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MASS BALANCE AND PROCESS

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SECTION 8 – MASS BALANCE AND PLANT PROCESS AND PRODUCT QUALITY

CHAPTER 8.1

PROCESS FLOW DIAGRAM

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8.1 Process Flow Diagram

This chapter provides a description of the process flow of material in the plant from its arrival in form of IO pellet to its departure from the plant in form of high purity pig iron ingots.

The flow of material in the plant can be logically divided in the following steps:

1. Arrival of the IO pellets in the plant and storage
2. Handling of the IO pellet from the storage area to the transformation equipment
3. Transformation of the IO pellets into liquid metal
4. Transformation of the liquid metal into ingots of high purity pig iron

Figure 8.1.1. below provides a graphical description of the process flow

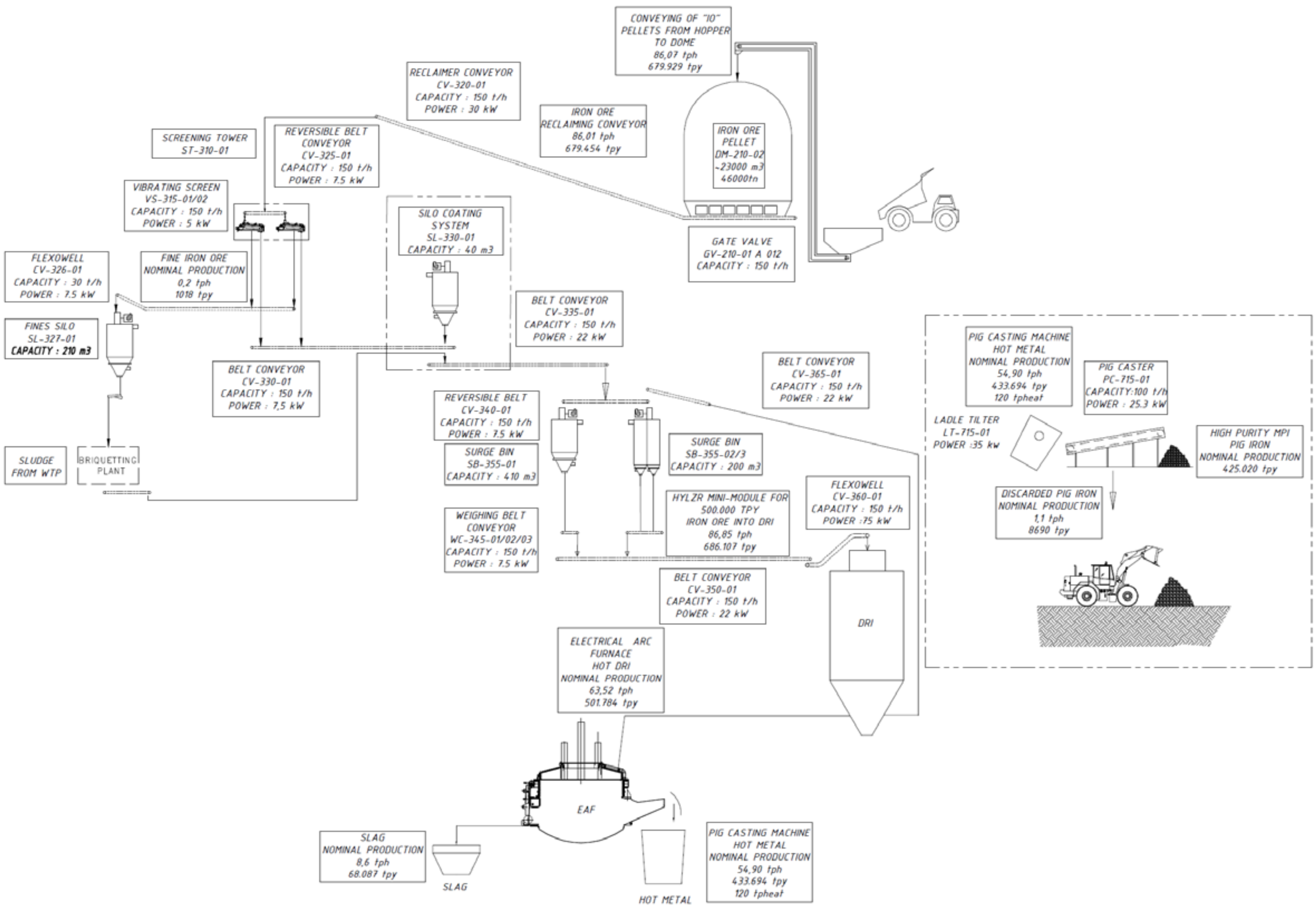

Figure 8.1-1.: Pig Iron Production Plant Process Flow Diagram

8.1.1 PFD description

8.1.1.1 Arrival of the IO pellets in the plant and storage

- This FS foresees the arrival of the iron ore pellets at the plant by truck. Up to two trucks can discharge at the same time IO pellets at a total max discharge rate of 500 metric tph.

- the IO pellet is discharged by each truck into a metallic hopper, equipped with a weighing system and a bottom gate & vibratory feeder to load the IO pellet charge onto an elevating belt conveyor

- the elevating belt conveyor has a maximum transportation rate of 500 metric tph and conveys the IO pellets into a storage dome [DM-210-02] of approximately 23,000 m3. The dome can store up to 46,000 metric ton of IO pellets, equivalent to more than 22 days of plant autonomy.

8.1.1.2 Handling of the IO pellet

- The IO pellets are reclaimed by a conveyor [CV-320-01] that runs underneath the dome and collects the pellets from six gate valves [GV-210-01/6] at a maximum rate of 150 tph.

- The reclaiming conveyor delivers the material onto a reversible belt conveyor [CV-325-01] or alternatively a diverter. The IO pellets pass onto one of the two vibrating screens [VS-315-01/02], one in operation, the other in stand-by mode, each one with a 150 tph capacity and 6 mesh screen.

- The iron ore fines from the screening process proceed onto a flexowell conveyor [CV-326-01] that unloads the fines into a storage silo [SL-327-01]. The storage silo is part of the different area of the process, the Briquetting Plant, whose role is to collect IO pellets fines, WTP sludge and FTP dust, to mix them and produce a briquette of these materials that will eventually be charged along with the IO pellets into the process.

- The IO pellets above 6 mesh will proceed on a 150 tph conveyor [CV-330-01] underneath the IO pellets Coating Station [SL-330-01]. During this step of the process the IO pellet will be sprayed with a thin layer of Portland cement as prescribed by the Energiron Process procedure.

- After being coated the IO pellets proceed onto an inclined transportation belt [CV-335-01] to reach a reversible belt conveyor [CV-340-01] located on top of a battery of three silos, the "curing bins" [SB-355-01/02/03]. The coated pellet requires a minimum of 4 hours of curing period. There are two type of curing bins: one of 410 m^3 capacity [SB-355-01] and two of 200 m^3 capacity [SB-355-02/03]. During normal operation the two 200 m^3 capacity bins [SB-355-02/03] will be used for IO pellet curing, while the third bin will be spare.

- After being cured, the IO pellet will proceed on weighing belt conveyor [WC-345-01/02/03] underneath the curing silos. The weighing belt conveyor is the piece of equipment that controls the feeding rate of the Energiron reactor.

- The weighed IO pellet will pass onto an inclined belt conveyor [CV-350-01]. This belt conveyor carries the IO pellet onto the elevating belt conveyor [CV-360-01] that directly feeds the Energiron Reactor.

8.1.1.3 Transformation of the IO pellets into liquid metal

- The Energiron reactor has a transition period of several hours at the beginning of each campaign. During this time, that can vary from 18 to 36 hours, the IO pellets that are processed in the reactor are not suitable for EAF charge and they will be conveyed back to the 400 m3 surge bin by the return belt conveyor [CV-365-01]. This partially reduced material is called "remet" and will be later added at a slow rate along with the cured IO pellet during normal operation.

- During normal operation, the IO pellets that are reduced in the Energiron reactor are DRI at a minimum of 94% metallization and 5% carbon content and will be feed at a rate of 63.5 tph the Electric Arc Furnace by a gravity chute at a minimum temperature of 600°C.

- The Electrical Arc Furnace melts the high carbon hot DRI thanks to the electric power of a 55 MVA transformer. The DRI is continuously added onto the EAF at a rate controlled by the feeding valves of the Energiron discharge system

- The EAF holds a 50-ton hot heel of liquid metal and once the molten bath reaches a mass of 170 tons, the EAF will be ready to tap a heat of 120 tons of liquid metal.

- The cycle for the EAF has a nominal slag production of 8.6 tons per hour and hot metal production of 54.9 tons per hour (120-ton heat). The EAF will tap a heat of liquid metal every 123 minutes approximately

8.1.1.4 Transformation of the liquid metal into ingots of high purity pig iron

- The EAF taps the hot metal into refractory ladle standing on a tapping car equipped with a weighing system, so to control the tapping weight.

- The hot metal overhead crane picks up the ladle and transports it to the Pig Casting machine, which produces 53.8 tons per hour of high purity pig iron (425,000 tons per year).

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SECTION 8 – MASS BALANCE

CHAPTER 8.2

MASS BALANCE

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8.2 Mass Balance

8.2.1 Process Areas

The plant is divided in the following areas:

1. Iron ore pellets receiving area
2. Iron ore pellets storage area
3. Material handling
4. Fines and sludge briquetting plant
5. DRI area
6. EAF area and ancillaries
7. Continuous pig casting
8. Auxiliary services and utilities

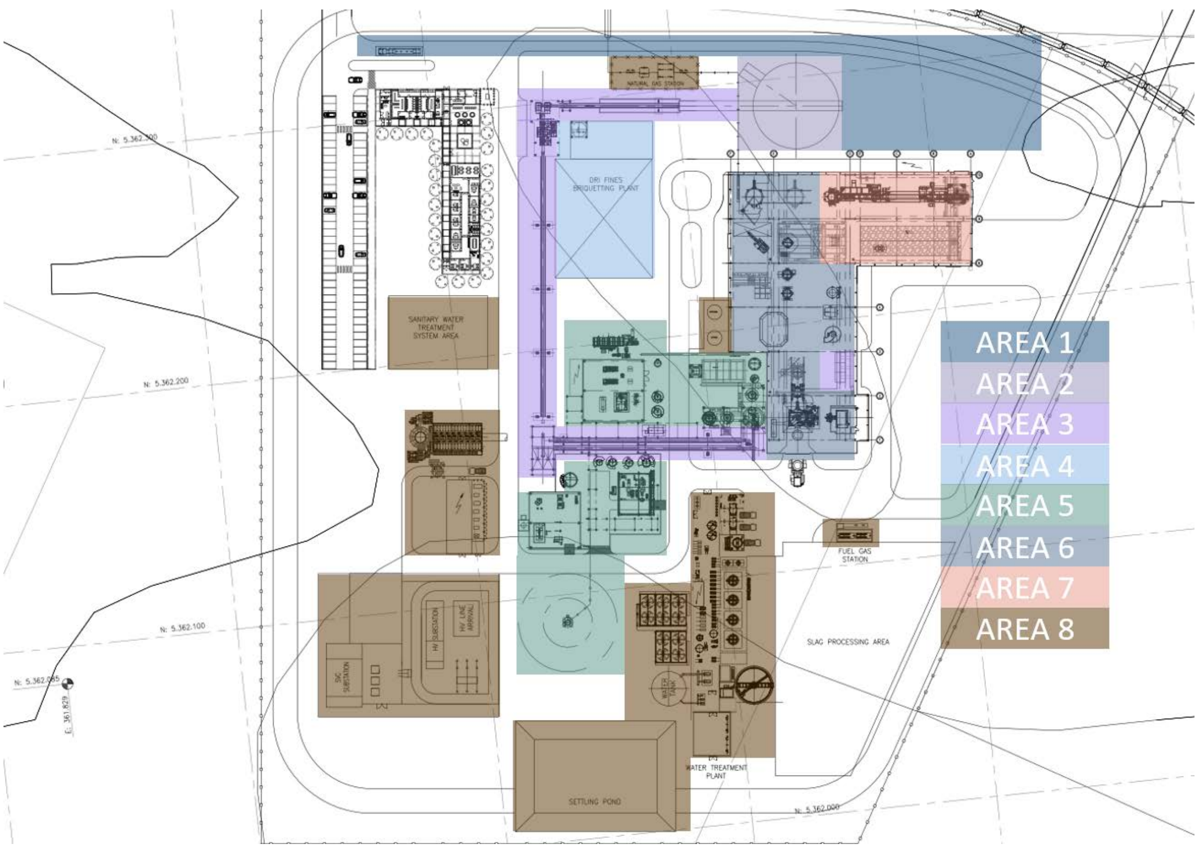

Figure 8.2-1.: Area division of the plant

The IO pellets are stored, transported and transformed in the first seven areas according to the following order:

1. Iron ore pellets receiving area

1.1. Transfer of IO pellet from ship to site by truck
1.2. Truck delivery to unloading hoppers
1.3. Conveying of IO pellets from hopper to dome

2. Iron ore pellets storage area

2.1. Dome storage
2.2. Dome discharge gate
2.3. Reclaiming Conveyor

3. Cold Processing Area

3.1. Diverter & Chutes
3.2. IO Pellet Vibrating Screens
3.3. IO fines transportation to storage bin
3.4. IO Pellet Feed Conveyor to Coating Station
3.5. Coating System
3.6. IO Pellet Feed Conveyor to curing bins
3.7. Reversible conveyor on curing bins head
3.8. Curing bins
3.9. Weigh Belt Feeders
3.10. IO Pellet Feed conveyor to DR tower
3.11. Elevating conveyor

4. Briquetting

4.1. Briquetting machine for fines and sludge

5. Direct Reduction

5.1. HYL ZR Mini-Module for 500,000 TPY
5.2. Hot discharge

6. Electric Arc Furnace

6.1. Electric Arc Furnace
6.2. Ladle on the tapping car

7. Pig Casting Machine

7.1. Pig Casting Machine
7.2. High Purity MPI

8.2.2 Mass balance

		mass loss (%)	IO / MPI (tph)	IO / MPI (tpy)	material loss (tpy)	direct recovery (tpy)	indirect recovery (tpy)
1.	**Iron ore pellets receiving area**						
1.1	Transfer of IO pellet from ship to site by truck	0.56%	86.64	684,445	(3,849)	-	(3,849)
1.2	Truck delivery to unloading hoppers	0.10%	86.15	680,596	(667)	-	(667)
1.3	Conveying of IO pellets from hopper to dome	0.02%	86.07	679,929	(136)	-	(136)
2.	**Iron ore pellets storage area**						
2.1	Dome storage	0.05%	86.05	679,793	(340)	-	(340)
2.2	dome discharge gates	0.00%	86.01	679,454	-	-	-
2.3	Reclaiming Conveyor	0.05%	86.01	679,454	(340)	-	(340)
3.	**Cold Processing Area**						
3.1	Diverter & Chutes	0.00%	85.96	679,114	-	-	-
3.2	Iron Ore Vibrating Screens	2.52%	85.96	679,114	(17,111)	17,111	-
3.3	Fines transportation to storage bin	0.02%	83.80	662,003	(132)	-	(132)
3.4	Iron Ore feed Conveyor to Coating Station	0.03%	83.78	661,870	(199)	-	(199)
3.5	Coating System	0.01%	83.76	661,672	(66)	-	(66)
3.6	Iron Ore feed Conveyor to curing bins	0.05%	83.75	661,606	(331)	-	(331)
3.7	Reversible conveyor on curing bins head	0.01%	83.71	661,275	(66)	-	(66)
3.8	Curing bins	0.00%	83.70	661,209	-	-	-
3.9	Weigh Belt Feeders	0.01%	83.70	661,209	(66)	-	(66)
3.10	Iron Ore Feed conveyor to DR tower	0.03%	83.69	661,143	(198)	-	(198)
3.11	Elevating conveyor	0.05%	83.66	660,944	(330)	-	(330)
4.	**Briquetting**						
4.1	Briquetting machine for fines and sludge		-3.23	(25,493)			
5.	**Direct Reduction**						
5.1	HYL ZR Mini-Module for 500,000 TPY	26.2%	86.85	686,107	(179,986)	4,045	-
5.2	Hot discharge	0.86%	64.07	506,121	(4,337)	4,337	-
6.	**Electric Arc Furnace**						
6.1	Electric Arc Furnace	13.57%	63.52	501,784	(68,090)	-	
6.2	Ladle on the tapping car	0.00%	54.90	433,694	-	-	-
7.	**Pig Casting Machine**						
7.1	Pig Casting Machine	2.00%	54.90	433,694	(8,674)		
7.2	High Purity MPI			**425,020**			-

Table 8.2-1.: Mass Balance

8.2.3 Analysis of the mass balance

8.2.3.1 Area 1: Iron ore pellets receiving area

Annually, 684,445 metric tons of IO pellets will be unloaded from approximately 20 ships with a 35,000 metric ton capacity.
Initially, the IO pellets will be transported from the dock to the plant site by truck. The mass balance considers that 0.62% of this initial quantity will be left at the dock or in the bottom of the trucks, a value of 4,226 tons per year.
This material is listed in the mass balance as "indirect recovery", which means that it is not directly collected by the process equipment, but will be eventually recovered during general maintenance time and added to the cycle of briquetting (area 4).

8.2.3.2 Area 2: Iron ore pellets storage area

A quantity of 680,219 metric tons of IO pellets will be stored every year in the storage dome, which has a max storage capacity of 46,000 metric tons (30% larger than a ship load).
The dome is closed and static storage, thus no loss of material is foreseen from the dome. The negligible amount of dust that is generated during dome storage will be collected by the Dedusting System duct connected to the plant baghouse.
The dome gates will load the IO pellets onto a belt conveyor. This conveyor may have a small production of dust, about 340 tons per year. This dust, or IO pellet fines, will also be collected during maintenance periods and so are considered as "indirect recovery".

8.2.3.3 Area 3: Cold Processing Area

This area comprises pellets screening, pellet coating and pellet curing. The pellet screening is equipment specifically designed to separate IO fines from the IO pellets (with a mesh 6 screen). A production of 17,111 metric tons per year of fines is foreseen. These fines are directly conveyed to a storage silo located in the briquetting plant.
The rest of the process and transportation equipment of area 3 will produce some material loss as dust to be collected during maintenance of the enclosed belting systems.

At the end of area 3, a quantity of 661,369 metric tons per year of coated and cured IO pellets will be delivered to the DR reactor

8.2.3.4 Area 4: Briquetting plant

This area is dedicated to recovering the fines and sludge of IO pellets and the dust collected at the plant baghouse, mainly DRI fines. This recovery of material is considered the "direct recovery", and accounts for 25,493 tons per year of total briquette production. This quantity is added to the coated and cured IO pellets at the entrance of the DR reactor

8.2.3.5 Area 5: Direct Reduction

This area is responsible for the largest weight reduction of material flow, which is 26.2% of the 686,107 tons per year of feed material to the DR, or 179,986 tpy. Part of this weight reduction is material loss as IO fines, about 4,045 tpy, while the rest is weight loss due to the reduction process (iron oxide transformed to metallic iron).

Once the DRI pellets leave the DR reactor and are charged into the EAF, less than 1% will be lost as DRI fines, about 4,337 tpy. These DRI fines will be collected in the baghouse and are part of the "direct recovery" amount in Area 4.

8.2.3.6 Area 6: Electric Arc Furnace

The quantity of hot DRI added to the EAF is 501,784 tpy and the material loss to EAF slag is about 68,000 tpy, for a liquid production of 433,694 tpy.

8.2.3.7 Area 7: Pig Casting

About 2% of the liquid pig iron produced in the EAF will not end up as ingots of high quality pig iron for different reasons: possible out-of-spec material, ladle remainders, etc. This quantity will be recovered as "cast-iron" and sold as pig iron scrap or cast-iron at a lower price.

The final production of high purity MPI is 425,000 tpy.

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SECTION 8 – MASS BALANCE AND PROCESS

CHAPTER 8.3

PLANT PROCESS

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8.3 Plant Process

This chapter provides in detail the plant process which are involved in the following areas:

1. Storage and Material Handling
2. Direct Reduction
3. Melting
4. Casting

8.3.1 Storage and Material Handling

Please refer to the equipment design section 10.3 of the report.

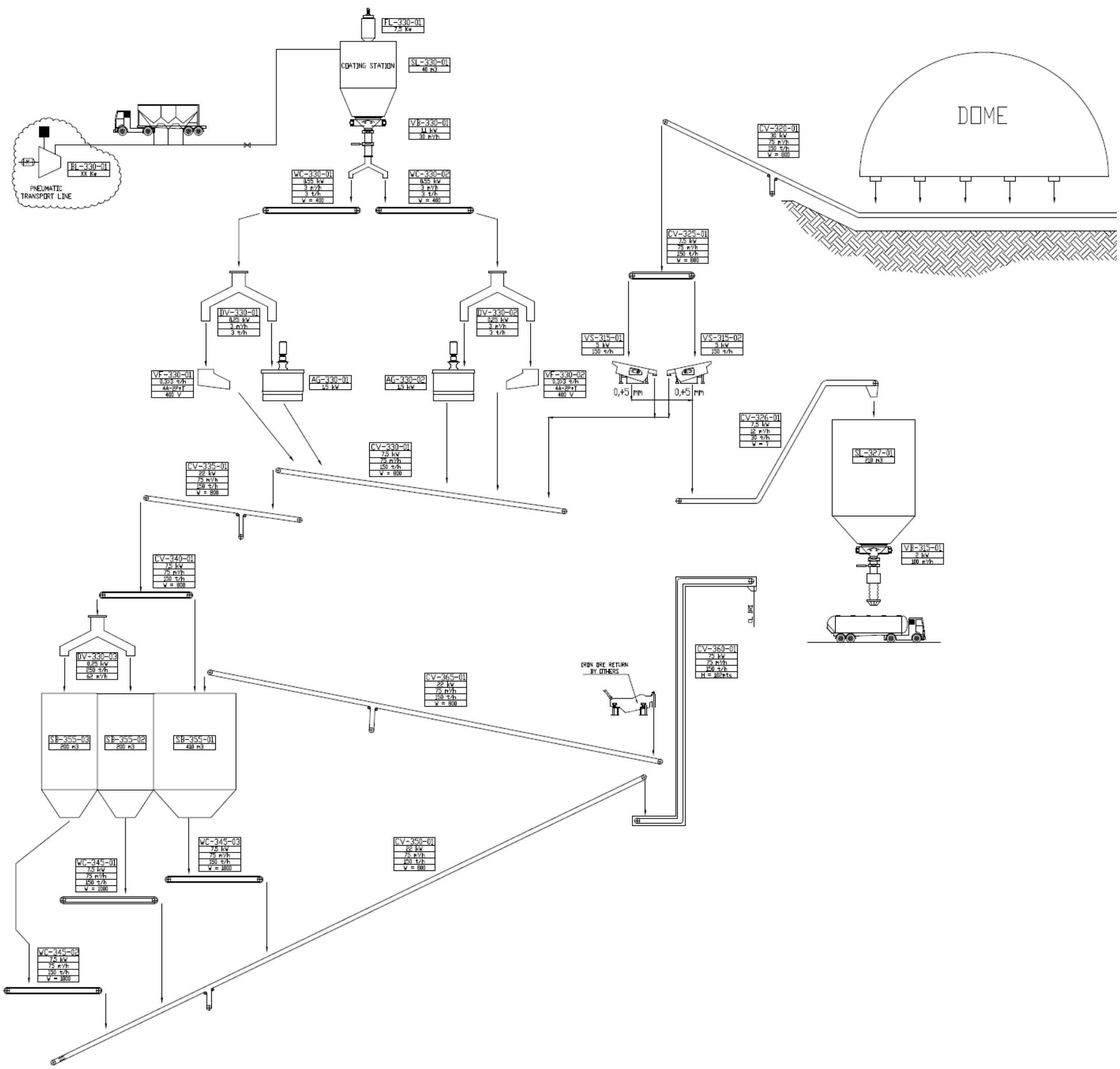

Figure 8.3-1.: IO pellet storage and material handling flow diagram.

8.3.2 Direct Reduction

8.3.2.1 Project Introduction

This project is related to an ENERGIRON Zero Reforming (following reported as ZR) Direct Reduction Plant for 513,500 metric tons per year (tpy) of HOT DRI production.

Process gas will be Natural Gas. The ENERGIRON ZR D.R. technology, without reformer, is the most modern technology under the specific consumption parameters and the very low environmental impact.

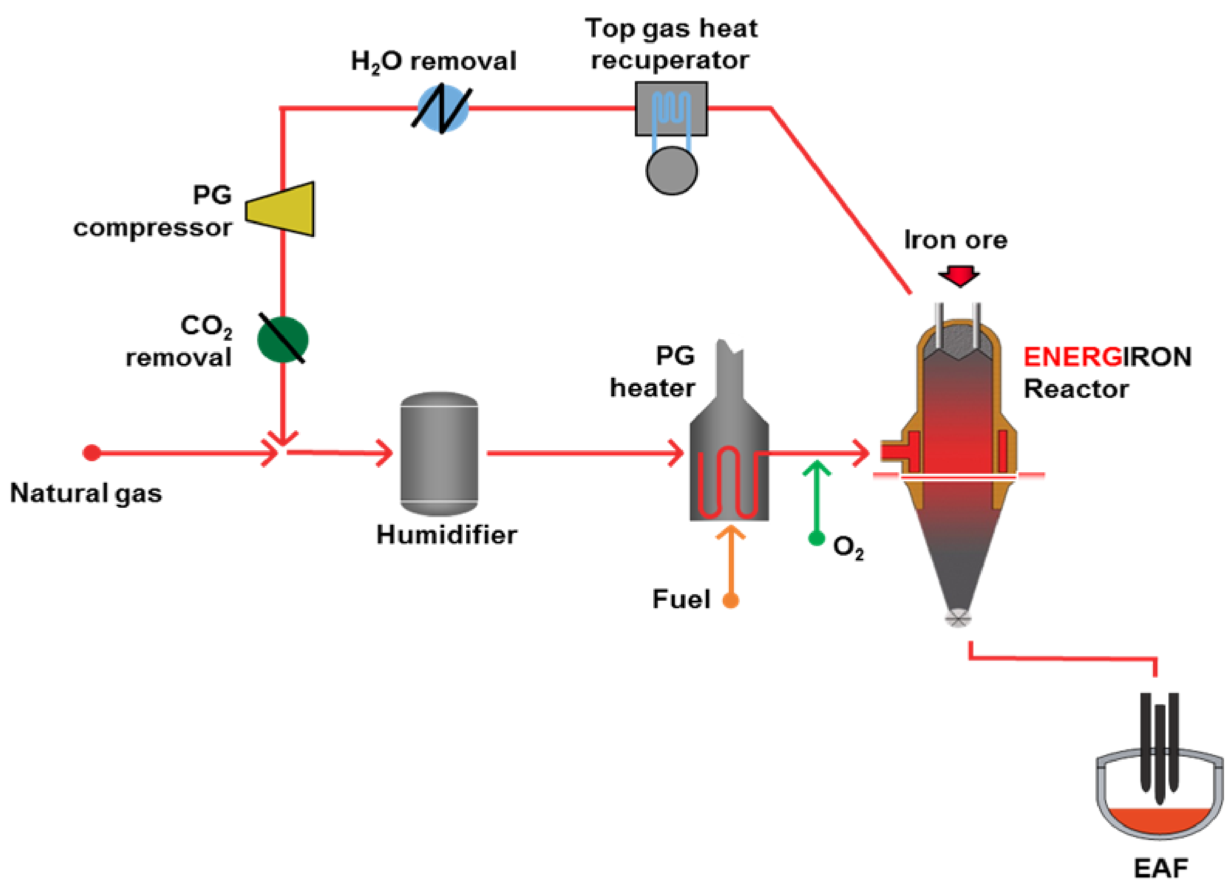

Figure 8.3-2.: General Process Diagram

8.3.2.2 Features of the Energiron Technology

The continuous development, optimization and maturity achieved by the Energiron D.R. technology gives the flexibility that allows offering tailor made solutions for each user. This versatility leads to important advantages for each particular project related mainly to investment, raw materials/energy utilization and by-products (CO_2) commercialization.

The main features of the Energiron technology are the following:

- Product flexibility
- High product quality
- High-Carbon content DRI
- Direct use of hot DRI in the EAF
- D.R. Plant and steelmaking integration
- D.R. Plant minimum reducing gas consumption
- D.R. Plant low production cost
- High metallic yield
- Use of alternative reducing gases
- Flow feeders for burden flow optimization
- Low environmental impact

8.3.2.2.1 Product Flexibility

The Energiron technology offers the unique flexibility to produce three different products as Cold DRI, HBI and Hot DRI, depending on the specific requirement of each user.

- *COLD DRI*

Cold Direct Reduced Iron, to be utilized in adjacent meltshop or transported safely to other final users.

- *HBI*

Hot Briquetted Iron, produced from hot discharge of DRI.

- *HOT DRI – **ROUTE CHOSEN FOR PURE FONTE LTÉE***

Hot Direct Reduced Iron pneumatically transported via proprietary *HYTEMP*® System or other systems directly to the electric arc furnace for steel production. This product reduces considerably the energy consumption in the melt shop, resulting in significant savings in the overall operations.

8.3.2.2.2 Higher Product Quality

The Energiron technology offers the unique flexibility to produce DRI with a wide range of metallization and carbon. Metallization can be controlled up to 95% and carbon content (mainly in the form of iron carbide, also called cementite Fe_3C) between 2.0% and 4.5%, due to improved carburizing conditions.

Worldwide, the Energiron is the only process which produces high-carbon DRI (or Energiron High-Carbide Iron).

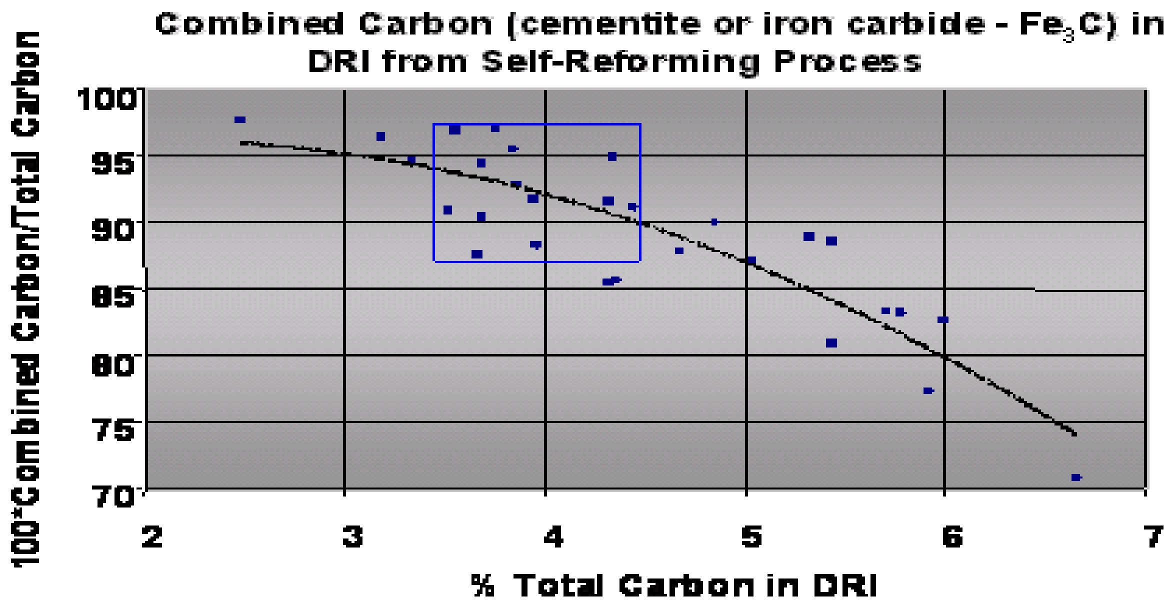

Figure 8.3-3.: Combined Carbon (cementite or iron carbide –Fe3C) in DRI from Self-Reforming Process

In general, carbon in the DRI provides chemical energy input to the EAF, decreasing electric power requirements. As compared to other sources of carbon injection, cementite (Fe_3C) in DRI is characterized by a higher recovery yield in the EAF. Benefits of high-carbon DRI in melt shop operations are related to power savings, decreasing graphite consumption and increasing productivity in EAF. The power saving is a result of the graphite replacement by cementite related to yield and heat of reaction.

DRI produced in this plant presents higher stability than DRI typically obtained in other DR processes. The reason is the high cementite content present in the DRI, which inhibits the reoxidation of metallic iron in contact with air. In general, carbon in Energiron DRI is in the form of cementite, and 1% of carbon is linked to 14% of iron or Fe°. The high carbon DRI with 4.5% C has about 63% of Fe° and C linked as Fe_3C, which increases significantly the DRI stability. This product is then safer for handling, transport and storage.

The following figures compare the reactivity of the produced DRI, evaluated by means of the product oxygen demand: higher the oxygen withdrawn from the ambient, higher the re-oxidation, therefore lower the product stability.

It’s clear that the ZR scheme, by its nature, allows the production of a DRI quality much less prone to re-oxidation than the classical scheme with Reformer. The tendency to reoxidation is close to zero; this means a product safer and more valuable.

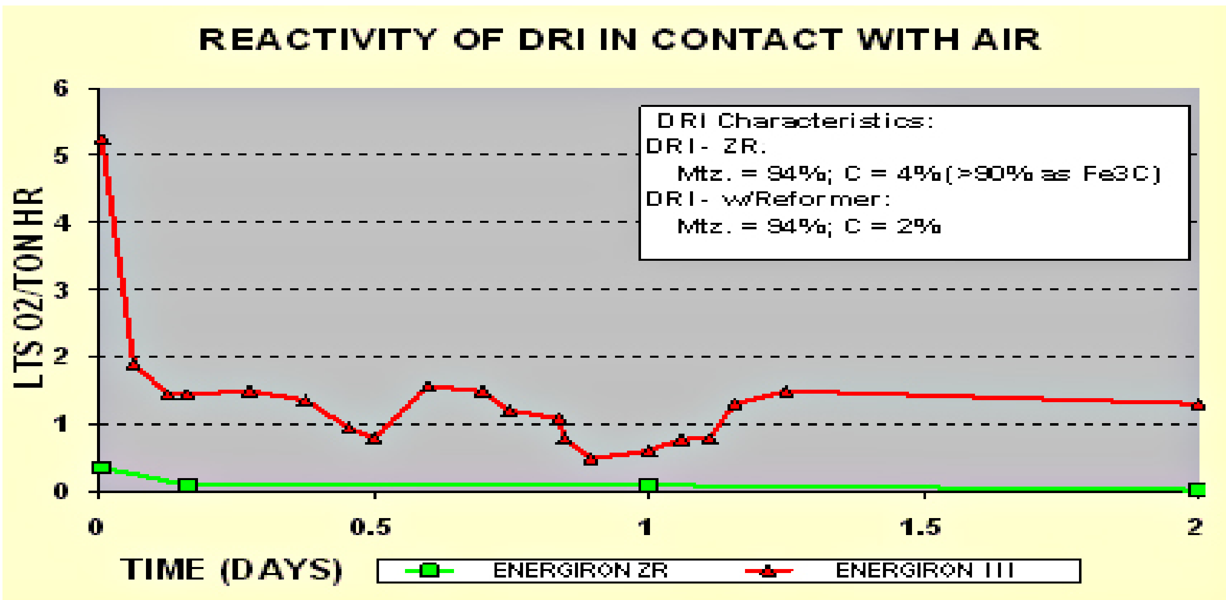

Figure 8.3-4.: Reactivity of DRI in contact with Air

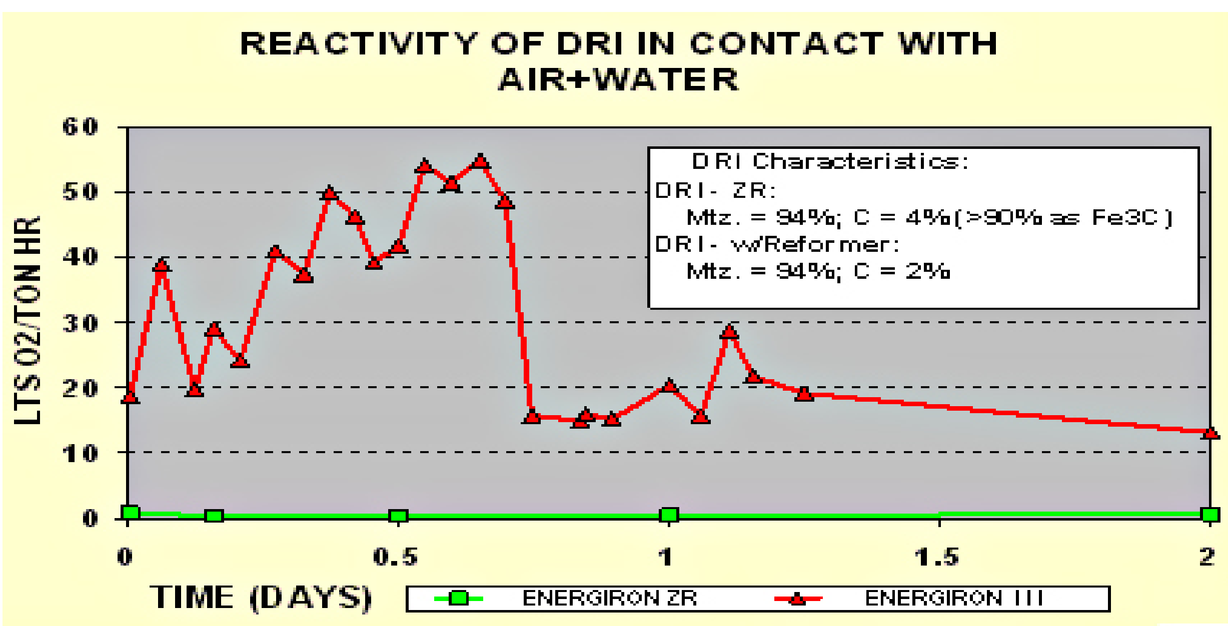

Figure 8.3-5.: Reactivity of DRI in contact with Air + Water

8.3.2.2.3 Use of HOT DRI in the EAF

With the HYTEMP® System, it is possible to charge hot DRI directly to the electric arc furnace in a flexible and efficient way. The main advantages of this scheme are the followings:

- Fines and dust, normally lost or burned off, are injected into the bath together with the hot DRI, resulting in a higher production yield.
- Because of the thermal energy in high-carbon DRI, the electric energy consumption is significantly decreased; with the associated benefits for the other EAF cost parameters.

Savings in EAF operations are about \$5 - \$7 US dollars/ton of liquid steel and potential productivity increase of more than 20%.

Figure 8.3-6.: charge of hot DRI in EAF, photo of a plant in operation

8.3.2.2.4 DRP Minimum Reducing Gas Requirements

The selective H_2O and CO_2 removal from the reducing gas circuit allow a maximum recycle of reducing gas to the reactor. Therefore, the reducing gas make-up is minimized.

8.3.2.2.5 DRP Low Production Cost

The Energiron process offers the flexibility to operate with low cost oxide pellets or mixtures of oxide pellets and lump ore. There is no practical limitation regarding the chemical composition of the iron ore. In particular, as reactor outlet gas is not recycled through a reformer, it can process the iron ores even with high sulphur content ensuring high process flexibility.

8.3.2.2.6 DRP High Metallic Yield

Due to the high operating pressure, low gas velocities and an internal reactor profile, the fine material losses are normally lower in Energiron plants, compared with those reported for other direct reduction processes.

8.3.2.2.7 DRP Use of Alternative Reducing Gases

The process can work with several sources of reducing gas make up.

The following can be mentioned:

- Reformed gas
- Hydrogen
- Gases from coal/hydrocarbon gasification
- Purge gases from iron making processes
- Coke oven gas

- Self-reforming (Natural Gas, in ENERGIRON ZR Process)

The process schemes based on the use of alternative reducing gases, from different suppliers and other direct reduction/iron making processes, have been extensively tested and analyzed and demonstrated. These schemes are fully developed and operating.

8.3.2.2.8 Low Environmental Impact

Energiron plants meet the most stringent environmental standards, especially in terms of CO_2 and the dust emissions.

8.3.2.3 Direct Reduction Plants Reference Lists

8.3.2.3.1 HYL I / HYL II

Plant	Country	Units	Scheme	Product	Design Capacity	Start Up
Hylsa 1M	Mexico	1	HYL I	DRI	0,10	1957
Hylsa 2M	Mexico	1	HYL I	DRI	0,19	1960
Tamsa	Mexico	1	HYL I	DRI	0,28	1967
Hylsa 1P	Mexico	1	HYL I	DRI	0,25	1969
Usiba	Brazil	1	HYL I	DRI	0,23	1974
Hylsa 3M	Mexico	1	HYL I	DRI	0,42	1974
Sidor I	Venezuela	1	HYL I	DRI	0,36	1976
Hylsa 2P	Mexico	1	HYL I	DRI	0,63	1977
PTKS I	Indonesia	1	HYL I	DRI	0,56	1978
PTKS II	Indonesia	1	HYL I	DRI	0,56	1978
PTKS III	Indonesia	1	HYL I	DRI	0,56	1981
PTKS IV	Indonesia	1	HYL I	DRI	0,56	1981
Sidor II	Venezuela	3	HYL II	DRI	2,11	1981
SEIS I	Iraq	2	HYL I	DRI	0,54	1988
SEIS II	Iraq	2	HYL I	DRI	0,93	1989
ASCO	Iran	3	HYL I	DRI	1,03	1993

Table 8.3-1.: HYL I/ HYL II Reference List

8.3.2.3.2 HYL III/ HYL ZR

Country	Units	Scheme	Product	Capacity Mt/y		Start Up
				Design	Achieved	
Mexico	1	HYL ZR	DRI	0,50	0,63	1983
Mexico	2	HYL III	DRI	1,00	1,20	1988
Mexico	2	HYL III	DRI	1,00	1,20	1991
India	1	HYL III	HBI/DRI	0,75	0,90	1993
Indonesia	2	HYL III	DRI	1,35	1,35	1993
Malaysia	2	HYL III	DRI	1,20	1,20	1993
Brazil	1	HYL III	DRI	0,31	0,35	1994
Mexico	1	HYL III	DRI	0,61	0,65	1995
Mexico	1	HYL ZR	HYTEMP®/DRI	0,68	0,93	1998
S. Arabia	1	HYL III	DRI	1,10	1,10	1999
Russia	1	HYL III	HBI	0,90	1,09	1999
Venezuela	2	HYL III	HBI	1,50	1,50	2004

Table 8.3-2.: HYL III/ HYL ZR Reference List

8.3.2.3.3 Energiron III/ZR

Plant	Country	Units	Technology	Product	Capacity Mtpy	Start-up
Emirates Steel I	UAE	1	ENERGIRON III	HYTEMP®/DRI	1,60	2009
Emirates Steel II	UAE	1	ENERGIRON III	HYTEMP®/DRI	1,60	2011
Nucor Steel	USA	1	ENERGIRON ZR	COLD DRI	2,50	2013
Emirates Steel I	UAE	1	ENERGIRON III	HYTEMP®/DRI	Increase capacity to 2.0	2013
Emirates Steel II	UAE	1	ENERGIRON III	HYTEMP®/DRI	Increase capacity to 2.0	2013
Suez Steel	Egypt	1	ENERGIRON ZR	HYTEMP®/DRI	1,95	2014
Al Ezz	Egypt	1	ENERGIRON III	COLD DRI	1,85	2015
Thai Chin	Far East	1	ENERGIRON ZR	COLD DRI	0,50	2017
JSPL	India	1	ENERGIRON ZR	HYTEMP®/DRI	2.50	2016

Table 8.3-3.: Energiron III/ ZR Reference List

8.3.2.4 Design Concept

8.3.2.4.1 Plant Capacity

The capacity of the DR Plant is 513,500 t/year of Hot DRI

The DR plant has been designed based on the ZR process scheme and to produce Hot DRI with 94% avg metallization and carbon content of 5.0% average.

The reactor has been designed for Hot DRI discharge.

8.3.2.4.2 Summary of Plant Characteristics

Process parameters have been established on the following basis for DR Plant:

- Product: Hot DRI
- Metallization: 94 % average
- Carbon: 5.0 % average
- Hourly capacity: 65.0 tonne/hr
- Annual Capacity: 513,500 tonne/year
- Operating hours per year: 7,900 hr
- Number of reactors: one (1)
- Number of gas heaters: one (1)
- Number of Process Gas Compressors: one (1)
- Number of CO_2 removal units: one (1)

8.3.2.4.3 Plant Take Over Points (TOP)

The TOP for raw materials, services and products to/from the DR Plant are the following:

<u>Feed Material</u>

8.3.2.4.4 Iron Ore

TOP for iron ore pellets is at the beginning of the flexowall conveyor RE 126-V feeding the iron ore loading bin RE 251-F above the reactor.

8.3.2.4.5 Iron Ore Fines

TOP for iron ore fines is the discharge of this material from the specific oxide fines bins RH 120-F.

8.3.2.4.6 Coating Material

TOP for coating material will be in the fill line of the Coating Station Storage Bin.

8.3.2.4.7 Hot DRI

TOP for Hot DRI is at the discharge of the Rotatory Loading Chute PH 149-L.

8.3.2.4.8 Sludge

TOP for sludge will be at the discharge sludge collection area (bunker on the ground) after the belt filter presses WS 580-G11/G12

8.3.2.4.9 Remet

The inlet TOP for the recycled remet material shall be at the beginning of the flexowell conveyor RE 126-V feeding the iron ore loading bin RE 251-F above the reactor

The outlet TOP for remet material shall be at the discharging point of the CDRI belt conveyor PH-104-V.

8.3.2.4.10 Natural Gas

TOP for natural gas will be after the DR Plant Natural Gas metering station.

8.3.2.4.11 Oxygen

TOP for Oxygen will be at the DR Plant Oxygen metering station.

8.3.2.4.12 Nitrogen

TOP for Nitrogen will be at the DR Plant Nitrogen metering station.

8.3.2.4.13 Potable Water

Potable make up water shall be available at distribution network located in the corresponding pipe rack within Plant boundary.

8.3.2.4.14 Industrial Water

Industrial water make up shall be available at distribution network located in the corresponding pipe rack within Plant boundary.

8.3.2.4.15 Effluent (Blowdown water)

TOP for effluent from the Cooling Tower will be at DR Plant Battery Limits (BL) to be defined in final Lay out.

8.3.2.4.16 Electric Power

One 10KV, 5 MVA, 3PH, 50 Hz circuit shall be available at the incoming terminals of the Main Substation of the DRI plant.

8.3.2.4.17 Sanitary Waste Water

TOP of sanitary waste water will be at the Plant BL.

For all above, TOP's details will be defined during engineering stage.

8.3.2.4.18 Plant Inputs

The plant design and product characteristics are based on the inputs to be supplied by the Owner, according to the characteristics listed below:

8.3.2.4.19 Iron Ore

The iron ore to be considered for the Energiron DR Plant is based on 100% pellet.

In the following tables, the chemical, recommended physical and metallurgical characteristics of the iron ore pellets considered to be used in the DR plant are shown:

8.3.2.4.20 Chemical Properties

The chemical composition for the iron ore pellet to be processed in this plant is the following

Component	% weight
Fe total	65.5
SiO_2	3.569
Al_2O_3	0.459
CaO	1.428
MgO	0.632
TiO_2	0.153
P	0.01
S	0.01
Mn	0.031
K_2O	0.025
Na_2O	0.036
Moisture	1.5

Table 8.3-4.: Iron Ore Pellet Chemical Properties

8.3.2.4.21 Physical Properties

The recommended physical and mechanical properties of the iron ores to be processed are the following:

Physical and Mechanical Properties		Pellet
a) Size distribution after screening		% weight
	+ 31.8 mm	0
	15.9 to 31.8 mm	5 max
	-9.5 mm	15 max
	-6.3 mm	1.5 max
b) Porosity (%)		20.0 min
c) Mechanical Strength		
Tumbler index (% w, +6.3 mm)		93 min
Tumbler index (% w, -0.5 mm)		5 max
Compression strength (kg/pellet, +10 mm –16 mm)		230 min

Table 8.3-5.: Expected Physical Properties

8.3.2.4.22 Metallurgical Characteristics

The recommended metallurgical properties of the iron ores to be processed are the following:

Metallurgical Properties	Lump ore	Pellet
a) Swelling index (% weight)		
At 800 °C	-	15 max
b) Reducibility index (k x 10-2 min-1)**		
At 800 °C	3.0 min	3.0 min
At 950 °C	4.0 min	4.0 min
c) Low temperature disintegration (% wt.)		
500 °C, +6.3 mm	70 min	80 min
500 °C, -3.2 mm	20 max	10 max
Unbroken pellets	-	60 min

Table 8.3-6.: Expected Metallurgical Properties

In case of no compliance with the recommended characteristics, corresponding tests of the pellets to be provided by BUYER will be required to adjust process parameters and/or specific consumption figures of the DR Plant.

The above Metallurgical characteristics are based on HYL Standard procedures, which are referred to:

For Reducibility test:

- ISO 2597, Iron ores - Determination of total iron content - Titrimetric methods.
- ISO-3081, Iron ores - Increment sampling - Manual Method.
- ISO-3083, Iron ores - Preparation of samples - Manual method.
- ISO-9035, Iron ores - Determination of acid soluble iron (II) content – Titrimetric method first edition.

For Swelling test:

- ISO-3081, Iron ores-Increment sampling-Manual method.
- ISO-3083, Iron ores-Preparation of samples-Manual method
- HYL Reducibility Test Standard

For Sticking test:

- ISO-2597, Iron ores-Determination of total iron content-Titrimetric methods.
- ISO-3081, Iron ores - Increment sampling - Manual method.
- ISO-3082, Iron ores - Increment sampling and sample preparation - Mechanical method.
- ISO-3083, Iron ores - Preparation of samples - Manual method.

For LTD test:

- ISO-3081 Iron ores-Increment sampling-Manual method.
- ISO-3083 Iron ores-Preparation of samples manual method.

As a reference, the following pellets and lump ores have been successfully used in HYL plants

Pellets		Lump ores	
Source	**Country**	**Source**	**Country**
Alzada	Mexico	Bailadhila	India
CMP	Chile	Alegría	Brazil
CVRD	Brazil	Corrego	Brazil
GIIC	Bahrain	El Pao	Venezuela
Hierro Peru	Peru	Esperança	Brazil
IMEXSA	Mexico	Feijao	Brazil
Kudremukh	India	Ferteco	Brazil
LKAB	Sweden	G.G. Brothers	India
Mandovi	India	Mineral Sales	India
Peña Colorada	Mexico	Mutuca	Brazil
Samarco	Brazil	NMDC	India
Sicartsa	Mexico	Sishen	South Africa
SIDOR	Venezuela	MCR	Brazil
Ferrominera	Venezuela		
Lebedinsky	Russia		
IOC	Canada		

Table 8.3-7.: Iron ore pellets and lumps reference list

8.3.2.4.23 Natural Gas

For design purposes the natural gas analysis is listed below:

Component	% Vol
CH_4	95.702
C_2H_6	1.624
C_3H_8	0.141
I-C_4H_{10}	0.018
N-C_4H_{10}	0.017
I-C_5H_{12}	0.004
N-C_5H_{12}	0.003
C_6H_{14}	0.001
C_7H_{16}	0.001
He_2	0.006
N_2	1.842
CO_2	0.641
LHV (Kcal/Nm^3)	8,475.6

Table 8.3-8.: Natural Gas Analysis provided by Gaz Metro

- Pressure: 15.0 Kg/cm^2 A
- Temperature: 25 °C.
- Flow rate (for design purposes): 21,305 Nm^3/h

8.3.2.4.24 Industrial Water

Industrial water shall be made available in the amount required for the first filling and make-up of equipment and quenching cooling water systems of the DR plant. Make up water consumption for design purposes of the DR Plant WTP is 64.15 m^3/h.

A typical water quality was considered for design in this project.

BUYER shall provide the Industrial water analysis to be used for this plant. In case of deviation from water quality considered, the consumption figures and water treatment system shall be adjusted accordingly.

8.3.2.4.25 Electrical Power

Incoming lines: 10.0 kV, 4.0kV and 400V, 3 phases, 50 Hz or any other applicable to the site where the plant is to be located.

Power estimated for DRP for design purposes is: 6.5 MW.

- The ENERGIRON plant will be equipped with an emergency diesel generator, which will operate automatically whenever an electric power failure occurs. This equipment is provided by others.

8.3.2.4.26 Oxygen

Oxygen at 99.5% purity and in amount not lower than 4,220 Nm^3/h.

- Pressure: 15.0 Kg/cm^2 A
- Temperature: 32 °C.

Oxygen will be provided at battery limits of the DR plant in the amount indicated above.

8.3.2.4.27 Nitrogen

Nitrogen at 99.9% purity minimum and not lower than 2,200 Nm^3/h.

- Pressure: 18.4 Kg/cm^2 A
- Temperature: 25 °C

Nitrogen is produced by an Air Separation Plant supplied by the Client and shall be supplied in a continuous and uninterruptible basis and shall be provided at battery limits of the DR plant in the amount indicated above.

8.3.2.4.28 Cement or Hydrated Lime

The oxide pellets are coated with Cement or Hydrated Lime before being fed into DR Reactor.

The coating station is designed for Hydrate Lime continuous dosing proportionally to the measured weight of the oxide pellets on the conveyor belt, mixing the coating suspension and spraying it on the pellets conveyed by the iron ore feed conveyors.

Hydrate Lime consumption for design purposes is expected to be: 2.0 to 6.0 kg/tonne of Iron Ore.

8.3.2.4.29 Plant Outputs

The plant design and product characteristics are according to the characteristics of the iron ore pellet listed above the outputs of the DR Plant are the following.

8.3.2.4.30 DRI

As a reference the Chemical Composition of the DRI produced with the above assumed oxide composition, is as follows:

Component	**% weight**
Total iron	85.265%
FeO	6.582%
Fe met.	80.145%
Metallization	94.00%
Carbon	5.00%
SiO2	4.646%
Al2O3	0.598%
CaO	1.859%
MgO	0.823%
P	0.013%
S	0.013%
TiO2	0.199
MnO	0.040
K2O	0.033
Na2O	0.047
Total gangue	8.271%

Table 8.3-9.: Cold DRI Composition

8.3.2.5 Process Description

8.3.2.5.1 Direct Reduction Process Technology Description

A schematic diagram of the Energiron process ZR scheme proposed for this project is shown below.

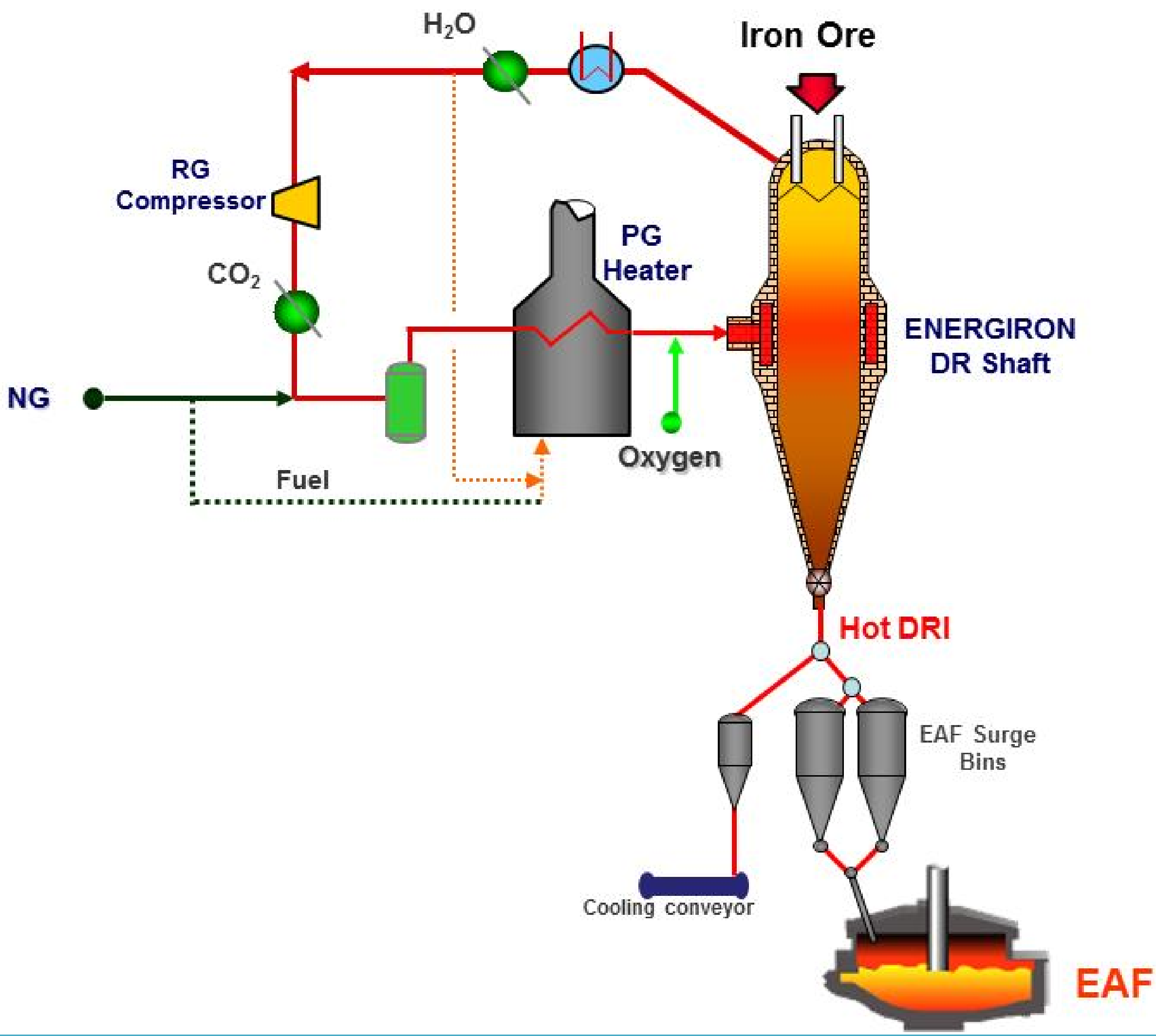

Figure 8.3-7.: Energiron ZR Process Diagram

8.3.2.5.2 Natural Gas Supply

The natural gas stream received from the battery limits is passed through the natural gas KO drum (RG 611-F), for removal of entrained liquids. Then the natural gas is split off into different streams:

- NG to reduction circuit
- As fuel in the process gas heater

The Energiron ZR process scheme has the capability to absorb fluctuations in the natural gas quality, such as the presence of heavy hydrocarbons and sulphur. The process does not foresee a catalytic reformer that has a danger of catalyst poisoning by sulphur.

8.3.2.5.3 Reduction Circuit

Refer to schematic below.

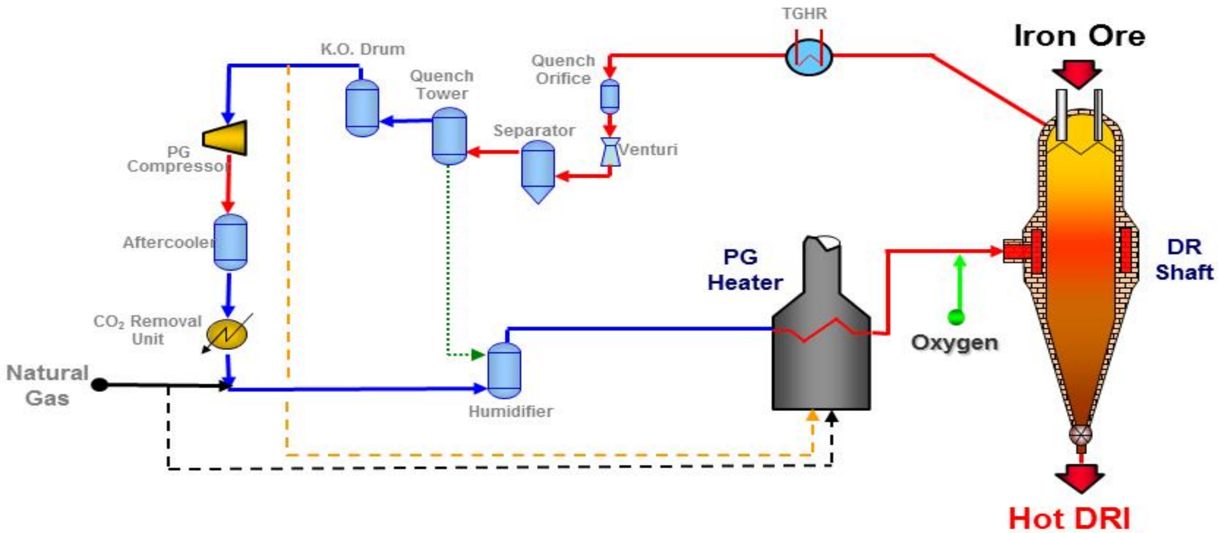

Figure 8.3-8.: Reduction Circuit

A stream from the cooling circuit is recycled to the reduction circuit as a make-up to this circuit and it is mixed up with the recycled reducing gas. The mixture is passed then through a humidifier for some water addition for carbon control in the DRI and then it passes through gas heater to get most of the temperature required. Oxygen is injected in the transfer line just before the reactor in order to increase the temperature of the reducing gas to the required level for in-situ reforming and reduction inside the reactor. The partial oxidation and pre-reforming reactions of natural gas with oxygen are carried out in the transfer line. In this manner, some reducing gases (H_2 and CO) are produced while increasing the reducing gas temperature to ≥ 1,050°C. Once in contact with the solid material inside the reactor, further cracking and reforming reactions are carried out due to the catalytic effect of metallic iron.

These partial oxidation and reforming reactions are the following:

$$CH_4 + \tfrac{1}{2} O_2 \rightarrow CO + 2H_2$$
$$O_2 + 2H_2 \rightarrow 2H_2O$$
$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$CO_2 + H_2 \rightarrow CO + H_2O$$

The set of components included in the reducing gas circuit of DR module are the following:

- Reactor reduction zone,
- Top gas heat recuperator,
- Top gas quenching/scrubbing system,
- Process gas recycle compressor,
- Compressor aftercooler,
- CO_2 removal system,
- Process gas humidifier and
- Process gas heater.

Hot reducing gas is fed to the reactor reduction zone, at about 9.5 kg/cm^{2}A and flows upward counter-currently to the iron ore moving bed. The gas distribution is uniform and there is a high degree of direct contact between the gas and solid.

The exhaust reducing gas (top gas) leaves the reactor by the two reactor top gas outlets, at about 460°C, and passes through the top gas heat recuperator where its energy is recovered and used to preheat the reducing gas before it enters to the Process Gas Heater.

After the heat recuperator, the top gas is passed through the quenching/scrubbing system. In these units, water produced during the reduction process is condensed and removed from the gas stream and most of the dust carried with the gas is also separated.

Scrubbed gas is then passed through the process gas recycle compressor, where its pressure is increased.

Compressed gas, after being sent to the carbon dioxide (CO_2) removal unit, is mixed with the natural gas make-up, thus closing the reducing gas circuit.

The following reactions occur in the DR reactor:

Reforming Reactions.

The generation of hydrogen and carbon monoxide takes place "in situ" reactor by reforming and cracking of methane, where water gas shift reaction also occurs:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$CO + H_2O \rightarrow H_2 + CO_2$$
$$CH_4 \rightarrow C + 2H_2$$

Reduction Reactions.

Iron ore is initially preheated up to the temperature level required for the reduction process by means of transferred heat from the hot reducing gases in the reactor reduction zone. After this preheating stage, the oxygen removal from the ore is initiated by the action of the reducing gases, hydrogen and carbon monoxide.

The mechanism of the reduction process can be represented as follows:

$$Fe_2O_3 \rightarrow Fe_3O_4 \rightarrow FeO \rightarrow Fe$$

Reduction reactions by Hydrogen

$$3Fe_2O_3 + H_2 \rightarrow 2Fe_3O_4 + H_2O$$
$$Fe_3O_4 + H_2 \rightarrow 3FeO + H_2O$$
$$FeO + H_2 \rightarrow Fe + H_2O$$

Reduction reactions by Carbon Monoxide

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$$
$$FeO + CO \rightarrow Fe + CO_2$$

Carburization reactions.

The gas composition and temperature of operation are favourable for the carburization process, incorporating most of the carbon into the product in the form of iron carbide (Fe_3C), mainly through the first reaction below.

$$3Fe + CH_4 \rightarrow Fe_3C + 2H_2$$
$$3Fe + 2CO \rightarrow Fe_3C + CO_2$$
$$3Fe + CO + H_2 \rightarrow Fe_3C + H_2O$$
$$CH_4 \rightarrow C + 2H_2$$

Process Gas Heater

Reducing gas is heated up in a directly fired high-efficiency Process Gas Heater. The required heat is released from firing Natural Gas and tail gas from Reduction Circuit under temperature control.

The design of the Heater is based on the forced combustion air and induced draft features.

The Gas Heater configuration consists basically of the radiant and convective zones, which are interconnected by a transition section. Flue gases are released through the stack to the atmosphere, by the induced draft fans.
The radiant section tubes are made of high alloy materials. Materials of the crossovers and convective section coils are specified according to the temperature and pressure design conditions.

The reducing gas already mixed with the gas make up coming from the humidifier is fed to the Heater through the convective section, where the combustion gases continues the preheating of this gas before it is sent to the radiant box.

This convective zone is arranged in sections of tube bundles, specified with different materials according to the temperature level in each section. The preheated gas passed through the radiant zone where it is heated by radiation transferred from burner flames and refractory walls. The combustion air is fed by means of the forced draft fans and it is preheated also in the convective section before going to the heater burners.

From the top of the radiant box, the hot reducing gas is collected and then passed through a transfer line. The oxygen injection is located on the transfer line before entering the reducing gas to reactor. The transfer line is furnished with two layers of refractory material. The outer layer is low-density material for thermal insulation and the inner layer is high-density material to minimize abrasion wear.

A system for Sulphur Injection to the process gas heater is provided to ensure the proper amount of H_2S in the reducing gas stream to prevent potential metal dusting of the heater tubes.

This injection is carried out at the Process Gas Heater convection section inlet.
Main parts of one the process gas heater as per design are (this description is preliminary, final design will depend on selected supplier):

- Inlet header for convection coils.
- Convection coils, for natural gas and combustion air, complete with tube supports.
- Radiant coils complete with bottom return bends, elbows, common headers and spring hangers to support the coils weight.
- Set of radiant burners.
- Induced draft fan, used for extraction of combustion gases from the radiant section and final release through the stack.
- Forced draft fan, used to supply the combustion air to the radiant burners of the process gas heater.
- Heater flue gas stack.
- Set of refractory lining and insulation.
- Transfer line.
- Heater steel structure, consisting of supporting constructions, with the necessary platforms, stairs and walkways.

Oxygen Injection System

The oxygen injection system consists basically of oxygen lances, installed in the transfer line and a set of pipes, fittings and valves. Lances are located between the outlet of the process gas heater and the inlet of the reactor reduction zone. Oxygen injection allows increasing the reducing gas temperature at the reactor inlet improving the reactions efficiency.

Reduction Tower

The equipment of the reduction tower consists of one Energiron moving bed reactor, the equipment and valves for feeding the reactor, and to handle the product discharge to the EAF feeding system. The geometry of the reactor allows a solids mass flow.

The reactor is a pressurized vessel, made of carbon steel plate, internally refractory lined in its upper cylindrical sections, having a cylindrical geometry in the upper part and conical shape at the bottom portion which provides a generalized free mass flow of solids towards the bottom opening. Solids descend by gravity and rotary feeder located at lower opening of the reactor maintains the discharge rate.

The iron ore burden is fed into reactor through four charging legs allowing a uniform material distribution. The section defined from the reducing gas inlet nozzles up to the lower edge of the charging legs is named "reduction zone".

This section is lined with refractory bricks and castable to withstand the high temperatures and erosion. In between the refractory lining and the carbon steel shell, low-density insulation castable is installed.

The lower section of the reactor consists of a carbon steel conical section, which is designed for Hot DRI production. The reactor cone is water-jacketed, there are several jackets distributed in this conical section and their function is to protect the carbon steel plate from overheat due to the high temperature of the product.
To support the refractory lining and achieve its bonding to the inside walls, the reactor is furnished on the inside with retaining brackets and expansion anchors. The retaining brackets, arranged one at the side of each other on the circumference of the reactor vessel, form complete supporting rings which are mounted at two different levels.
Besides the reactor, main equipment installed in this tower is the following:

Charge system:

- A rotary charger (RE 250-F) used to distribute the iron ore pellets and lump onto the iron ore loading bin.
- One iron ore loading bin (RE 251-F), which holds the iron ore feed delivered by the reactor loading conveyor.
- Four iron ore pressurized bins (RE 253-F11… F14), working intermittent at atmospheric pressure and at reactor operating pressure. The charge and discharge sequence of these bins ensures a continuous iron ore feed to the reactor.
- One set of hydraulically operated valves, some of them to stop the solids flow and some other to provide a gas tight shut-off function for each of the mentioned bins.

Discharge system:

- One reactor discharge rotary valve (RE 276-L), which controls the production rate at the reactor discharge.
- One diverter valve (RE 278-L), which directs the material to the Sampling Bin RE 255-F or to the diverter valve (PH 134-L).
- One diverter valve (PH 134-L), which directs the Hot DRI to one of the EAF Surge Bins (PH 112-F1/F2).
- Two EAF Surge Bins (PH 112-F1/F2)
- One set of hydraulically operated valves, some of them to stop the solids flow and some other to provide a gas tight shut-off function for each of the mentioned bins.

The hot reducing gas stream from process gas heaters passes through a refractory lined transfer line where the oxygen for partial combustion is injected, prior to be fed to the reactor through the reducing gas inlet located at the lowest part of the reduction zone. The reducing gas stream passes to an internal plenum where it is uniformly distributed around the perimeter of the reactor, before being injected through a set of ports into the solids moving bed. Once in contact with the burden material the reduction reactions take place.
The DR Module is designed for processing 100% pellets; however it can be fed some blends of pellets and lump ore.
Percentage of lump ores in blending with pellets will depends very much on the characteristic of ores. Nevertheless, the amount of fines generated by lumps will also depend on the percentage and characteristics of the lump being processed.

Top Gas Heat Recuperator
A counter-current shell and tube heat exchanger (PG 221-C) is used for heat recovery purposes from the exhaust top gas before it is quenched and cleaned. The recovered energy is used to generate steam for the CO_2 removal unit. The exhaust gas leaving the reactor passes throughout tubes side of the top gas heat recuperator, while the water for steam production is contained in the shell side. Downstream the heat exchanger, the exhaust gas is quenched in a direct contact quench orifice..

Process Gas Quenching and Scrubbing
The process gas circuit includes one quenching system and one scrubbing system, located close to the reduction tower, for cooling and cleaning of the exhaust process gas stream from the top gas heat recuperator.

This gas cleaning and cooling arrangement consists of:

- Process gas quench orifice,
- Process gas venturi,
- Process gas separator,
- Process gas quench tower and
- Process gas KO drum.

The gas leaving the top gas heat recuperator passes to the quench orifice, where it is cooled down; then through a venturi, which promotes solids settling. The gas stream coming from the gas venturi passes through the process gas separator, where solids are separated from the gas stream.

From the process gas separator, the cleaned gas goes to the process gas quench tower, where its temperature is decreased by means of water injection, and from there the gas passes finally to the process gas KO drum, which separates the remaining water from the gas stream.

This quenching system is capable of recovering the water generated by the reduction reactions. This condensed water is sent to the Quench cooling water system.

Process Gas Compressor

To recycle the process gas stream to the DR reactor, a process gas recycle compressor is installed in the process gas circuit.

This compressor, furnished at the inlet with a set of gas filters, a lube oil console and process gas compressor aftercooler, will be located in the process gas circuit, downstream the process gas K.O. drum.

The process gas compressor takes the clean and cold gas from the process gas quenching to balance the pressure losses of the reducing gas circuit. Due to the compression effect its temperature also increases; hence the gas goes to the process gas compressor aftercooler where the gas is cooled. The compressor is driven by electric motor.

8.3.2.5.4 CO_2 Removal Unit

To remove the CO_2 from the recycle process gas, a CO_2 Removal System is provided downstream the process gas compressor.

The system mainly consists of one CO_2 absorption column (CO 323-E), and one stripping column (CO 324-E). Other main equipment are: the reboiler (CO 316-C), reboiler condensate drum (CO 335-F), reboiler condensate pumps (CO 336-J1/J2), lean solution circulating pumps (CO 322-J1/J2), rich/lean solution heat exchanger (CO 314-C), lean solution heat exchanger (CO 320-C), stripper overhead condenser (CO 315-C), stripper overhead K.O. drum (CO 313-F), decarbonated gas washer (CO 333-E), gas washing water pumps (CO 331-J1/J2), incinerator (CO 347-B), and auxiliary equipment.

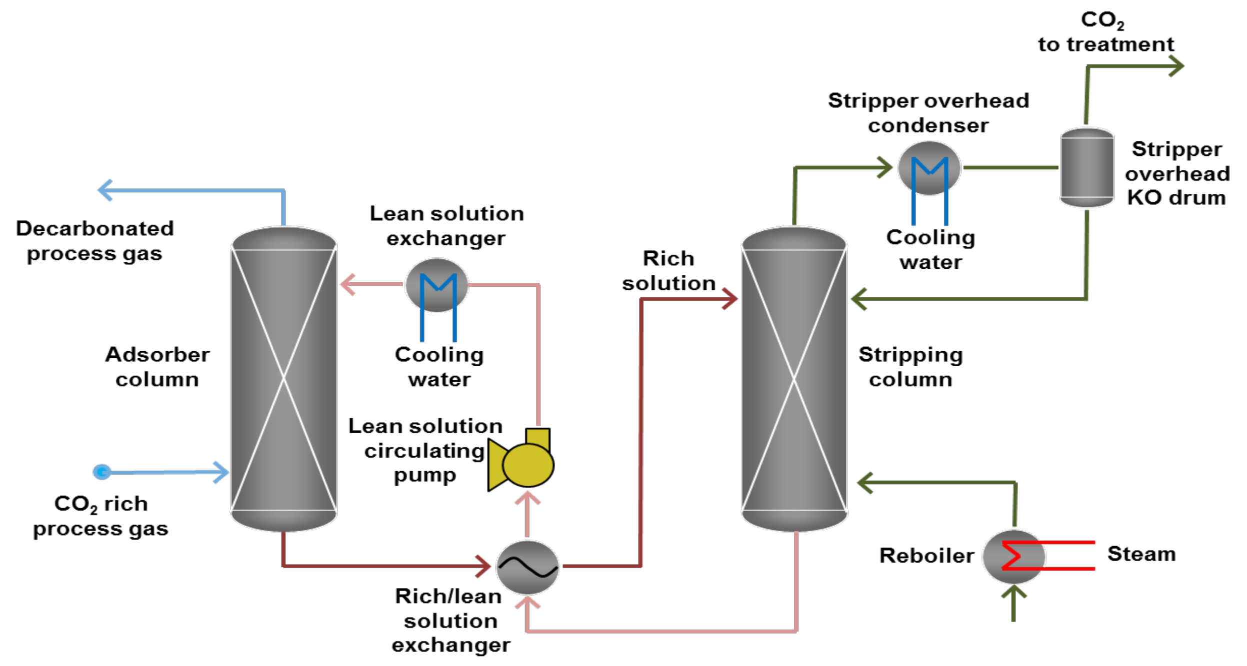

Figure 8.3-9.: CO_2 Removal System

The recycled reducing gas with a CO_2 content of about 7.9%, is fed to the CO_2 removal system at the bottom of the absorption column (CO 323-E). This is a packed bed tower where the gas is decarbonated by counter-current contact with cold lean absorbing solution coming from the stripping section. The absorbent is an amine-based or potassium carbonate solution, containing vendor's proprietary activators and corrosion inhibitors.

Decarbonated gas exits at the top of the absorption column (CO 323-E) with a CO_2 content of about 1.5%, then it goes to the decarbonated gas washer (CO 333-E) for solution and water removal, and then routed back to the reducing gas circuit. Water condensed from the decarbonated gas and separated in the same decarbonated gas washer (CO 333-E) is recycled to the process.

Rich solution exits from the bottom of the CO_2 absorption column (CO 323-E), and it is heated up in the rich/lean solution heat exchanger (CO 314-C) by transferring the heat from the hot lean solution coming from the stripping column (CO 324-E). Then, it is sent to the top of the same stripping column.

The stripping column (CO 324-E) is an internally packed tower, in which the CO_2 is stripped off from the rich solution by stripping vapour generated in the reboiler (CO 316-C). Low-pressure steam coming from LPS header is used as heating medium in the reboilers. The condensate generated in the reboilers is recovered in the condensate drum (CO 335-F) and sent back by means of the condensate pumps (CO 336-J1/J2) to the deaerator.

The lean solution leaves the bottom of the stripper and passes through the rich/lean solution exchanger (CO 314-C). It is pumped through lean solution cooler (CO 320-C) to the top of the CO_2 absorption tower (CO 323-E).

The CO_2 rich vapour stream from the stripper is cooled down in the stripper overhead condenser (CO 315-C). Condensate is recovered in the K.O. drum (CO 313-F), and returned to the process as the stripper reflux, by means of the condensate pumps (CO 325J1/J2).

The CO_2 rich gas is sent to the incinerator where the H_2S compound present in the off gas stream will be converted into SO_2.

To remove solid particles and trace reaction impurities, which can promote equipment corrosion and solution foaming, a slipstream of lean solution from the low-pressure stripper bottom is recycled through centrifuge filters (CO 330-G1/G2), activated carbon filter (CO 337-G), and mechanical filters.

The system is also equipped with a solution sump (CO 341-F) and solution sump pump (CO 329-J) which are used to prepare the solution and to feed it directly to the lean solution return or to the solution storage tank (CO 317-F).

8.3.2.5.5 EAF Charging System

Hot DRI will be discharged from the reactor (RE 221-D) through a rotary valve (RE 276-L), which controls the production rate, to the EAF Surge Bins PH 112-F1/F2. When being filled, the EAF Surge Bins will be pressurized by means of nitrogen up to the same reactor pressure to receive Hot DRI. Once the bin is full, it is depressurized and be ready to be discharged. As soon as the bin is empty, the refilling cycle starts again. Each EAF Surge Bin is equipped with a rotary valve (PH 176-L11/L12) which regulates the Hot DRI feeding to the EAF.

8.3.2.5.6 Plant Operating Data

Main average specific consumption figures, per metric tonne of total DRI production, considering 100% Iron Oxide Pellets charge, with 94% metallization and 5.0%C, are expected to be as indicated in the following table (as per calculated parameters), provided that raw material and utilities specification given in the present section are fulfilled:

Energiron Plant	*Units*	*Hot DRI*
Iron Ore (after screening on dry basis)	t/t	1.38
Natural Gas[1]		
For 5.0% carbon DRI production	Gcal/t	2.53
Oxygen (based on 99.5% purity)	Nm^3/t	59
Nitrogen (based on 99.9% purity)	Nm^3/t	31
Electric Power:	kWh/t	60
- Core Area(2)	KWh/t	91
- Including Material Handling and Utilities (Estimated)		
Industrial make Up water	m^3/t	0.90
Cement or Hydrated lime	**kg/t of iron ore**	2 - 6

Table 8.3-10.: Plant operating data

[1] Natural Gas energetic specific consumption is given referring to its Low Heating Value (LHV).
[2] Core area includes all process equipment of the DRP excluding Material Handling and Utilities

8.3.3 Melting

8.3.3.1 Introduction

The following resumes the operating profile and expected performance for a 120 tls/heat EAF designed for the smelting of High Carbon DRI (HC DRI), coming directly from a HYL ZR direct reduction module; the resulting hot metal will be used for the production of nodular pig iron.

The HC DRI and the required carburizing (if necessary) and slag forming additives will be fed through the furnace roof by gravity.

Due to the nature of the process, the furnace shall be operated almost air-tight and slag removal shall be performed only at the end of the charging, just before tapping.

Productivity estimates have been performed considering 21 days/year of plant shutdown, 3 days of downtime for contingencies, 4 hours per week for programmed maintenance (with shell change practice) and other delays leaving an effective time of 320 days/year.

The EAF has been sized as follows:

- Nominal tapping size: 120 t.
- Nominal hot heel: 50 t.
- Nominal liquid metal capacity: 170 t (sum of the above)
- Internal hearth diameter (refractory): 5.1 m.
- External hearth diameter: 6.2 m.
- Internal volume: ~120 m^3.
- Electrode diameter: 24” (600 mm).
- Electrode pitch circle diameter: 1200 mm.

8.3.3.2 Raw Materials and Process End Point

Metallic Charge (Hight Carbon DRI)

Method for charging into the furnace	Through the roof by gravity
Charging temperature	675 °C
Dimensions	pellets 6-18 mm
Bulk density	1.65-1.85 t/m^3
Characteristic size of cavities	-
C	5.00%
Si	-
Mn	0.04%
Ni	-
Cr	-
Mo	-
S	173 ppm
P	130 ppm
Total gangue	8.21%
SiO_2	4.65%
TiO_2	0.20%
Al_2O_3	0.60%
CaO	1.86%
MgO	0.82%
Fe_{total}	85.26%
$Fe_{metallic}$	80.14%
Metallization	94.00%
Moisture	-
Other	-

Table 8.3-11.: Metallic Charge Raw Material Assumptions

Slag Forming Additives

Composition	CaO [%]	MgO [%]	SiO2 [%]	Al_2O_3 [%]	P [%]	S [%]	H2O [%]	Size [mm]	LOI[2] [%]
Lime[1]	$\geq$ 89	~ 2.0	$\leq$ 1.0	$\leq$ 1.0	$\leq$ 0.03	$\leq$ 0.08	$\leq$ 0.5	15÷50[3]	$\leq$ 5.0
Dolomitic lime	$\geq$ 55	≥ 35	$\leq$ 1.5	$\leq$ 1.0	$\leq$ 0.03	$\leq$ 0.08	$\leq$ 0.5	15÷50[3]	$\leq$ 5.0

Table 8.3-12.: Slag Forming Additives Assumptions

[1] Reactivity test ASTM-C110: ΔT @ 3' ≥ 25 °C.

[2] Determined by heating the sample up to 975±25°C.

[3] The allowed amount of grain size < 15 mm shall not exceed 10%.

Carburizing Additives (shown for reference, notneeded for the process)

Composition	C [%]	Ashes [%]	S + P [%]	H_2O [%]	Grain size [mm]
Coal lumps	> 85 %	< 10 %	$\leq$ 1.0 %	$\leq$ 1.0 %	20÷50 mm [1]

Table 8.3-13.: Carburizing Additives Assumptions

[1] The allowed amount of grain size < 20 mm shall not exceed 10%.

Process End Point and Slag Composition

Tapping temperature	1560 °C
Tapping carbon content	4.1 %C
FeO	1.82%
MnO	0.16%
CaO	42.98%
MgO	14.15%
Cr_2O_3	0.00%
Al_2O_3	4.71%
SiO_2	33.75%
TiO_2	1.42%
P_2O_5	0.02%
Other	1.00%
$Ib_2 = CaO/SiO_2$	1.27
$Ib_4 = (CaO+MgO)/(SiO_2+Al_2O_3)$	1.49
Optical Basicity	0.696

Table 8.3-14.: Process End Point and Slag Composition Information

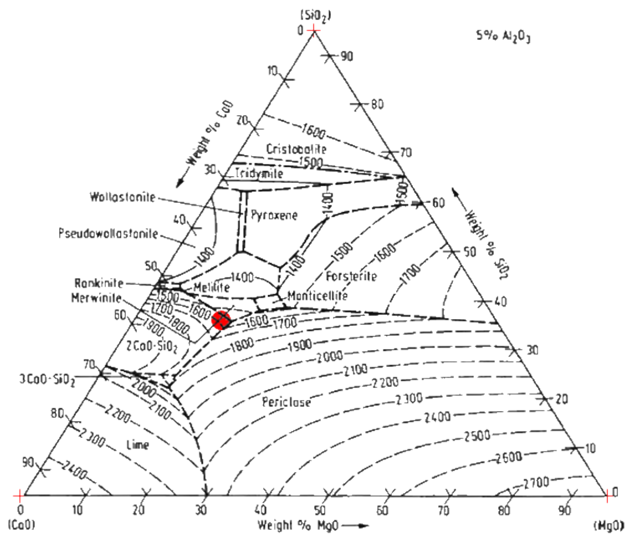

Figure 8.3-10.: Ternary Phase Diagram MgO-SiO_2-CaO

8.3.3.3 Injection System Configuration

Provision (not installation) for three bottom purging plugs in the furnace hearth.

8.3.3.4 Primary Fumes Extraction

Expected primary off-gas after complete combustion (assuming adiabatic conditions):

Flow	Nm^3/h	25000
Temperature	°C	800
H_2O	%	10.0
H_2	%	0.0
N_2	%	68.8
O_2	%	12.7
CO	%	0.0
CO_2	%	8.0

Table 8.3-15.: Off-gas Chemical Composition

In order to minimize the oxidation of the melt and to ensure the complete combustion of the CO released during the smelting reduction of the pellets, the draft air intake in the furnace shall be minimized at all times (sealed furnace) providing the necessary amount of air and turbulence by air injection in the suction ductwork immediately downstream of the furnace: use air injectors in substitution of the conventional moving sleeve. The injectors should provide roughly 5000 Nm3/h of air.

The primary off-gas system shall be equipped with temperature and composition measurement devices.

As a further measure against the emission of unburnt CO (in case of excessive draft air intake causing CO combustion quenching) the settling chamber can be equipped with post-combustion burners: 3 Air/NG burners rated for 3.5 MW of power should be sufficient but, in this case, the primary off-gas suction line shall be sized in order to treat up to 55000 Nm^3/h at 800°C.

8.3.3.5 Transformer IP Cosphi Diagram

The following I-P diagram describes the solution being proposed (55 MVA Transformer).

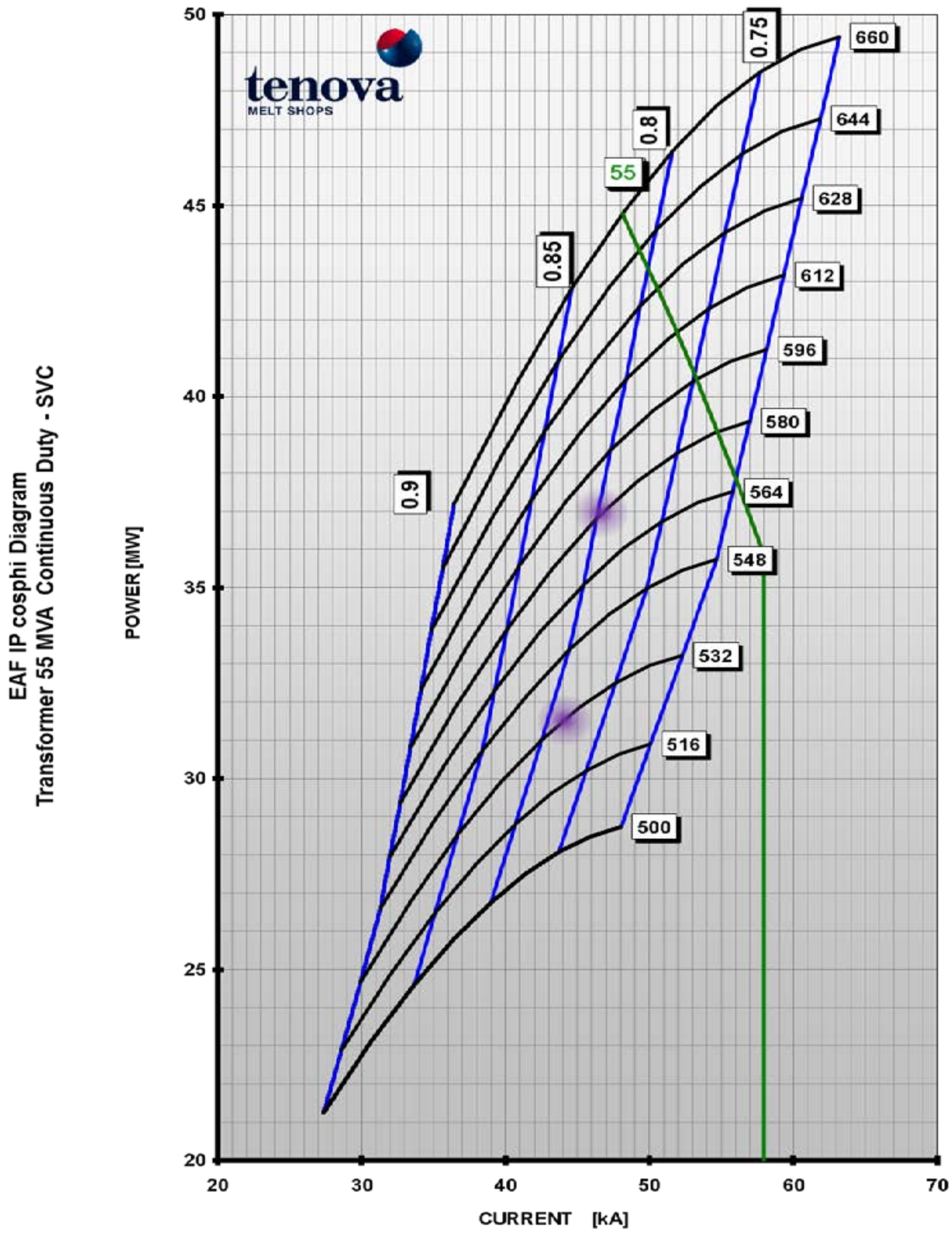

Figure 8.3-11.: IP Cosphi Diagram 55 MVA Transformer

8.3.3.6 Smelting Process

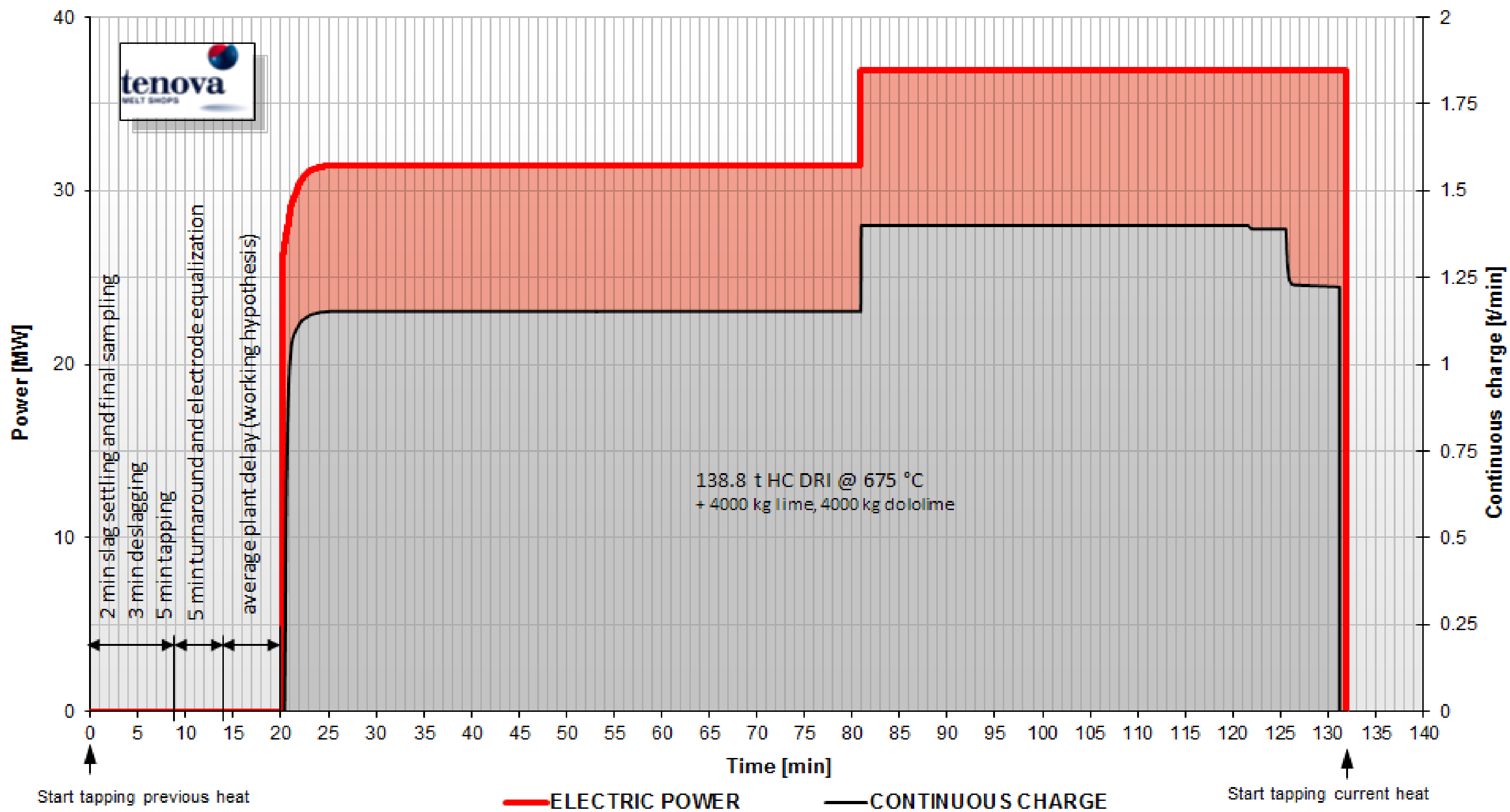

Figure 8.3-12.: EAF Melting Profile, showing electrical power and rate of DRI charge

8.3.3.7 Performance Data

		[total]	[/tls]
Metallic charge*	[kg]	138800	1157
Coal lumps	[kg]	0	0.0
Lime	[kg]	4000	33.3
Dololime	[kg]	4000	33.3
Magnesite	[kg]	0	0.0
Limestone	[kg]	0	0.0
Calcined Bauxite	[kg]	0	0.0

Table 8.3-16.: Charge Composition
* Including alloys into tapping ladle

Liquid steel in ladle	[tls]	120
Hot heel	[tls]	50
Tapping temperature	[°C]	1560
Alloys added into the tapping ladle *	[kg/tls]	0
Slag production **	[kg/tls]	159

Table 8.3-17.: Process Parameters
* Excluding reducing and slag forming additions
** Excluding deslagging losses

Total charge by bucket	[min]	0.0
Tapping sequence	[min]	10.0
Turnaround	[min]	5.0
Technological power-off	[min]	15.0
Total power-on	[min]	111.8
Tap to tap	[min]	126.8

Table 8.3-18.: Characteristic Process Times

		Max	Average
Electric power	[MW]	36.9	33.9
Electric current	[kA]	48.9	47.8
Oxygen	[Nm^3/h]	0	0
Natural gas	[Nm^3/h]	0	0

Table 8.3-19.: Main Power Inputs

		[total]	[/tls]
Electric energy	[kWh]	63207	527
Oxygen	[Nm^3]	0	0.0
Natural gas	[Nm^3]	0	0.0
Stirring gas (Argon or Nitrogen)	[Nm^3]	0	0.0
Injectable coal	[kg]	0	0.0
Electrode	[kg]	221.7	1.85

Table 8.3-20.: EAF Consumptions

8.3.3.8 Productivity

Number of 8 hours shifts per week	[#]	21
Number of furnaces	[#]	1

Table 8.3-21.: Main Operative Parameters

Calendar time	[d]	365.0
General maintenance shutdowns and holidays	[d]	21.0
Contingencies	[d]	3.0
Time lost due to shifts organization *	[d]	0.0
Possible time (work force present)	[d]	341.0
Time lost for scheduled maintenance **	[d]	8.1
Time lost due to power supply limitations	[d]	0.0
Available time	[d]	332.9
Delays ***	[d]	12.9
Effective time	[d]	320.0

Table 8.3-22.: Time Utilization in One Year

* Considered usable for scheduled maintenance by dedicated personnel.
** 4 hours for every week of operation (with shell-change practice).
*** Time beyond normal tap-to-tap (e.g. waiting for ladles, extra power-on for furnace restarting etc.)

Production / effective time	[tls/h]	56.8
Production / available time	[tls/h]	54.6
Heats per day	[#]	10.9
Heats per year	[#]	3633
Yearly production	[tls]	435,911

Table 8.3-23.: Productivity Results

8.3.4 Casting

Please refer to the equipment design section 10.3 of the report.

REV.	DESCRIPTION	DATE	PROJ.	EXEC.	CHECK.	APPR.
1	ISSUED	4/4/18	JAZ	JAZ	GMB	TEI
0	FOR INFORMATION	9/5/16	JAZ	JAZ	GMB	TEI

Pure Fonte Ltée

PURE FONTE LTÉE

PIG IRON PRODUCTION PLANT – FEASIBILITY STUDY

CUSTOMER Nº: 1821

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TECHINT ENGINEERING & CONSTRUCTION

SECTION 8 – MASS BALANCE AND PLANT PROCESS AND PRODUCT QUALITY

CHAPTER 8.4

SECTION 8 DRAWINGS

ESC.: N/A

JOB: CD-335

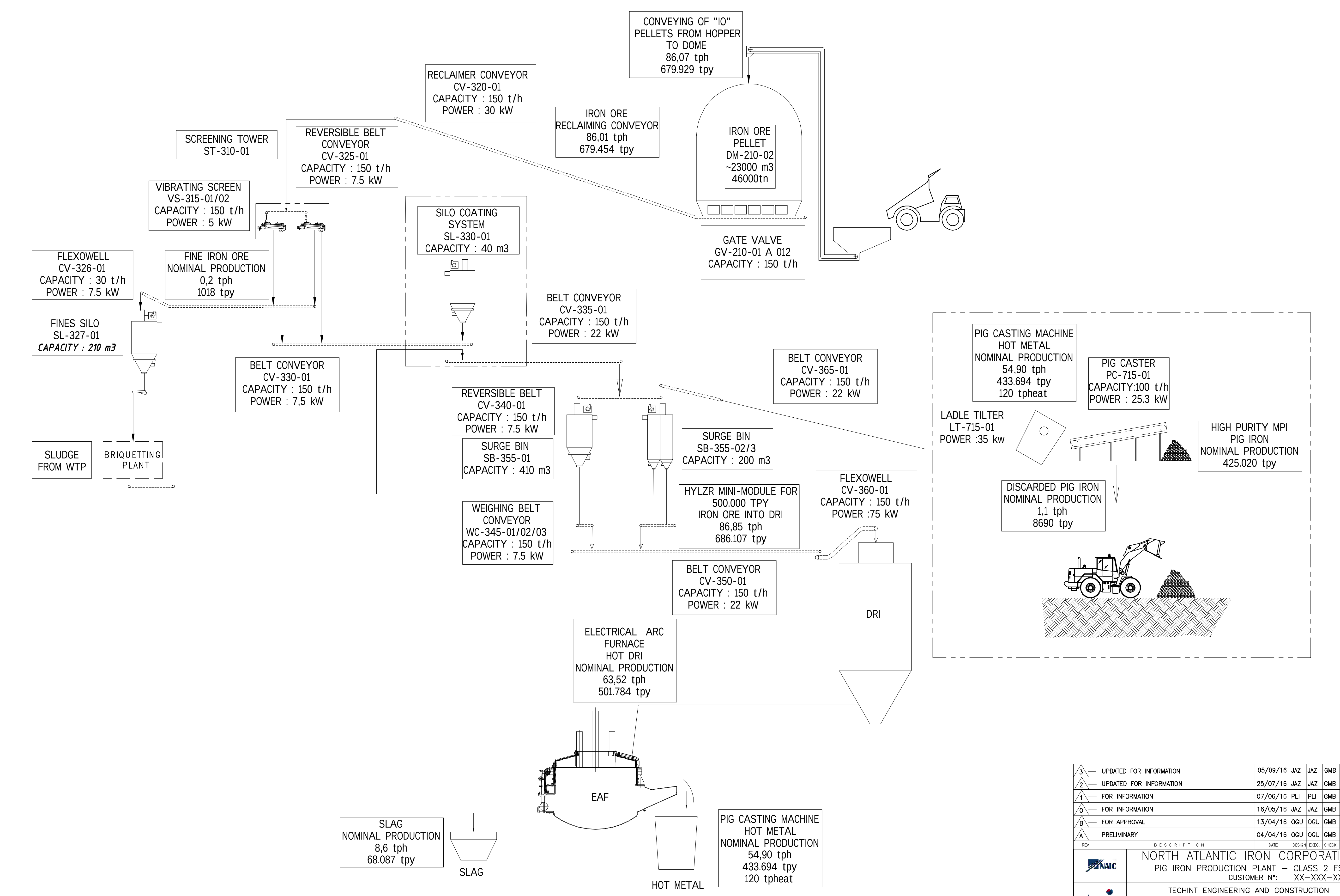
REVISION 1

REVISION

CHAPTER’S DRAWING LIST

METAL PLANT

3786-TARG-X-FD-000-001	PIG IRON PROCUCTION PLANT - FLOW DIAGRAM	Chapter 8.4



REV	DESCRIPTION	DATE	DESIGN	EXEC.	CHECK.	APP.
3	UPDATED FOR INFORMATION	05/09/16	JAZ	JAZ	GMB	TEI
2	UPDATED FOR INFORMATION	25/07/16	JAZ	JAZ	GMB	TEI
1	FOR INFORMATION	07/06/16	PLI	PLI	GMB	TEI
0	FOR INFORMATION	16/05/16	JAZ	JAZ	GMB	TEI
B	FOR APPROVAL	13/04/16	OGU	OGU	GMB	TEI
A	PRELIMINARY	04/04/16	OGU	OGU	GMB	TEI

NORTH ATLANTIC IRON CORPORATION
PIG IRON PRODUCTION PLANT – CLASS 2 FS
CUSTOMER N°: XX–XXX–XX–XX

TECHINT ENGINEERING AND CONSTRUCTION

GENERAL
PIG IRON PRODUCTION PLANT
FLOW DIAGRAM

3786–TARG–X–FD–000–001
ESC.: –
JOB: XXXXXXXX
3 REVISION