1. **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 to 300,000 tpy. Its flexibility allows the burdening from 100% lump ore to any blend of lump ore and agglomerates (sinter or pellets) in the burden composition. It can be projected to use charcoal or coke as reducer.

2. **DESCRIPTION**

The MBF concept corresponds to Blast Furnaces with working volume up to 350 m$^3$ with the following features:

2.1. **Burden preparation/charging system**

All the required raw materials for the Mini Blast Furnace are discharged in a receiving ground hopper, from where are conveyed by belt conveyors to the day bins for storage and posterior handling in the burden preparation.

The burden preparation is made per batching; the system comprises screens and vibrating chutes as well as weighing bins.

The burden preparation system can be dimensioned to operate with charcoal or coke.

The use of sinter in the MBF burden improves considerable the operational conditions reducing the consumption of reducer (charcoal or coke) and increasing the productivity.

After the raw materials weighing, the same ones are carried to the MBF top though belt conveyors.

The entire weighting process and loading 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 in bag filters – this is the first part of the secondary dedusting.

2.2. The Blast Furnace Proper

The furnace shell is built of carbon steel plate of different thicknesses. It is lined internally with dense alumina and alumina carbon refractory bricks and the hearth is lined with carbon blocks. 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 slug 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 recourse is not economic – this is one of the differentials of the MAF installation cost comparing to the conventional MBF.

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.

2.2.1. 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% Al2O3 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 big MBF - this option is the most attractive in function of specific investment, when is compared with the most onerous alternatives required by the big MBF.
2.2.2. MBF Top Equipment

The MBF 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.

2.2.3. 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.

2.3. Cold Blast System

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 stand by. The pressure in the cold blast system exit is 1,5 kg/cm² (15.000 mm CA), 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/cm² (4,000 mm CA), sufficient to assure an efficient top gas cleaning, assuring solids content in suspension below 10 mg/Nm³.

As an alternative to the fans in series, can be utilized also turbofans, being one in operation and the other one on stand by.

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

2.4. 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 900ºC.

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 start up 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 1,200ºC. Notice that for each 100ºC added to the blast, correspond to an economy of 15 to 20kg of charcoal or coke per ton of pig iron.

2.5. MBF Control Cabin

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.
2.6. Slag Granulation System

During tapping the slag will be skimmed out from the runner to a slag granulation station located close to the furnace operation platform. The granulated slag is stored and sent to the cement plant.

The water utilized in the granulation system is recycled in closed circuit avoiding the liquid effluents emission in the process.

2.7. Gas Cleaning System and Effluent Treatment System

The gas captured in the furnace top (BFG) to a temperature varying 100 to 180ºC is conducted through appropriate pipeline to the dust catcher, where the biggest particles are retained.

From the dust catcher the BFG is conducted to the saturator, where is cooled and saturated the temperatures below 70ºC, through intense water spraying.

The BFG already pre-cleaned passes through two Venturis, being one fixed throat and the other variable throat.

The second venturi follows a system of BFG dehumidification that avoids the dragging of water droplets. The dust concentration into the BFG after the cleaning system described will be 10mg/Nm³ maximum.

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.

The water utilized in the Gas Cleaning System (GCS) is conducted 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 conducted to a press filter; the separated water is re-conduced to the thickener and the filtration cake with 30% moisture can be discarded or conducted for sintering.
A torch 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 torch.

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

2.8. Water System

Several areas of MBF require industrial water continuously in determined qualities, tapping and pressure. These areas are:
- Blast furnace shell cooling.
- Cooling of tuyeres and tuyere coolers
- Gas cleaning system
- 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 and tuyere coolers.
An overhead water tank shall be installed for emergencies – generally power failure.
The main parameters related to all water systems are monitored through the Central Supervisory System, from the control room.

2.9. Compressed Air System

The main points of compressed air consumption are the equalization of MBF top, tap hole drilling machine, bag filters and driving cylinders of raw materials weigh bin gates. A centralized compressed air station is responsible to supply the air required in the pig iron production process.

2.10. Electrical System

The electrical system takes care of power distribution for the whole plant. It comprises substations, PCCs, MCCs, illumination, earthing, etc.

2.11. Instrumentation and Control

Control and supervising of the whole MBF operation will be performed from the MBF control room, installed at MBF working platform. This includes also the whole MBF load preparation.
The system comprises three supervisory stations and a main PLC.
Several field instruments are installed to measure and control all MBF process parameters.
2.12 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 solids effluents as well as the sound emissions are dully treated taking in consideration the parameters required by the environmental legislation.

a- 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.

b- Gaseous wastes

i- 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.

ii- Control Measures for atmospheric emissions

The dust generated in the productive process, during the raw materials handling, products, subproducts and solids residues in general, are captured through the systems endowed with hoods/pipelines and treated in appropriate equipments 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 CO₂ and H₂O.

c – Solid Rejects

I - 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 150kg 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.
II – 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 sintering plant in the locality, the charcoal and/or coke fines will be utilized integrally as fuel in the sintering.

III - Iron Ore Fines

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

IV – Dust Catcher

The dust catcher generated the rate 10 to 20 kg/t of pig iron is compounded of coke fines (>60%), ore and limestone. Its granulometry is between 0,2 and 0,3mm. It can be integrally recycled in the sintering or will be deposited, not having aggressive elements to the environment.

V – Thickener Slurry

The thickener slurry after pressed the rate is 3 to 5 kg/t pig iron, containing basically ore, charcoal, coke or limestone in granulometry very fine (<0,2mm). It can be recycled in sintering or deposited, not containing aggressive elements to the environment.

2.13. 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: conveyor belt and wheel.
3. MBF PERFORMANCE DATA

3.1 MBF productive parameters for pig iron of steel plant and foundry

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.

<table>
<thead>
<tr>
<th>Production ton/day</th>
<th>MBF working volume (cu.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>175</td>
</tr>
<tr>
<td>Charcoal and granulated ore</td>
<td>385</td>
</tr>
<tr>
<td>Charcoal and granulated ore + sinter and/or pellets</td>
<td>445</td>
</tr>
<tr>
<td>Coke and granulated ore</td>
<td>350</td>
</tr>
<tr>
<td>Coke and granulated ore + sinter and/or pellets</td>
<td>405</td>
</tr>
</tbody>
</table>

(1) Project data

<table>
<thead>
<tr>
<th>Pig iron of steel plant</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>% 3.50 minimum</td>
</tr>
<tr>
<td>Silicon</td>
<td>% 0.4 to 1.0 (2)</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>% depends on ore analysis</td>
</tr>
<tr>
<td>Manganese</td>
<td>% 0.10 to 0.50 (3)</td>
</tr>
<tr>
<td>Sulfur</td>
<td>% 0.05 maximum</td>
</tr>
<tr>
<td>Hot metal temperature</td>
<td>°C 1400 to 1460</td>
</tr>
</tbody>
</table>

(2) Adjustable, according to final product required
(3) Also influenced by iron ore analysis
3.2. Production parameters for foundry grade pig iron

<table>
<thead>
<tr>
<th>Production ton/day</th>
<th>MBF working volume (cu.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>175</td>
</tr>
<tr>
<td>Charcoal and granulated ore</td>
<td>355</td>
</tr>
<tr>
<td>Coke and granulated ore + sinter and/or pellets</td>
<td>410</td>
</tr>
<tr>
<td>Coke and granulated ore</td>
<td>330</td>
</tr>
<tr>
<td>Coke and granulated ore + sinter and/or pellets</td>
<td>375</td>
</tr>
</tbody>
</table>

(1) Project data

<table>
<thead>
<tr>
<th>Foundry pig iron</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon %</td>
<td>3.50 minimum</td>
</tr>
<tr>
<td>Silicon %</td>
<td>1.5 to 3.0 (2)</td>
</tr>
<tr>
<td>Phosphorous %</td>
<td>depends on ore analysis</td>
</tr>
<tr>
<td>Manganese %</td>
<td>0.10 to 0.50</td>
</tr>
<tr>
<td>Sulfur %</td>
<td>0.05 maximum</td>
</tr>
<tr>
<td>Temperature at tapping launder °C</td>
<td>1450 to 1500</td>
</tr>
</tbody>
</table>

(2) Adjustable, according to final product required
(3) Also influenced by iron ore analysis

3.3 Blast Characteristics

- Blast Temperature : 900 ºC maximum (metallic blast preheater).
  max. 1.200ºC (cowpers).
- Blast Pressure : max. 15.000 mmCA.

3.4 Top Gas

Lower Heating Value (dry basis) : 1000 kcal/Nm³ (charcoal).
: 850 kcal/Nm³ (coke).
Dust concentration : < 10 mg/Nm³ after gas cleaning system.
Top pressure : max. 4.000 mmCA.

4. CONSUMPTION OF MAIN RAW MATERIALS (INDICATIVE)

<table>
<thead>
<tr>
<th>Pig iron kg/ton (dry basis)</th>
<th>Charcoal</th>
<th>Coke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron Ore</td>
<td>1.500</td>
<td>1.500</td>
</tr>
<tr>
<td>Charcoal / Coke</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Limestone</td>
<td>65</td>
<td>200</td>
</tr>
<tr>
<td>Dolomite</td>
<td>35</td>
<td>100</td>
</tr>
<tr>
<td>Manganese Ore</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>
5. CONSUMPTION OF MAIN UTILITIES (INDICATIVE)

5.1. Make up water requirement (m³/h)

<table>
<thead>
<tr>
<th>MBF working volume</th>
<th>m³</th>
<th>175</th>
<th>215</th>
<th>250</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make up water</td>
<td>m³/h</td>
<td>53</td>
<td>60</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Make up water</td>
<td>m³/t</td>
<td>3.30</td>
<td>3.03</td>
<td>2.62</td>
<td>2.50</td>
</tr>
</tbody>
</table>

5.2. Power

<table>
<thead>
<tr>
<th>MBF working volume</th>
<th>m³</th>
<th>175</th>
<th>215</th>
<th>250</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total connected load</td>
<td>kW</td>
<td>2500</td>
<td>3000</td>
<td>3500</td>
<td>4600</td>
</tr>
<tr>
<td>Specific power consumption</td>
<td>kWh/tHM</td>
<td>130</td>
<td>130</td>
<td>125</td>
<td>120</td>
</tr>
<tr>
<td>Maximum power demand</td>
<td>kW</td>
<td>2080</td>
<td>2575</td>
<td>2865</td>
<td>3850</td>
</tr>
<tr>
<td>Average power demand</td>
<td>kW</td>
<td>1970</td>
<td>2430</td>
<td>2710</td>
<td>3630</td>
</tr>
</tbody>
</table>

6. ADVANTAGES OF MINITEC MINI BLAST FURNACE

- 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, Argentine, Indonesia).
MINITEC MBF is the most flexible and cheapest solution for hot metal production.

For more detailed information please contact:

Minitec Minitecnologias Ltda.
Henrique Carlos Pfeifer.
Phone: +55-37-3085-7113 / 3222-7113
Fax: +55-37-3085-7115
E-mail: minitec@minitecnologias.com.br

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