THE 1.2 MTPY STEELMAKING PLANT AND COMBICASTER FOR THE NEW MINIMILL AT SIDERURGICA BALBOA, SPAIN[1]

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Abstract

During September 2004, Alfonso Gallardo Group, awarded Danieli as supplier of a new Minimill to be installed in the existing Balboa Complex, located in Jerez de los Caballeros, Spain. The Steelmaking Plant of about 1.2 is basically made up of one 130-t full platform split-shell FASTARC EAF equipped with a 140 MVA + 20% transformer, one 130-t inert-roof Ladle Furnace equipped with a 20 MVA + 20% transformer, one Fume De-dusting Plant and one 6-strands multi-bending 10/19 m radius FASTCAST Combicaster for billets (up to 160 mm), blooms (up to 250 mm) and beam blanks (up to 610x320 mm). The supply, including also Water Treatment Plant and raw Material Handling System, covers all electricals and an advanced automation system for the whole Minimill. The high performances of the Furnace drop the TTT time down to 45 min guaranteeing the 173 t/hr required productivity, as well as providing the best meltshop labour and transformation cost optimization. The single heavy bay layout configuration allow an easy and smooth process route of the EAF tapped liquid steel passing through the in-line Lade Furnace refining station before feeding the Combicaster.

Key words: Balboa; Minimill; Combicaster; Billets; Beam blanks.

A NOVA ACIARIA E LINGOTAMENTO DE 1.2Mtpa PARA A NOVA MINIMILL NA SIDERÚRGICA BALBOA, ESPANHA

Resumo

Durante setembro de 2004, o Grupo Alfonso Gallardo, elegeu a Danieli como fornecedor de uma nova Minimill a ser instalada no Complexo Balboa existente, localizado em Jerez de los Caballeros, na Espanha. A aciaria de aproximadamente 1.2Mtpa é basicamente composto de um FEA FASTARC de plataforma de 130 t de carcaça bi partida equipado com um transformador de 140 MVA + 20%, um Forno Panela de 130-t com abóboda inerte equipado com um transformador de 20 MVA + 20%, um Despoeiramento e um Lingotamento FASTCAST Combicaster para 6 veios de raios múltiplos com 10/19 m de raio para Tarugos (até 160 mm ou até 250mm)e "beam blanks" (até 610x320 mm). A fornecimento também Tratamento de água e movimentação de matérias-primas, abrange toda a parte elétrica e um avançado sistema de automação para toda a Minimill. O alto desempenho do Forno diminuiu o tempo do TTT para 45 min. garantindo a 173 t/h de produtividade exigida, bem como proporcionou o melhor trabalho da aciaria e otimização dos custos de transformação. Uma configuração de layout em único galpão permite uma rota de processo fácil e simples desde o vazamento do FEA passando em linha para a estação de refino Forno Panela antes de alimentar o Combicaster.

Palavras-chave: Balboa; Minimill; Combicaster; Tarugos; Beam blanks.

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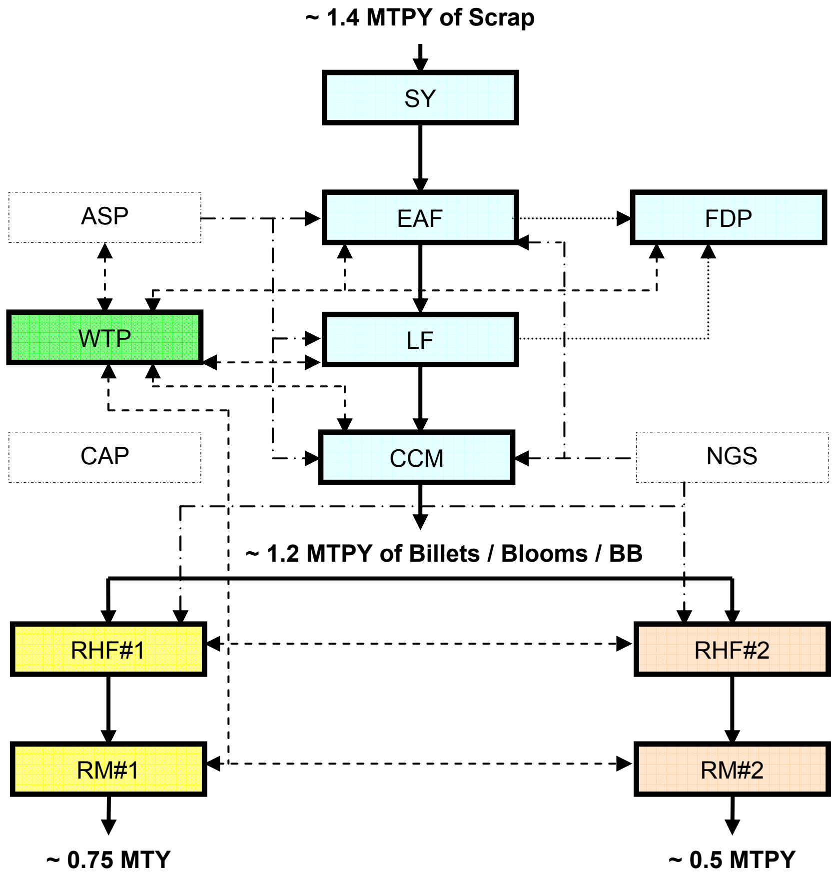
INTRODUCTION

Today, more than ever, when uncertainty prevails over the market, the flexibility may be the key factor to pass through the negative trend reducing the losses to the minimum.
The new Danieli Minimill *Balboa 2*, installed in the existing Balboa Complex of Alfonso Gallardo Group is the paradigm of how flexibility together with reliability may be reached with the Danieli state-of-the-art equipment.
In this respect, the Alfonso Gallardo Group with the new Danieli facilities is able to serve the construction industry with a very flexible plant, although sophisticated, in order to meet the market demand with a wide range of finished products, even in very small lots.
As a consequent, an important characteristic to be highlighted is the Balboa Mission to create not only a big plant to serve the international market but also a “regional mill” able to transform local scrap into finished products for the local markets assuring additional saving in the transportation costs.

Figure 1 - Balboa 2 Minimill

The complete Minimill for small and medium size long products, shown on Figure 1, is made up of a Steelmaking and Combicasting Plant for billets, blooms and beam blanks of about 1.2 Mtpy, a Medium Section Mill of 750,000 tpy (RM #1 for beam and large size-profiles) and a Multi-Line Super Flexible Mill of 500,000 tpy (RM #2 for round bars, spooled bar-in-coils, wire rod coils and small medium sections). The Danieli supply, including also Water Treatment Plant, covers all electricals and an advanced automation system for the whole Minimill.
The following Figure 2 - **Block Flow Diagram**shows all the main plant units of the Minimill distinguishing the ones supplied by Danieli (coloured and bold outlined) from the auxiliary plants provided by the customer (dotted-dashed outlined).



Legend:
SY = Scrap Yard
EAF = Electric Arc Furnace
LF = Ladle Furnace
FDP = Fume De-dusting Plant
CCM = Continuous Casting Machine
CAP = Compressed Air Plants (feeding all the new mentioned plant units)
ASP = Air Separation Plant
Material flow =
Fume/Dust =

RHF #1 / #2 = Reheating Furnace for RM#1 / #2
RM #1 = Rolling Mill #1 (Medium Section Mill = MSM)
RM #2 = Rolling Mill #2 (Super Flexible Mill = SFM)
WTP = Water Treatment Plant
NGS = Natural Gas Reduction Station
Cooling water =
Technological/Natural Gases/Oil =

Figure 2 - Block Flow Diagram

PLANT CONCEPT

The new Minimill *Balboa 2*, erected during 2006 and 2007, has been built in the existing Balboa complex, located in Jerez de los Caballeros, Spain, which was already featuring a facility for bars and a combined galvanizing / colour coating line both supplied by Danieli and originally put into operation in 1996.
The technological solutions have been selected in order to have the most innovative systems and the highest quality level within the adopted compact configuration of the three main facilities highlighted in Figure 3 (Steel Making Plant, Medium Section Mill and Super Flexible Mill), by which it is possible to achieve extremely efficient operating results with low manpower and specific energy consumption, thereby making the plant highly competitive.

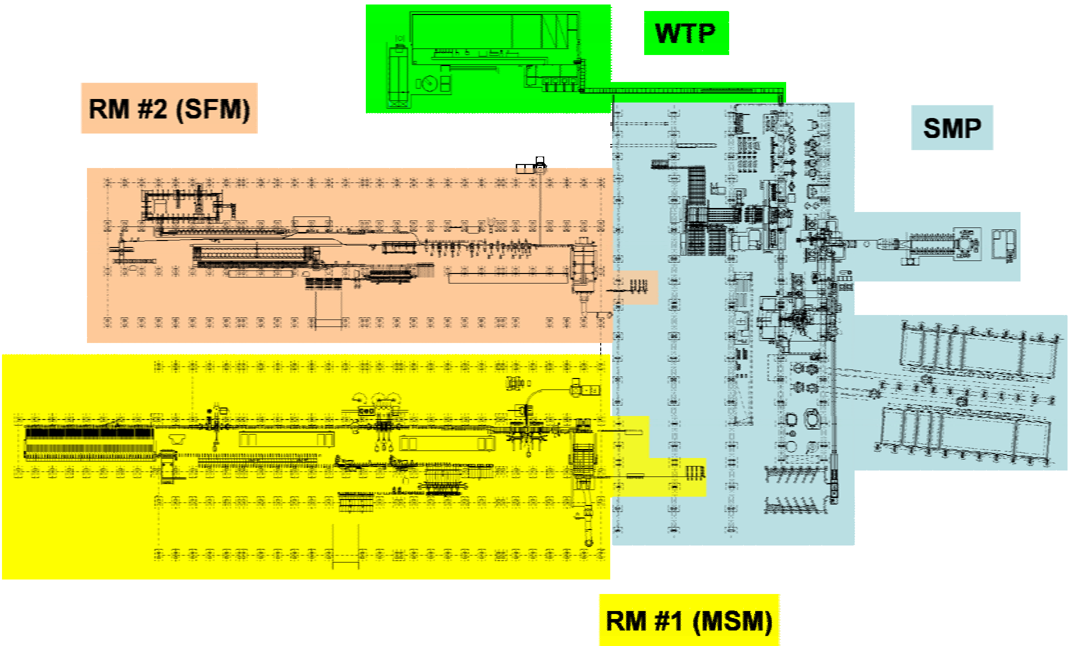


Figure 3 – Balboa 2 Minimill Layout

In this respect, going through the Steel Making Plant shown in Figure 4, to guarantee the high performances of the Furnace dropping the TTT time down to 45 min for the 173 t/hr required productivity, the single heavy bay layout configuration has been chosen. As a matter of fact this configuration allows an easy and smooth process route of the EAF tapped liquid steel passing through the in-line Lade Furnace refining station before feeding the Combicaster.

The Steel Making Plant is basically made up of one 130-t full platform split-shell FASTARC EAF equipped with a 140 MVA + 20% transformer, one 130-t inert-roof Ladle Furnace equipped with a 20 MVA + 20% transformer, one Fume De-dusting Plant and one 6-strands multi-bending 10/19 m radius FASTCAST Combicaster for billets (up to 160 mm), blooms (up to 250 mm) and beam blanks (up to 610x320 mm).

The Steel Making Plant supply includes also an integrated Material Handling System (MHS) and all the equipment are controlled and optimized by an innovative and fully integrated Automation System.

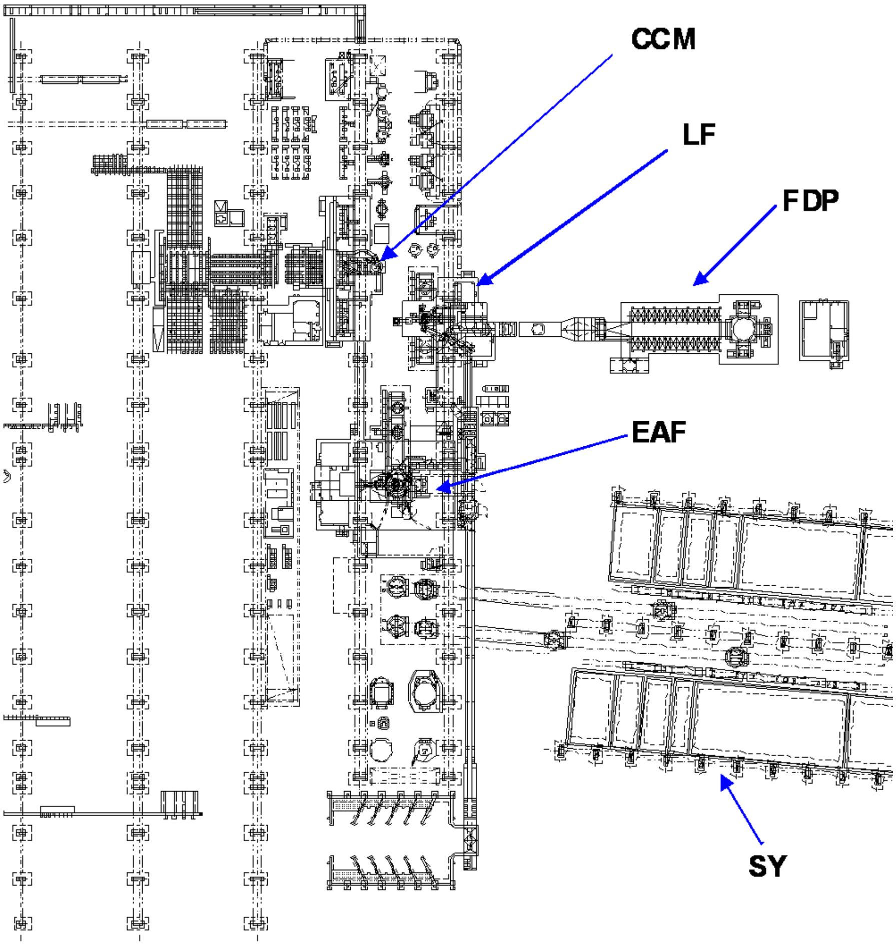


Figure 4 - SMP Layout

Highlights of ELECTRIC ARC FURNACE

The Steel Making Plant is served by a high voltage line which feeds the substation consisting of 3 transformers of 60 MVA. The medium voltage busbar is equipped with a Static Var Compensator, to deal with the power factor compensation and the harmonic filtering. The furnace is fed by a single transformer of 140 MVA as rated power, with an allowable overload of 20%. Thanks to EAF transformer tap changer, it is possible to work with high flexibility and to select the proper working point according to the required process phase:

- fast boring in the starting phase;
- maximum active power and long arcs during melting phase;
- Refining at maximum current thanks to the arc covered by foaming slag.

The EAF transformer secondary circuit (tubes, water cooled cables, conductive arms and electrodes) is designed for a maximum current of 85 kA.
The main data of the electrical equipment are listed on the following Table 1.

Table 1 - Electrical System Data

Network:

Short circuit power of the line	MVA	3470
Rated high voltage	kV	400
Frequency	Hz	50

Step down transformer:

Rated Power	MVA	3*60
Short circuit voltage at 180 MVA	%	15
Primary rated voltage	kV	400
Secondary rated voltage	kV	33

Power factor compensation and harmonic filtering system:

SVC rated power	MVAr	200
TCR rated power	MVAr	200
Tuning frequency of the filters	Hz	100-150-200-250

Furnace transformer:

Rated Power	MVA	140
Overload	%	20
Rated Frequency	Hz	50
Primary rated voltage	kV	33
Number of Taps	#	21
Secondary voltage at maximum secondary current	V	736-1230
Secondary voltage at maximum power	V	1230-1330

The main feature of the EAF shown on Figure 5 is the extremely high available power. Considering the nominal tapped weight of 130 t, the specific available power of the furnace is 1.3 MVA/t, which is much higher than the standard values used for EAF designs.

Figure 5 - EAF

During the Commissioning carried out on January 2008, with the furnace operation it was possible to reach and overcome the limit of 120 MW, obtaining some advantages in terms of process performances. The Figure 6 shows how a maximum active power of around 125 MW was already achieved in the starting phase of the plant commissioning, leading to a Power On of around 31 min. In this case the high power was used only in the last minutes of the buckets melting. On the other hand, by using high power immediately after the boring phase, lower Power On values (28 - 29 min) have been achieved (please refer to Figure 11).

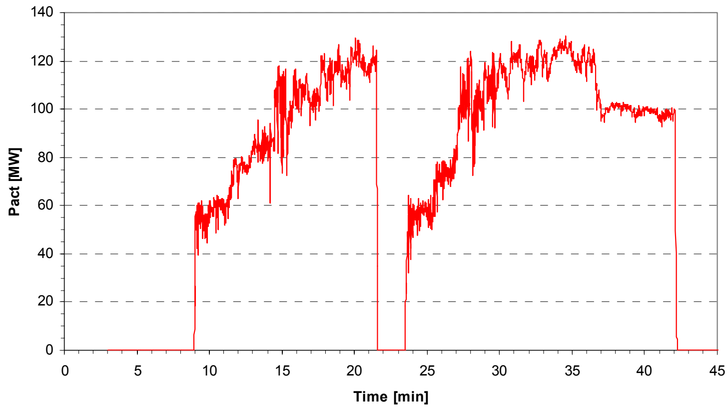


Figure 6 - Active Power vs Time

Danieli's technology succeeds to use the above mentioned high power limiting all the connected risks thanks to:

- HIREG® PLUS electrode regulation system, which carefully controls the electrodes motion while keeping the proper working points during all the heats, increasing arc stability, reducing electrode consumption and preventing electrode breakages due to the scrap collapse;
- DANARC module injection system, which includes 5 Oxygen jets, 3 Carbon injectors, 5 Burners and 1 Lime jet. Thanks to their high technological and automation level, these facilities allow an easy process control and a good foaming slag formation protecting the panels by the high irradiation.

The evolution in the electric arc furnace has, in fact, progressively led to the utilisation of alternative energy to contribute the heat balance, optimizing the consumption of electrical energy and increasing productivity. A further effect of a correct adoption of this practice is the formation of a high level of foaming slag, with all the benefits arising from the subsequent arc coverage.
The main features of the modules are listed on the following Table 2.

Table 2 - DANARC Modules System

Oxygen jet		
Number	#	5
Nominal Flowrate	Nm3/h	2500
Power	MW	3.5
Carbon injection pipes		
Number	#	3
Maximum Flowrate	kg/min	45
Regulation Range	kg/min	5-45
Burners		
Number	#	5
Power	MW	3.5
Lime jet (from the roof)		
Number	#	1
Maximum Flowrate	kg/min	300

Figures 7 and 8 show respectively an injectors' new installation and an oxygen jet in operation.

Figure 7 - New installation **Figure 8 -** In operation

The injectors' layout shown in Figure 9 - **Chemical Energy Configuration** was selected in order to have as much homogeneous as possible chemical energy supply to the bath.

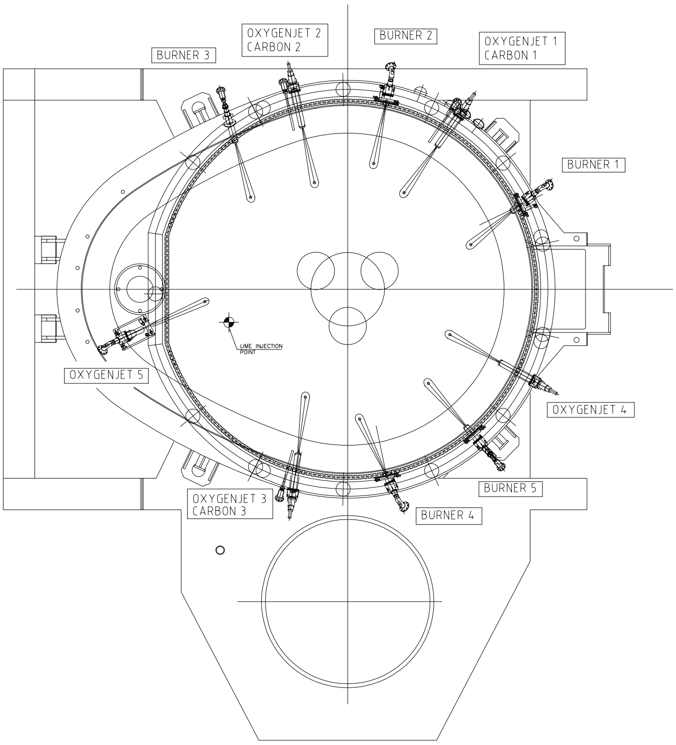


Figure 9 - Chemical Energy Configuration

The DANARC Module philosophy focuses on an efficient management of the electrical and chemical energy, which is done by combining efficient dynamic control of the electric arc with a balanced injection of oxygen and carbon in order to increase the EAF productivity.
To achieve these goals the reactions occurring within the melting process have been carefully evaluated / analyzed and various solutions have been studied and developed to optimize this process. By examining the fundamental mechanisms and the chemical reactions taking place inside the furnace, it is possible to increase the contribution of the exothermal reactions inside the furnace by directly regulating oxygen and carbon injection.
Oxygen jets allow supplying of the necessary oxygen amount in order to boost chemical reactions with the elements in the bath (Si, Mn…), injected carbon and charged one. The De Laval nozzle design of the injectors allows a very coherent flow

with high efficiency. Moreover these injectors give an important contribution to the bath stirring leading to chemical and thermal homogenization.
The carbon injectors give the opportunity to control the bath conditions (more oxidizing or reducing) by regulating the flowrate and promote the slag foaming. As said above, this slag condition gives many advantages in terms of furnace walls protection, higher power utilization and maintenance reduction.
The Lime jet gives the possibility to feed lime during the process allowing more precise slag control (foaming phenomena, basicity…) and reducing the powder production, negative phenomena when lime is charged within the scrap bucket.
Moreover, burners and injectors are used in burner mode to heat the scrap and to make it collapse during the first minutes of the buckets melting before starting the lance phase (no backflash…).
When these modules are not used, oxygen and natural gas lines are purged with air in order to reduce the consumption of both gases. Air is also used to transport carbon / lime and to purge their lines.
The DANARC Module technology optimizes all these functions in a single, compact, fixed and fully automatic dynamically controlled unit by means of a process automation, that, while allowing high flexibility, reduces all the troubles due to human errors, leading to a reliable and repetitive process.
The main advantage of extremely high power utilization is the strong reduction of the Power On time which can be assessed to be around 0.8 min / MW. Figure 10 shows as the Power On depends on the maximum power supplied during the process.

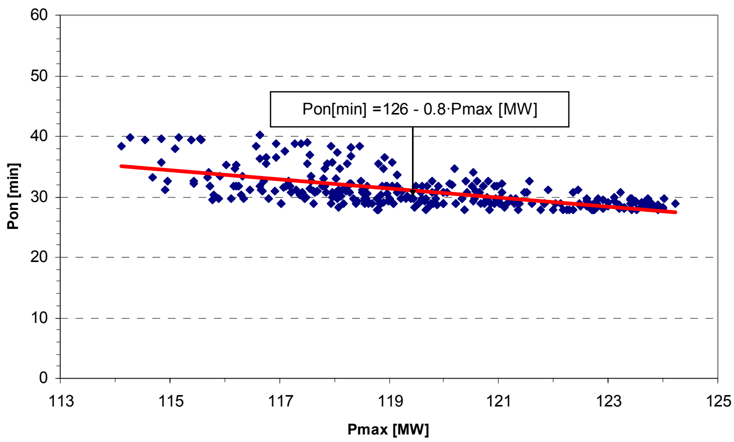


Figure 10 - Power On vs Maximum Power

In the graph it’s evident that if the maximum power is higher than 120 MW, Power On(s) equal to or lower than 30 min are achievable. This so high available power gives the opportunity to have an extremely fast process.
If the Power Off time and the tapped steel weight can be considered as constant values (assuming that the plant is working at the nominal capacity), the immediate consequence of the Power On reduction is the increase of the furnace productivity:

$$\text{Productivity}\left[t/h\right]=\frac{\text{Tapped}\left[t\right]}{\text{TtT}\left[h\right]}=\frac{\text{Tapped}\left[t\right]}{\text{Pon}\left[h\right]+\text{Poff}\left[h\right]}=\frac{k1}{\text{Pon}\left[h\right]+k2}$$

It’s possible to assess how the productivity depends on the average power by making the following assumptions:

- tapped steel weight = 130 t (nominal tapped);

- Power Off time = 14 min (7 preparation, 4 buckets loading (2 x 2), 3 tapping);
- correlation between Power On and maximum power derived from the correspondent graph (Pon = 126 – 0.8 Pmax).

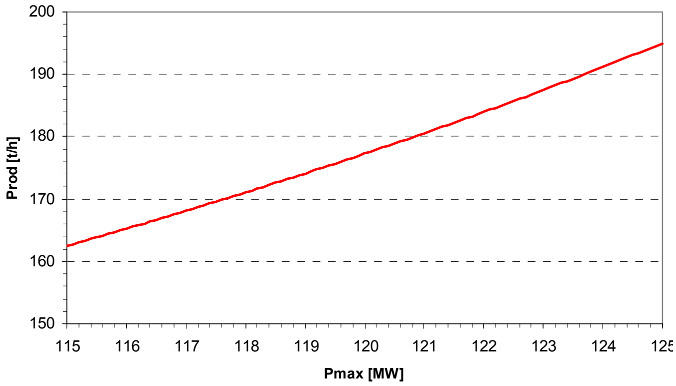


Figure 11 - Productivity vs Maximum Power

The slope of the curve is approximate 3.3 (t/h)/MW. This estimation makes evident how the efficient electric supply (stable arc, foaming slag, high automation level) can give great advantages in terms of EAF productivity.
The availability of this high power, without ignoring all the necessary capabilities required to handle and control it, allows choosing a smaller size furnace, however keeping a very high productivity. In this way it is possible both to reduce the investment cost, and to simplify the furnace management compared with the ones requested for a bigger size EAF.

Highlights of LADLE FURNACE

The final quality of the steel is obtained by means of a powerful ladle furnace in accordance to the short tap-to-tap required. The ladle furnace, shown on Figure 12 is foreseen with the following main equipment:

- Liftable system for electrodes and water cooled roof;
- 20 + 20% MVA transformer;
- Two ladle cars;
- Automatic sampling equipment;
- Wire feeding system;
- Emergency stirring lance;

The Ladle furnace is equipped with an "inert roof" to minimize the air infiltration for reducing electrode consumption, gases pick-up (N, H…) in liquid steel and slag oxidation.

Figura 12: LF

Highlights of FUME DE-DUSTING PLANT

The above detailed EAF powerful melting process requires a proper Fume De-dusting Plant, able to process a flow rate up to 220,000 Nm^3/hr from the primary duct and about 2.2 Mio m^3/hr in total.
The huge flowrate leads to a pulse jet filter with three high efficient design fans foreseen downstream. Each fans is powered with a 1,800 kW M.V. motor. Along the suction line an extensive cooling is provided by a quenching tower that also minimise the dioxin emissions.

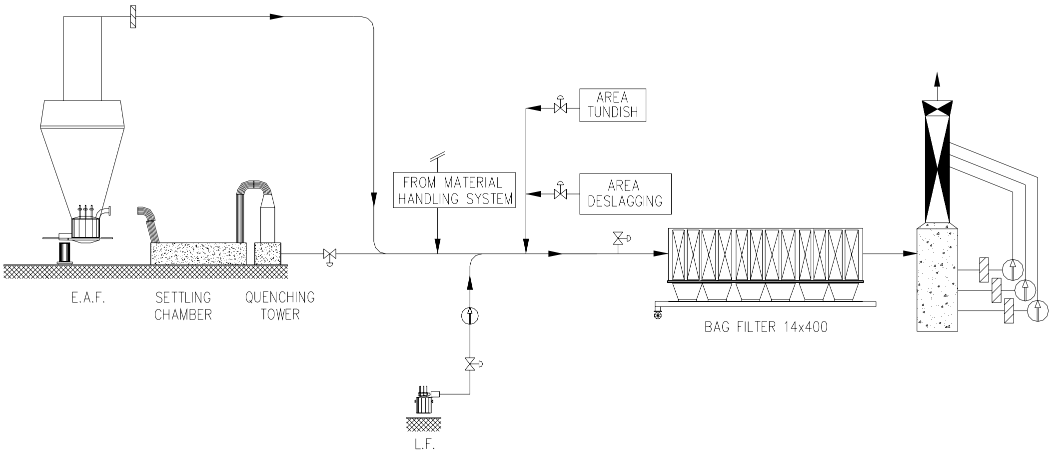


Figure 13 - FDP Flow Diagram

Highlights of CONTINUOUS CASTING MACHINE

The start up of the Continuous Casting Machine, shown on Figure 14, successfully took place during the end of January 2008.

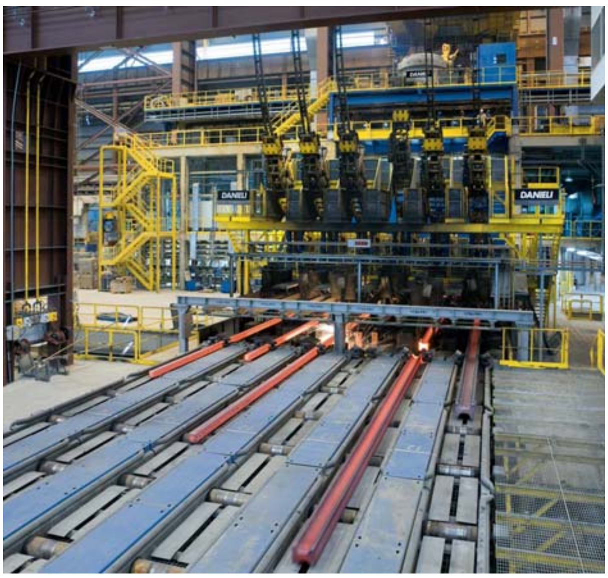


Figure 14 - CCM

This FASTCAST *Combicaster* can boast of a high flexibility, due to the wide range of sections that can be cast simultaneously on its six strands, all designed to be independent. Billets up to 160 mm square, blooms up to 250 mm square and beam blanks up to 610x320x100 mm can be cast at the same time, thus meeting every production requirement.
From the very beginning the caster showed a satisfying good behaviour in terms of productivity, reliability and product quality.
A full control of the machine in each phase of the process, thanks to the Danieli technology, assures, via a simple machine management, high production and quality index values.
As shown on Figure 15 - **CCM Layout**and Figure 16 - **CCM Section**, the Casting Machine is a 6-strand, 10-meter-radius caster, with two unbending points. It is designed for the production of structural, low carbon and Si-killed steel grades.

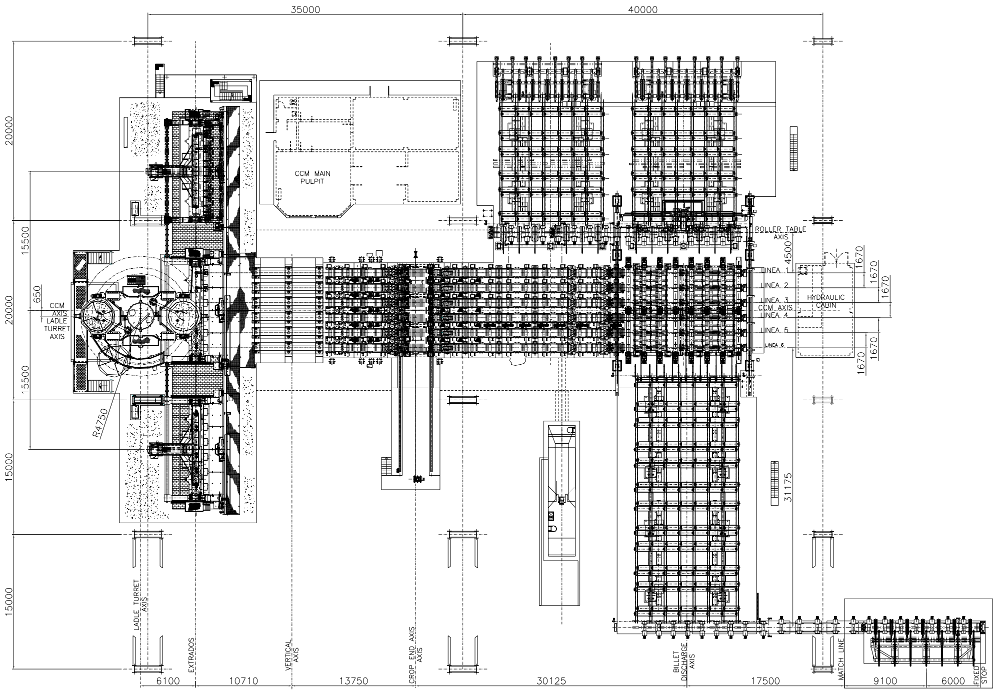


Figure 15 - CCM Layout

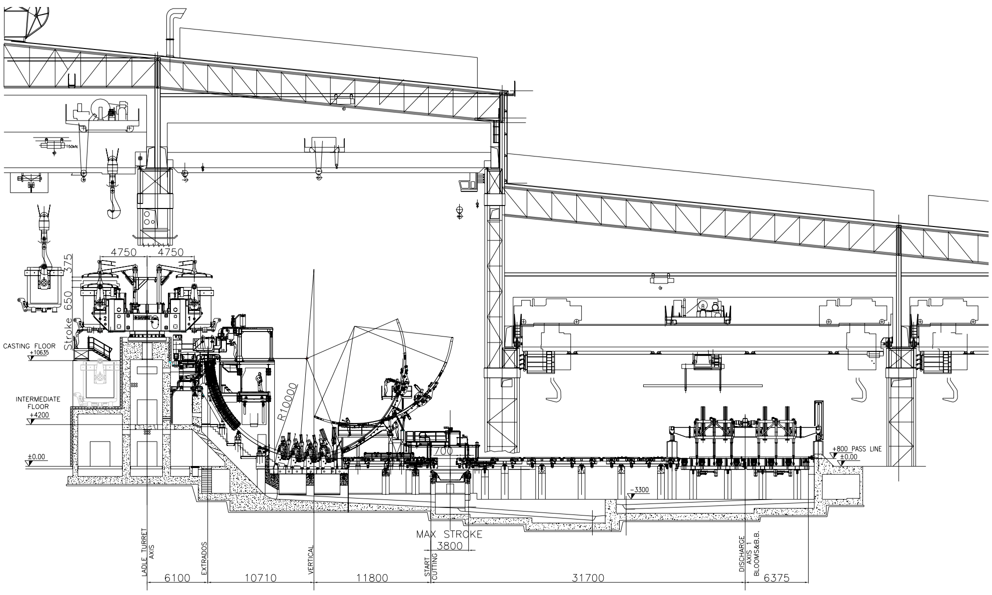


Figure 16: CCM Section

On Figure 15 - **CCM Layout** it is possible to see the caster evacuation, consisting of, downstream the discharge roller table and the relevant liftable side transfer, three walking beam cooling beds: the longer one, for billets and blooms, designed in order to rotate the semi-finished products during cooling and the two shorter ones, for beam-blanks, equipped with flat blades.
The cast sections, as well as the maximum casting speeds and productivity for six strands, are shown in Table 3 - Billets / Blooms Casting Speed & Productivity and Table 4 - **Beam-blanks Casting Speed & Productivity**

Table 3 - Billets / Blooms Casting Speed & Productivity

	Billet		**Bloom**
Section [mm]	160x160	140x140	250x250
Maximum Casting Speed [m/min]	3.2	3.9	1.3
Maximum Productivity [t/h]	223	208	222

Table 4 - Beam-blanks Casting Speed & Productivity

	Beam Blank		
Section [mm]	280x220x90	400x320x100	610x320x100
Maximum Casting Speed [m/min]	2.2	1.35	1.2
Maximum Productivity [t/h]	250	286	323

All the steel grades are cast in open stream, using the FNC (Fast Nozzle Changing) device for long casting sequences in order to reach very good productivity and reliability. For all the beam blank sections, as shown on Figure 17, the steel pouring into the mould is made using two teeming points, thus reaching the best control of the liquid bath kinetics and optimizing the first solidification.

Figure 12 - BB Pouring

Beside the extreme flexibility, the main value added of the CCM is the capability to cast beam blank sections, giving to the Rolling Mill #1 the advantage of starting the reduction process from a near-net-shape. This drops down costs and time requirements.
The CCM configuration has been developed according to simulation results. The secondary cooling and the containment of each beam blanks section, as well as of the other ones, have been designed to mach with the shell growth and the internal and surface temperatures as reported on Figure 18 and 19.

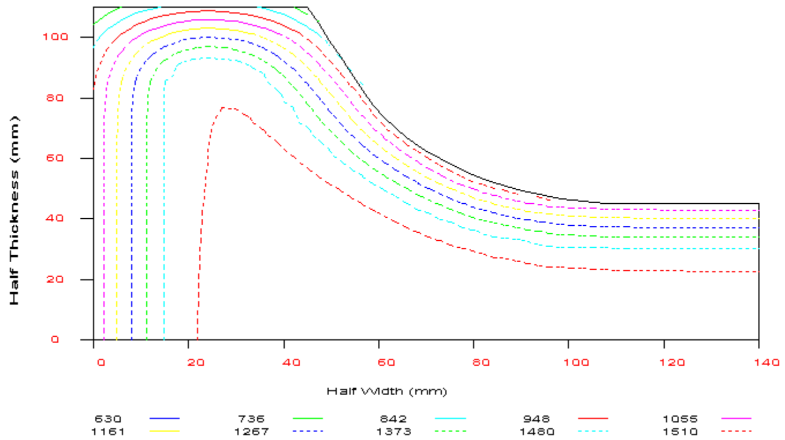


Figure 18 - Isothermal lines at 680mm from meniscus Dim 280x220x90

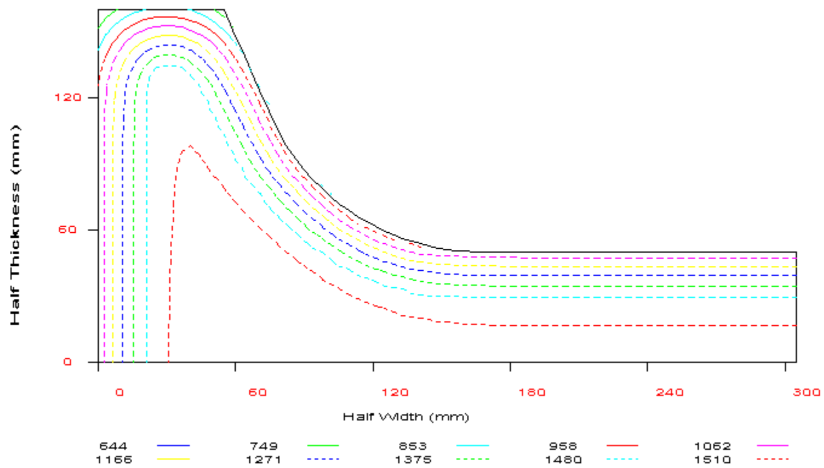


Figure 19 - Isothermal lines at 680mm from meniscus Dim 610x320x100

Figure 20 shows the beam-blanks containment and the area of the relevant secondary cooling.

Figure 20 - BB Containment

The good quality results have been achieved thanks to the design of the secondary cooling system and its properly setting. A “four zones only-water” system is foreseen as follows:

1) foot rolls - two regulation loops
2) mobile sector - three regulation loops

3) fixed sector 1 - three regulation loops
4) fixed sector 2 - three regulation loops

The cooling system is automatically controlled and regulated depending on the casting speed. Flowrates and pressures are designed in order to ensure the best cooling uniformity, avoiding surface reheating and thus reaching the correct conditions for unbending in the withdrawal & straightening unit. For this purpose, the specific cooling rate ranges between 1.44 l/kg and 0.7 l/kg, depending on steel grades, sections and casting speeds. Even the shape of the water jet (full circular cone vs full oval cone) is designed taking into consideration the requirements of each section in each cooling sector.

According, not only to, but also to all the above mentioned technologies, the DANIELI CCM Combicaster is nowadays producing, as shown on Figure 21, the whole range of sections shown on the below Figure 22 - RMs Starting Materials at the guaranteed tolerances and quality, in order to feed the two Rolling Mills with the requested input of semi-finished products.

Figure 21 - Beam-blanks

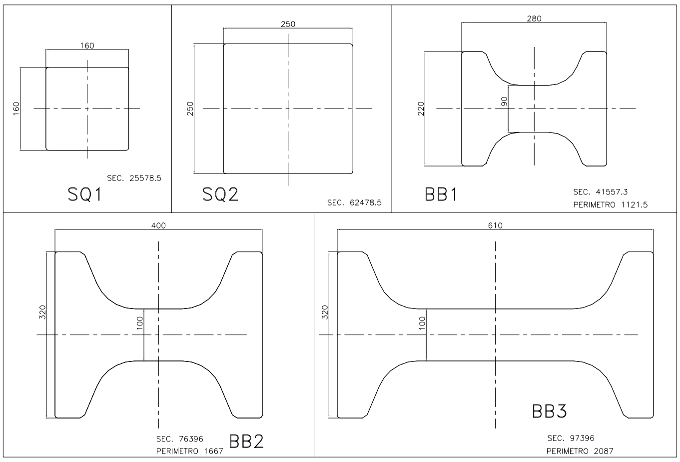


Figure 22 - RMs Starting Materials