MINITEC® MINI BLAST FURNACE

www.minitec.eng.br

COSIPAR, Barcarena, Brazil, 2x 320 m³ MINITEC Blast Furnaces.

INTRODUCTION

The Mini Blast Furnace (MBF) is a very flexible and competitive equipment, suitable for both basic and foundry grade hot metal production, in the range of 80.000 (eighty thousand) to 700.000 (seven hundred thousand) tpy.

The flexibility of the MBF allows the burdening from 100% lump ore to any blend of lump ore and agglomerates (sinter, pellet and/or briquette) in the burden composition.

The MBF can be designed to use coke or charcoal as reducer.

Integration of smelting technologies, plants, and control, management of modern mini blast furnaces, in addition to providing all-around solutions of engineering design, equipment manufacturing, installation, commissioning and startup, all help MINITEC to obtain a long reference list of more than 40 mini blast furnaces, mainly in India and Brazil.

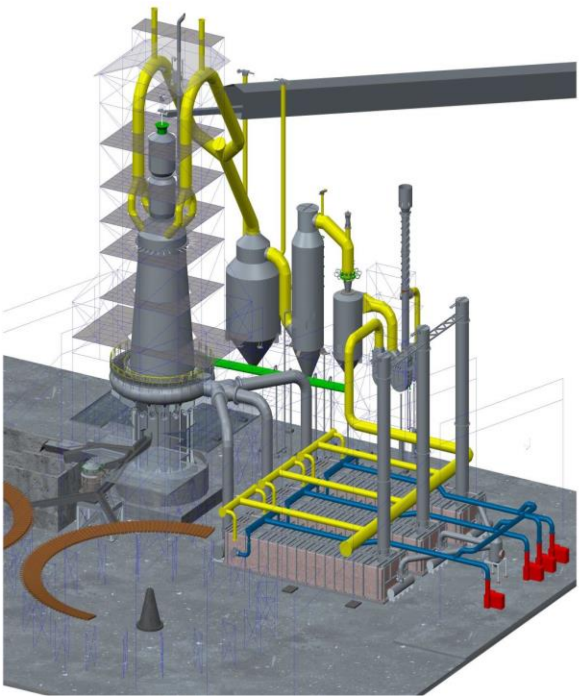
DESCRIPTION

The MBF concept corresponds to Blast Furnaces with working volume up to 500 (five hundred) m³ with the following features:

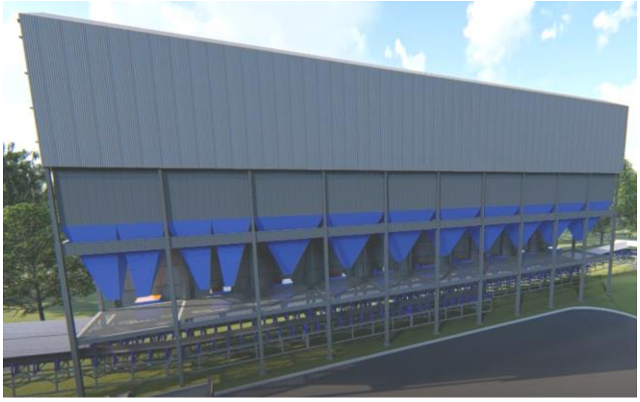
- Raw Material Handling System;
- Mini Blast Furnace Proper;
- BLT (Bell-less top) or Double Bell Top;
- Cast House, including tap hole, operation and maintenance platform;
- Blower House (Serial or Turbo Blower);
- Hot Blast System (MBP or Stoves);
- Slag Granulation System;
- Gas Cleaning System (Wet or Dry type);
- TRT (Top Pressure Recovery Turbines) or BPRT (Blast Furnace Power Recovery Turbine);
- Environmental Control System;
- PCM - Pig Casting Machine;
- PCI - Pulverized Coal Injection;
- Utilities:
  - Water System;
  - Compressed Air System;
  - Nitrogen System.
- Electrical System;
- Instrumentation and Control.

The main advantages of MINITEC's Blast Furnace are:

- Low specific investment;
- Flexibility on burden preparation and composition;
- Easy operation and maintenance;
- Proven technology by numbers of MBF already installed in several countries (Brazil, India, Syria, USA and Indonesia).



RAW MATERIAL HANDLING



BURDEN PREPARATION AND RAW MATERIAL BINS

For MBF burden preparation, MINITEC develops the best solution for each case. It depends on each furnace, layout and client requirements.

Usually, the required raw materials are discharged in a receiving ground hopper, from where they are conveyed by belt conveyors to the day bins for storage and posterior handling in the burden preparation. The burden preparation is made by batching. The system comprises of vibrating screens and chutes as well as weighing bins.

After the raw materials weighing, the same ones are carried to the MBF top through conveyors belt. The entire weighting process and charge of raw materials on MBF top is made automatically by the supervisory system through the furnace control cabin.

The system that involves the handling and storage of raw materials is equipped with devices to capture dust collected by cyclone and bag filter – this is the first part of the secondary dedusting system.

The bins are designed according to each material and its characteristics and properties to avoid “bridging” within the bins, to provide proper mass flow and to reduce the segregation of coarse and fine particles during charging and discharging.

CONVEYOR SYSTEMS

MINITEC specifies and works only with robust and powerful equipment for belt conveyor systems to ensure a reliable and efficient transfer and handling of different bulk materials (including lump iron ore, sinter, pellet, briquette, limestone, quartz, coke, charcoal etc.). All material handling systems are designed to minimize and optimize the overall handling operation.

The result: a significant decrease in investment costs, improved overall logistic process, and homogenized material quantities. The ability to handle different products gives plant operators much more flexibility in securing their plant’s future. And all solutions are available from a single source.

MINI BLAST FURNACE PROPER

The furnace shell is built of carbon steel plate of different thicknesses. Lately it has been lined internally with dense alumina and alumina carbon refractory bricks and the hearth is lined with carbon blocks. Stave cooler may be installed also. The MBF shell is fixed directly on the concrete base.

The tuyeres are fed with hot blast from the bustle main through articulated blow pipes.

The number of tuyeres depends on the MBF working volume and the specified blowing flow.

The furnace has one taphole from where both hot metal and slag will flow. The slag is separated of the hot metal in the taping spout by a properly contention system. This system is located in the working platform.

Hot metal flows into the ladle or torpedo car and casted in wheel or strand type pig casting machine, while the slag is directed to the granulation system. The granulated slag is raw material for the cement industry. Alternatively, it can be utilized for paving of streets and roads.

Usually the MBF shell is externally cooled by water spray nozzles, in closed circuit. The internal cooling may be an option.

The tuyeres and tuyere coolers are adopted of cooling system in closed circuit, with cooling towers, similar to large MBF.

The tapping areas of hot metal and slag are adopted of a dusting captive system – the second part of the secondary dedusting system.

HOT METAL TAPPING

The tapping area is equipped with pneumatic drilling machine for taphole aperture and hydraulic mud gun of mass injection to effectuate the furnace closing. Both are projected to work under severe operational conditions predominance in this area.

The ladle heating system is incorporated to the tapping area utilizing as fuel part of the MBF top gas surplus.

The tapping area is equipped with a complete dedusting system.

REFRACTORIES

The MBF is entirely refractory lined. In the hearth are utilized carbon blocks, while bosh and lower stack are lined with high alumina content. The stack is lined with fireclay bricks about 40% Al_2O_3 dense bricks. Runner and ladles are also lined with fireclay bricks. The expected campaign life of MBF lining is 5 to 6 years, defining the duration of campaign.

The lower line cost and the internal cooling absence (boxes, staves), as well as the relatively short time to reline the MBF refractory line – 30 to 40 days, against 90 days for the large BF – this option is the most attractive in function of specific investment, when is compared with the most onerous alternatives required by the large BF.

MBF TOP EQUIPMENT – BLT or DBT

The MBF DBT (Double Bell Top) equipment consists:

- Rotary distributor to ensure uniform distribution of raw material into the MBF.
- Loading system / double bell sealing or, alternatively with tight valves.
- Internal distributor, with fixed blades.
- Equalizing system.
- Sounding system of automatic loading.

The entire operation of the MBF top is automatic and handled by PLC, as the rotary distributor operation, opening and closure of bells; equalizing system and load level sounding.

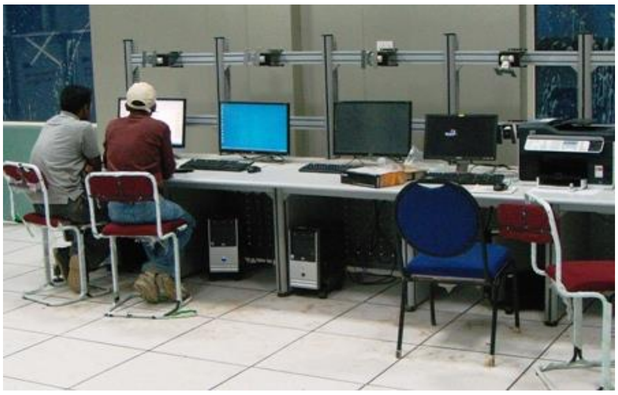
Alternatively, the BLT (Bell-Less Top) can be utilized. This system is designed for the charging of the solid feed into the furnace, providing better performance in burden distribution and uniformity. Also reduce grain size segregation. Modern blast furnaces use this type of system.

The main units of the bell-less top charging device are:

- Hoppers;
- Weighing hopper;
- Control valves;
- Rotating chute;
- Chute distributor.

The entire operation of the MBF top is automatic and handled by PLC.

MBF CONTROL ROOM



MBF is equipped of a control cabin acclimatized located in the working platform. The entire installation control, since the load preparation till the pig iron tapping, is made from this control cabin.

Equipped with supervisory stations, all the operational parameters are monitored and registered automatically. In case any operational parameter comes out of the pre-established, automatically corrections are made and/or alarms are activated.

BLOWER HOUSE

This system is responsible for the supplying of blast air required in the MBF productive process.

In a normal version it is compounded in a set of six centrifugal fans operating in series, one of them is on standby. The pressure in the cold blast system exit is 1.5 kg/cm^2 (15,000 mmWC), necessary and sufficient to operate the MBF with granulated ore and to maintain adequate top pressure.

The MBF top pressure is up to 0.4 kg/cm^2 (4,000 mmWC), sufficient to assure an efficient top gas cleaning, assuring solids content in suspension below 10 mg/Nm^3.

As an alternative to the fans in series, can be utilized turbo blowers, powered by electric motors. These Turbo Blowers will be installed on a closed room, equipped with air filtering system, noise insulation and provided with electrical hoist for maintenance.

All operating parameters are displayed in the Supervisory System, including alarms and general protections.

BPRT – BLAST FURNACE POWER RECOVERY TURBINE

Blast Furnace Power Recovery Turbine (BPRT) is a high efficiency and energy saving technology intended to recover energy from the residual heat and pressure of blast furnace process. Without extra power input, the developed machine with this technology could convert the residual heat and pressure energy directly into mechanical driving power by connecting the air compressor and gas expander on a common shafting. This technology realizes air supplying to blast furnace and energy recovery from blast furnace residual gas simultaneously. It simplifies the original complicated system by canceling the generator, integrating the oil system and control system and generally cut the cost.

TRT – TOP PRESSURE RECOVERY TURBINE

Top Pressure Recovery Turbine (TRT) is a generating system utilizing the exhaust pressure and heat from the blast furnace as its energy source. In this system, the blast furnace gas produced during iron smelting process is utilized to generate electricity by going through the TRT. Without TRT power generation system, the blast furnace gas will be treated by various processes to decrease its pressure and temperature.

PCI – PULVERIZED COAL INJECTION

PCI plant is made up of coal charging system, heating furnace system, coal milling system and coal fine injection system. This system will adopt direct injection process that combined coal pulverizing with coal fine injection in the same shop.

Pulverized Coal Injection (PCI) is a process that involves blowing fine coal granules into the blast furnace. This provides a supplemental carbon source to speed up the production of metallic iron, reducing the need for coke or coal production. As a result energy use and emissions can be reduced. The amount of coal that can be injected will depend on the coal and coke and operational practices.

HOT BLAST SYSTEM

The blast air heating is normally made in metallic preheaters of exclusive design containing two or three modules operating in parallel.

Metallic Blast Preheaters (MBP) of MINITEC's design consist of a set of centrifugal tubes of special alloys welded as specific method being designed to reach blow temperatures up to 900 °C.

The fuel utilized to heat the blast air is the proper gas generated in the blast furnace (BFG). About 45% of the generated BFG total volume is utilized for the blast air heating. Admitting a loss of 5%, remaining 50% available for others purposes normally utilized to generate electric power (about 180 kWh per ton of produced pig iron).

The burners of MBP are designed to operate with BFG and also with other auxiliary fuel necessary during the startup of installation.

MBP operation is automatically controlled by the Supervisory System located in the MBF control cabin.

The alternative for MBP is the ceramic regenerators (Stoves or Cowpers) able to reach temperatures up to 1,250°C. Notice that for each 100 °C added to the blast, correspond to an economy of 15 to 20 kg of charcoal or coke per ton of pig iron. Hot Stoves will operate on conventional cycle, with two stoves in heating process and one on blast.

BLAST CHARACTERISTICS	
Blast Temperature	900 °C maximum (Metallic Blast Preheater) 1,250 °C maximum (Stoves)
Blast Pressure	15,000 mmWC maximum (Metallic Blast Preheater) 30,000 mmWC maximum (Stoves)

SLAG GRANULATION SYSTEM

During tapping, slag will be skimmed out from the runner to a slag granulation station located at the side of the cast house. After granulation the slag is stored in the slag granulation pond. Through the bottom of this pond the water is filtered and drained, flowing by gravity to a dedicated water sump and pumping station.

A Collecting hood has to be installed to collect the steam produced during granulation process. An exhaust fiberglass duct will be connected to this collecting hood and deliver the steam to the atmosphere, on BF top. This duct will be supported on the BF structure and the delivery point will be 3 m above the highest equipment installed at BF top.

The slag is handled either by pay-loader or by grab bucket from the pond to a storing bin, from where it is discharged into dumper trucks, to be conveyed to the nearest cement plant. Usually the granulated slag yields a good selling price.

Water utilized in the granulation system is recycled in closed circuit avoiding the liquid effluents emission in the process. Estimated water loss by vaporization is 10% of the total volume pumped. About 50% of the total make up water required will be supplied by the thickener blow down. Another 10% will be supplied by cooling towers blow down. Balance will be supplied by the makeup water system.

GAS CLEANING SYSTEM – Wet Type

The gas captured in the furnace top (BFG) to a temperature varying 100 to 180 °C is conducted through appropriate pipeline to the dust catcher, where the larger particles are retained. From the dust catcher, for wet GCS, the BFG is conducted to the saturator, where it is cooled and saturates at temperatures below 70 °C, through intense water spraying.

The BFG already pre-cleaned passes through two Venturis, being one fixed throat and the other variable throat. After each venturi there is a fixed rotor for BFG dehumidification that avoids the dragging of water droplets. The dust concentration into the BFG after the cleaning system described will be around 10 mg/Nm³.

Part of the clean BFG (about 45%) is utilized for the blast air heating and the rest is available for others applications, as power generation or substitution of others fuels utilized in the plant. A flare is installed to burn the BFG eventually exceeding and to control the line distribution pressure. In case the installation of a power Generate Unit, the distribution line pressure is controlled by a small gasholder or by the proper flare.

The entire Gas Cleaning System is automatically controlled through the Central Supervisory System.

GAS CLEANING SYSTEM – Dry Type

This system starts from gravity dust catcher outlet to differential pressure power generation system and regulation valve units, including dry type dedusting equipment, civil structures, automation & detection devices and auxiliaries. Crude gas (dust content of 10 g/m³, temperature at 200 to 300 °C) from gravity dust catcher will enter pulse bag filter chamber for filtering, and then the filtered clean gas contented with dust of ≤ 10 mg/m³ or so will come to clean gas main pipe.

Bag filter is made up of several chambers with, arranged in lines. The operation of reverse blowing may be activated by differential pressure (or timing), as the filtering bag is accumulated with dust, the resistance of chamber will be increased. At this time high pressure nitrogen started by pulse valve regularly will clean the dust of filtering bag and thus it will resume the filtering performance. Accumulated dust in the lower cone chamber will be released on time. First it will be blown into big dust storage pneumatically, after being humidified, the mud will be unloaded into truck and transported out.

ENVIRONMENTAL CONTROL SYSTEM

EFFLUENT TREATMENT SYSTEM

The water utilized in the Wet Gas Cleaning System (GCS) is conduced to a thickener for the particles disposition followed by filter and chemical treatment viewing the reutilization in the GCS.

The decanted sludge in the thickener bottom is conduced to a press filter; the separated water is re-conduced to the thickener and the filtration cake with 30% moisture can be discarded or conduced for sintering.

ENVIRONMENTAL CONTROL FACILITIES

Due to characteristics of the pig iron production process, special attention is given during the project development in order to adequate the installation to the requirement established by government environmental control.

Liquid and solid effluents as well as the sound emissions are dully treated taking in consideration the parameters required by the environmental legislation.

- **Liquid wastes**

  The entire system works in closed circuit, in other words, there is not emission of liquid wastes. The gas scrubbing water is contaminated with the dust caught from the MBF top gas. After leaving the gas scrubbing station, slurry is pumped to thickener, where is treated. This water is recirculated again in the process. The dust retained in the thickener is deposited in appropriate place or reutilized in sintering process.

- **Gaseous wastes**
  - **Source of Air Pollution**

    The major atmospheric pollutants in a hot metal plant are the fumes generated in the burning of BFG and the raw materials handling such as iron ore, charcoal or coke and fluxes. Other emitter sources are the handling of fines generated in the raw material screening processes.

  - **Control Measures for atmospheric emissions**

    The dust generated in the productive process, during the raw materials handling, products, sub products and solids residues in general, are captured through the systems endowed with hoods/pipelines and treated in appropriate equipment such as bag filters, cyclones, electrostatics precipitators, etc. The emission standard of MINITEC's MBF attends to all legislation parameters.

    The BFG collected in the MBF top after cleaned is burnt in part in the blast air heater; the surplus gas if not used for other purposes such as power generation, is burnt to the atmosphere through an adequate Flare Stack generating only CO_2 and H_2O.

- **Solid Rejects**
  - **Slag**

    The slag volume generated in the MBF depends directly the raw materials utilized, as well as slag to be produced. Normally the slag volume is 100 to 150 kg per pig iron ton for operation with charcoal and 250 to 300 kg/t for operation with coke. The granulated slag is utilized as raw material for cement plants.

  - **Charcoal and/or Coke fines**

    The charcoal and/or coke fines generated in the screening process can be reutilized in the MBF injection system. The dust collected in the bag filters (charcoal and/or coke dusts) are also reutilized in the injection system. Optionally these dusts can be sold for cement plants. If there is a sinter process in the locality, the charcoal and/or coke fines will be utilized integrally as fuel in the sintering.

  - **Iron ore fines**

    Iron ore fines separated during screening are stored in bins and reutilized in the sinter plant or for road paving purposes.

  - **Dust catcher**

    The dust catcher generated at the rate of 15 to 35 kg/t of pig iron is compounded of coke fines (>60%), ore and limestone. Its granulometry is between 0.2 and 0.3 mm. It can be integrally recycled in the sinter plant or will be dumped.

  - **Thickener slurry**

    The thickener slurry after pressed the rate is 5 to 10 kg/t pig iron, containing basically ore, charcoal, coke or limestone in granulometry very fine (<0.2 mm). It can be recycled in sintering or dumped.

PCM – PIG CASTING MACHINE

Hot metal produced in the MBF, whenever not used directly in the steel melt shop or foundry, is cast in the Pig Casting Machine (PCM). There are two usual casting systems: straight and wheel type.

UTILITIES

WATER SYSTEM

Several areas of MBF require industrial water continuously in determined qualities, tapping and pressure. These areas are:

- Blast furnace shell cooling;
- Stave coolers cooling;
- Cooling of tuyeres and tuyere coolers;
- Gas cleaning system (wet type);
- Slag granulation system;
- Blower bearings cooling system;
- Cooling system of hydraulic units.

All the water is recirculated. Small cooling towers are required in the cooling water circuit of tuyeres, tuyere coolers and stave coolers. An overhead water tank shall be installed for emergencies – generally for power failure.
The main parameters related to all water systems are monitored through the Central Supervisory System, from the control room.

COMPRESSED AIR SYSTEM

The main points of compressed air consumption are:

- The equalization of MBF top;
- The tap hole drilling machine;
- The bag filters;
- The driving cylinders of raw materials weigh bin gates.

A centralized compressed air station is responsible to supply the air required in the hot metal production process.

NITROGEN SYSTEM

The main points of nitrogen consumption are:

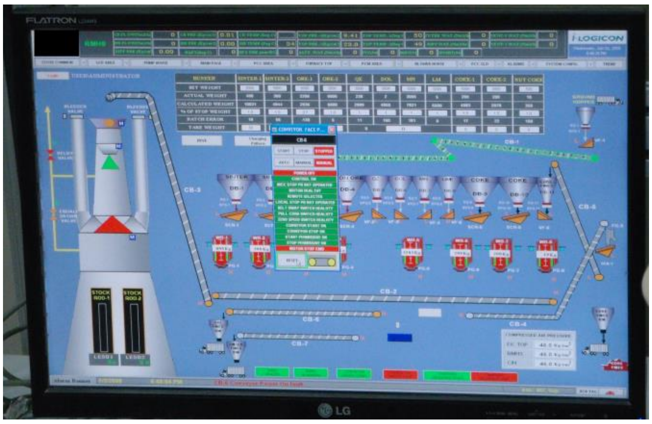
- The gearbox of MBF top;
- Bag filter of Gas Cleaning System (Dry type);
- Line purging;
- Service/Maintenance points.

Nitrogen station is responsible to supply the nitrogen required in the hot metal production process.

ELECTRICAL SYSTEM, INSTRUMENTATION AND CONTROL

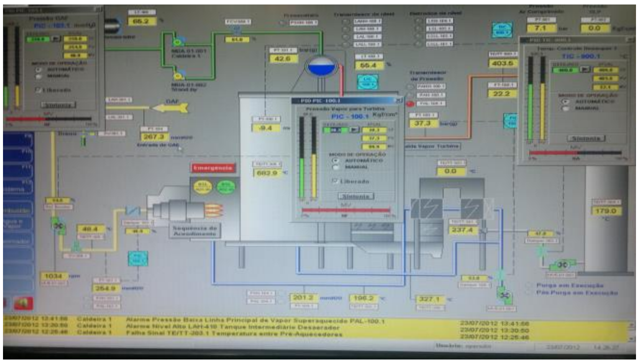
Operation of the MBF is remotely controlled and monitored from a central control room. This concept allows:

- A continuous observation and assessment of the process and the operational status of the main equipment.
- A correction or adjustment, if necessary, of the actual conditions to set point or other required values.
- Plant operation with a minimum of personnel.
- The automation system is based on micro-processor equipment (PLC).



At the level of process/technological controls, the primary applications are:

- Raw material bin filling;
- Free configurable raw mix proportioning system;
- Air and gas flow control;
- Control of off-gas system.



PLANT DESIGN AND MAIN

PRODUCTION PARAMETERS FOR BASIC GRADE PIG IRON

The nominal production of various sizes of MINITEC's MBF and the pig iron average analysis produced are presented in tables as following. The presented values are averages data and the effectives productions will be strongly influenced by the raw materials quality and by the team experience of operation.

Production t/day (1)	MBF working volume (m³)					Productivity (2)
	175	215	250	350	500	
Coke and lump ore	420	516	600	840	1200	2.4
Coke and lump ore + sinter and/or pellets	525	645	750	1050	1500	3.0 (3)
Sinter and/or pellets + lump ore + coke	700	860	1000	1400	2000	4.0 (3)

(1) Project Data.

(2) The productivity of the MBF will depends on the raw materials quality and MBF equipment arrangement and process parameters, such as, type of hot blast generator, blower, furnace top system, oxygen enrichment, auxiliary fuel injection etc.

(3) The productivity is considering ≥70 % of sinter/pellets and ≤30 % of lump ore.

Basic Grade Pig iron	Unit	Range
Carbon	%	3.50 minimum
Silicon	%	0.4 to 1.0 (4)
Phosphorous	%	depends on ore analysis
Manganese	%	0.10 to 0.50 (5)
Sulfur	%	0.05 maximum
Hot metal temperature	°C	1,400 to 1,480

(4) Adjustable, according to final product required

(5) Also influenced by iron ore analysis

PRODUCTION PARAMETERS FOR FOUNDRY GRADE PIG IRON

Production t/day (1)	MBF working volume (m³)					Productivity (2)
	175	215	250	350	500	
Coke and lump ore	385	473	550	770	1100	2.2
Coke and lump ore + sinter and/or pellets	473	581	675	945	1350	2.7 (3)
Sinter and/or pellets + lump ore + coke	630	774	900	1260	1800	3.6 (3)

(1) Project Data.

(2) The productivity of the MBF will depends on the raw materials quality and MBF equipment arrangement and process parameters, such as, type of hot blast generator, blower, furnace top system, oxygen enrichment, auxiliary fuel injection etc.

(3) The productivity is considering ≥70 % of sinter/pellets and ≤30 % of lump ore.

Foundry Grade Pig Iron	Unit	Range
Carbon	%	3.50 minimum
Silicon	%	1.5 to 3.0 (4)
Phosphorous	%	depends on ore analysis
Manganese	%	0.10 to 0.50 (5)
Sulfur	%	0.05 maximum
Hot metal temperature	°C	1,450 to 1,500

(4) Adjustable, according to final product required

(5) Also influenced by iron ore analysis

TOP GAS

DESCRIPTION	Unit	COKE
Lower Heating Value (dry basis)	kcal/Nm³	850
Dust concentration (after gas cleaning system)	mg/Nm³	< 10
Top pressure (maximum) with serial blowers	bar	0.4
Top pressure (maximum) with turbo blowers	bar	1.5

RAW MATERIAL SPECIFIC CONSUMPTION

RAW MATERIALS (6)	Unit (dry basis)	COKE
Iron Ore / Sinter / Pellet	kg/t Hot Metal	1,640
Fuel (coke + coal)		540 – 650
Limestone		200
Dolomite		100
Manganese Ore		40

(6) Depends on iron ore analysis

UTILITY SPECIFIC CONSUMPTION

- Make up water

Description	Unit	MBF working volume (m^3)				
		175	215	250	350	500
Make up water (1)	m^3/h	53	60	60	80	120
Make up water (1)	m^3/t	3.30	3.03	2.62	2.50	2.29

(1) Considering open circuit cooling water

- Power

Description	Unit	MBF working volume (m^3)				
		175	215	250	350	500
Total connected load (2)	kW	2500	3000	3500	4600	16000
Specific power consumption	kWh/tHM	130	130	125	120	220
Maximum power demand	kW	2080	2575	2865	3850	13000
Average power demand	kW	1970	2430	2710	3630	12480

(2) The power rating data informed is for reference only and shall be confirmed by respective Supplier. It also depends on MBF equipment arrangement and process parameters, such as, type of hot blast generator, blower type, furnace top system, auxiliary fuel injection system etc.

REFERENCE LIST

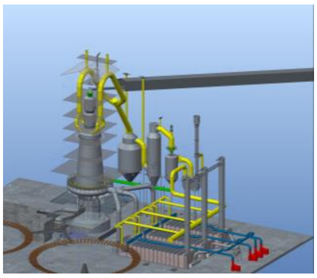
Customer: GERDAU
Local: Divinópolis, Brazil
Volume: 250 m³
Year: 2004

Customer: COSIPAR
Local: Barcarena, Brazil
Volume: 2 x 320 m³
Year: 2005

Customer: VETORIAL
Local: Ribas do Rio Pardo, Brazil
Volume: 302 m³
Year: 2008

Customer: EMMAR INDUSTRIES (former HMISHO)
Local: Homs, Syria
Volume: 2 x 250 m³
Year: 2010

Customer: VETORIAL
Local: Argentina
Volume: 2 x 302 m³
Year: 2012



Customer: IRONTON
Local: Paducah, USA
Volume: 250 m³
Year: 2018

PARTNERS

Company:	OM Engineering & Construction
Headquarter:	Italy
Actuation region:	Worldwide
Site:	www.omsiderurgica.it
E-mail:	sales@omsiderurgica.it

Company:	EVOTECH
Headquarter:	India
Actuation region:	Worldwide
Site:	www.evotech.in
E-mail:	evcon@evotechltd.com

Company:	YOJANA Engineering Solutions
Headquarter:	India
Actuation region:	India
Site:	www.yojanaengsol.com
E-mail:	sbburde@yojanaengsol.com

HEADQUARTERS

MINITEC MINITECNOLOGIAS LTDA
Rua Bananal, 405, 5º Andar, Santo Antônio
Divinópolis, Minas Gerais, Brasil
CEP: 35500-036
Phone: +55 37 3085-7113
E-mail: minitec@minitec.eng.br
www.minitec.eng.br

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