APPLICATION IN GERDAU DIVINÓPOLIS PLANT OF NEW TECHNOLOGIES FOR OXYGEN INJECTION IMPROVEMENT AND REFRACTORY CONSUMPTION OPTIMIZATION: A TEST FOR BRAZILIAN STEEL INDUSTRY

Francesco Memoli[1]
Jorge Villares de Freitas[2]

SUMMARY

Four years ago Techint has started to test new technologies for oxygen injection improvement and refractory consumption optimization on the furnaces of Techint Group and then on many other furnaces around the world.
Thanks to the application of new software for fluids and flames modeling, oxygen penetration and others, these technologies have become the state of the art in the Steel Industry.
The application of these technologies to the EOF of Gerdau Divinópolis is an important test due to the process characteristics of this kind of furnace. Oxygen injection is the only power source for the EOF and refractory consumption is the highest voice of cost for consumables.
Aim of the project is the reduction of bricks usage thanks to the use of special copper cooled boxes and replacement of the existing bottom tuyeres with the new KT Oxygen Lances.
Characteristics of the elements installed and results achieved are detailed in this paper, where special emphasis is given to the engineering details and process features.

KEY WORDS

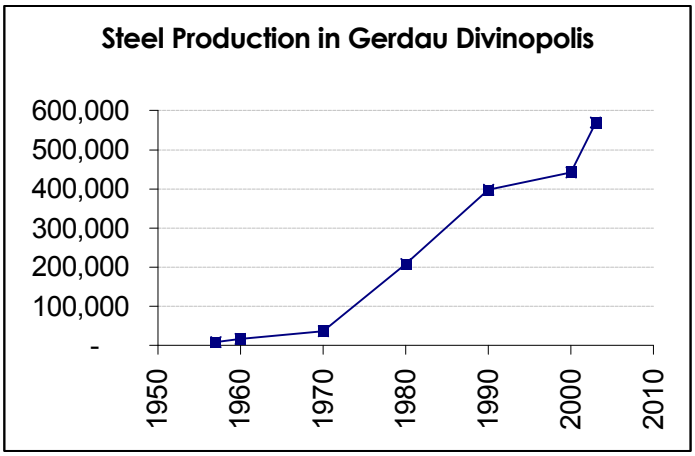
EOF, Refractory, Foamy Slag, Oxygen, Injection, Multipoint, Postcombustion, Lime, EBT.

XXXV Seminário de Fusão, Refino e Solidificação dos Metais - 2004
[1] Technology Service Manager, Techint S.p.A., Italy
[2] FHE Freitas & Heer Engenharia, Brazil

GERDAU DIVINÓPOLIS STEEL PLANT

The steel plant at Divinópolis was founded in 1953, as Cia. de Cimento Portland, with a rolling mill. The first heat of its Siemens Martin Furnace occurred in 1957.
In 1982, already named as Cia. Siderúrgica Pains, the Energy Optimizing Furnace - EOF I, started up. The second EOF began its operation in 1988.
Six years later, Gerdau incorporated the plant to its Group.

Today, Gerdau Divinópolis operates three Blast Furnaces, one EOF, one Ladle Furnace, one Billet Continuous Caster and two rolling mills. The original 8,400 tpy production of liquid steel in 1957 increased to 570,000 tpy in 2003.



Products for civil construction represent around 80% of the plant production. Steel for automotive industry, tools and agriculture implements complete the mix.

Gerdau Divinópolis is located in an important Brazilian area of pig iron production. Additionally to its own production, the plant continuously receives liquid pig iron from third party blast furnaces in the nearby, on a special road logistic operation.
The surrounding conditions allow Gerdau Divinópolis to have low operating costs of its melt shop.
Considering also the absence of intensive electric energy on the EOF process, the importance of refractory and chemical energy consumptions is enhanced.

STEEL PRODUCTION AT GERDAU DIVINÓPOLIS WITH EOF TECHNOLOGY

The EOF is an oxygen steelmaking process with scrap preheating thanks to high post-combustion.

The process in the case of Gerdau Divinópolis charges about 30% of scrap and 70% of Hot Metal, depending on scrap density and availability.

Hot metal is charged into the vessel from the furnace side and scrap is charged from the top, falling from the lower preheating chamber of the shaft structure, which is located right on the top of the furnace shell. Scrap is charged in the beginning of the heat in only one charge.

The scrap is preheated in a preheating chamber to about 800 to 1000°C. About 60 Nm^3/ton of oxygen are used for the process of injection into the steel bath and for post-combustion of the CO generated.

The post-combustion gas is conveyed into the exhaust gas duct passing through the scrap, so it is used to preheat the scrap.

Instead of “Power On Time”, typical parameter of an EAF, for the EOF it is considered the “Blowing Time”. In the case of Gerdau Divinópolis, the blowing time is about 22 minutes and Tap-to-Tap is less than 40 minutes.

Refractory consumption depends on scrap percentage and it is one of the variable costs associated to the steel production on the EOF, as it is a direct consequence of bath oxidation and oxygen is the only source of energy of this process.

Apart for the EOF furnace operating in Gerdau Divinópolis (40 ton furnace, the first to operate), other EOF are located in India (80 ton furnace at Tata Steel, plus two 40 ton furnaces) and in Italy (60 ton furnace at Lucchini Servola).

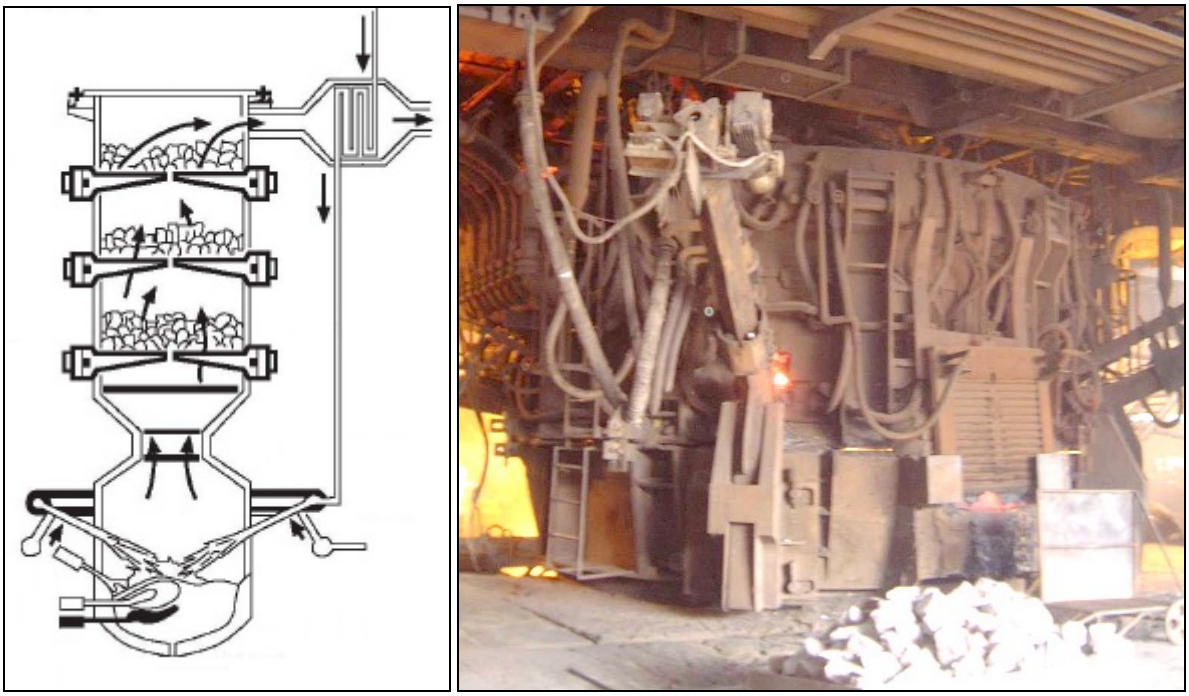
The productivity of an EOF can be compared to the one of EAF and the yield with a 30/70 charge mix can be around 88-90% slightly lower than a BOF.

For what concerns the production at Gerdau Divinópolis, the plant is capable to produce per annum more than 13,000 tons of billets per each ton of EOF capacity installed.

The EOF is a technology which can allows higher scrap mix charge than the BOF, and together with the BOF is the only converter based process which has still industrial applications, even if few of them are working.

CHEMICAL LAYOUT OF THE EOF IN GERDAU DIVINÓPOLIS

At the present on the EOF of Gerdau Divinópolis it is installed:
1. One set of Post combustors, 4 points 1000Nm^3/h each
2. Two tuyeres installed on the spout side, 540 Nm^3/h each
3. Two supersonic lances installed on the door side, 840 Nm^3/h each



(in the pictures, the EOF scheme of flows, left, and an EOF view, right)

CHALLENGES FOR THE FUTURE: PRODUCTION AND COSTS

One of the most important challenges for Divinópolis' EOF is the reduction of the refractory wear. Over the history, in this plant the use of oxygen tuyeres, the first responsible for refractory wear, has been implemented and optimized. For what concerns this kind of tool the operational personnel have developed an important experience, which has no comparison worldwide. Anyway, nowadays the refractory consumption due to the sidewall position of the tuyeres is not compatible with the planned plant growth.

As already shown in the chemical Layout of this EOF, the number of tuyeres originally installed has been reduced to only two, while other traditional systems of oxygen injection have been installed. Unfortunately, these supersonic lances do not have the same oxygen efficiency than the tuyeres, so that they can only be a support for the job of the remaining tuyeres, not really a replacement. As a matter of fact, in case of use of only these traditional supersonic lances, the "blowing time" would increase, as the consumption of oxygen.

The challenge of refractory consumption is then intrinsically linked with the change of oxygen technology.

Whenever a steel plant is planning to change or improve a certain technology, the objective must always include an enhancement of the furnace figures.
That's why the new challenge is considering three simultaneous items: refractory consumption, increase of overall oxygen injection efficiency and lower blowing time for productivity increase.

If we take into account the particular metallurgical process of the EOF, compared to the most well known EAF process, the slag situation is much more critical from a chemical point of view.
As a matter of fact, the only source of energy is oxygen, so the risk of slag overoxidation is always present. The balance of lime in the charge is crucial for the good conclusion of the EOF campaign not earlier than the planned maintenance scheduled stop.

In any case, the development of the metallurgical reactions in the EOF slag is well studied in order to maintain an appropriate basicity index during the whole process. The slag starts its formation since the very beginning, when the hot metal is poured into the furnace from the side-wall.
In that period, a particular emulsion of hot metal and slag is created and a controlled carbon coiling reaction is developed into the furnace. An appropriate furnace volume and door level must be assured, to avoid the overflow of this emulsion from the door, with the consequence of yield loss.

Considering the need to increase the productivity, one of the first sources of productivity increase is the reduction of power off time, moreover in a plant where wall gunning is a strict requirement for the shell. Any solution to reduce power off time passes through the reduction of gunning time, which is achievable reducing the refractory wear.

The standard way of productivity increase, the tapping weight increase, is also considered as the final challenge.
For Divinópolis EOF, tapping weight may be increased from 40 up to 50 ton, modifying the refractory or shell profile. Then, the valve stands must be redesigned in order to fulfill the flow rates to work with 50 ton.



(in the pictures, the hole of the tuyere and the spout, left, and an EOF view, right)

As a resume of the challenges of this EOF, we have:

1. Decrease of the refractory wear due to the oxygen tuyeres
2. Increase of efficiency of oxygen injection using new lancing technologies
3. Decrease of Power Off time – Gunning time / consumption
4. Increase of tapping weight
5. Increase of EOF productivity

PLAN OF EOF TECHNOLOGICAL DEVELOPMENT

The project of EOF implementation is summarized then in the following steps, which are part of a Development Master Plan:

The submerged tuyeres are intended to be replaced by other oxygen device.

The existent post combustion devices will be kept in operation in a first step.

EOF water-cooling system will be checked and verified to locate the new oxygen devices in the upper shell and to insert new cooled parts in the lower part of the upper shell to replace the last lines of bricks with long-life devices.

The tapping weight will be increased from 40 up to 50 t in steps. Just modifying the refractory profile in a first step, and modifying the EOF shell in a second step. This means to change the tapping system from old spout configuration to a modern bottom tapping system

The lime addition system will be changed by a modern lime injection system, which can take into consideration the possibility of parallel carbon injection into the slag, in case of need for the slag metallurgy in the new EOF configuration.

TECHNOLOGIES CONSIDERED FOR THE DEVELOPMENT PLAN

The technologies considered in this case for the EOF revamping are summarized here below:

KT Oxygen Lances, for the multipoint injection of oxygen, with the characteristics of high jet penetration, maximum lance safety in order to keep the closest position to the bath, submerging the lance into the slag-emulsion.

Copper Cooling Boxes, for the replacement of the slag-line bricks and the reduction of gunning consumption and time.

KT Lime Injectors, for the multipoint addition of powder lime during the blowing time, and with the possibility of parallel injection of powder carbon.

Techint Bottom Tapping configuration of the lower shell, to increase the furnace volume/size, increase the melting yield, decrease of power-off time due to spout cleaning and refilling.

One of the reasons to choose these technologies is the proven efficiency in other Melt Shops and the fact that all of them can be available from the same supplier, Techint, who tests in its own furnaces most of these solutions before marketing them.

EXPECTED RESULTS

The table below matches the items of the Master Plan with the technologies considered for this revamping and with the challenges considered in the beginning, to analyse each one of the benefits achievable:

EOF Revamping	Blowing Time	Power Off	Gunning consumption	Lime consumption	Yield
KT Oxygen Lances replacing Oxygen tuyeres	- 1 min	- 1 min	- 0.3 kg/ton	n.a.	n.a.
Copper Cooled Boxes installed in the slag refractory line	n.a.	- 0.5 min	- 0.2 kg/ton	- 0.5 kg/ton	n.a.
KT Lime Injectors instead of normal lime addition	n.a.	- 0.5 min	- 0.5 kg/ton	n.a.	+ 0.5 %
New Shell bottom tapping configuration instead of spout	- 1 min	- 0.5 min	- 0.5 kg/ton	- 2.5 kg/ton	+ 1.0 %
TOTAL BENEFITS	***- 2 min***	***- 2.5 min***	***- 1.5 kg/ton***	***- 3.0 kg/ton***	***+ 1.5 %***

The line of total benefits gives an idea of the conservative results that are achievable with the aforementioned technological revamping of the EOF.
As explained before, this revamping is programmed in different steps, of which the first one is already started with the implementation of the Copper Cooled Boxes in the slag refractory line.

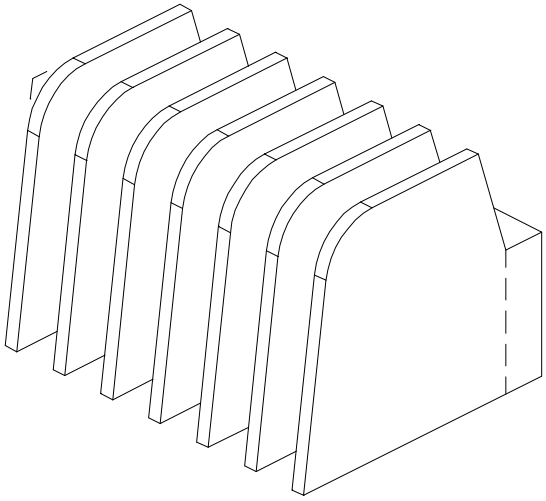
Thanks to the minor mechanical changes needed for each one of these improvements, except for the last one, which is the new bottom shell configuration with eccentric bottom tapping system, the steps can be implemented in different times, considering case by case the market situation and all the other matters involved in such jobs.

COPPER BOXES FOR REFRACTORY REPLACEMENT

Due to the good experience of this kind of technology, since more than 15 years in Electric Arc Furnaces, this practice can be introduced also to the EOF technology, which is a peculiar case due to the different slag conditions.

The aim is replace the upper line of refractory bricks with these cooled elements, to decrease the refractory consumption.

The first step decided for Gerdau Divinópolis is the test of a couple of these blocks in one portion of the upper shell, to check the operational conditions, the wear of the installed device and the maintenance of this item.

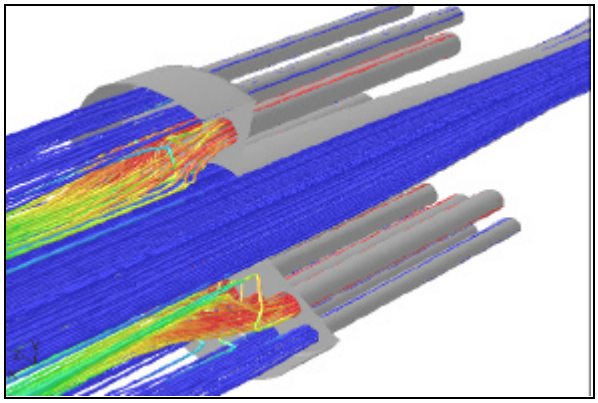


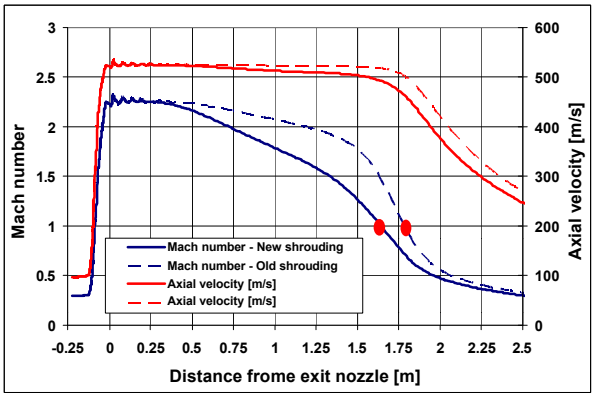
From the construction point of view, the Copper Cooled Box, water cooled in the back part, is entirely cast in one unique block, including the fins. The material is 100% copper.
In the EOF it is installed with the cooled part in correspondence to the water cooled panels, while the fins are entering inside the furnace, replacing the bricks. Between the fins it is poured special refractory glue, which is synterising also to lower temperatures than the normal gunning material, as during the operation, the area between the fins is maintained to a lower temperature, thanks to the cooling.

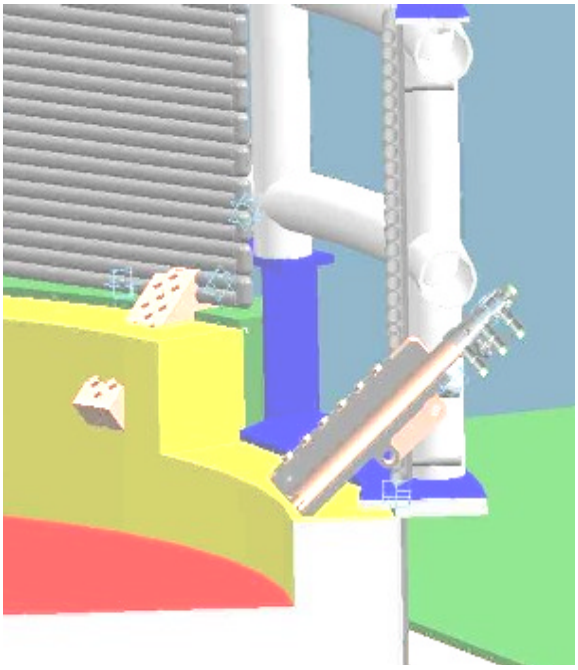
The heat absorbed by the block is entirely evacuated by the cooling water. A detailed study of the water cooling flow has been developed, to assure that a thermal equilibrium is maintained between the water flowing on the back and the heat absorbed by the fins. In this way the dimension of the fins is stable.
Cooling block is intrinsically safe, as the water is flowing in a position which is out of the shell, so that it is not possible that leaks of water enter in between the refractory.

MULTIPOINT OXYGEN INJECTION

It has to be remarked that the tuyere is studied to have the highest efficiency in oxygen injection, as it is submerged into the steel bath.
For what concerns efficiency of the injection, KT Oxygen Injectors, thanks to the shrouding flame that characterizes the coherent stream of oxygen, are very close to the tuyeres.
Several studies developed with numerical analysis systems (for instance CFD Simulations as shown in the pictures) have demonstrated that the KT lance is capable of a very deep and coherent stream. These studies have been proven in many field applications.
Bath penetration with oxygen is a need in the case of the EOF, where it is a critical aspect to penetrate and stir the liquid bath.



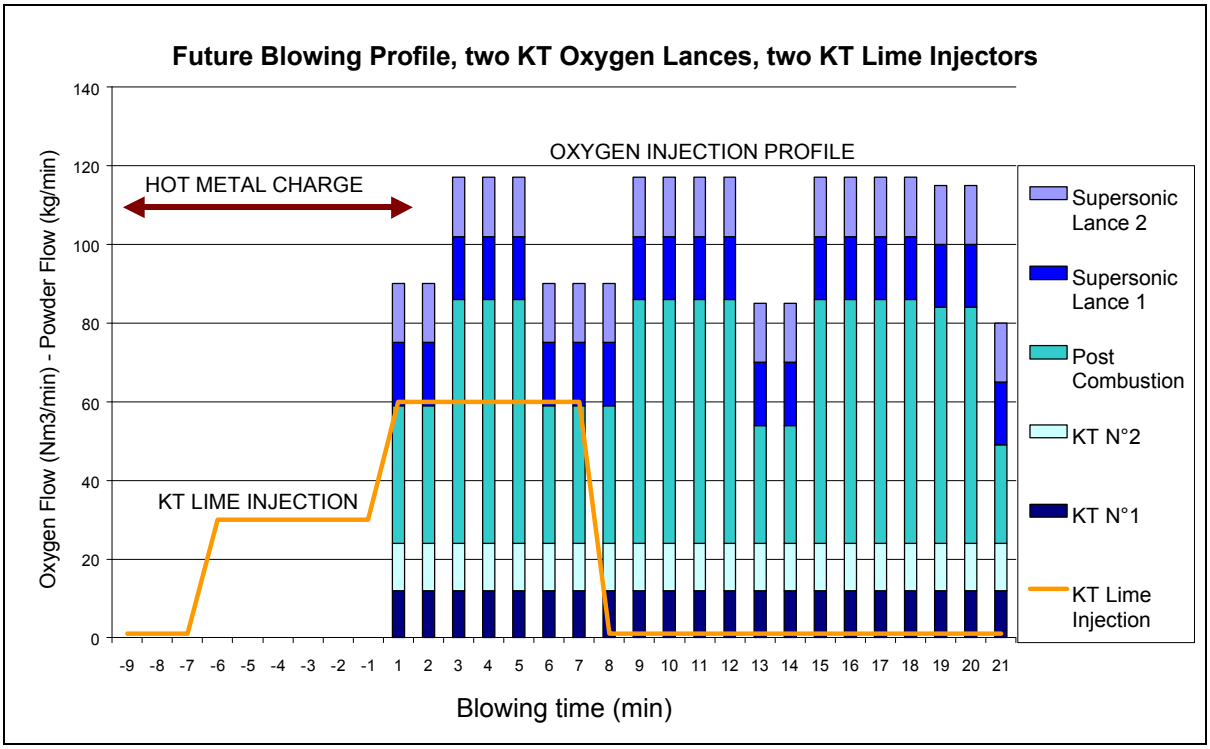




An additional point is that KT Oxygen Lances do not require as a must the use of Natural Gas for shrouding. In the case of DIV plant, the shrouding flame can be done using the present Blast Furnace Gas (BFG), or even using a very small amount of LPG, which can be used to maintain only a pilot flame.

The real shrouding combustible is the same CO gas generated by the decarburization reactions, which is coming from the bath and which is going to the postcombustion area where is used then to preheat the scrap waiting for the next heat.

Increase of lifetime of the refractory, and less refractory gunning is coming thanks to the elimination of the two tuyeres, which are wearing out the bricks covering all around the hole of the tuyere.
KT Oxygen Lances benefit also the oxygen injection equilibrium. The four devices for O_2 injection can be set to have the same, or similar, O_2 injection rate so that there is the possibility to assure the bath temperature equilibrium.
One minute less in blowing time is explained because with KT Lances it is possible to inject with higher flow with respect to the tuyeres.



MULTIPOINT LIME INJECTION

As far as the KT technology has already the possibility to inject the Powder lime, this option has been very simple to be considered into account, for a following step of technological revamping. There is no change to be done on the EOF configuration, apart of having an additional lance doing the job of lime injector, and a Pneumatic System for powder lime transportation.

The half of the CaO traditionally added from the roof can be directly injected through the KT Lime Injector. Lime quality considered feasible for this purpose is of grain size from 3 to 6 mm. The condition of Basicity index is improving, as the powder lime melts faster than the Lime in pieced added from the roof.

The refractory profile can be slightly changed to increase the tapping weight of at least one ton. According to metallurgical simulations the Basicity index is changing as shown below:

Period	*Present Basicity Index*	*Future Basicity Index*
At 10 minutes of blowing	1.4	1.8
At 15 minutes of blowing	1.6	2.0
At Tapping	2.0	2.0

The use of powder carbon can be useful during the final minutes of Oxygen Blowing, as it permits to maintain the Tapping Carbon Content in the bath and using the Oxygen injection at the full power till the end. This is the reason why a parallel injection of powder carbon is taken into account as possible further implementation.

CONVERSION FROM SPOUT TO BOTTOM TAPPING SYSTEM

In the last step of revamping, the new configuration of the tapping system, from spout to eccentric bottom tapping is considered.
In this way it is easily achievable the new tapping weight of 50 tons of liquid steel, to which it has to be added from 8 to 10 tons of liquid heel, a need for the new tapping practice.

This revamping is guarantee that the level of the bath is lower than the old configuration, so that no slag-steel mixture overflows out of the door during first minutes of the heat. This benefits the liquid yield.

Blow on time is reduced of an additional minute, as the KT Oxygen lances can mount the appropriate nozzles to increase the nominal flow rate.

The power off time is lowered of an additional minute, thanks to lower time needed for repairs (less gunning operations, as far as the KT lances will guarantee better penetration of the oxygen into the bath). Also the refractory gunning material is lowered in terms of specific consumption (kg/ton).

With the new shell it is included the installation of the Techint Bottom Tapping System, the patented slag free system to clean and close the tapping hole.

Here below the main modifications are summarised:

New lower shell.

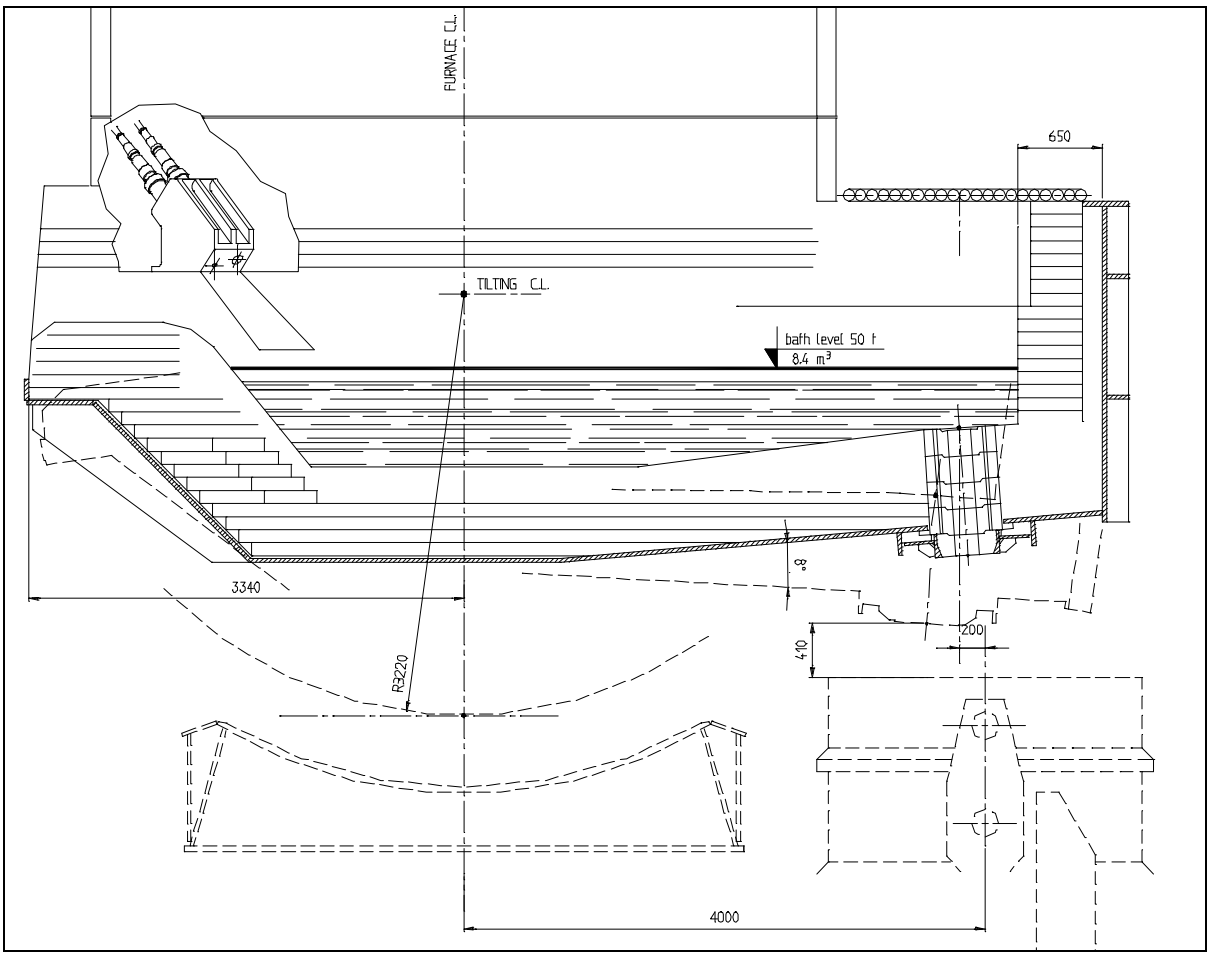
Modification of the front part of the existing upper shell (structures and water cooled panels).

Installation of the Tapping Mechanism, on the furnace platform.

Modification of the hydraulic tilting system by adding fast back tilting.

A new tilting control desk.

Modification of various accesses and service platforms.



A TEST FOR BRAZILIAN STEEL INDUSTRY

The application of these technologies in Gerdau Divinópolis is a test for the Brazilian Steel Industry, as it is the fist time that these products, apart for the well known bottom tapping system, are installed in a Brazilian Plant. With this project, other Brazilian Melt Shops can verify the efficiency of these systems and carry on their own revamping studies, considering that there are proven technologies in its own Country that are already working and well performing.