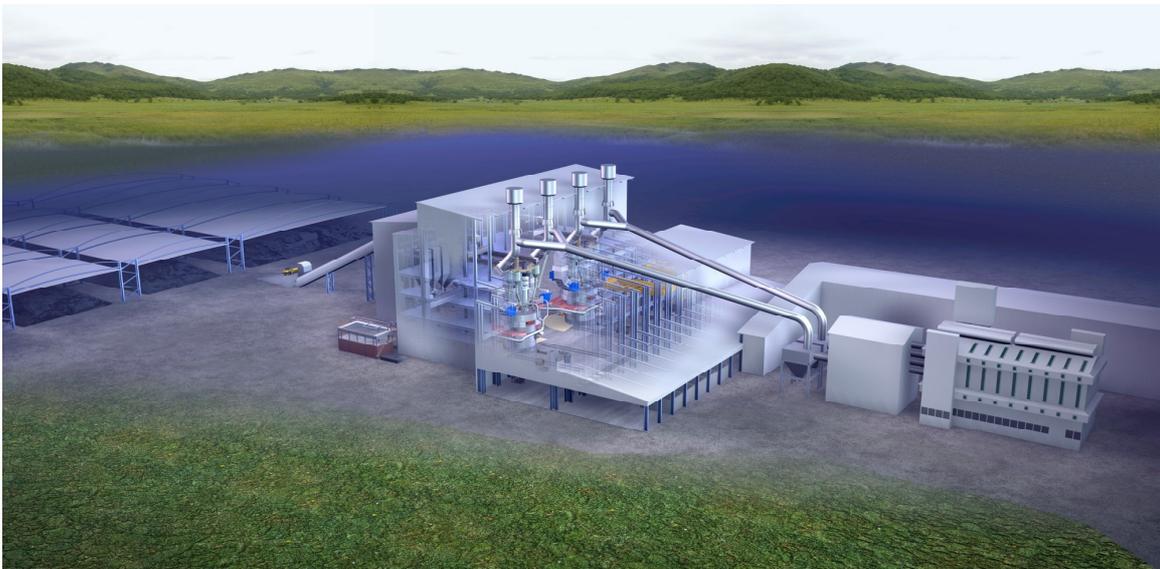
## Silicon metal and FeSi

SMS Siemag has supplied the majority of large-scale submerged-arc furnaces for FeSi and silicon metal production, which typically operate at 12 to 22 MW. The demand for high-grade silicon is growing, mainly due to increasing demand from aluminium, silicon, and other industries. A large-scale modern Si-metal plant is shown in Figure 8.

The process requires an energy input of about 12 MWh per ton of silicon, with high-quality raw materials, such as high-quality quartz and low ash reductants. It is sometimes economically feasible to install energy recovery systems. The

specially designed furnace hood allows an off-gas temperature of approximately 600 to 800°C. Additionally, the patented fume exhaust gas is injected in the hood, which eliminates the necessity for a bag-house for the secondary de-dusting system in this area<sup>15</sup>.

The company RWS in Bavaria, southern Germany, has awarded a contract to SMS Siemag to revamp its old # 4 furnace. The furnace # 4 (former Demag furnace) was commissioned in 1955 and is still in operation. SMS Siemag supplied three electrode columns of its latest design and a new water-cooled gas hood.



**Figure 8:** 3D illustration of a modern Si-metal plant

SMS Siemag is at present supplying two furnaces for Si-metal production, each of 30 MVA transformer capacity. The scheduled annual production capacity is 24 000 tons per annum of Si-metal. The first furnace was commissioned in the fourth quarter of 2010.

Besides the furnaces themselves, the entire plant engineering, from raw material handling to packing of the final product (four different grain sizes of Si-metal) falls under SMS Siemag's scope. The contractual partner of SMS Siemag is Thyssen Krupp Mannex (TKM). The end customer is BASCO COMPANY with its subsidiary TOO 'SILICIUM KAZAKHSTAN', Almaty, Kazakhstan, which has been newly established to operate the plant (see Figure 9).



**Figure 9:** Si-metal plant for BASCO

In April 2008, SMS Siemag received an order from Bluestar for the supply of two 30 MVA Si-metal furnaces. Their capacity is comparable to the Basco project.

SMS Siemag is of the opinion that DC technology is not applicable for the production of raw silicon metal. A Scandinavian company is considering using DC furnaces for the refining of the Si-metal to high-grade solar Si-metal.

### **TiO<sub>2</sub>**

Ilmenite smelting can be carried out in a DC or AC furnace, depending mainly on the preference of the producer. In this process, pre-treated ilmenite ore is smelted in an electric furnace to form TiO<sub>2</sub>-rich slag and hot metal (pig iron), as illustrated in Figure 10. Most TiO<sub>2</sub> slag is produced in AC furnaces. Numerous AC-based plants are in operation in Scandinavia, Canada, China, and South Africa. During the past two decades, a number of companies have also implemented DC technology.

SMS Siemag was strongly involved in the introduction of DC technology in this segment. The first furnaces were developed in the 1990s for Namakwa Sands (1 x 25 MW and 1 x 36 MW) and Ticor (2 x 36 MW) in South Africa. The Namakwa Sands smelter was commissioned in 1999, and Ticor in 2003. SMS Siemag supplied the two Ticor furnaces, and provided some key equipment for the Namakwa Sands furnaces.



**Figure 10:** Slag and metal tapping area of a DC-based TiO<sub>2</sub> smelter

SMS Siemag's most recent reference in  $\text{TiO}_2$  smelting is a 30 MW (36 MVA) DC smelter for XinLi in Kunming, China, which was commissioned this year<sup>4</sup>.

### PGM smelting

Mintek has developed an alternative technological solution, compared to the conventional AC-based matte-smelting furnace, for the smelting of platinum group metals (PGMs). This process, known as ConRoast, is centred on the smelting of low-sulphur feed materials in a DC arc furnace, resulting in the production of an iron-based alloy<sup>13</sup>. The sulphide concentrate is dead-roasted in a continuous fluidized-bed roaster. Successful pilot-plant smelting tests on UG2 concentrates at Mintek demonstrated the technical feasibility of this process<sup>13</sup>.

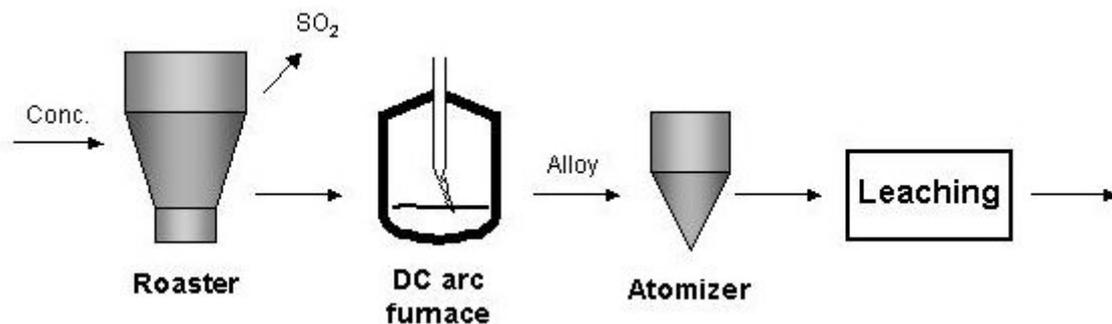


Figure 11: Basic flowsheet of the ConRoast process

### Test furnace at the IME in Aachen/Germany

SMS Siemag has recently supplied a new electric smelter test furnace to the IME (Institute for Metallurgical Processes and Metal Recycling) at the Technical University of Aachen/Germany.

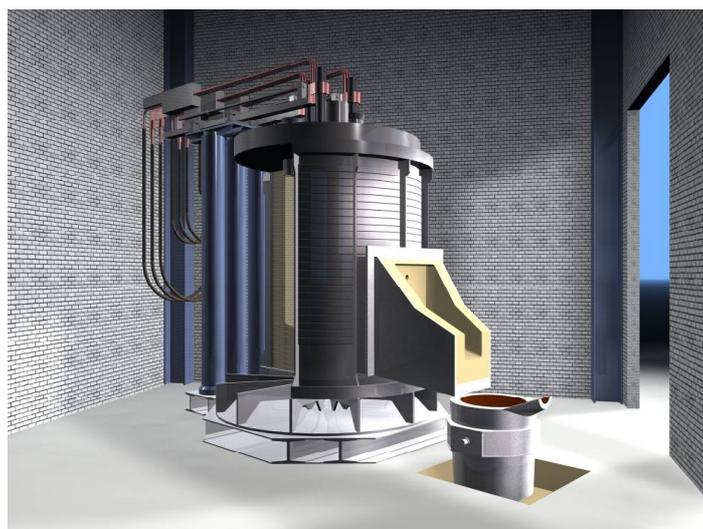


Figure 12: New AC/DC-based 1 MVA test furnace at the IME in Aachen/Germany

The unit will allow the testing of various metallurgical smelting processes, such as steel production, ferro-alloys, non-ferrous metals, mineral wool, slag

cleaning, steel-mill waste recycling, and also the recycling of non-ferrous wastes and ferroalloy residues, in DC as well as AC mode (see Figure 8). This will provide important comparative results between the two basic process principles<sup>4</sup>.

The heart of the 1 MVA furnace is an intelligent power connection allowing the following modes:

- Three-electrode AC operation mode
- Two-electrode AC mode
- One-three-electrode DC mode

The furnace is equipped with a conductive hearth. The charge can be fed either via charging tubes or hollow electrodes, which facilitates the evaluation of optimized feeding patterns. The unique multiple-section design allows the testing of various side-wall cooling systems, such as spray cooling, channel cooling, and intensive copper cooling. The size of the furnace would provide important information for the scale-up of new processes. SMS Siemag expects the furnace to be commissioned shortly.

## **CONCLUSIONS AND OUTLOOK**

The first SAF was commissioned more than 100 years ago in Germany. Since then, the remarkable development of this smelting tool has been recognized all over the world, and submerged-arc furnaces are now operating in at least twenty different industrial fields. SMS Siemag looks back proudly on the significant role of the company in the history of this unique and highly efficient unit - for AC-based furnaces as well as for DC-based furnaces. Today especially the potential of DC-based smelters raises worldwide attention and some projects have already started to implement this kind of technology. Many pyrometallurgical processes can be carried out in either AC or DC furnaces. Depending on the local conditions, SMS Siemag sees good potential for DC technology, especially in FeCr and TiO<sub>2</sub>-slag applications. SMS Siemag believes that DC application potential for the production of other ferro-alloy products, due to technological and economical reasons, is limited. With ongoing innovation and adaptation to customer and market requests, we are convinced that the units will also be successful in the future. To avoid conclusions based just on traditional views, SMS Siemag has started a longer-term research and development project. The investigation regarding the comparison of AC versus DC is jointly carried out with the Technical University in Aachen/Germany.

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### **Rolf Degel**

*GM Submerged Arc Furnaces and Electric Smelters, SMS Siemag AG*

Rolf graduated from the University of Aachen in 1996, and then went to work for NSM in Chonburi, Thailand, as GM of the DRI plant and head of R & D. In 1999, he was appointed as Senior Sales Manager for SMS Siemag in Pittsburgh, USA. He has been in his current position as General Manager, Submerged Arc Furnaces and Electric Smelters, for SMS Siemag in Düsseldorf/Germany, since 2002.

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