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START UP OF THE VSB MELTSHOP: THE FIRST CONSTEEL®-EAF IN BRAZIL[1]

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Abstract

Vallourec & Sumitomo Tubos do Brasil has recently installed the EAF-Consteel® in its new plant of Jeceaba, Minas Gerais. This equipment has a 140 metric tons ladle capacity and has been designed to produce one million tons per year of liquid steel. The EAF-Consteel® had to be designed for a very flexible mix of metallic raw materials, including hot metal, pig iron and scrap in various percentages. This fact has increased the level of complexity of the project in terms of layout and operational process. This paper relates about the design and engineering solutions adopted for the case and the team-building achievements, all ingredients for the successful result of this project.
Keywords: Consteel® system; Electric arc furnace; Continuous scrap charge; Energy savings; Productivity increase.

PARTIDA DA ACIARIA VSB: O PRIMEIRO FEA CONSTEEL® NO BRASIL

Resumo

A Vallourec & Sumitomo Tubos do Brasil instalou recentemente o FEA-Consteel® em sua planta de Jeceaba, Minas Gerais. Esse equipamento possui capacidade de panela de 140 t e foi projetado para produzir um milhão de toneladas anuais de aço líquido. O FEA-Consteel® foi projetado para um mix variado de matérias primas metálicas, incluindo gusa líquido, gusa sólido e sucata em diversas porcentagens. Esse fato aumentou o nível de complexidade do projeto em termos de layout e de processo operacional. Este trabalho apresenta as soluções de projeto e de engenharia adotadas na instalação e as conquistas na montagem da equipe: todos ingredientes importantes para o sucesso do projeto
Palavras-chave: Sistema Consteel®; Forno elétrico a arco; Carregamento contínuo de sucata; Economia de energia; Aumento de produtividade.

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1 INTRODUCTION ON THE CONSTEEL® SYSTEM

The Consteel® system, shown in Figure 1, was invented by a visionary engineer, Mr. John A. Vallomy, and the first industrial plant of this kind was started up in 1989 in North-Carolina, where it is still in operation.

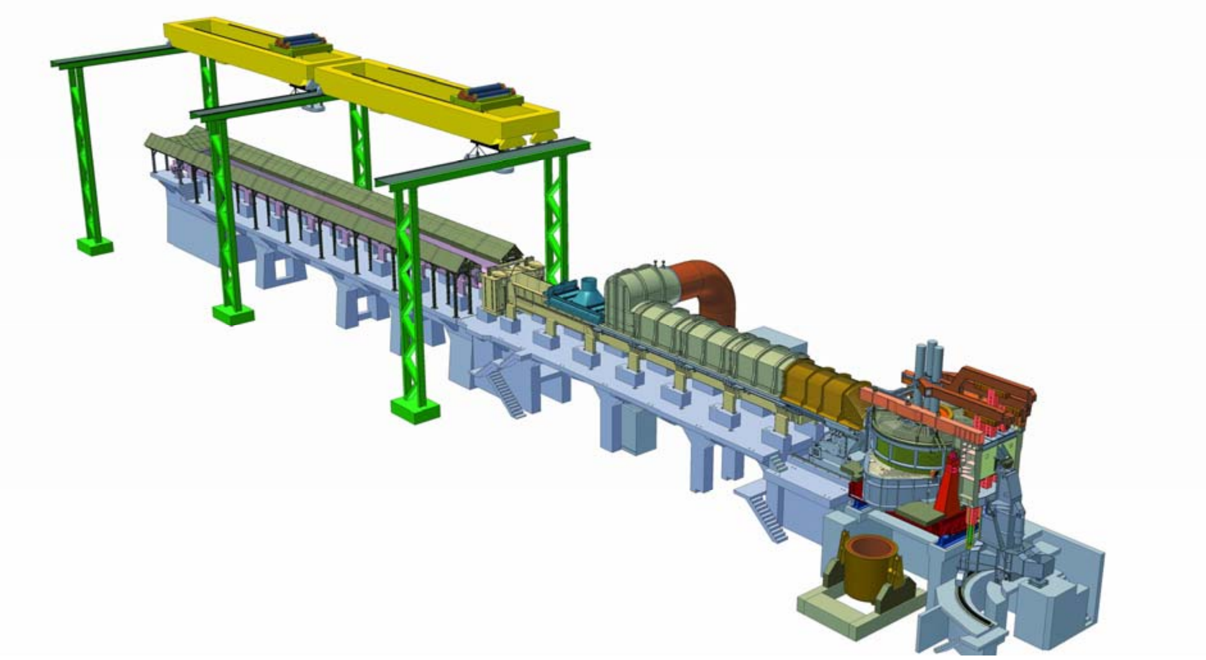

Figure 1. The EAF Consteel® System.

Up to now 41 Consteel® installations have been ordered in sixteen different countries and none of the 33 plants already in operation has been dismantled or substituted with another technology; arguably, no other innovative melting technologies can state the same track record.
The Consteel® system performs the continuous feeding of the metallic charge to the EAF by means of conveyors that connects the scrap yard to the EAF. The various conveyors are oscillating with a slow forward stroke and a fast backward stroke that achieves a slip-stick action that makes the charge advance towards the furnace. The Consteel® conveyor is very flexible in terms of the charge characteristics and allows the use of scrap with a wide range of densities and minimum preparation.
The charging section of the Consteel® conveyor is open to allow the loading of the metallic charge by crane and belt conveyors whilst the last section, connected to the furnace, is enclosed into the furnace off-gas suction duct, to heat the charge by means of the hot off-gas developed during the melting process.
In the Consteel® process, the metallic charge continuously heated and fed to the furnace is finally melted by immersion in the liquid bath, always present in the furnace. The liquid bath is heated by electric arcs and by the exothermic chemical reactions that take place due to oxygen injection. Carbon injection is also performed to promote the slag foaming process which allows the achievement of very high average heating efficiency with the electric arcs and a great reduction of noise and electrical disturbances on the network (flicker).
Constant flat bath operation and foaming slag practice reduce the disturbances on the electrical network to such an extent that, in many cases, has allowed significant savings in the equipment necessary to the reduction of the flicker level below the

required threshold. Less noise, less production of dust and much less uncontrolled emission of pollutants due to the conventional bucket charge allowed by the Consteel® process have significantly improved the environmental friendliness of the EAF process.
The traditional bucket charge of the furnace is practically eliminated by the Consteel® process (it is used basically only for the first heat of the furnace campaign). Drastically reducing the occurrence of the charge by bucket has proven to be a great benefit not only in terms of emission of pollutants but also in terms of operating time and energy efficiency, since a lot of heat is dissipated when the furnace roof is open. Maintenance has been also greatly reduced because of the significant reduction in the stress of the charging crane and on the furnace panels that don't suffer from arching and scrap impacts anymore.
On the energy efficiency side, the Consteel® process has also proven its advantages over the conventional bucket charge furnaces; these advantages come from the elimination of the losses due to the opening of the furnace, from the recovery of the process off-gas energy for the heating of the charge and from the higher average electric arc heating efficiency.
The Consteel® process has also demonstrated benefits on the material efficiency, with a typical metallic charge yield improvement of 1% compared with the equivalent melting process carried out in a conventional EAF. This effect is due to the natural recovery of heavier iron-rich dust particles that deposit onto the scrap inside the heating tunnel and from the minimization of the iron lost to the slag as FeO, owed to a slower oxidation process that is much closer to the theoretical C-O equilibrium.
Because of its efficient use of materials, energies, operating time and environmental friendliness, the Consteel® is increasingly becoming the technology of choice for those steelmakers that are looking after the highest productivity per installed MW with the minimum operational cost and environmental impact.

2 VSB PROJECT

2.1 General

On 19th of August 2011 VSB has started the new Consteel® EAF installed in Jeceaba, Minas Gerais.

Figure 2. VSB site.

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This EAF has a capacity of 140 metric tons with the following main characteristics:

EAF hourly productivity	150	t/h
Heat size	140	t
Required tap-to-tap	57	min
Tapping condition: temperature	1650	°C
Base charging sequence	Continuous charging	
Annual liquid steel nominal production	1,050,000	tls

The Consteel® EAF design concept has been developed with the following standard charge mix requirements:

- 30 t Scrap;
- 70 t Hot Metal;
- 55 t Pig Iron.

The mentioned standard charge mix is only one of the different charge mix scenarios – with its own consumptions and performances - with which the Consteel® system can work.
The flexibility of the Consteel® system allows recipes with scrap from 20% to 80%, pig iron from 5% to 80% and hot metal from 20% to 45%.

Table 1. Different EAF charge mixes

Charge mix		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Hot metal	%	45	45	45	40	30	30	20					
Pig iron	%	35	20	5	40	50	40	40	20	35	50	65	80
Scrap mix	%	20	35	50	20	20	30	40	80	65	50	35	20

All the auxiliary systems supplied (fume treatment plant, material handling system, etc.) has been design so has to work properly with each one of the mentioned scenarios.
In the first step of the project, VSB is running the plant only with scrap and pig iron (45% Pig Iron and 55% Scrap).
Together with EAF and Consteel®, a complete package of auxiliary equipment (EFSOP® system, KT injection system, hot metal charging system, EBT sand system, Ferroalloy handling system, pig iron charging system, fume dedusting system) have been supplied.

2.2 Scrap Yard

The scrap yard is designed in order to have train cars parallels to the Conveyor of the Consteel®. Train enters into the scrap yard from west to east.

Figure 3. VSB Consteel® scrap yard.

Train cars transport into the scrap yard the recycled scrap coming from rolling mill and CCM (crop ends etc.).
Other type of scrap can also be transported by train into the scrap yard, or by normal trucks, which access will be on the open side of the scrap yard (south side).
The scrap yard is equipped with two overhead cranes for the scrap handling and a front end loader can be adopted to move the pig iron from the ground to the pig iron skip receiving hopper.
Apart of the first bucket to be charged at the beginning of each campaign, all the scrap is charged directly by crane onto the Consteel® conveyor.
The layout arrangement permits to avoid any bucket transfer car as the scrap yard crane can reach the EAF position.
The pig iron is charged on the Consteel® by skip equipment. This skip equipment is provided by a receiving hopper of 25 m^3 volume in order to receive a complete truck of Pig Iron. From the receiving hopper the skip transfer the pig iron (with a rate of 60-70 t/h) to the hopper (25 m^3 volume) located on the top of Consteel®. As alternative this hopper can be filled also by crane. From this hopper by vibro feeder, the pig iron is loaded on the Consteel® conveyor.

2.3 Shell Maintenance Area

The EAF shell, upper shell and bottom shell are splitted type and can be removed for maintenance by the casting overhead crane. The EAF shell maintenance stand is located on the east side of the EAF position and there are two stands in order to take the old shell from its working position, sitting it in the maintenance stand, picking up the new EAF shell from the second maintenance position and putting it into the actual working position. The layout of the area has been studied so as to permit the

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replacement of the shell without any relevant interferences with all the other equipment on the platform and in the rest of the bay.
For this reason the shell change procedure can be performed in approximately 2-3 hours.

2.4 Hot Metal Charging System

The hot metal will be fed from the ladle to the furnace, through the EAF sidewall, by a refractoried channel.
The device is anchored on working platform level, on proper foundation by means of a counter-frame.
The system is positioned between the EAF slag door and the transformer cabin, in such a way to not interfere with the movement of the EAF tilting platform installed on wheels.
The hot metal ladle will be positioned on the tilting system having the axle of the trunnions perpendicular to the Consteel® axis.
The tilting movements, forward and backward, are operated by two hydraulic cylinders.
If necessary, it will be always possible to stop and restart the tilting movement by manual control.
The EAF overhead crane will pick up the ladle (one 70 ton ladle every hour) and position it on the tilting device on south-east of the EAF side.
Once the ladle will be emptied, approximately 20 to 30 minutes after the heat beginning, the empty ladle will be transferred to the ground in order to wait for the next full hot metal ladle.

Figure 4. VSB Hot metal charging system.

2.5 KT Injection System and TDR-H System

The following equipment has been installed on VSB furnace:

- n.4 Fixed Supersonic Oxygen Lances
- n.2 Fixed Coal Powder Injectors
- n.1 Fixed Lime Injector

KT Injection System is particularly indicated for Consteel® EAF which operates with high charge mix flexibility.
The low position of lances and injectors, with respect to the level of the steel bath, gives the highest efficiency of injection for oxygen and powder carbon inside the liquid steel.
This technology has been implemented taking care of the modular engineering, compact design, easy maintenance and long lifetime of the parts. In particular, the KT oxygen helicoidal nozzles (copper tips) are studied for the customized conditions of each furnace. Each EAF has its own distinctive nozzle, the only different part of all.
The KT Injection system has been integrated with the new generation Tenova EAF regulation, which manages dynamically all the energy sources, chemical and electrical. The new generation of TENOVA EAF's includes the ultimate features combined and controlled under the Energy Efficiency Management Package as part of the process automation.
The TDR-H (Tenova Digital Electrode Regulation System integrated with the Harmonic distortions analyzer) incorporates the full regulation of the electrode movement including the fast raising/lowering of the electrodes thus avoiding the electric arc interruption.
The direct and instantaneous measurements of the arc parameters (without conversion of signals and with simultaneous processing of the same signals) combined with the fume analysis and linked to the KT Multipoint Injection System allow the achievement of top level performances and constant operation conditions.

2.6 EFSOP® System

VSB decided to include in the supply also the EFSOP® technology (Expert Furnace System Optimization Process) to continuously sample furnace off-gas and use this off-gas analysis along with real-time operating data from select process points to provide dynamic process control and optimization.
The benefits to be pursued with EFSOP® Optimization are:

- reduce overall operating costs,
- increase productivity and yield,
- minimize process variability,
- detect unsafe levels of H_2O, H_2 and CO to improve furnace and bag house safety,
- achieve lower chemical and electrical energy consumption,
- reduce use of consumables such as electrodes,
- realize environmental benefits from a more efficient use of energy and materials.

The EFSOP Holistic Optimization® system is shown schematically in Figure 2 and consists of several key features.

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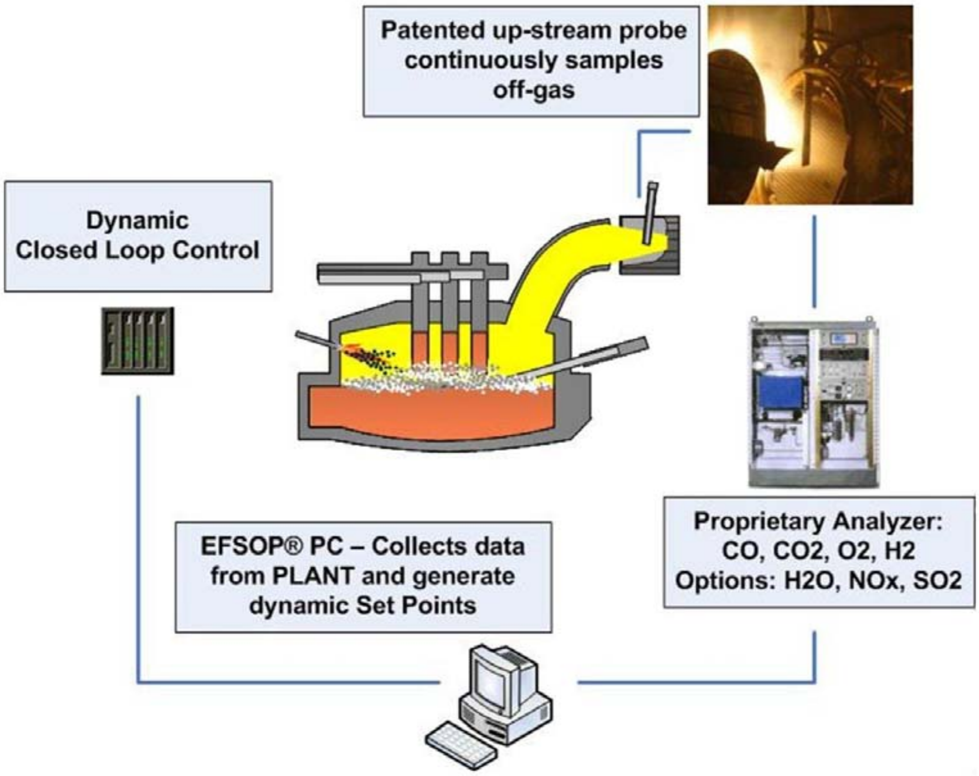

Figure 5. EFSOP Holistic Optimization® for Consteel® EAF Steelmaking.

Patented EFSOP® water cooled probe is positioned directly inside the cone of off-gas exiting the EAF to ensure continuous, fast-response, accurate off-gas analysis without the complications associated with gap air dilution.
The probe maintenance is required only at weekly intervals usually during a plant down-day. The probe uses an automatic back-purge cycle which coincides with power-off periods together with a specialized design and a proprietary internal filter to prevent blockage. Maintenance is typically only 15 minutes per week for a primary filter change along with minor mechanical cleaning to remove any accumulated particulate.
A heated line prevents condensation during transport of the off-gas from the probe to the analyzer.
A conditioning system first cleans and dries the off-gas prior to analysis.
The analyzer uses a variety of analytical systems to continuously analyze for CO, CO_2, H_2 and O_2.
In VSB Consteel® a dual probe design maintains continuous analysis with automatic and controlled cycling between back-purge & off-gas sampling.
The EFSOP® analyzer is installed in a controlled environment enclosure within about 30 meters of the probe, with a response of 15-20 seconds.
The EFSOP® computer uses real-time off-gas analysis to perform dynamic closed loop control calculations and sends process set-points back to the plant PLC for fully optimized dynamic lances control.

2.7 EBT Sand System

This system allows the discharge of the sand required to fill the EBT hole after furnace tapping.
The advantages of this system are:

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- fast download of the sand;
- reduction of power off time;
- possibility to perform the operations by remote control (i.e. from furnace pulpit).

The system is designed to make automatic lockup of EBT with the furnace tilted with an angle of 10°; the admissible tolerance to guarantee the operation in automatic cycle is of about ± 1°.
The objective of the system is to discharge sand in EBT in automatic mode, with direct visual monitoring of operations.

2.8 Ferroalloys Handling System

The system will be composed by a material storing and dosing system, and a transport line to the EAF.

Figure 6. VSB Ferroalloy handling system.

The system will store materials in the underground receiving weighing hopper fed by truck and extract them through electromagnetic vibrating feeders. By means of an elevator belt conveyor and through a reversible shuttle belt conveyor, materials are transferred and stored inside nr. 06 storage bins of 50 m^3 capacity.
Then alloys are conveyed via electromagnetic vibrating feeders to nr. 01 fixed weighing hopper of 2.5 m^3 capacity.
From the fixed weighing hopper materials are extracted through electromagnetic vibrating feeder, and conveyed to the users by means of a cups elevator belt conveyor and one horizontal belt conveyor that, through an electro-mechanic vibrating feeder, discharges them in a fixed weighing hopper.
From the fixed weighing hopper the materials are discharged into the ladle through a pneumatic valve.

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2.9 Fume Dedusting System

The system is dedicated to the suction and cleaning of the off-gas coming from EAF and from the LF, the emissions from the canopy hood installed in the roof structure, the emissions from additive plant for EAF, Fe-alloys plant for LF, Ladle deslagging station and VD plant.
The primary off-gas is sucked from the EAF via CONSTEEL® off-take hood, while the secondary fumes are those emitted during steel tapping or scrap charging.
The main parts of the system are:

- Primary suction line for EAF off-gas (Consteel® Off-Take Hood),
- Drop Out Box for primary off-gas,
- Water cooled ducts,
- Quenching Tower,
- Spark arrestor on primary off-gas line,
- Canopy hood for EAF secondary fumes and relevant ductwork,
- Suction line for LF off-gas with booster fan,
- Additive plant for EAF suction hoods and ductwork with booster fan,
- Fe alloy plant for LF suction hoods and ductwork with booster fan,
- Ladle deslagging station ductwork with booster fan,
- VD plant ductwork with booster fan,
- Primary and secondary suction circuits and mixing duct,
- Bag Filter,
- Main fans station,
- Stack,
- Dust transport and storage system,
- MCC, instrumentation and Automation.

WC elbow with a diameter of 3.2 m sucks the fumes from the Consteel® Off-Take Hood.
The elbow duct enters a drop out box (DOB) where the gas combustion is completed and the heavier particles of the fumes are settled to avoid deposits along the duct. This chamber is accessible from a large door to remove the settled dust and has the lateral refractory lined and the roof will be made in WC panels.
Another WC duct installed at the outlet of the DOB with a diameter of 3.0 m is foreseen to reach a max temperature of the fumes of about 700°C.
A quenching tower with a diameter of 5.2 m reduces the fumes temperature at about 350°C, with a consumption of water of about 43 m^3/h as peak and an average consumption of about 35 m^3/h.
A spark arrestor with an internal static turbine is foreseen on the primary line just after the quenching tower upstream the connection of primary and secondary fumes.
The canopy hood over the roof of the building has a volume of about 5300 m^3 and inlet section of about 530 m^2.
A secondary fumes duct from the canopy has a diameter of 4.8 m.
A mixing duct with a diameter of 5 m mixes the fumes coming from the primary line, the LF line and auxiliary suctions with secondary fumes.
The duct that drives the mixing of the primary fumes collections and the canopy hood duct is a dry duct with a diameter of 3.2 m.
The bag filter - designed for a nominal flow-rate of 1.900.000 m^3/h and about 19.600 m^2 of filtering surface - has polyester bags with a dust storage silo and a dust transport system by chain conveyors.

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During EAF melting it will treat 1.650.000 m^3/h at 115°C, while during EAF tapping (or charging), it will treat 1.850.000 m^3/h at 60 °C.
The filter is equipped with three fans of 1.600 kW each.
The stack has a diameter of 6 m and a total height of about 35 m.
Dust emission content at the stack is less than 20 mg/Nm^3.

Figure 7. VSB Fume dedusting system.

2.10 Commissioning and start-up

The scope of work of Tenova was the design and supply of the equipment above mentioned, which were erected by a group of erection companies directly selected by VSB.
During the erection phase, Tenova supervisors of various discipline, as well as different manufacturer's specialists, were involved: this till the last phase of commissioning, start up and setting up of the plant.
To stick with the target deadline requested by VSB for the start up, during the last period of erection, a detailed program of activities was prepared by VSB, with the aim to anticipate as much as possible the tests on equipment/area that time to time were becoming ready.
As result at a certain stage, in different areas erection, cold test and run test were in progress simultaneously.
All these strengths allowed to have the first heat on 19th of August 2011.
After a first period of setting up of the different parts of the Tenova supply, as well as on LF and CCM, and because of the lack of hot metal availability (Blast Furnace not yet ready), the daily production was planned to reach 14 heats a day for 5 days a week, till June of 2012.
During the presence of Tenova supervisors and of the manufacturer's specialist, different sessions of training on maintenance and operation, as well as on automation and process, were completed.
Since the start up, the plant was conducted by VSB personnel with Tenova assistance, but from the November 2011 on, VSB started running the plant on their own, calling Tenova assistance whenever necessary.
Since the start-up of August 19th the EAF has been operated without hot metal, having a very flexible scrap mix with Pig Iron up to 45%. The design of the EAF and

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the Consteel® are extremely integrated and thanks to this the system can work at the same time with the usual high efficiency in scrap melting typical of a scrap-based Consteel® and with a decarburization speed very similar to a converter.
In order to prevent any excessive preheating of the pig iron while moving into the Consteel® preheating area due to the high flowrate and temperature of the fumes coming from the EAF, a dedicated flap system is used in combination with a particular design of the hoods; this system can protect the scrap and pig iron layer on the Consteel® according to the different phases of the process.
Thanks to the high efficiency and stirring effect from the KT lances in combination with the 4 purging plugs on the EAF bottom (continuous flow rate of 40 Nl/min for each plug) the decarburization has always been extremely smooth, despite of the high percentage of Pig Iron in the charge.

3 FINAL CONSIDERATIONS

The project of the Consteel® EAF for Vallourec & Sumitomo Tubos do Brasil has been certainly a challenge for the level of complexity of the job in terms of layout and operational process.
Our deepest gratitude goes to the many VSB employees who have participated to the different phases of this job and whose hard work and dedication has made this project a success.