TENOVA PYROMET'S BASE METAL ELECTRIC FURNACES

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ABSTRACT

Tenova Pyromet's core electric furnace knowledge and expertise has been developed world wide in the ferroalloy, platinum group metal (PGM) and base metals smelting industries. This expertise is well recognised by other technology suppliers as the Tenova Pyromet electrode column, the heart of the process, has been selected for a number of projects. Pyromet Technologies has itself been building furnaces for over 30 years. Following the integration within the Tenova Group, which included Techint Technologies (Tagliaferri) and Core Furnace Systems Corp (Lectromelt), Tenova Pyromet's combined electric furnace experience now dates back over a century. Modern electric furnaces have been installed at AngloPlatinum, Norilsk Nickel, Glencore/Xstrata, Kazchrome, Lonmin and Assmang, among others. During the 1990s, Tenova Pyromet built two 5 MVA primary electric furnaces for Barplats (now under Eastplats) and three 5 MVA electric furnaces for Lonmin to treat copper-nickel-PGM concentrates. In the early 2000s, a 30 MVA slag cleaning furnace was supplied and commissioned for AngloPlatinum. The furnace functioned as both a copper-nickel-PGM slag cleaning furnace and primary furnace to smelt concentrates. In 2009, Tenova Pyromet completed the refurbishment of two copper-nickel slag cleaning furnaces for Norilsk Nickel. In 2010, Tenova Pyromet commissioned a new 12 MVA smelting furnace for Lonmin. Tenova Pyromet's most recent project within copper-base metals is the Northam Platinum 24 MVA furnace. A review of the implementation of Tenova Pyromet's electric furnace technology in the copper-base metals industry is discussed.

INTRODUCTION

Tenova Pyromet is a leading player in the field of smelting technology and equipment. Pyromet Technologies had been building furnaces for over 30 years, and following its integration within Tenova, part of the Techint Group, in 2006, which included Techint Technologies (Tagliaferri) and Core Furnace Systems Corp (Lectromelt), the combined group's electric furnace experience now dates back over a century. Tenova Pyromet has a reputation for providing dependable innovative smelting technology, high quality equipment and sound project execution to a worldwide client base.

Tenova Pyromet's core knowledge and expertise was developed in the South African ferroalloy and base metals-platinum smelting industries. Tenova Pyromet has spent considerable effort on development, and has contributed significantly to improve the state of the smelting industry. Tenova Pyromet's electrode columns have become widely renowned and are now providing significant benefits, especially in increased furnace availability, to many smelting furnace operators. The electrode column is the heart of the furnace as it delivers a controlled amount of electric energy at an optimum depth in the burden/bath to the smelting process. Every furnace is custom designed to the specific operating range and optimal operating point of that furnace. In addition to the South African industry, Tenova Pyromet has supplied smelting furnace plants in Europe, North America, South America, Russia, Kazakhstan, the Middle East, South Korea, and India.

OVERVIEW OF TENOVA PYROMET ELECTRODE EQUIPMENT

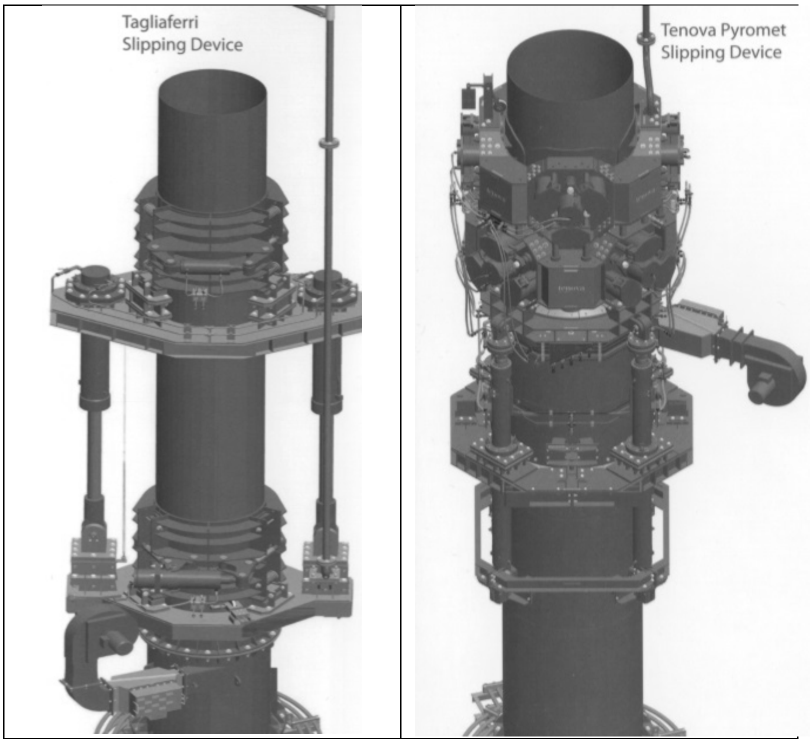
The quantity and size of projects undertaken by Tenova Pyromet has provided the opportunity to continuously improve our electrode column designs. This has resulted in improved electrode availability and performance, even in the demanding operating environments seen in the metallurgical industry.

Upper Electrode Assembly

The upper electrode assembly, refer to Figure 1, comprises three main functional components:

- Slipping device
- Electrode guide
- Upper mantle.

The unification of Tagliaferri, Core and Pyromet brands under Tenova has enabled the offering of a design best suited to the needs of the particular application and one that benefits the client most. Broadly these design options include either a suspended slipping device, known as the Tagliaferri design, Figure 1(a), or a segmented slipping device, known as the Pyromet design Figure 1(b). The versatile design of the suspended slipping device, Figure 1(a), allows the slipping clamps to be placed at the optimal height and distance apart to accommodate the required height of the contact shoes above the bath as well as the extended electrode stroke necessary to facilitate maintenance. The segmented slipping device, shown in Figure 1(b), comprises two clamping rings that are configured to be interlocking, resulting in a compact design that reduces the required headroom. This design is generally preferred for larger diameter electrodes, and where it is convenient to support the electrodes at a lower level in the building. Both slipping devices fully support back slipping (where the electrode is lifted up) without requiring a reduction in contact shoe clamping force. The electrode is guided at two levels: on the casing floor with a guide tube and on the slipping floor with a ring of guide rollers.



(a)	(b)

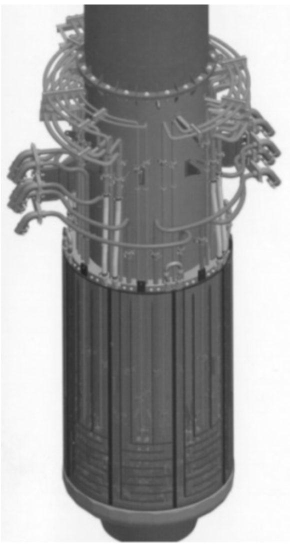
Figure 1 – Tenova Pyromet Slipping Device Arrangements, (a) Suspended, (b) Segmented

Lower Electrode Assembly

Tenova Pyromet's lower electrode assembly, shown in Figure 2, consists of six main components:

- Contact shoes
- Pressure bellows
- Pressure ring assembly
- Heat shield assembly
- Bus-tube and cooling water risers
- Lower mantle.

Tenova Pyromet's lower electrode assembly features a robust design, as the key equipment is well protected from the furnace environment. A uniform ambient temperature and electrical current distribution within the electrode baking zone is ensured. The pressure ring has an efficiently cooled protection skirt that covers and protects the contact shoes and other components.



(a)

(b)

Figure 2 – (a) Tenova Pyromet's Lower Electrode Assembly and (b) View of the Contact Shoes within the Heat Shield of the Lower Electrode Assembly

The protection skirts are manufactured from forged copper slabs that allow efficient cooling through increased thermal conductivity. The pressure ring is assembled with the pressure bellows bridging between contact shoes to equalise contact pressure and electric current. This prevents hot spots around the contact shoes in high current applications, resulting in lower electrical losses associated with high circulating currents.

The bellows are independent and can be changed without removing the pressure ring segment. The bellows have a separate water circuit operating at low velocity and high pressure, which provides a high bellows force, generating the necessary contact pressure. The contact shoe design incorporates a self-cleaning feature, ensuring optimum electrical contact between the contact shoe and the casing.

The lower electrode incorporates a segmented design that allows easy access to the components, so that if there is a need to work on or remove a component, this can easily be done. The heat shield protects the internal electrode components from the hot furnace environment. The design features a unique segmented heat shield with a quick release mechanism for individual segments, allowing easy removal during maintenance shutdowns.

The bus-tube risers are water cooled and are fabricated from copper. The cooling water risers are fabricated in stainless steel. The lower mantle is fabricated in stainless steel and provides the support for the pressure ring assembly, heat-shield assembly, bus-tube and cooling water risers.

Electrode Sealing

The Tenova Pyromet electrode seal, shown in Figure 3, ensures effective sealing of the electrode against fugitive emissions where it passes through the furnace roof. The seal has either a water-cooled or dry-cooled copper base that withdraws heat from the rope seal, reducing the rope working temperature and leading to longer rope life. The upper clamping ring (made from stainless steel), clamps the rope seal using actuators. The furnace operator can adjust the clamp pressure without shutting down the furnace.

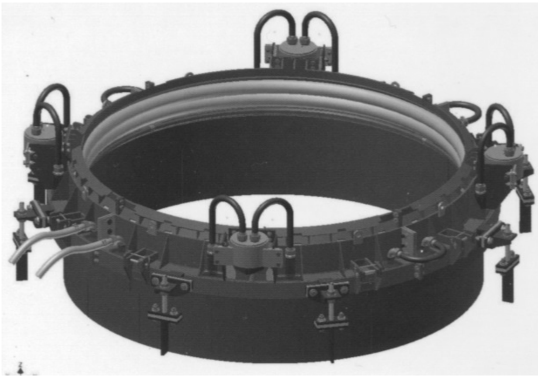


Figure 3 – Tenova Pyromet's Electrode Seal

Electrode Paste Heaters

The electrode paste heater is used for improving baking of the electrode. The paste heaters heat the air supplied by the mantle fans. This warm air passes between the electrode casing and the mantle. The increased ambient temperature around the electrode casing assists with increasing the liquid paste level and helps to improve the overall baking process. The heaters are supplied with a control unit for automatic control of temperature.

Electrode Breakage Detection and Length Determination System

The Electrode Breakage Detection and Length Determination System (EBDS) utilises the electrode slipping device and a data processing system to determine the mass of the electrode. Factoring in the electrode geometry, paste levels and regulating position, the electrode length is estimated and provides the operator with a recommended slipping procedure for each electrode at a particular time. The system will detect any electrode breakage immediately before or during the next slipping action and will recommend the baking schedule to extrude the electrode to the desired length. With the electrode length known to the operator, the electrode control can be optimized for more stable furnace operation.

AutoFurn® Furnace Controller System

Automatic furnace control software was introduced during the early 1990s to assist operators by automating the process of achieving and maintaining the required furnace power input and electrode resistances or electrode currents[1]. This reduces operator involvement in routine activities, enabling operators to concentrate on higher level tasks.

Tenova Pyromet’s AutoFurn® Furnace Controller automatically adjusts transformer settings and electrode positions to optimise power input to the furnace, whilst safeguarding the electrical equipment against overcurrent situations and minimizing furnace trips. Figure 4 displays the overview page of the Tenova Furnace Controller. This screen provides a complete view of what is happening in the furnace. Graphical elements are used to provide the maximum amount of useful information to the user. The page is divided into 3 sections, displaying general furnace operational information, transformer information and electrode information[2].

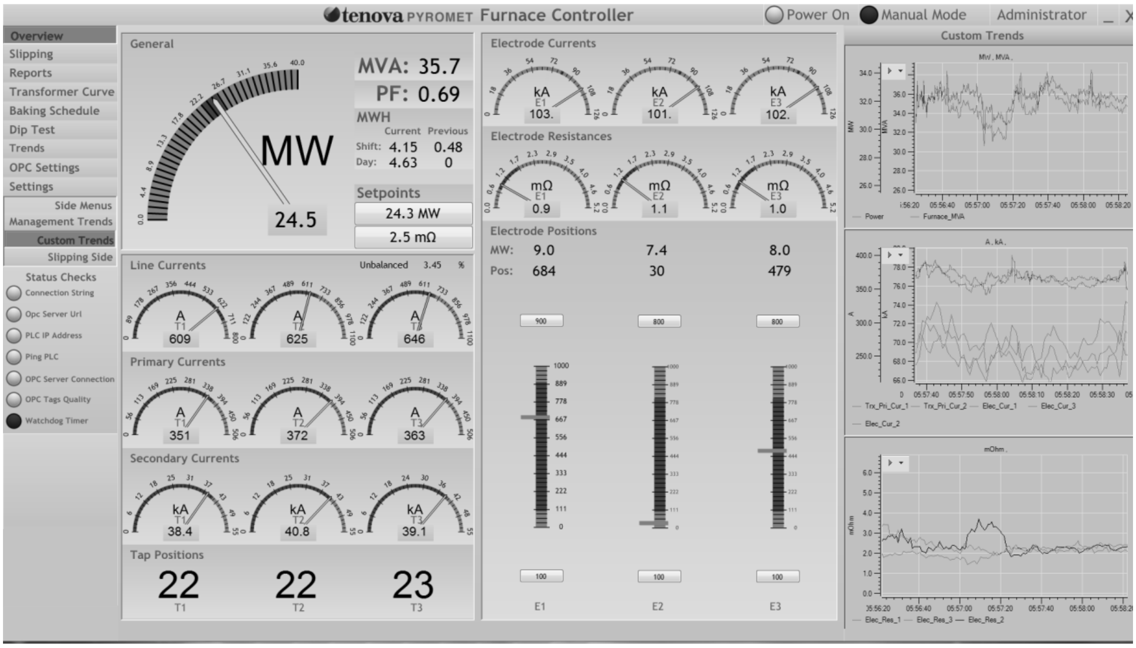


Figure 4 – Overview Page

The Furnace Controller is designed to react to the furnace conditions and take the most appropriate control actions to maintain stability for that particular instance. The controller uses two control methodologies to stabilise and maximise furnace power input, firstly the manipulation of the transformer tap positions and secondly electrode regulation. Changing tap positions affects the furnace power (furnace MW) whilst regulating the electrode affects the electrode resistance and current. There will be different levels of control depending on the furnace stability. For example, if there are large disturbances caused by an electrode break or fine feed, the controller will react to re-establish stable running conditions as quickly as possible.

Managing electrodes effectively and consistently can prove to be a difficult task as there are many variables that play a role in electrode health. The Tenova Pyromet Controller provides effective, consistent electrode management that requires minimal operator input. Electrode consumption is monitored by analysing paste consumption and total slip measurements over a given period of time. By using a combination of the electrode burn off, the previous slip distance and the furnace current operating conditions, the controller determines when it is necessary to slip the electrode. The slipping function may be fully automated, where the controller initiates slipping of electrodes when required in order to maintain the best working hoist position. Alternatively, an advisory mode may be activated, where the controller prompts the operator to perform a manual slip when conditions indicate that slipping is necessary. The controller also indicates when conditions are unfavourable and slipping should not be performed. The system can cater for changes in process and bath conditions without requiring any operator input. This leads to more stable operating conditions and consistently baked electrodes.

A recent addition to the controller functionality is an automated dip test sequence, which may be performed on each electrode individually, to provide an indication of the position of the electrode tip in the bath.

TENOVA PYROMET FURNACE TECHNOLOGY IN THE COPPER AND BASE METALS INDUSTRY

Tenova Pyromet's expertise in electric furnace technology has been utilised in many projects within the copper/base metals industry. Tenova Pyromet has either supplied a complete furnace package or other technology suppliers have selected the Tenova Pyromet electrode column, the heart of the process, for their project. A list of furnace and electrode column projects conducted in the base metals industry from the year 2000 onwards is shown in Table 1. Within the same period over 35 furnaces or electrode column projects were completed by Tenova Pyromet in other industries.

Table 1 – List of Base Metals Projects for Furnace or Electrode Column since 2000

Date	Client	Furnace Power	Description
2001	Anglo Platinum	30 MVA	1 x Furnace, 3 x Electrode Columns
2006	Outotec	20 MVA	6 x Electrode Columns
2008	Norilsk Nickel	30 MVA	2 x Furnace re-build, 6 x Electrode Columns
2010	Lonmin	12 MVA	1 x Furnace, 3 x Electrode Columns
2010	Outotec	15 MVA	3 x Electrode Columns
2015	Northam Platinum	24 MVA	1 x Furnace, 3 x Electrode Columns

Anglo Platinum Furnace

The slag cleaning furnace at Anglo Platinum's Waterval smelter is a circular three electrode furnace with a power rating of 30 MVA, and power input of 23 MW. The furnace was designed to treat a combination of Anglo Platinum Converting Processes (ACP) slag, concentrate, reverts, silica, and coke[3, 4]. The furnace can also accept molten feed through a separate charge port. The main product from the furnace is a copper-nickel platinum group metal (PGM) rich matte, which is sent back to converting. The position of the Tenova Pyromet furnace in the Waterval flowsheet is shown in the dashed rectangle in Figure 5[3].

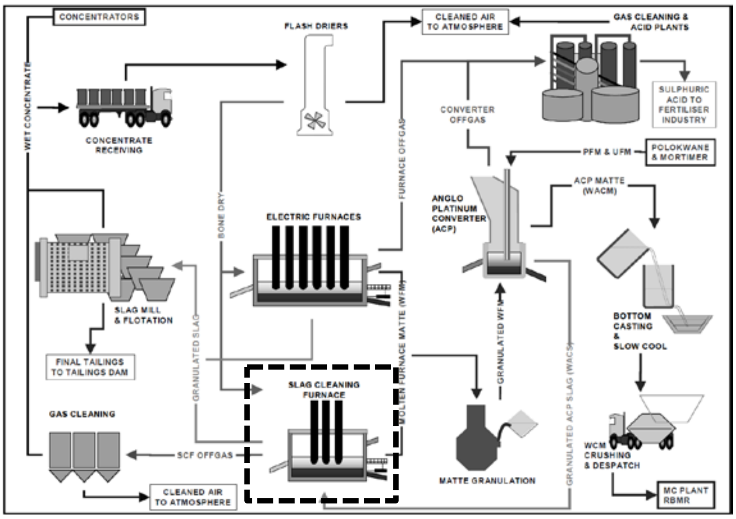


Figure 5 – Anglo Platinum Waterval Smelter Flowsheet[3] Showing the Integration of the Tenova Pyromet Slag Cleaning Furnace

During the design phase of the project it was determined that the slag generated in the furnace would be extremely aggressive towards the sidewall lining. For this reason the Tenova Pyromet designed intensively cooled MAXICOOL® elements. A full description of the application of these coolers has been published elsewhere[5], with the operating results indicating that the design is comfortably able to cope with even the most rigorous of operating conditions in the furnace.

Norilsk Nickel Furnace Upgrades

In 2008, Norilsk Nickel selected Tenova Pyromet for the upgrade of two of their slag-cleaning furnaces at their Nadezhda metallurgical plant. These two particular furnaces take molten slag from the flash furnace and slag from the Peirce-Smith converters to recover copper, nickel and cobalt in matte. The upgrade of the furnaces required an increase in their diameter and power input. In total the furnaces were designed to allow the processing of approximately 2,400 t/d of slag each. The furnace power rating was increased to 30 MVA, with a maximum power input of 25 MW, depending on process requirements and conditions. The first upgraded slag-cleaning furnace came online in October 2011, whilst the second came online in December 2012. The position of these furnaces in the Nadezhda metallurgical plant is shown in the dashed rectangle in Figure 6[6].

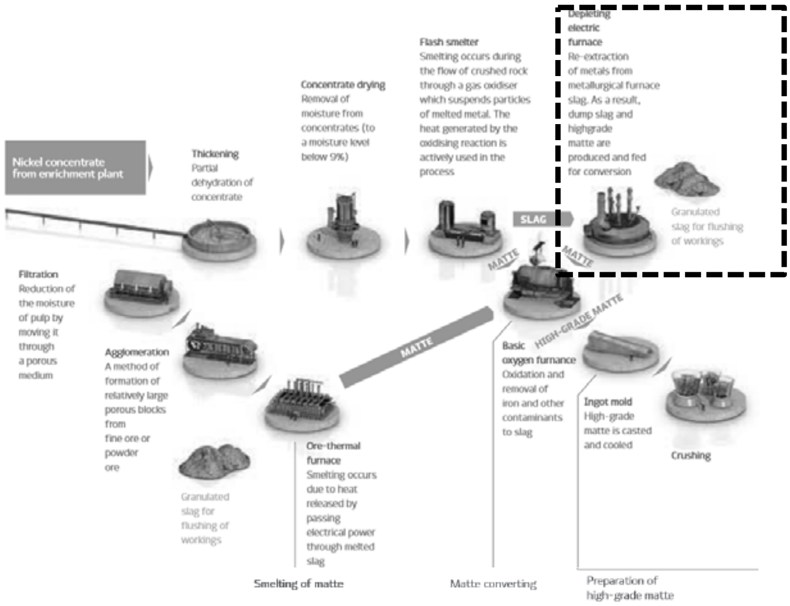


Figure 6 – Nadezhda Metallurgical Plant Flowsheet[6] with the Tenova Pyromet Furnace Upgrades Completed on two of the Depleting Electric Furnaces

The Tenova Pyromet scope of supply included the hearth cooling system, the steel shell and refractory lining, MAXICOOL® sidewall copper cooling system, the furnace refractory roof with support structure, and the electrode columns. In addition the gas cleaning plant, the secondary electrical supply system, the furnace control system, lining management system and programmable logic controllers (PLC), as well as key components of the furnace feed system were part of the supply. Supervision during installation and commissioning was also included as a part of the complete Tenova Pyromet package.

Lonmin Plant

The Lonmin smelter at the Marikana Process Division produces copper-nickel-iron sulfide PGM rich matte for further refining. The smelter comprises of five furnaces: a Hatch furnace, the new Tenova Pyromet furnace called Furnace No. 2 and three small circular furnaces built by Tenova Pyromet in the 1990s[7]. The new Tenova Pyromet furnace (Furnace No.2) is a three electrode 10 MW circular furnace and was built to replace a six-in-line Barnes-Birlec Furnace. Unlike the six-in-line furnace, the Tenova Pyromet furnace had sufficient hearth power density at the required feed rates and could operate at sufficiently deep electrode immersions at appropriate power to deal with UG2 rich blends[8]. Upgrading the six-in-line to achieve a similar performance would have required extensive changes and therefore Lonmin decided to instead contract Tenova Pyromet to supply the optimal furnace that would have the ability to handle variable material feed, start-ups and turn-down ratios. A view of the first refractory installation for this furnace and slag tapping floor is shown in Figure 7.

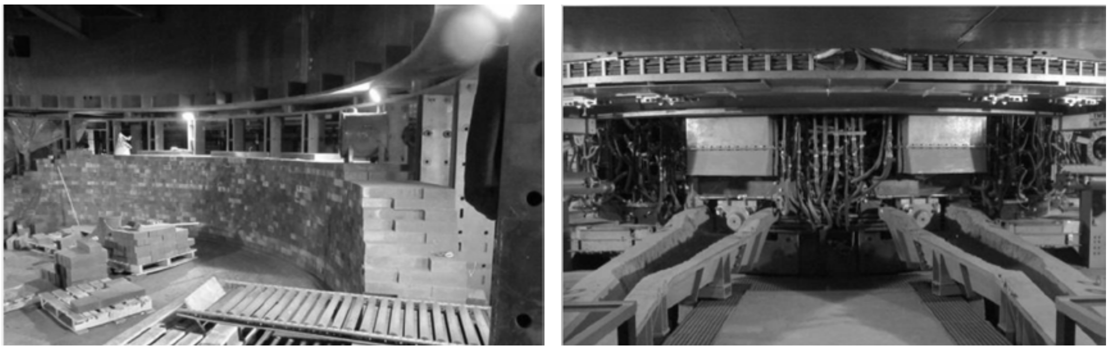


Figure 7 – Tenova Pyromet Supplied 10 MW Furnace at Lonmin's Marikana Process Division Showing Refractory Installation (left) and Tapping Floor (right)[7]

A novel approach to the lining design was taken for this furnace due to the severe process conditions associated with a superheated matte and corrosive slag. A summary of the methodology involved in the design is presented elsewhere[9] with the final design involving an indirectly-cooled graphite ring applied in the matte/slag bath zone combined with refractory bricks on the hot face. The graphite was cooled by a copper plate cooler in the slag zone, obviating the need for copper cooling elements in this area. During construction of the furnace, thermocouples were placed in the graphite confirming the successful application of this novel sidewall design.

Northam Platinum

The Northam Platinum project involves the expansion of its' smelter facilities in Thabazimbi, South Africa to support its planned growth in PGM production through additional copper-nickel matte production from both the base metal-rich Merensky Reef ore as well as the chromite-rich UG2 reef ore. Furnace designs to accommodate either of these concentrate streams are normally very specific because of the large heat variations in the placement of the electrodes in the furnace, either submerging them in the concentrate or keeping them slightly above the material to be smelted. Each process presents separate technical challenges, but Tenova Pyromet has come up with a furnace design that allows tremendous flexibility to process both concentrate streams and cope with the 2% or more of chromite in the UG2 concentrate.

The relationship between Tenova Pyromet and Northam Platinum dates back to the 1990s and include the recent design of a complete furnace cooling system for Northam's existing 15 MW six-in-line furnace. Tenova Pyromet's scope on the new furnace project covers the smelting furnace, feed system and off gas handling plant, as well as the furnace building and all associated civil works, infrastructure and services. The basic engineering for the 20 MW smelting furnace and ancillary systems has been completed, and the detail engineering is currently in progress. Commissioning is expected for December 2017[10].

CONCLUSIONS

Tenova Pyromet's core knowledge and expertise has been developed world wide in the ferroalloy, platinum group metal and base metals smelting industries. Tenova Pyromet's electrode columns and furnace controllers have become widely renowned and are now providing significant benefits, especially in increased furnace availability, to many smelting furnace operators. A review of the most recent implementations of Tenova Pyromet's electric furnace technology in the copper and base metals industry at Anglo Platinum, Norilsk Nickel, Lonmin and Northam Platinum were discussed.

ACKNOWLEDGEMENTS

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