# Implementation of the first commercial scale DC smelter for ferronickel production from low grade laterite ores—technology building blocks and lessens learned

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## Synopsis

Mechel, a large, integrated steel, stainless steel, and ferroalloy producer in Russia is committed to upgrading its facilities to world class pyrometallurgical process and environmental practice. Yuzhural Nickel currently uses shaft furnaces to produce a matte containing iron, nickel and traces of cobalt. This rather old technology is thermally inefficient and is characterized by high operating costs. Mechel has investigated suitable equipment and processes to upgrade the plant, and awarded a contract for the construction of a 12 MW DC smelter, located near the town of Orsk, to Bateman Engineering Projects in June 2008. The selection of DC furnace technology for laterite smelting can be considered as a strategic highlight for the pyrometallurgical treatment of low-grade lateritic ores, and could be the first industrial-scale implementation of this technology.

This project has been designed to achieve multiple goals including the demonstration of the process and associated equipment technology at commercial scale, to confirm the scale-up design parameters of the forthcoming 2 x 90 MW, twin electrode DC furnaces, and to prove the environmental emission superiority of closed furnaces. It also provides a valuable operator training platform. This paper deals with the process design, key technology building blocks and design features which have been incorporated to produce a pyrometallurgical vessel capable of (i) resisting slag superheat and chemical aggressiveness, (ii) process fine material without pre-agglomeration, (iii) achieve high nickel recoveries and (iv) being tolerant to the variations in chemical composition of laterite ore. The approach to increasing campaign lives between partial and complete rebuilds, through the use of composite furnace module (CFM) technology originally developed and patented by the University of Melbourne, is also followed in more detail. Unfortunately, results from hot commissioning and lessons learned from initial operation are not available because the project completion has been delayed due to the worldwide downturn in demand for commodities.



**Keywords**

DC furnace, ferronickel laterite smelting, corrosive slag, copper cooler technology.


## Introduction

Yuzhural Nickel, part of the Mechel group, produces nickel from locally mined laterite ore in shaft furnaces. The ore is mixed with coke and pyrites before being sintered in Dwight-Lloyd type sinter machines to produce a lumpy material with the necessary permeability characteristics required by the shaft furnace operation. The hot sinter is transferred to the smelter building in railway wagons, unloaded, elevated to the furnace charge floor and tipped sideways into the top of the furnaces. Large volumes of air are blown through the furnace to sustain the process conditions, and a synthetic matte is periodically tapped. The slag is water granulated and removed from the site by rail. The plant is environmentally unfriendly due to the multiple handling of the sinter, and the discharge of raw furnace off-gas. Much of the heat content in the sinter material is lost during transportation to the smelter, reducing the overall thermal efficiency. The cost of metallurgical coke and low process efficiency makes the plant economically uncompetitive compared to modern rotary hearth—electric furnace (RKEF) smelting operations.

Mechel approached Bateman in early 2006 to undertake various studies in order to establish the economic feasibility of converting the Yuzhural Nickel Plant to DC arc smelting integrated with the existing sinter plant or alternatively employing modern flash preheaters. This process route, a competitor to RKEF smelting was preferred because the technology is able to smelt raw material with a wide particle size distribution range and variable chemical composition, producing a ferronickel alloy of consistent grade and metallurgical recovery. This has been demonstrated several times at small scale[1,2]. Falconbridge have developed a flowsheet incorporating a flash preheater, fluid bed pre-reduction stage and 2 x 80 MW DC furnaces, for their Koniambo project in New Caledonia[3].

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This culminated in a decision by Mechel to proceed to a DC arc demonstration smelter project with an installed power of 12 MW. The factors influencing the decision included the generation of acceptable scale-up parameters to the final plant capacity of 2 x 90 MW based on the capacity of the existing sinter machines; verification of all process design criteria; an opportunity to produce saleable product to recover the capital costs of the facility; representative production of alloy to develop downstream refining and extraction processes; and provision of an operator training platform to develop the operational skills necessary for the conversion of the plant from thermal to electric smelting.

The project constraints included the location of the demonstration smelter within an existing building, which is equipped with an electric overhead travelling crane, to save capital and reduce the construction duration in harsh Russian climatic conditions; interface with sinter handling logistics and slag disposal systems within the existing plant; and make use of existing plant utility infrastructure. The plant was designed to comply with all regional heath, safety and environmental legislation, and demonstrate compliance with future western emission standards which are anticipated to become more stringent.

The contract was awarded in April 2008, and was scheduled for commissioning in early 2010. Design and equipment procurement was carried out on a fast-track basis to match the tight schedule, and provide the necessary data for regulatory authority approval, customs classification and design data for Mechel's structural, civil and electrical consultants. All equipment will be delivered by the end of 2009. Unfortunately, the construction of the project has been delayed due to the downturn in the worldwide commodity market and is now due for commissioning late 2010/early 2011. The planned report on lessons learned from the commissioning and performance testing are therefore deferred to a future paper.

## Raw material selection

The demonstration plant will utilize sinter diverted from the normal feed stream to the blast furnaces, anthracite and dolomite to produce a crude ferronickel product (Table I).

The sinter will be stored on a stockpile prior to crushing in a jaw crusher to obtain the required particle size distribution for which the furnace feed system has been designed to handle. A decision was made not to reheat the crushed sinter to the temperatures anticipated in the future commercial plant (600°C–900°C) as the effect of hot feed on the process specific energy requirement (SER) can be estimated directly without the need for demonstration. The residence time on the stockpile and significant changes in ambient conditions throughout the year have made it difficult to predict the sinter feed temperature. The sinter-to-power ratio (SPR) control algorithm has been designed to compensate for this variable over a range of 0°C–200°C.

The sinter contains significant amounts of carbon; therefore, accurate control of the anthracite-to-sinter ratio (ASR) is required to maintain a balance between product grade/recovery and the optimum slag conditions. As the ASR is increased, the slag becomes depleted of nickel (and any cobalt present) and reduction of iron oxide increases (see Figure 1). This causes a marginal increase in nickel recovery which is then offset by the decrease in alloy grade, reducing the effective value of the product. Also, the slag liquidus temperature will increase, resulting in a high viscosity slag which is difficult to tap and more prone to foaming. A decrease in the ASR will improve the alloy grade which in turn is offset by low nickel and iron recoveries. The slag liquidus temperature will decrease as the iron oxide increases which will assist slag tapping; however, the slag freeze lining is at risk of dissolving and exposing the lower side wall furnace containment components to the aggressive slag.

The addition of flux (dolomite) has been allowed for in the design to modify the slag properties in order to obtain the necessary viscosity and liquidus temperature without compromising product grade.

## Flowsheet development

The smelting of low grade laterite ores using DC furnace technology is well established[1,2]. The process principles and grade-recovery performance are similar to the cobalt from slag recovery process which has been in commercial scale operation at Chambishi (PLC), Zambia for some eight years[4].

*Table I*

**Guaranteed sinter, anthracite and dolomite parameters**

| Item | Unit | Sinter | Anthracite | Dolomite |
|---|---|---|---|---|
| Ni | Mass % (Dry) | > 1.1 | - | - |
| Fe | Mass % (Dry) | 22.15–23.7 | - | - |
| $SiO_2$ | Mass % (Dry) | 43.5–45 | - | - |
| MgO | Mass % (Dry) | 9.59–10.25 | - | 19 |
| CaO | Mass % (Dry) | - | - | 30 |
| C | Mass % (Dry) | 1.47–1.6 | 79.59–80.44 | - |
| Ash | Mass % (Dry) | - | 17.18–18.02 | - |
| Volatiles | Mass % (Dry) | - | 2.82–2.92 | - |
| LOI | Mass % (Dry) | 0.6–0.7 | - | - |
| Size | mm | < 30 | 1–10 | 5–25 |
| Temperature | Deg C | < 200 | Ambient | Ambient |

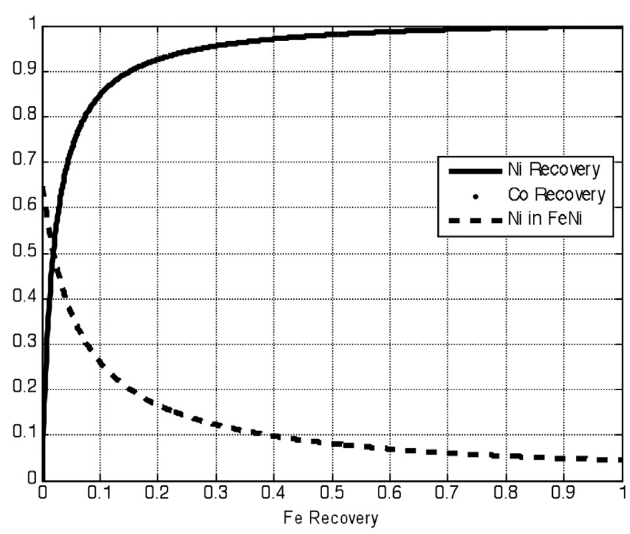


**Figure 1—Relationship between Ni, Co and Fe recoveries and alloy Ni content[2,4]**

The future smelting facility will utilize, together with the DC furnace, the latest proven technology in the field of laterite smelting which includes the following key technology building blocks:

- Wet scrubber technology to cool and clean the furnace off gas and recover the energy contained in the gas by utilizing it as fuel source to the driers, preheaters and other possible consumers.
- Alloy granulation of the refined FeNi product.
- Slag granulation, since slag pot hauling is an impractical option due to the harsh climatic conditions and high slag volumes produced.

The design of the demonstration plant was kept as similar as possible to the design envisaged for the future expansion project; however, due to several constraints (as discussed in subsequent sections) the design in some of the areas was revised, which resulted in new designs that may prove advantageous in the future.

## Key technology building blocks

### *Feed system*

Conventional feed system design incorporates elevation of the raw materials to furnace intermediate storage bins within the smelter building followed by feed rate (dosing) control and final distribution over the molten bath area of the furnace vessel by gravity. The design of the feed system for the demonstration furnace was constrained by the existing building height and the requirement to reuse the existing feed conveyor gantry of the crushing plant previously housed in this building. Preliminary layout work established that one elevation stage and gravity feed for raw material distribution would not be possible within the available height. This resulted in the need to transfer the blended material to the elevated final feed distribution system above the furnace by conveyor. The feed is distributed to two ports in the refractory dome adjacent to the electrode by means of vibratory feeders. The feed system therefore requires two feed controls systems—one to obtain the desired feed recipe, and one to maintain the level in the feed distribution hopper. The residence time in the distribution hopper and the transfer time across the conveyor have necessitated minor time delay compensation algorithms for both SPR and ASR control. This level of complexity was unavoidable for the demonstration plant, and will not be repeated in the commercial installation.

The electrical isolation dome of the furnace containing the electrode port and the two feed ports is a high wear item which requires periodic replacement. This is caused by thermal radiation exposure to the superheated slag pool associated with the arc attachment point, as well as blow-back of high temperature gases deflected towards the roof by the saucer shaped arc depression zone in the slag. A solution was sought to avoid excessive dismantling of the feed system in order for the building crane hook to gain unobstructed access to the roof, thereby allowing the spent dome to be rapidly lifted out and new dome to be installed. The design which evolved incorporates a gantry on wheels which supports the transfer conveyor, blended feed hopper and distribution vibratory feeders. The feed system is disconnected from the batching hoppers and the furnace feed ports, and the entire structure is winched away from the furnace, providing clear access to the roof. The performance of this concept during operation will provide valuable guidelines for the design of a removable feed system for the commercial unit (Figure 2).

### *Furnace vessel design*

The critical area of the process containment vessel is the lower side wall in contact with the molten contents of the furnace. The slag produced by the process is unsaturated in magnesite (MgO), and contains between 200°C and 400°C of superheat above its solidification temperature. The open bath operation associated with DC smelting allows fresh, unsaturated slag to wash against the refractory lining, resulting in continuous dissolution of any MgO refractory lining constituents into the slag. A ceramic lining capable of resisting this condition for acceptable vessel campaign durations has not been established.

A recent example is the slag cleaning furnace at BHP Billiton's Olympic Dam Operation (ODO), which produces a slag with similar chemical composition to that of laterite smelting. The MgO lining cooled by means of an external falling film was achieving campaign lives of 11–13 months[5]. Different formulations of MgO bricks produced incremental improvements, and an alternative solution was sought.

The University of Melbourne developed a copper panel and refractory composite, later named composite furnace module (CFM) technology, which was demonstrated to be capable of resisting the corrosive slag during trial tests in the ODO slag cleaning furnace[5]. The module consists of a copper base panel incorporating water cooling passages. Pins are cast onto the hot face of the panel, and refractory is cast into the space between the pins. The resulting composite is

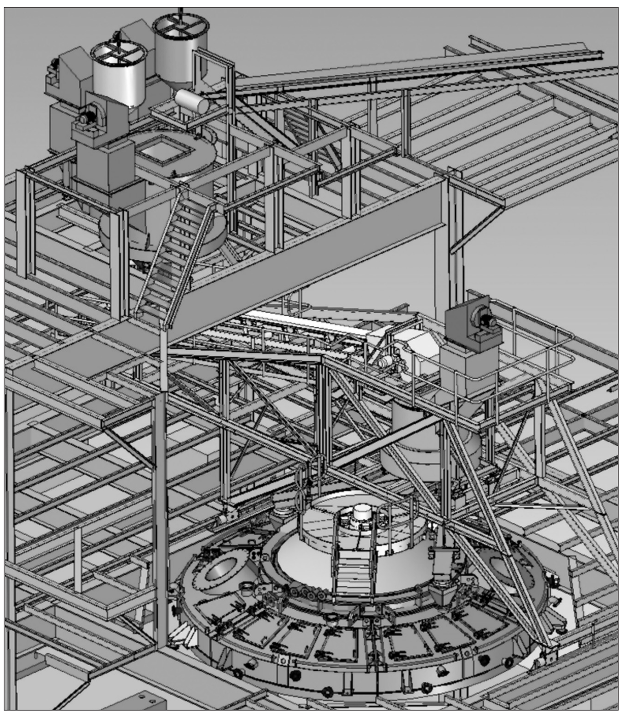

Figure 2—3D CAD rendering of the furnace feed system

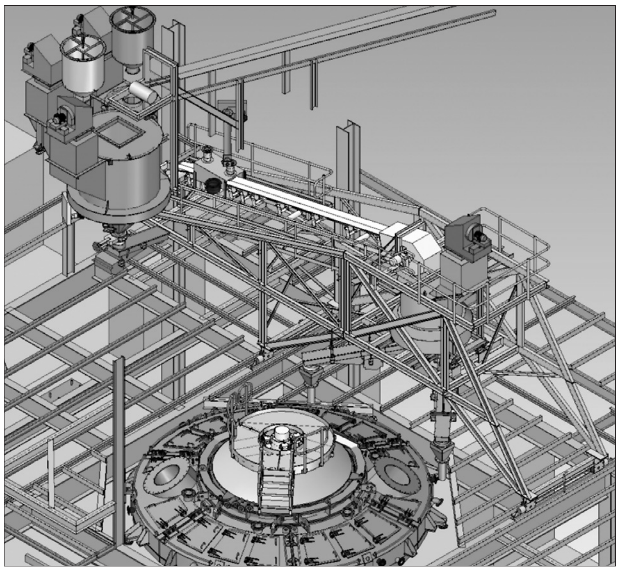

Figure 3—3D CAD rendering of the removal gantry in the maintenance position

capable of conducting a heat flux of such a magnitude that the temperature in the slag boundary layer adjacent to the hot face of the panel is depressed to its solidification temperature. This causes a freeze lining comprised of slag constituents to form on the refractory, thereby protecting the refractory from further corrosion. Experience has demonstrated that the freeze lining is vulnerable to periodic, localized failure caused by thermal gradient induced stresses in the plane of the lining, as well as process disturbances including chemical composition changes and process temperature fluctuations. However, the sudden increase in heat flux when the lining breaks away results in the rapid formation of a new layer, thereby forming a refractory lining of virtually unlimited life. The trial panel was ultimately commercialized when the lower sidewall lining was replaced with CFMs fitted with cast-in monel water passages during the 2003 shutdown, and the replacement refractory lining is still in operation.

The major advantages of the CFM concept are the customization of the pin configuration to suit the heat flux capacity and freeze lining formation in different zones of the furnace, customization to suit different processes, virtually uniform temperature distribution in the plane of the hot face which limits thermally induced stress failure in both the freeze lining and the underlying refractory matrix, and geometric configurability to suit a wide range of application including slag tapholes, metal tapholes, and off gas ports. This was further demonstrated when a lower sidewall CFM lining was designed and installed in a trial furnace for the Shevchenko laterite ore smelting campaign at Mintek in 2005, which formed part of a definitive feasibility study (DFS) to facilitate Oriel Resource's attempt to advance the exploitation of laterite orebodies in Kazakhstan[6]. The autopsy of the trial furnace lining at the end of the campaign clearly demonstrated the suitability of CFM technology for laterite processing.

The lessons learned from this campaign as well as the operational data available from ODO were used to design the lower side wall of the Mechel 12 MW demonstration smelter. The iterative design procedure and computational fluid dynamics (CFD) conjugate heat transfer analysis to achieve the simultaneous convergence of layout, thermal duty and project schedule constraints is documented in another Infacon XII paper[7].

The Mechel lower side wall is comprised of 16 panels, each covering a 22.5 degree arc segment. Two panels have cut-outs for the slag taphole inserts and two panels have cut-outs for the alloy tapholes. All the panels are fitted with dual cooling coils, each capable of operation at the maximum design heat flux to provide online back-up if one coil develops a leak. Dual thermocouples are installed in sleeves cast into the core of strategically selected pins which facilitate heat flux and lining status monitoring, providing the operators with an early warning of incipient lining failure and process disturbances. The panels are designed to support the upper side wall without assistance from a conventional, full cylindrical shell, so the backs of the panels are completely exposed to the outside. This combined with the wedge shaped coolers installed between the top of the panels and the upper side wall refractory support beam facilitate easy replacement of an individual cooler without a major shutdown in the unlikely event of a catastrophic localized failure (typically stray arc strike or metal ingress into a water passages). The panels are supported from two brick courses which are primarily in contact with the alloy. Finite element analysis (FEA) was used to demonstrate that this is the optimal configuration to prevent excessive heating of the panel footings by contact with the alloy, while providing sufficient cooling to prevent excessive corrosive and erosive wear from the movement of the slag-metal interface. The weight of the coolers, the entire upper sidewall and roof are applied to the hearth skew back bricks, thereby maximizing stability of the hearth, and ensuring tight joints between adjacent refractory courses.

Slag is tapped directly through the slag taphole insert. The pins of the insert are configured to follow the anticipated wear profile of the taphole as it ages. Experience confirmed by CFD analysis has shown that this provides the optimal trade-off between wear, ease of tapping, and taphole stability after plugging by the clay gun. The cooling coils of the insert are configured in an inverted 'U' shape around the taphole to provide security against slag burn through into the water passages caused by downward migration of the tap channel as the insert wears. The insert is designed to facilitate ease of replacement without disturbing the main panel which supports it.

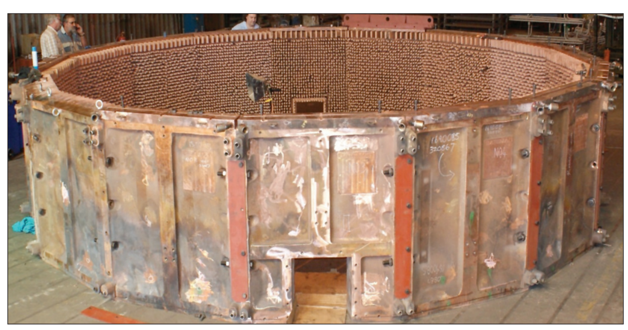

Figure 4—Shop assembly of the 12 MW DC furnace CFM sidewall cooling panels

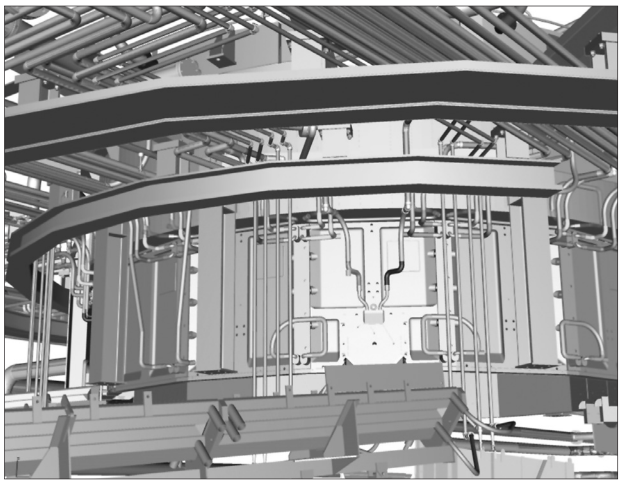

Figure 5—3D CAD rendering of the cooling water piping around the CFM

The alloy taphole insert is configured in the shape of a door frame, and houses conventional refractory taphole blocks. The design philosophy for cooling coil configuration and replacement is similar to that of the slag taphole insert. The geometry of the opening is designed to interface with standard block shapes, allowing a suitable margin for partial repair from the outside, while ensuring a tight fit to provide adequate cooling of the refractory composite. The alloy taphole is fitted with an external copper block housing a replaceable, conical shaped silicon carbide insert. The block is fitted with an inverted 'U' shaped cooling coil to protect the silicon carbide. The entire taphole assembly is designed so that first line maintenance is carried out on the silicon carbide insert and taphole block, second line maintenance on the refractory taphole blocks in the front of the insert, and third line maintenance by removal of the taphole insert without disturbing the panel which supports the taphole assembly. This is designed to maximize the campaign life of the highest wearing component of the furnace containment system.

### *Anode*

The anode is based on the design originally developed and patented by ABB/Concast Standard. It forms the hearth (bottom) of the furnace and takes the form of a spherical dish. In vertical cross-section, working from the outside to the inside through the conductive portion of the hearth, the anode is comprised of the primary structural support steelwork dish, strengthened by radial beams, to which the copper current collector dish and anode terminals are mounted. The safety lining conductive refractory bricks, in this case carbon impregnated magnesite bricks, are placed in contact with the copper collector plate on a bed of graphite powder which simultaneously smoothes out construction tolerance irregularities and ensures electrical continuity. The working lining is comprised of double taper magnesite bricks ground to tight tolerances with a stainless steel plate (or clad) bent in an 'L' shape attached to one vertical face and the bottom of the brick. These bricks are placed on top of the safety lining on a layer of graphite powder, analogous to the description of the back-up lining.

In the radial direction, the central core of the anode is constructed of electrically isolating bricks of the same geometry as the conducting bricks. The core is surrounded by a doughnut shaped ring of conducting bricks. The space between the edge of the conducting bricks and the periphery of the hearth is filled with non-conducting bricks similar to the core of the hearth. This ensures that the electrically active portion of the anode is isolated from the hearth periphery and shell. The transition from the dish shaped refractory material to a cylindrical ring of bricks is formed by the so-called skew back bricks, which transfer thermal expansion forces from the tangent to the dish to tensile circumferential forces in the lower shell. The peripheral brick ring is separated from the lower furnace shell by a layer of refractory with a specific crushing characteristic. All bricks are installed in a regular pattern, including provision for expansion papers. The thickness and intervals of the papers, together with the crush zone allow for absorption of 90% of the overall expansion of the refractory material hot face. The balance of the expansion causes tension in the cylindrical shell and provides the binding force to close the vertical gaps between the bricks, as well as a certain amount of downward pressure through the cross-section of the hearth to promote electrical continuity. Maintaining tight vertical joints is critical to preventing metal penetration into the refractory composite which increases wear and inhibits arch buckling instability promoted by buoyancy forces generated if the bricks become effectively immersed in a metal bath.

The bottom of the anode is force air cooled to remove the heat conducted through the refractory composite and maintain the freeze isotherm of the alloy as close to the refractory hot face as practicable to limit wear of the lining. This anode configuration provides uniform current distribution across the hearth coupled with even heat flux distribution from the process to the cooling air. This avoids the formation of hot spots, formation of thermally induced stress concentrations and ensures that the arc does not favour a particular radial deflection towards a zone of lowest electrical

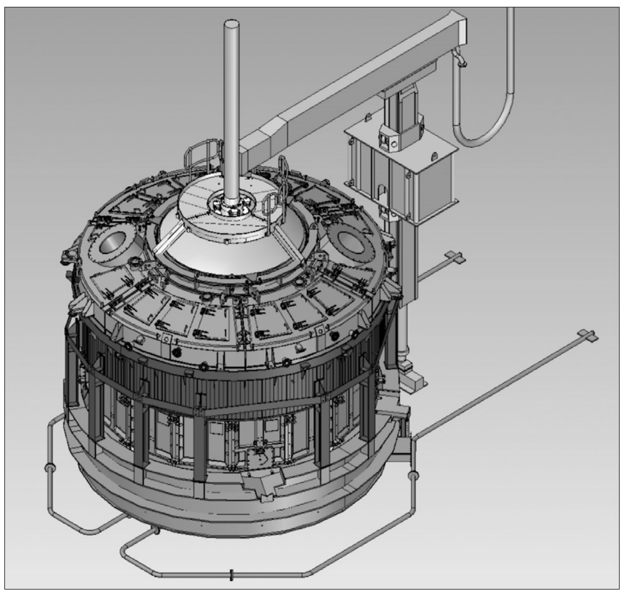

Figure 6—3D CAD rendering of the 12 MW DC furnace

resistance. The edges of the stainless steel plates in contact with the process are gradually replaced by alloy to the level of the freeze isotherm, which protects the rest of the cladding from further attack.

### *Slag granulation*

Processing of low grade laterite ores is similar to slag cleaning operations in which slag handling dominates metal/alloy production rates. A key technology building block which requires operational demonstration in the variable Russian climate is a continuous slag granulation system. Although Mechel currently granulate the slag produced by the blast furnaces using water, the specific technology proposed for the future plant was incorporated within the space constraints of the existing plant to verify granulate particle size distribution and product dewatering performance (Figure 7).

The furnace is equipped with one duty and one standby taphole. They will be swapped over approximately once per day to allow for self repair of the taphole freeze lining and planned maintenance (depending on operational experience). The slag from each taphole is directed to the granulation launder via inclined, water cooled slag launder which is supported on a hydraulically actuated mechanism to allow for rapid changeover from normal to emergency slag ladle operation. Two granulation launders (also used alternatively) are provided which enter the primary granulation tank tangentially. As the slag is discharged from the water cooled launders, it is contacted with high pressure water flowing from two horizontal nozzle slots, located one above the other. The top water jet facilitates primary granulation, and the lower jet granulates any slag which breaks through the upper jet and simultaneously provides the sluicing water to transport the slurry into the tank. The tangential flow of water into the tank promotes a cyclonic action which enhances solid separation. Warm water is discharged under gravity flow to the return water pumps via the centrally located, baffled overflow pipe. This arrangement maximizes the initial solid-liquid separation. The granulation thermal energy is dissipated in conventional open circuit cooling towers equipped with clog resistant packing material.

The slurry concentrated in the lower conical section of the granulation tank is fluidized by auxiliary water jets, and discharged to the dewatering screen equipped with 250 micron slotted type screen panels by the slurry extraction pumps. Previous test work has demonstrated that the autogenous filter bed forming on the screen is capable of dewatering the screen overflow to 8–10% water content while only allowing particles < 50 micron to report to the underflow. The dewatered granulate is discharged from the smelter via a conveyor installed in the tunnel previously used to discharged crusher product. The screen underflow is pumped to a hydrocyclone. The dirty water from the cyclone overflow is discharged back into the granulation tank, and the underflow is discharged on top of the filter bed on the screen.

### *Alloy granulation*

Alloy granulation of refined FeNi alloy is proposed for the production of saleable product in the future plant. Hence a granulation process demonstrating the ability to produce alloy nodules of the required particle size distribution without the excessive fines generation was included in the smelter design. Refining (typically sulphur and phosphate removal) was not included for demonstration as third party technology is available and the granulation performance of crude and refined alloy is anticipated to be similar. Although the plant compactness is important for countries with harsh climates to save building sizes and costs, particular attention was paid to the layout of this area of the smelter because of space constraints in the existing building. In addition, optimization of alloy ladle handling logistics also influenced the layout and design of equipment (Figure 8).

Alloy is tapped from one of two tapholes alternatively by conventional drilling and oxygen lancing in batches, and flows under gravity via refractory lined runners into the alloy ladle. The alloy ladle is supported on a combined tilting machine-transfer car, normally located in one of four positions—the ladle preheater station, below either of the two alloy runners, or in the granulation position. The layout includes provision for alloy discharge under various emergency scenarios including self-tapping and emergency dumping. This design was developed to avoid the need to move and accurately position the ladle by means of the

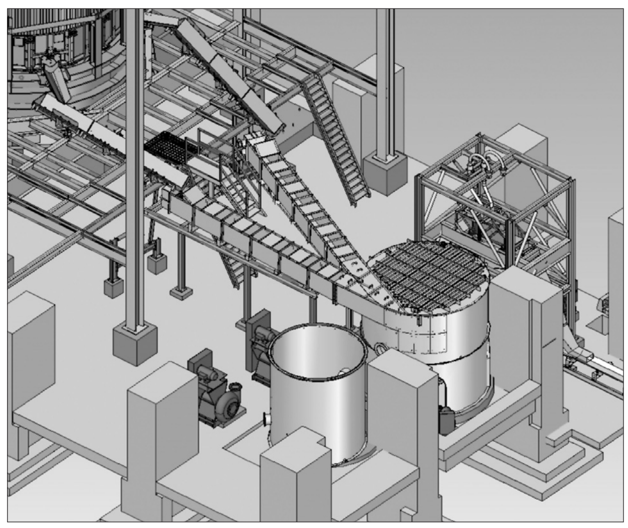

**Figure 7—3D CAD rendering of the slag granulation area**

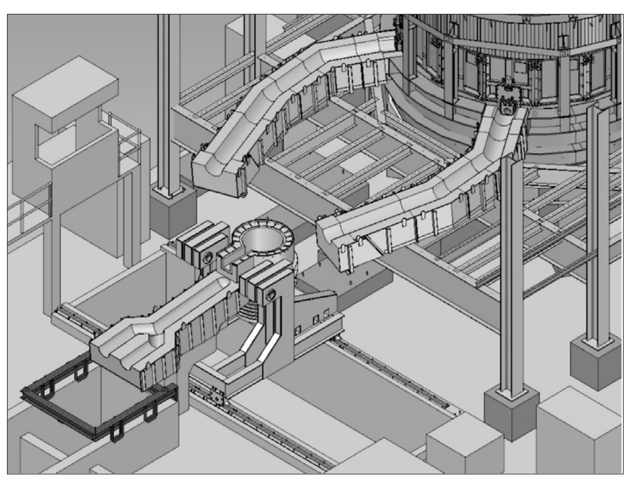

**Figure 8—3D CAD rendering of the alloy granulation area**

overhead crane in the restricted space available. This keeps the ladle handling time between end of tap and start of granulation to a minimum, thereby limiting the tapped alloy superheat required to minimize residual ladle scrap, and prolonging the vessel refractory life by limiting the average process operating temperature.

Once the taphole is closed by means of the conventional clay gun, the transfer car is aligned with the granulation runner. The ladle is tilted at high speed until molten material is first discharged into the runner, after which the ladle is tilted at slow speed to achieve the design granulation flow rate. The alloy flows under gravity to the end of the bifurcated runner, terminating in two streams discharging into the granulation sump filled with water. The drop height is optimized to allow for initial fragmentation and air cooling of the stream before the droplets contact the water surface, while limiting the entry velocity. The sump depth is designed to allow for outer layer solidification of the largest nodules while in free fall to the bottom of the sump. Nozzles positioned strategically within the sump discharge recooled, high pressure water to increase the effective free-fall retention time, increase heat transfer between the nodules and the water, and promote vapour release, while turbulence generation is minimized to avoid excessive fines generation. Monitoring the sump water temperature is critical to ensure safe operation; safety interlocks in the control algorithm will automatically prevent further granulation should an unsafe condition develop.

The nodules are collected in a stainless steel hopper which is submerged in the sump by the overhead crane prior to the start of a granulation run. The bifurcated runner is removed for cleaning and maintenance at the end of a granulation run, and allows for the extraction of the loaded granulate collection hopper by the crane. Water drains from the hopper through nozzles equipped with fines retention baffles when the hopper is lifted clear of the water surface. Granulate is discharged by tilting the hopper with the auxiliary crane hoist.

The granulation cooling process water is cooled in conventional, open circuit cooling towers. Cooling is maintained after the end of a batch to the lowest temperature possible in the prevailing ambient conditions which provides a thermal safety reservoir for the next batch.

### *Off-gas treatment*

Wet scrubber technology will be required to flash cool and clean the CO produced by the reduction process, thereby rendering it suitable for use as a heating and drying fuel in the future plant, thus improving the overall thermal efficiency of the plant. This technology was not included as it is well evolved and readily available, and because the volume of CO generated cannot be economically recovered in the demonstration plant (Figure 9).

A conventional combustion process was designed. Hot CO off-gas from the furnace and ambient air is drawn into the water cooled, refractory lined combustion chamber under the action of the induced draught extraction fan. The CO enters from below while the air enters tangentially. The CO combusts to $CO_2$ and is cooled by the excess air drawn into the process. The combustion products are further cooled in water-cooled ducts followed by cooling in a radiant (trombone) cooler before the particulates are removed in a bag house filter. Protection has been provided for both undercooling to avoid condensation formation and high inlet gas temperature to prevent damage to the bags. The treated furnace off-gas is discharged to atmosphere in a stack together with the cleaned taphole fume.

Auto-changeover to an emergency stack has been provided in case the treatment plant unexpectedly becomes unavailable. A safety burner has been provided to initiate combustion when the CO concentration is too low, particularly when the furnace is switched out in an emergency.

## Conclusion

Mechel, a large, stainless steel and ferroalloy producer in Russia have embarked on an upgrade and expansion programme at their Yuzhural Nickel Plant located in Orsk, Southern Russia. They ultimately plan to convert the plant from the thermal production of ferronickel matte to 2 x 90 MW DC arc furnaces producing ferronickel alloy from laterite ore. A 12 MW demonstration plant is being built in an existing building on the site to confirm process and scale-up parameters, produce saleable product, produce alloy for refining test work, and train operators for the future plant conversion.

The demonstration plant will utilize sinter diverted from the normal feed stream to the blast furnaces, anthracite, and dolomite to produce a crude ferronickel product. The production for the demonstration plant is summarized in Table II.

The design of the demonstration plant was kept as similar as possible to the design envisaged for the future expansion project; however, the design was customized to suit physical space constraints, and focused on critical technology packages which need to be demonstrated at commercial scale to ensure satisfactory operation of the future full sized plant. These included performance assessment of the anode and composite furnace module (CFM) lower sidewall furnace containment components for laterite ore processing which are associated with chemical corrosion of magnesite refractory materials, a continuous slag granulation system for convenient disposal of the major furnace by-product, and an alloy granulation process capable of producing granulate with the required particle size distri-

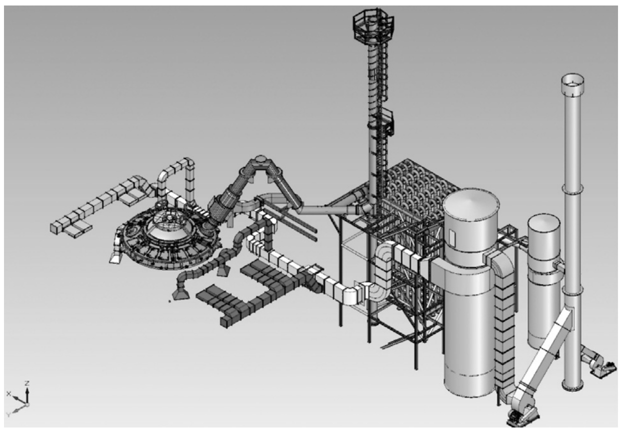

Figure 9—3D CAD rendering of the off-gas and fume extraction area

*Table II*

**Estimated furnace production summary**

| Item unit | Consumed/produced ton/year (ton/day) | Temperature Deg C | Ni Mass % | Ni % Recovery | Fe Mass % | Fe % Recovery |
|---|---|---|---|---|---|---|
| Sinter | 119520 (327.5) | < 200 | 1.1 | - | 22.93 | - |
| Anthracite | 663.5 (1.8) | < 25 | - | - | - | - |
| Dolomite | TBA | < 25 | - | - | - | - |
| Alloy | 5300 (14.5) | 1550 | 21.6 | 88 | 77.4 | 15 |
| Slag | 99325 (272.1) | 1650 | 0.1 | 9 | 18.4 | 82 |

bution and without excessive fines generation. Sinter/ore pre-heating was not included, as these parameters do not require demonstration. The off gas plant utilizes conventional $CO_2$ combustion, cooling and baghouse filter technology to avoid the cost and complexity of including a wet CO scrubber to recover the relatively small volume of CO as a fuel. Wet scrubbing is also considered an established technology and therefore does not require demonstration. This philosophy produced a cost-effective plant which will enable both designers and operators to gain the required information for successful execution and commissioning of the full-scale expansion project.

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# SAIMM Publications Committee member receives Wits Faculty of Engineering Best Research Award

Dr Cuthbert Musingwini, a member of the SAIMM Publications Committee and Senior Lecturer at the University of the Witwatersrand, was this year a recipient of the Wits Faculty of Engineering and Built Environment (FEBE) Best Researcher Award. He walked away with a R20 000 research grant to fund his research activities. The award is given to an academic who has produced the highest improvement in the weighted average research output based on journal publications, international conference proceedings publications, and postgraduate research students graduated by the academic among the seven Schools within the FEBE. Cuthbert is grateful for the assistance and advice given by Mike Rogers and Gordon Smith of Anglo Platinum towards his research efforts. The Publications Committee is delighted with the honour bestowed on Cuthbert and wishes him well for the future. ◆