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THE 420 TON TWIN DC, JUMBO SIZE FASTARC® AT TOKYO STEEL – JAPAN[1]

Tokuo Ogawa [2]
Romano Sellan [3]
Enzo Ruscio [4]

Abstract

A single 420 t total capacity twin DC ultra high power EAF equipped with the Consteel® system has been successfully started up in June 2010 at the Tokyo Steel Tahara Plant. The Jumbo Size EAF is the largest ever built and is designed to achieve a yearly productivity of 2.6 Mt/yr, with 360 t/h: this EAF has extreme efficiency in terms of operating costs due to low manpower and low energy demands. The construction of a single, high capacity EAF (tapped size 300 t) is in line with the steelmaking trend of last years: meltshop sizes are increasing to reach higher productivities and efficiencies, with limited investment in order not to affect margins with high fixed and variable costs. The most advanced technologies have been employed, due to relevancy of the main issues related to fast process in large size EAF: ultra high power supply, which is particularly critical in this case because of the weak network available, and high efficiency of metallurgical processes, needed to achieve constant steel quality in a short tap to tap. The plant also includes secondary metallurgy equipment for the production of high quality steel (low and ultra low carbon for hot rolled coils) and a powerful fume treatment plant.

Key words: Electric arc furnace; DC; Twin electrodes.

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[2] General Manager – Tokyo Steel
[3] Executive Vice President – Danieli Steel Making
[4] Executive Vice President – Danieli Centro Met

PLANT LAYOUT

The layout of the meltshop has been studied in order to achieve extremely efficient operations through an optimal space arrangement: this result is achieved with a single bay design, which optimizes infrastructural investment (Figure 1).

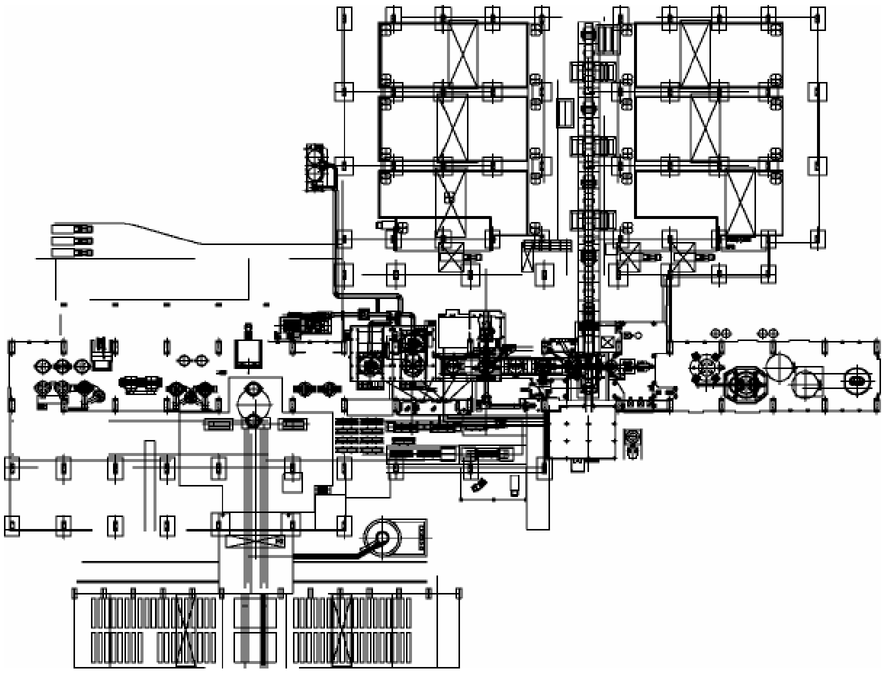


Figure 1 – Plant layout.

The 420 t, Ultra High Power, Twin DC EAF is continuously fed through the Consteel® system, as a result of the exclusive agreement between Danieli and Tenova.
Tokyo Steel has developed an innovative charging system, which feeds the scrap from ship yard to Consteel in automatic mode.
Secondary steelmaking is performed by a 300 t ladle furnace (LF) equipped with two ladle cars, and by a vacuum degassing station (VD) with twin tanks and twin covers, connected to a 700 kg/h ejector pump. The fume treatment plant (FTP) is equipped with a 3.2 Nm^3/h double filter, reverse type. All equipments are controlled and optimized by an innovative and fully integrated automation system.

EAF FEATURES

The achievement of 2,6 Mt/yr productivity with a single EAF is a major technological advancement, which has required proper design in order to supply ultra high power (up to 175 MW) limiting the level of disturbances even with the weak network available, and at the same time to obtain bath homogenization and quality of the final product, with a short tap to tap.
The plant will produce medium, low and ultra low carbon grades.
The following performances has been guaranteed:

- Power on time: 42 min
- Tap to tap: 50 min
- Productivity: 360 t/h
- Charge mix: 100% scrap
- Charging capacity: up to 9 t/min

- Electric consumption: 387 kWh/tls
- Oxygen consumption: 33 Nm^3/tls
- Electrode consumption: 1,2 kg/tls

The EAF design consists on a full platform, split shell furnace, 9,7 m shell diameter, with continuous scrap charging and twin DC power supply technology.
The EAF is designed to tap 300 ton of liquid steel and keep 120 ton of hot heel, with a total capacity of 420 ton: such a high level of hot heel has the duty to enhance the melting rate of continuous scrap fed by Consteel.
The use of Consteel® and twin DC technologies is the best solution, which allows to apply such a high power level (175 MW)., even with the presence of weak network (1700 MVA as SCC).

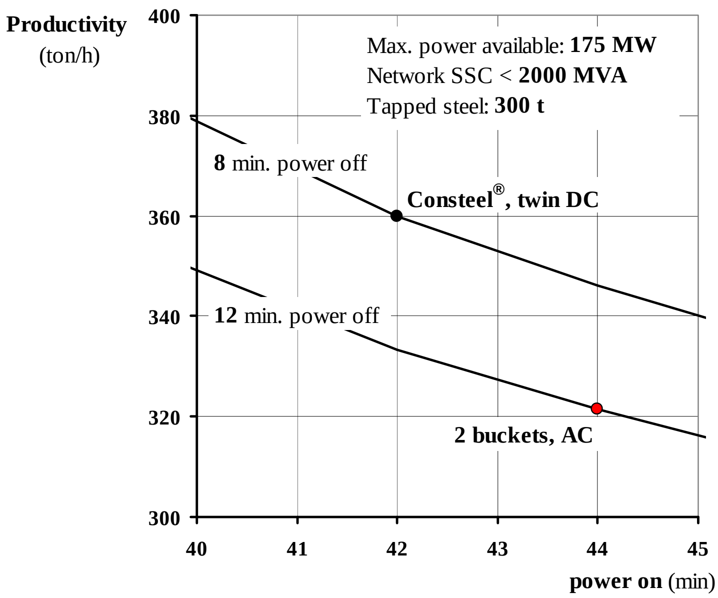


Figure 2 – Comparison between Consteel - twin DC and 2 buckets - AC technologies, with high power and weak network.

The Figure 2 shows a productivity comparison between Consteel technology and a conventional EAF (2 buckets charge): about 4 minutes power off will be saved (absence of buckets charge into the furnace), and power on is reduced of about 2 minutes, thanks to a better ratio between average and maximum applied power. In fact, in order to reach the extremely high power value of 175 MW, power ramp-up in the boring phases would require about 2-3 minutes for each bucket, during which average power would be half of the maximum power.
On the contrary, continuous scrap charging (with the presence of a molten metal heel which ensures quick scrap melting throughout the process) and twin DC supply (with full control of current between anodes and reduced network disturbances) allow employing very high power from the beginning of the process, with stable arc conditions.
The high efficiency of Twin DC is coming from the fact that the arc is converging between the two electrodes and the scrap is fed towards the arc converging area achieving the best melting efficiency.
The formation of the desired slag composition and consistency throughout the process is achieved by adding slag builders continuously from the fifth hole: also the melting of the charged slag builders is very quick, since the feeding is directed close

to the arc converging area and to oxygen injection. As a result, power is employed very efficiently: average power is 95% of maximum power, with a melting rate equal to 2,1 ton/h/MW available.
Moreover, continuous scrap charging results in improved meltshop logistic, less noise and electrical network disturbances.

TWIN DC TECHNOLOGY FOR ULTRA HIGH POWER SUPPLY

The requirements in terms of low electrical disturbances, due to the presence of weak network (SSC = 1700 MVA), has been solved by means of the twin DC technology.
Tokyo Steel EAF is the most powerful DC in the world, designed for a maximum power of 175 MW. The EAF has been designed with the two cathodes (twin DC technology) and four water cooled bottom anodes: each anodes has the capacity to operate up to 70 kA.
The twin DC technology, compared to single cathode design, allows providing extremely high power, carrying total 280 kA with smaller electrode diameter, and reducing the network disturbances.
The main technical features of the equipment for DC power supply (Figure 3) are the following:

- Primary voltage: 33 kV
- Transformers: 4 x (2 x 32 MVA)
- AC / DC converters: 8 x 35 kA
- Reactors: 8 x 350 µH
- Operating current: 4 x 70 kA
- Operating voltage: 600 V
- Cathodes diameter: 30”

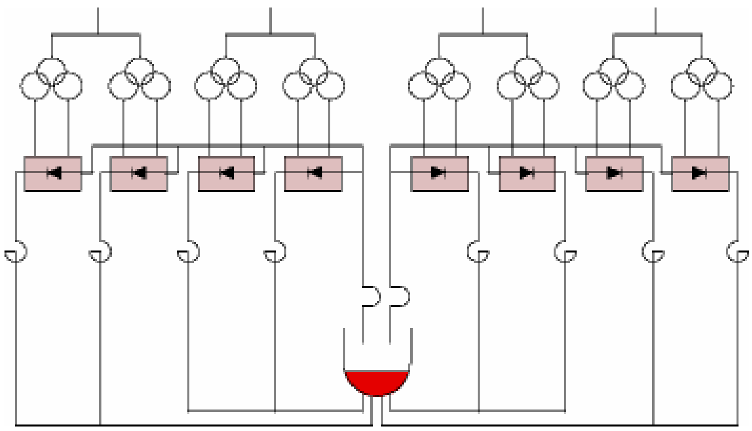
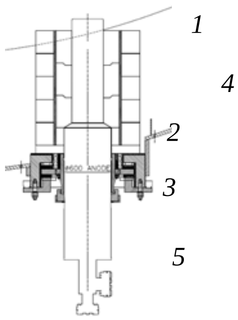
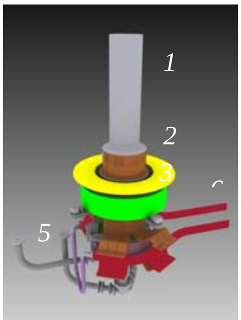


Figure 3 – Electrical network for twin DC power supply.

Maximum flexibility in power regulation is reached by individual control of current conduction and distribution between each of the four anodes. The particular design of the water cooled bottom anodes (Figure 4) allows standard type of refractory to be used. The anode cooling is located inside the refractory and, together with the full control of anode conditions in terms of water flow, temperature and pressure, ensures low thermal stress for refractory and electrical insulation, thus increasing life and safety of the installed components. This design allows also providing intermediate repairs to the anode refractory, prolonging the anode life.



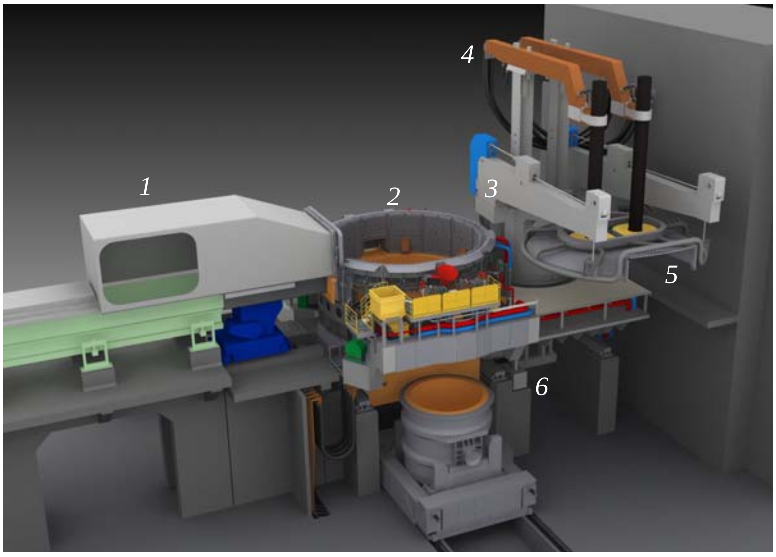


1- liquid metal
2 - solid metal
3- water cooled copper part
4- wearing refractory part
5- cooling water connections
6- on board connections

Figure 4 – Water cooled bottom anodes design.

EAF MECHANICAL DESIGN

As shown in Figure 5, the EAF has a full platform design, which allows compact installation, limited erection and civil works execution time.
The electrode masts-and thrust bearing position allows designing shorter electrode arms, having higher mechanical rigidity and better electrode regulation performance.
The tilting platform is based on 3 rockers design, providing better operational stability on bearing area. The rockers misalignment with furnace ensures safe back tilting.



1- Consteel®
2- EBT, split shell
3- Superstructure
4- conductive electrode arms
5- water cooled roof
6- tilting platform

Figure 5 – EAF mechanical design.

Innovative water cooled panels (Danieli patented design) are installed, based on advanced design resulting from numerical analysis of temperature profiles (Figure 6). This particular design, made up by double tube layers, lowers the risk of breakage, increasing panels life (experienced already more than 20000 heats in other plants) and safety of operation. Most of all, significant decrease of energy consumption is reached, due to radiation losses, which are 25% less compared with conventional panels.

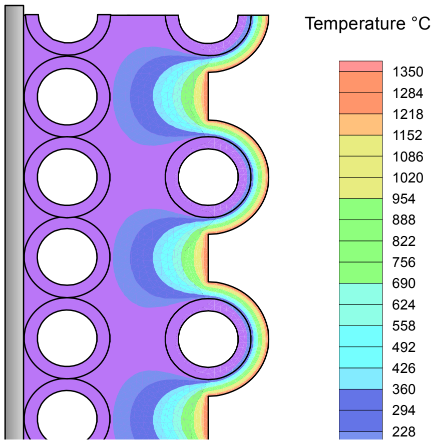


Figure 6 – Energy saving, water cooled panels.

CHEMICAL ENERGY ARRANGEMENT

Due to the high required melting rate and large bath dimension Danieli has developed a special design of oxygen and carbon injectors, whose layout is reported in Figure 7.

The optimal injector distribution and installation arrangement ensure proper stirring pattern, homogeneous liquid steel temperature and fast decarburization. In particular, the injection of carbon close to oxygen enhances its reactivity and therefore improves foaming slag efficiency, which is of great importance in this kind of process (flat bath) to increase arc coverage, heat transfer rate to the melt and to protect walls, refractories and panels from thermal stress.

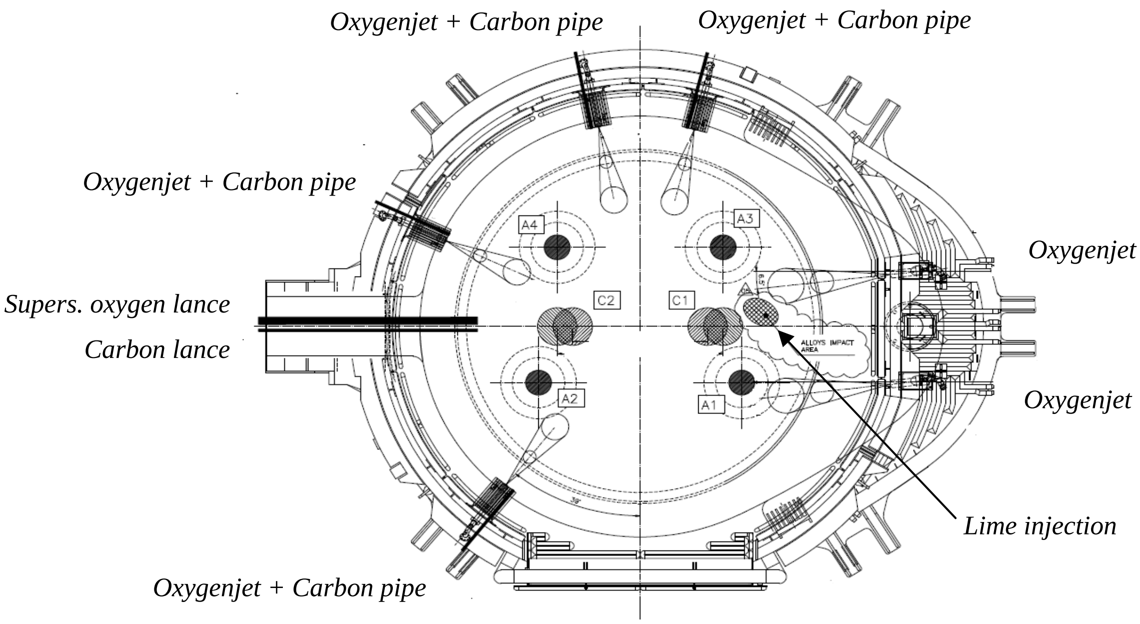
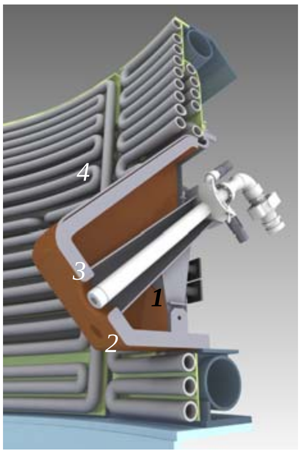


Figure 7 – Oxygen and carbon injectors layout.

Supersonic oxygen and carbon lances are automatically introduced into the furnace through the door by PARPI manipulator (Figure 8): it can be moved towards the melt, promoting injection efficiency, mainly during the initial phase, with very low bath level.

Figure 8 – Parpi Oxygen and carbon manipulatort.

The oxygen jets and carbon pipes are installed inside water cooled copper bulged boxes (Figure 9), which provides proper injector protection, reduces the distance between injectors tip and liquid steel and improves the refractory life under the injector.



1- Oxygenjet
2- Carbon pipe inlet
3- Water cooled bulged panel
4- Energy saving panels

Figure 9 – Water cooled bulged panel with oxygen and carbon injectors.

The following table shows the injectors flow rates:

Oxyjets	6 x 2600 Nm3/h
Supersonic Oxygen lance	1 x 4000 Nm3/h
Carbon pipe	4 x 70 kg/min
Carbon lance	1 x 70 kg/min

MELTING PROFILES

The presence of a molten metal heel with absence of scrap, made possible by the Consteel® technology, and the reliability of Twin DC supply enable high power to be used from the very early stages of the process, as shown in Figure 10, with limited network disturbances.
The highest values of scrap feeding rate (9 t/min), power (175 MW) and oxygen flowrate (15000 Nm^3/h) are reached after only 4 minutes of power on.
Carbon injection is gradually raised in order to achieve in every phase of the process an optimal balance between electrical and chemical energy and homogeneous CO bubbles generation which ensures, together with slagbuilders injection from fifth hole,

an adequate slag foaming and therefore a high efficiency of heat transfer from the arc to the bath.

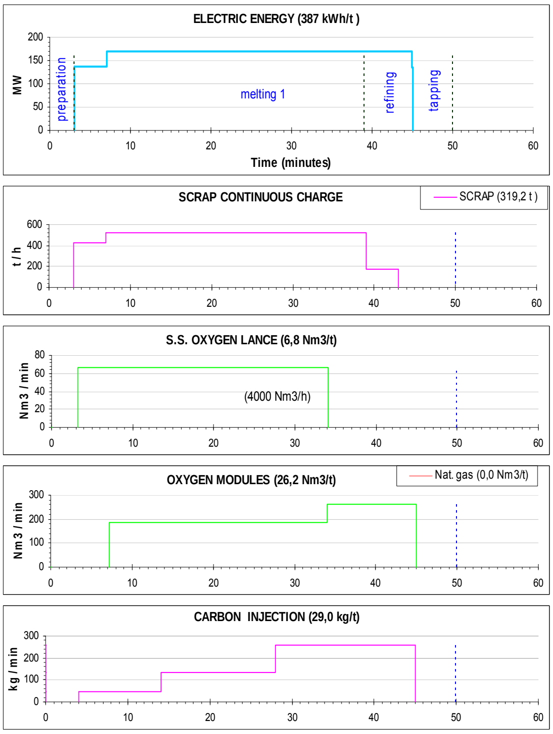


Figure 10– Melting profiles.

AUTOMATION SYSTEM

All operations are controlled and optimized by an innovative and fully integrated automation system, in order to minimize operator's intervention, achieve a high repeatability of results and reduce power off. The automation system covers both equipment control (Level1) and process control (Level 2) and is based on state of the art hardware and software platforms, while the application software is the well proven Danieli Automation package, result of over 40 years of experience in the steelmaking field.

Besides the Consteel® scrap charging system, the meltshop is provided with an integrated material handling system (IMHS).

The electrode control package Hireg® and hydraulic system design, guarantee very fast response time, enhancing the average power to the melt.

The on-line monitoring of process data and recording of process data for subsequent analysis also improves the knowledge of arc behaviour, which is particularly important considering the extremely high power input.

Full control of all electrical and chemical furnace parameters is provided, with working points being automatically variated according to the process phases, guaranteeing high repeatability of furnace performances in terms of steel quality and energy consumption.

As already mentioned the Consteel is charged automatically, and in order to control the level of scrap inside the Consteel, Danieli Automation has developed an innovative monitoring system, based on laser technology, which provides step by step the level of scrap in the Consteel.

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MECHATRONICAL PACKAGES

The demanding requirements in terms of high productivity have imposed the minimization of power off time, and this has been reached installing reliable mechatronical equipments. These equipments have also increased the operators safety, avoiding operators direct exposure to the process and allowing the remote control, operating in the main control room even if located far from EAF.
Danieli has provided the following equipment:
Besides and EBT sand refilling, the following operations can be carried out automatically:

- Motank robot (Figure 11): this equipment has a sturdy design and allows to keep clean the slag door during power ON time in safe and consistent mode;
-

Figure 11 – MOTANK robot for slag door cleaning in power on.

- automatic tapping system: this is full package including:
  - infrared camera (Figure 12) for fast and reliable remote detection of tapping stream; the fast thermal image response avoids slag carryover into the ladle;
  - high resolution camera for remote ebt control;
  - automatic sand refilling system to ebt.

which allows to control the tapping procedure from the main pulpit.

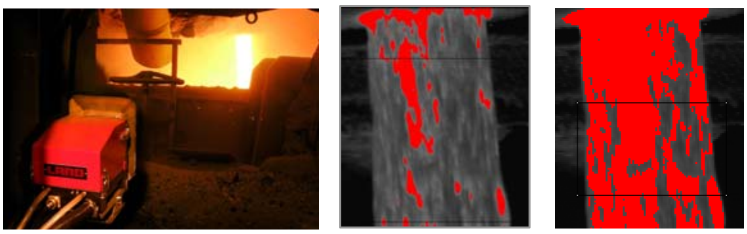

Figure 12– Automatic tapping system through infrared slag detection.

EAF OPERATIVE RESULTS

Furnace start-up has been successfully completed in June 2010. The reliability of mechanical and electrical equipment, as well as simplification of operations due to efficient automation system, has made it possible to reach relevant and consistent performances after one month from the first heat. The following table shows the main operating values obtained.

Table 1. Main operating values.

	unit	*Contract*	*3 month after start-up*
Tapped steel	*t*	300	305
Tap to tap	*min*	50	52
Power on	*min*	42	43
Productivity	*t/h*	360	352
Electric energy consumption	*kWh/tls*	387	392
Oxygen consumption	*Nm^3/tls*	33	20
Injected carbon consumption	*kg/tls*	7	11
Tapping temperature	*°C*	1640	1650

Ultra High Power is being supplied without introducing disturbances to the network. This allows high and stable power input throughout the process, as shown by Figure 13.

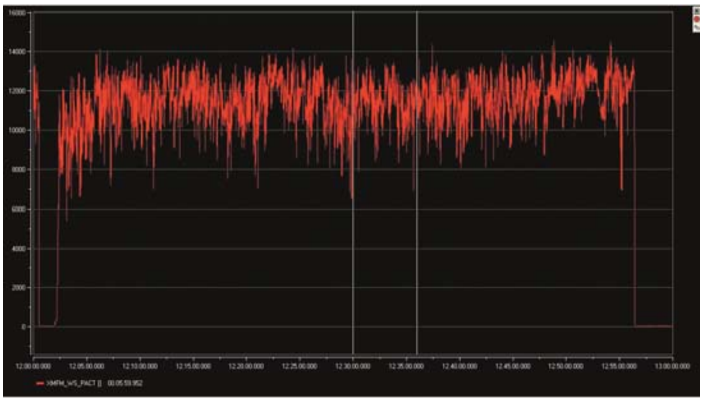

Figure 13– Active power during the process.

SECONDARY METALLURGY

Final steel quality for all grades (medium, low and ultra-low carbon for hot rolled coils) is obtained by means of a ladle furnace and a twin tank vacuum station.
Ladle furnace is equipped with a 45 MVA transformer which enables a maximum power supply of 32 MW, with a heating rate of 3,3 °C/min. Operations are made fast and efficient by automatic feeding system and sampling equipment.
The ladle furnace is equipped by inert roof design (Figure 14) that provides a neutral pressure inside the ladle furnace via a pressure damper regulating the draft on secondary hood suction line. Consequently, air infiltration is strongly reduced and the following benefits are obtained:

- reduced electrode side-oxidation;
- reduced oxidation in the slag which results in lower FeO and oxygen content in the steel;
- reduced hydrogen and nitrogen pick up from the furnace atmosphere.

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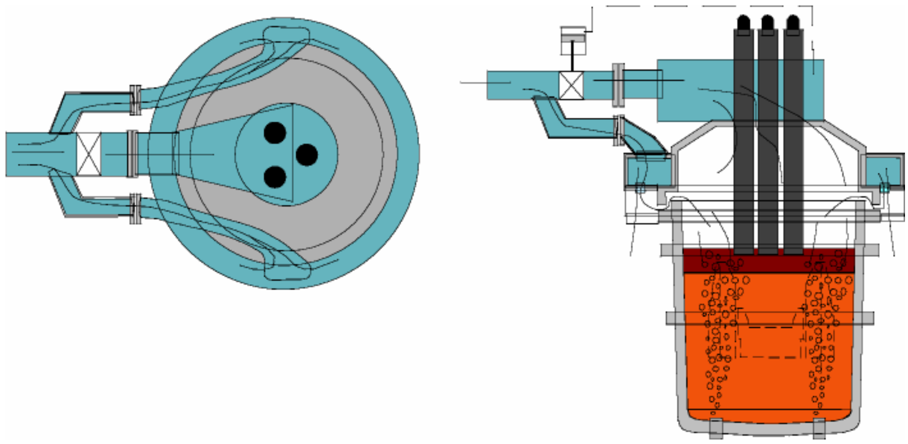

Figure 14– Ladle furnace with inert roof.

The vacuum system, obtained by means of a 4 stage steam ejector pump with water ring pumps as backing stage is capable to provide 700 kg/h suction capacity at 0,5 torr, ensuring a pump-down time down to 0,5 torr in less than 5,5 minutes. Twin tanks installation, with switchable suction line, allows high operational flexibility, with the possibility to position two ladle at the same time.
Oxygen lance has also been provided and will give the flexibility to produce also ultra low carbon grades, providing the required decarburisation.

FUME TREATMENT PLANT

An extremely powerful fume treatment plant has been provided (Figure 15) in order to fulfil the strict environmental requirements. The plant processes a total flow 1650 MNm^3 / h of fumes, of which 400 MNm^3 / h from primary suction. Fumes are filtered in a double bag filter, with a cleaning system based on reverse air type. This cleaning system allows for low air to cloth ratio, resulting in a long lasting bag life. An axial cyclone, acting as spark arrester, is installed in front of Bag Filters in order to protect the bags from damages related to sparks coming from the EAF.

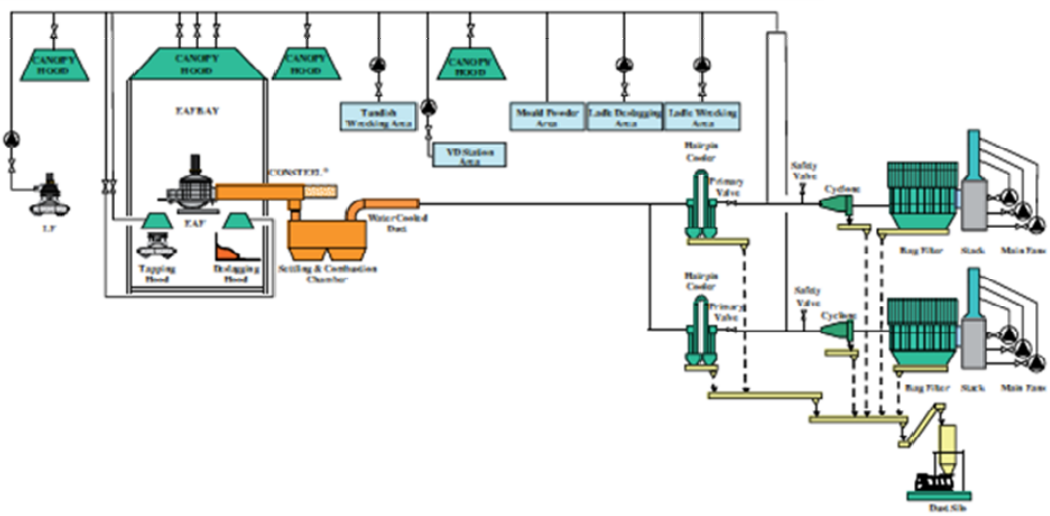

Figure 15– Fume treatment plant.

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CONCLUSIONS

The new Jumbo Size Twin DC EAF, described in this paper, is successfully operating in Tokyo Steel, Tahara plant. This design is representative of the last years market trend, which has brought the steel producers to focus more and more on the increase of the meltshop productivity and efficiency for flat products, as well as ensuring high quality of steel produced.
The furnace is the largest ever built, with 420 ton capacity: state of art technology (Consteel® and Twin DC) has been applied to obtain from the maximum power available (175 MW) the highest possible productivity with limited disturbances to the weak existing network (SSC = 1700 MVA). Process efficiency is reached through optimal design of chemical energy configuration and the implementation of an innovative and fully integrated automation system. The last innovative mechatronical packages are employed in order to reduce power off, increasing safety and efficiency of operations.
The EAF, even if is still in learning curve phase, has already demonstrated a very positive trend in term of productivity and efficiency, and our expectation is to obtain very quickly the performance parameters.