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The Orinoco Iron FINMET® Plant Operation

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Abstract:

When the plant status of the Orinoco Iron plant in Puerto Ordaz, Venezuela was presented here in 2003, the operation had been affected by shutdown of 2 of 4 trains in the plant. At present the plant is operating well and the 4 trains are in service as the plant was designed.

The Orinoco Iron FINMET plant has improved the iron ore physical quality due to systems added to the plant after its startup. This has improved the size and consumption rate of the Venezuelan iron ore and the briquette quality. The product from Orinoco Iron is exported to the North America, Europe and Asia at present. Smaller size briquettes are being developed for use in blast furnaces.

Siemens VAI is working on the improvement of the plant design and operation in order to improve the operation in the future.

Introduction

Orinoco Iron uses a FINMET® based process. It is located in a region in Venezuela of intense direct reduction activity where a number of direct reduction plants are now in operation. Orinoco Iron has an design annual capacity of 2.2 million tonnes of hot briquetted iron (HBI) and started operation in May 2000. The FINMET Process jointly developed by FIOR de Venezuela and VOEST-ALPINE Industrieanlagenbau GmbH & Co (VAI) of Austria is a Fluidized Bed Direct Reduction Process converting iron ore fines into HBI using natural gas as the primary energy source for generation of reducing gas.

The source of oxide material charged to the Orinoco Iron FINMET Plant are Los Barrancos, Las pailas and San Isidro" iron ore fines, a mixture of up to 20 different components (iron ore fines from different locations) , each of them having different characteristics.

The plant site takes advantage of the proximity of ore mines, natural gas wells, and a large hydroelectric power system. It also has a good infrastructure and is located on a river which allows shipping by bulk carrier world-wide. It is an ideal location to produce direct reduced iron.

Orinoco Iron has signed contracts for supply of HBI with consumers in North America, Europe and Asia. HBI is mainly used as a feed material for steelmaking in Electric Arc Furnace (EAF) steelmelt shops, BOF and blast furnaces. Depending on the customer's requirements, the quality of the HBI - mainly the carbon content - has to be adjusted accordingly and at the same time the metallic iron content and/or or the metallization of the HBI has also to meet the contract

Historical Review of the Process

In 1992, FIOR de Venezuela decided to enter into a FINMET® technology development program with VAI. The FIOR plant, which is now shut down, was a pioneer merchant HBI plant. The initial FINMET® process development phase was carried out in a laboratory scale and pilot plant tests were carried out in VAI's installations in Linz, Austria over a 3 year period from 1993 to 1995. Tests were also carried out at the FIOR plant during the same period to verify operating conditions for the FINMET® Process, and to test new equipment to be used by it.

The Orinoco Iron project in Puerto Ordaz, Venezuela was originally a joint venture between IBH and BHP of Australia. The project was originally conceived by IBH as a 1 million tonne/year plant, but was later changed to 2.2 million tons/year when BHP became involved. As a result, the layout features two independent plant modules of two reactor trains each. These 4 trains are connected to a common utilities block. The plant uses iron ore fines from the Ferrominera mines located close to the plant site in Puerto Ordaz, Venezuela. BHP, now named **bhpbilliton**, has removed itself from the Venezuelan project.

The process development phase took place in lab scale and pilot plant tests carried out in VAI's installations in Linz, Austria. Reduction tests were carried out in the lab. Tests were carried out at the FIOR plant to verify operation of the Orinoco Iron plant using hot fluidized beds to model the process. Large operation conditions for the FINMET process and to test in a cold fluid bed unit was set up to study the fluid bed and equipment to be used in the process. Tests of Australian iron, cyclone behavior under different cyclone configurations and reactor velocity were carried out.

The civil work for the Orinoco Iron plant began in January 1998, and mechanical erection in July 1998. Commissioning activities started in November 1999 and initial production of HBI commenced in May 2000 with one train.

FINMET® Process Description

The iron ore is delivered to the plant by bottom dump rail cars from the Ferrominera iron ore facility in Puerto Ordaz. (**Figure 1**). The plant uses ore that is principally from the San Isidro mine and which contains around 66-65 % iron. The iron ore is less than 12 mm in size and contains up to 30% of particles under 0.15 mm. The ore cars dump the ore into an underground hopper from where the ore is transferred either directly to the FINMET® process, or to large storage piles in the plant for later use.

In order to remove any oversize ore lumps or debris that could cause problems downstream in the process, the wet ore is screened on vibrating screens shown in **Figure 2**. The screens remove any material greater than 12 mm in size. This oversize ore material is ground in a new system in the FINMET plant to reduce its size. This is detailed in a following section.

The oxide feed is lifted to the top of the reactor structures by a pocket type conveyor, and is discharged into ore feed lockhopper systems. These charge the ore feed continuously into the reactors. There are two feeders for each reactor train and both feeders can handle the full ore flow rate of 105 tonnes/hour.

The oxide fines are preheated to about 450-500ºC in the first reducing reactor. The preheated ore fines pass down through the other 3 reducing reactors in series, where they are further heated and reduced by the upcoming reducing gas. The reactor system operates at high pressure, about 11-13 bars gauge, in order to increase the productivity. This is the highest pressure ore reduction system presently in operation in plants.

There are 4 reactor trains, two trains in each of the two modules which face each other. The briquetting area is between the two reactor modules. The reactors are arranged in a stepwise fashion so that the ore introduced into the uppermost reactor will flow downwards by gravity while the reducing gas flows upwards. The reactor configuration is shown in **Figure 3** when the system was under construction. The 16 reactors in the plant can be seen in this photo.

The reducing reactors for the 550,000 tons/year trains at Orinoco Iron are 4.5 meters inside diameter at the gas distribution grid and are 22 meters high. They have internal cyclones to remove entrained fines from the reducing gas leaving the fluid bed before it exits the reactor. The reactor shells are fabricated from carbon steel and have refractory linings to prevent the shell from being excessively heated. All the internal parts are made of alloy steel to resist high temperatures, which range from 450 to 850ºC. The reducing reactor internals are shown in **Figure 4.**

The hot reducing gas entering the bottommost reactor is distributed by the grid, then passes through the fluid bed where reduction occurs, and exits the reactor via the cyclones, which are located inside the reactor vessel. The cyclones remove most of the dust carried out with the gas. The gas passes on to the other three reactors so that a countercurrent flow between ore and gas is established. Reduction temperatures range from 450-500ºC in the top (ore inlet) reactor to about 800ºC in the lower one where the ore has a high percentage of Fe.

The gas plant is typical of what would be used in a refinery or petrochemical plant. It has a steam-gas reformer and a gas scrubbing system. There is one reformer for each two reactor trains. The fresh reducing gas, or makeup, required for the process is produced in the steam reformer.

The reactor and reducing gas system is shown in **Figure 5.** Since not all the reducing gas is utilized in one pass through the reducing reactors, the top gas from the uppermost reducing reactor is regenerated for use in the process. It is scrubbed to remove dust and to condense out H_2O formed in reduction. A small amount of gas is removed for fuel and the remaining gas is compressed in a centrifugal compressor and is recycled. The combined stream of reformed and recycle gas (called reducing gas) is then heated in a gas fired reducing gas heater to around 850ºC before it is introduced to the bottom reducing reactor.

The reduced ore fines exit the last reactor with a metallization of 93% and carbon in the range of 0.8 to 1.5%. The product is pneumatically transported via a pressure letdown system to a sealed, atmospheric pressure briquetter feed bin, from where it is fed into briquetting machines. There are 3 briquetters for each train, there are 6 briquetters for one module (2 trains) and one briquetter is common in each module.

The reduced ore fines are compacted to a density of over 5.0 g/cc in 1.5 meter diameter briquetting presses and are separated into individual briquettes weighing around 0.5 kg. in a tumble drum type stringbreaker. The final product is formed in briquetting presses seen in **Figure 6**. These briquetters have two counter-revolving rolls fitted with molds made of tool steel. The hot reduced iron ore from the reactors is fed into the rolls where it is compressed into briquettes.

The string of briquettes exits out of the bottom of the briquetter into the string breaker. The string breaker is followed by a hot screen, which separates out fines, and these are recycled to the briquetter machines. The briquettes are then air passivated by a product cooler and are piled in outdoor storage piles.

Once the briquettes have been cooled by air in the product cooler, they are transported by belt conveyors either to piles, or to large briquette storage silos located over the rail lines (in **Figure 7**). From these silos the briquettes are discharged into rail cars for transport to the port facility in Puerto Ordaz. At the port, briquettes are loaded into bulk carriers for the journey down the Orinoco River and transport by sea to the final destination.

The overall plant is shown in **Figure 8.** The two trains of two reactor lines in each are seen on both sides of the photo. The briquetting sections are located towards the center of the photo.

Iron Ore Problems and Solutions

The physical and reduction characteristics of a particular iron oxide feedstock are important in the direct reduction FINMET process because of a fluid bed operation. The preferred ore feedstock should:

- Have a size range between 0 mm and 7 mm
- The -100 mesh or -150 µm fraction should not exceed 18-20 % (depends on iron ore)
- Have a good reducibility.
- Have a high sticking temperature so that reduction can be carried out under the most favorable conditions.

Ferrominera or FMO's Iron ores processed in the FINMET plant Orinoco Iron are mined in the open pits of San Isidro, Las Pailas and Los Barrancos. **Figure 9** shows operation in one of the FMO mining areas.

The iron ore has presented problems to the plant in two areas regarding physical quality. The amount of *coarse* and *fine* material in the ore had resulted in a high ore usage rate in Orinoco Iron and the return of part of the ore to the supplier. The FINMET plant has now been modified to grind the ore that is oversize and this can be used in the process. The excess fine material (under 100 mesh or 150 µm) is screened out of the ore and returned to the supplier.

The iron ore from FMO has around 6-7% moisture and 25-30 % of fines under 100 mesh when delivered to the plant by train. This prevents the ore from flowing freely, which is required in order to feed it into the process. The free moisture is removed in one of two fluid bed driers shown in **Figure 10**. The iron ore fines are heated to about 100-120 ºC in the air fluidized beds.

The system also allows the amount of ultrafine ore to be adjusted before feeding it to the reactors. The plant presently adjusts the ore under 100 mesh to under 18-20%. The excess amount of under 100 mesh ore is returned to FMO. From these driers, the ore goes directly to one of the four reactor trains in the structure

The quality of the iron ore supplied by FMO had an increase in the +1/4" size fraction, that was not sent into the process to avoid defluidization in the reactors. The coarse material was also causing pluggage in reactor transfer lines as can be seen in **Figure 11**.

The coarse ore also is reduced in the reactor system slower and the results are shown in this slide. The percentage of Fe in the finer ore fraction in the lab test was in the range of 82 to 84% as shown in the graph. The coarse ore dropped to 73% in the graph shown in **Figure 12**.

Orinoco Iron in July 2004 installed two screens and a grinder temporarily in the drying area to remove and grind the particles greater than 6mm in size.

In January 2006, the new system of screening and grinding entered into operation, to guarantee that the iron ore used for the hot briquette production achieves and maintains the ore size required by the FINMET reduction process with a size of the material between 100 mesh (or 0.15 mm) and 7 mm. This screening and grinding system is done in Phases 1 and 2 are shown in **Figure 13**.

Important dates for this system are as follows:

- The system for ore preparation entered into service on January 15, 2006.
- The system has processed 1.030.000 tons (June 2006).
- The ore preparation system has processed 220.000 tons through June 2006.

The particle size distribution of the ore fractions and the percentage of ore greater than ¼" or 6.5 mm is up to 15% as received. It was necessary to reduce the percentage of very coarse ore. The drier area screening and crushing has been improved this year and is shown as the percentage of coarse material. The iron ore sent to reactors has a smaller % of iron ore over ¼" as is seen in **Figure 14.**

Finally, the delivery of iron ore to the plant has been limited due to availability in the mine. When ore delivery is reduced, the plant makes the required adjustment by reducing the capacity. This is the situation at present. A loss of production equal to 8% has been experienced in the present fiscal year. FMO is upgrading the operation at the mine in order to improve ore availability and price.

New Ore System Improvements/Developments

Orinoco Iron, in order have an increased flexibility in the storage pile, preparation, and oxide drying will achieve the improvements by incorporating additional equipment in the area of material handling. The action will be taken is the following:

- Addition of a second plow feeder
- Chevron piling with a stacker
- Addition of vibrofeeders on the ore reception hoppers
- Addition of a third dryer.
- Addition of a third and fourth mixers humidifier(Ultra fines discharge to send ultra fines loading bin)
- Addition of a third ultra fines loading bin.
- To limit one settling pond only to the ore preparation area, to recover the iron ore fines.

Orinoco Iron HBI Quality

The quality of the HBI produced at Orinoco Iron is in the range shown in this slide. The total iron is in the range of 92.5 to 93.5%, and the pure iron ranges from 84 to 85% for a metallization normally around 91%.

Carbon is specified to be greater than 0.8% and recently has been in excess of 1%. The other components are as shown below. The silica in the briquettes is low since the process does not process pellets that contain a binder based upon silica.

% FeT	92,50-93,50
% Fe°	84,00-85,00
% Met	> 91,00
% C	≥ 0,80
% S	<0,027
% MgO	0,20-0,25
% SiO2	< 1,50
% P	0,070-0,090
Dens. (g/cm3)	≥5,00

Orinoco Iron is selling the HBI worldwide and to date has been in 24 countries as shown in **Figure 15**. Due to the impact of shipping cost, we are selling a higher percentage to the United States as compared to Europe.

The plant production has exceeded 5 million tons to date since the startup as is seen in **Figure 16**. The yearly production is now at 1.3 million tons per year and is expected to increase once the iron ore becomes available. In October 2006 the plant could not operate all 4 trains due to a limited ore supply and one train remained in standby for several weeks.

Briquette Sizing for Blast Furnaces

There has been a program at the Orinoco Iron plant to reduce the size of the product briquettes to allow the use in blast furnaces where the feed size is limited. The briquette weight has been reduced from an average of 500-600 grams to 300 -400 grams. At the moment We are carrying out tests in the plant, in order to produce briquettes of minor size. The quality has to be maintained. A comparison of the sizes of the two briquettes is shown in **Figure 17.**

Future FINMET Technology Development

Siemens VAI is now involved in the development of a future program to improve plant production capacity and operation. The company will supply technical assistance with the following goals:

- Simulation and specialized technical support considering current feedstock quality and conditions in order to achieve 160 days campaign average.
- Evaluation and conceptual engineering to provide two risers per train.
- Feasibility study to use nitrogen or Natural Gas and inert gas mix during Reducing Gas to Inert Gas conditions transition.
- Evaluate the Let Down Gas System (LDGS) to be used as fuel in the ore drying system.
- Study to increase dryers' capacity and reliability, including evaluation of technology alternatives to install a third dryer or pre-dryer equipment.
- R-40 temperature effect on product quality.
- Evaluate options to increase R-40 temperature to improve the product quality and make more flexible the feedstock quality requirements.

This program is expected to begin in 2007 and will help to increase the plant capacity.

FINMET HBI: Conclusion

Present plant operation as compared to the startup phase has been improved. Orinoco Iron is achieving operation of the 4 trains simultaneously.

The iron ore reception system has been improved to allow grinding of the larger diameter ore and to improve the ore size and usage of the ore. Ore delivery still needs to be improved.

One outcome of the sales of the FINMET® HBI produced by Orinoco Iron is that the physical quality is superior to any other HBI presently being marketed. There is significantly less breakage and fines generation during handling and shipping, which has been recognized by the users of the product.

Orinoco Iron has produced over 5 million metric tons to date.

Smaller briquette sizes are being developed for blast furnaces.

The plant operation will be improved in the future as a result of the technology development to be undertaken with Siemens VAI.

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List of Attachments

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Figure 1
Iron Ore Delivery

Figure 2
Orinoco Iron Ore Wet Screening

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Figure 3
Reducing Reactors During Construction

Figure 4
Reducing Reactor Internals

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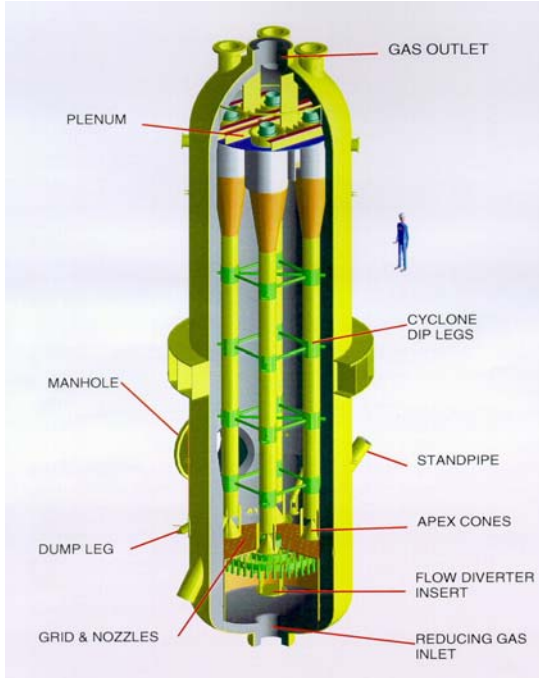

Figure 5
Orinoco Iron Reactor Train System

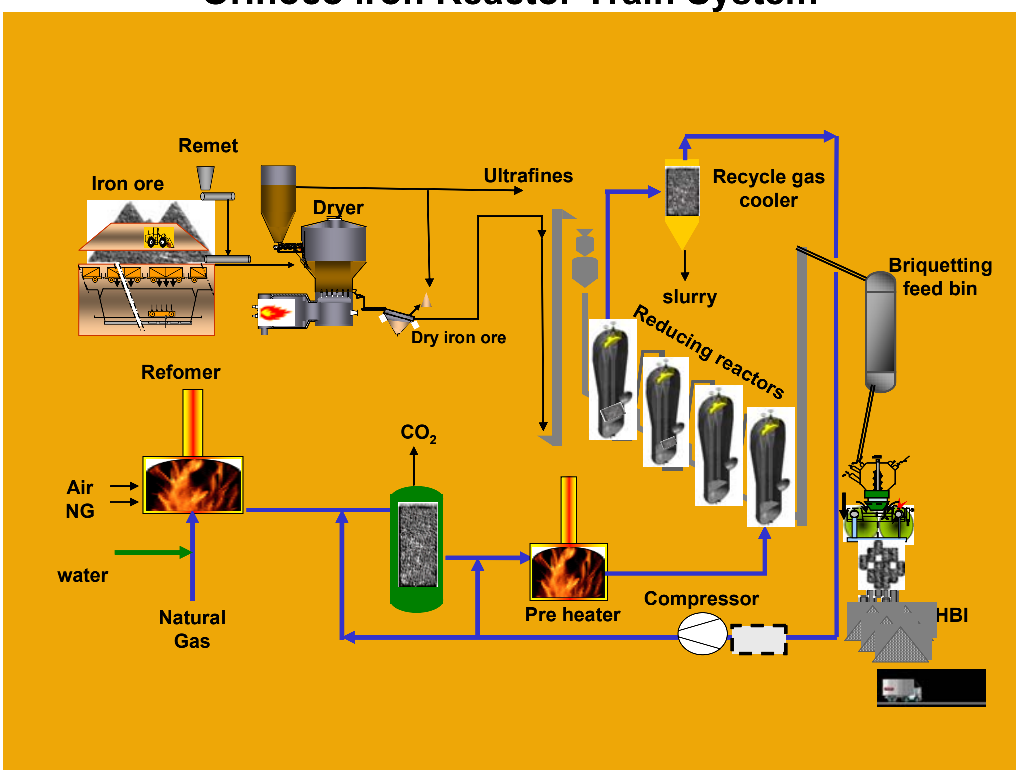

Figure 6
Briquetting System (3 presses per train – 12 total)

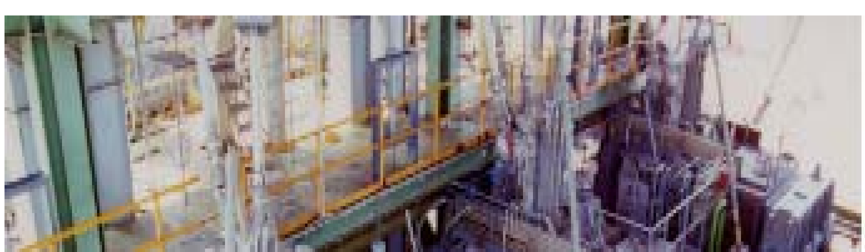

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Figure 6

Figure 7

Figure 7

FINMET® Production to Shipping Silos

Figure 8

Orinoco Iron FINMET Plant

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Figure 9
FMO Mining System

Figure 10
Plant Ore Drying System

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Figure 11
Plug from Lowest Plant Reactor

Figure 12

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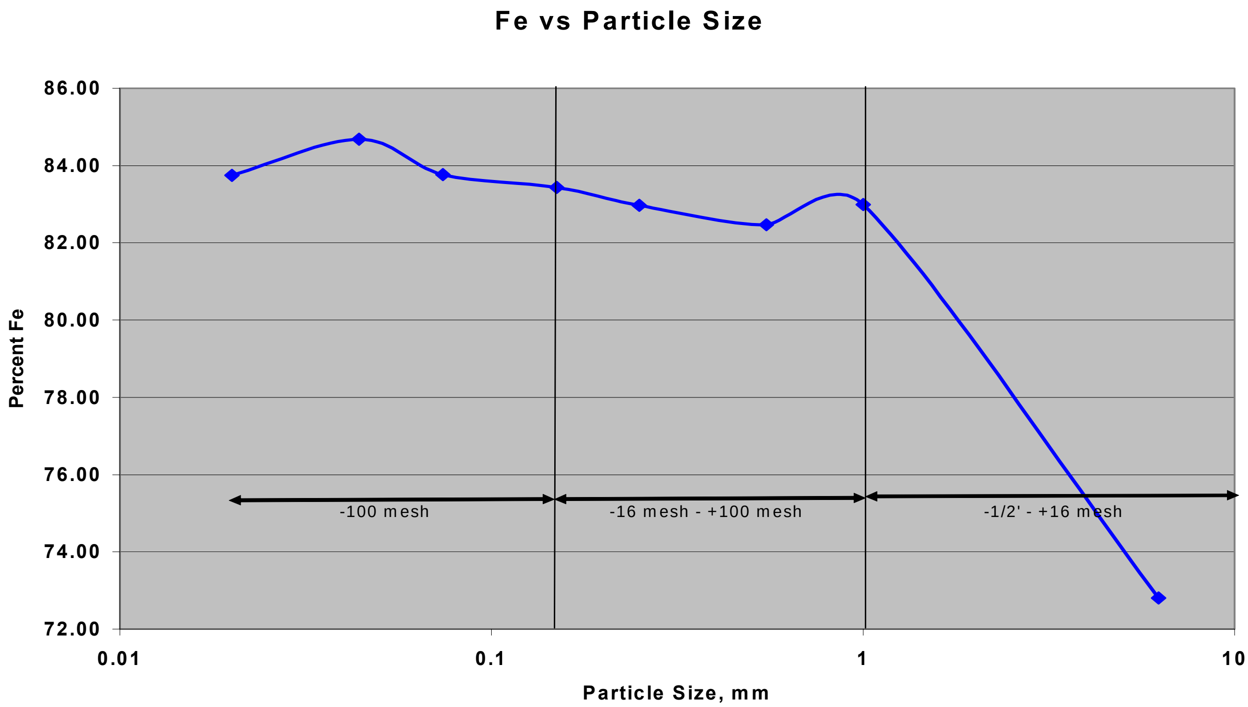

Figure 13
Crushing and Grinding in Driers Discharge

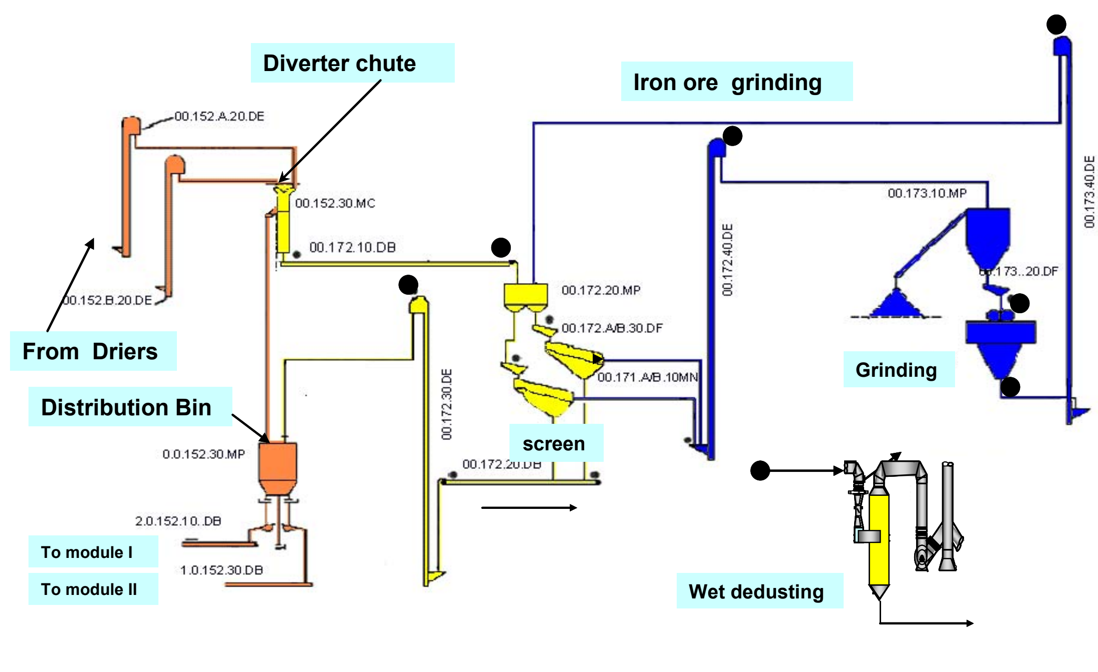

Figure 14
Orinoco Iron Ore Feed Size

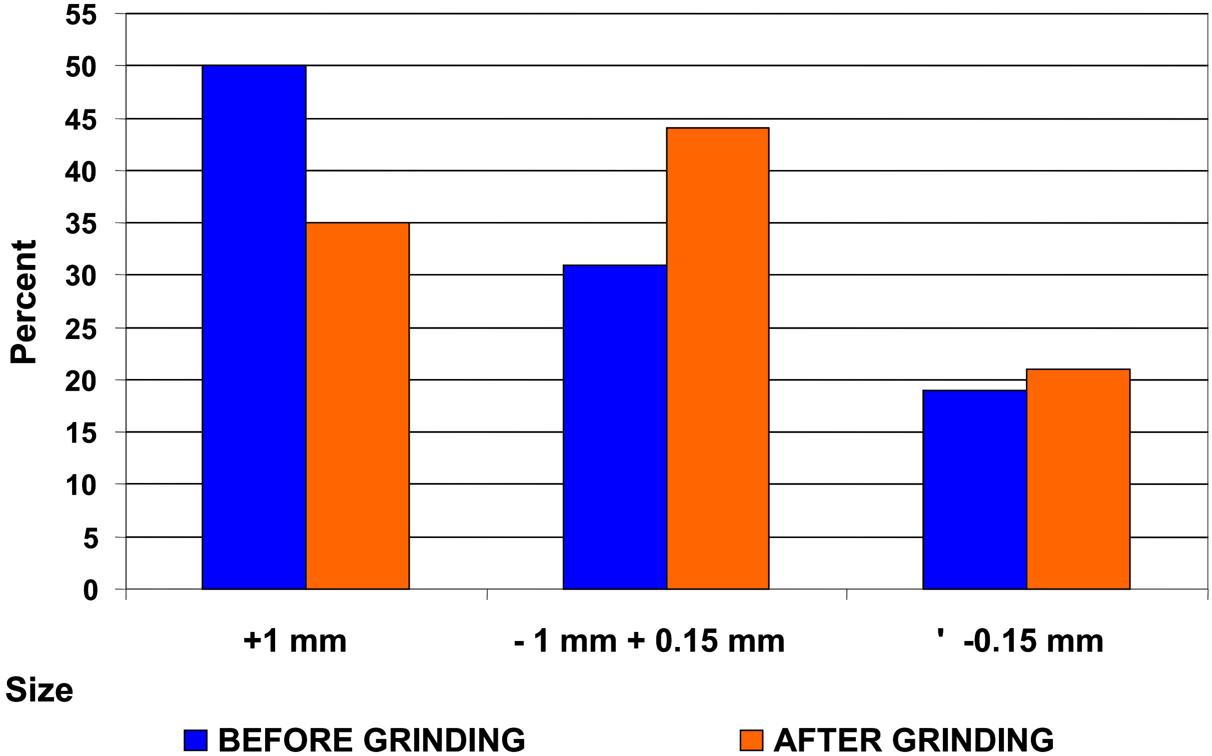

Figure 15
Orinoco Iron Briquettes Around the World

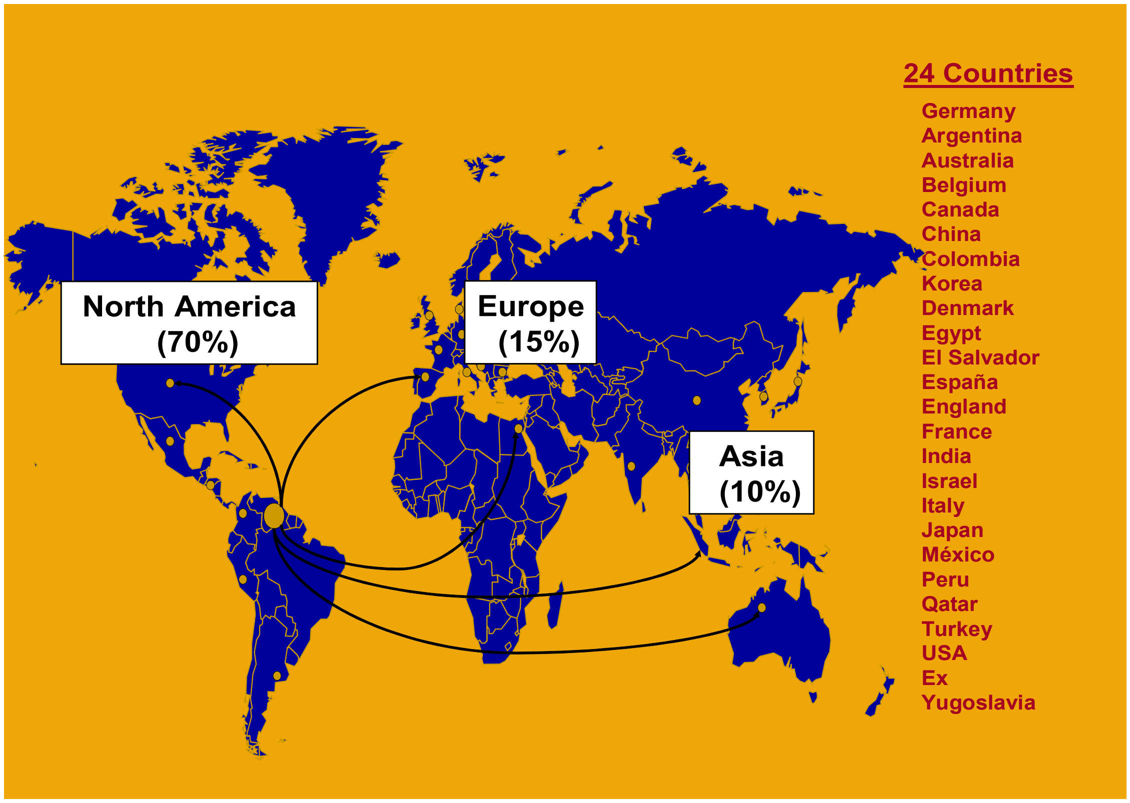

Figure 16
Orinoco Iron Yearly Production

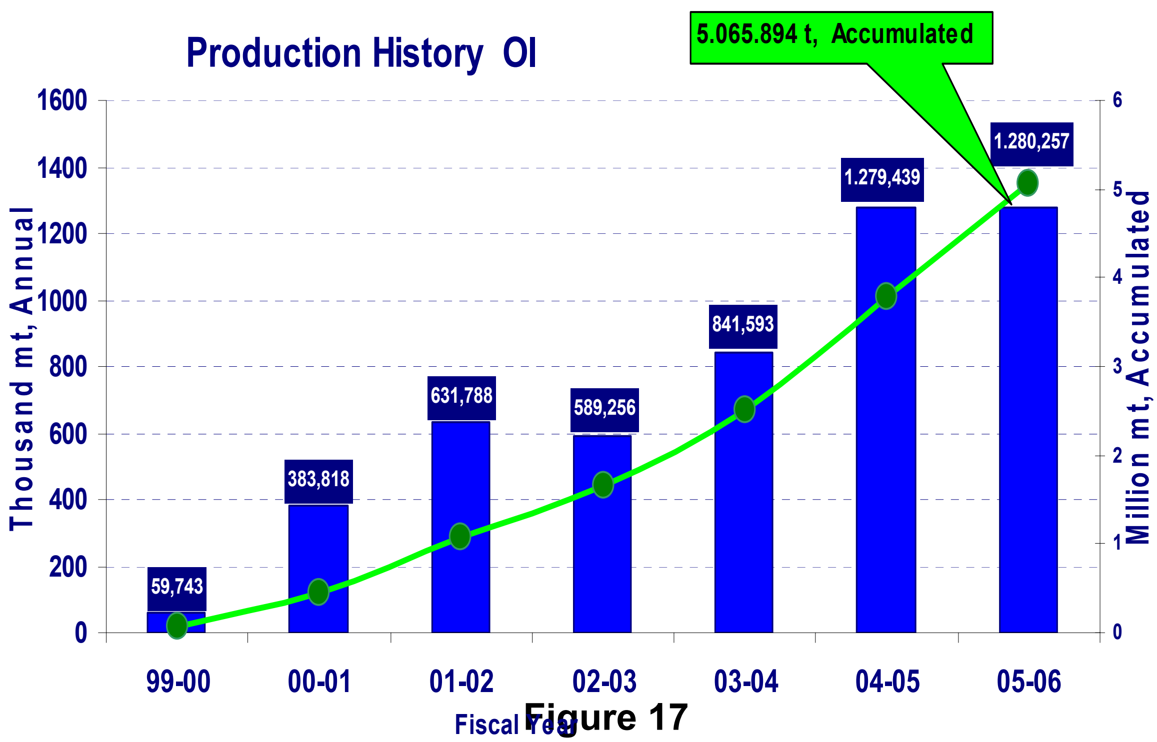

Figure 17
Smaller Mini-Briquettes for Blast Furnace Plants

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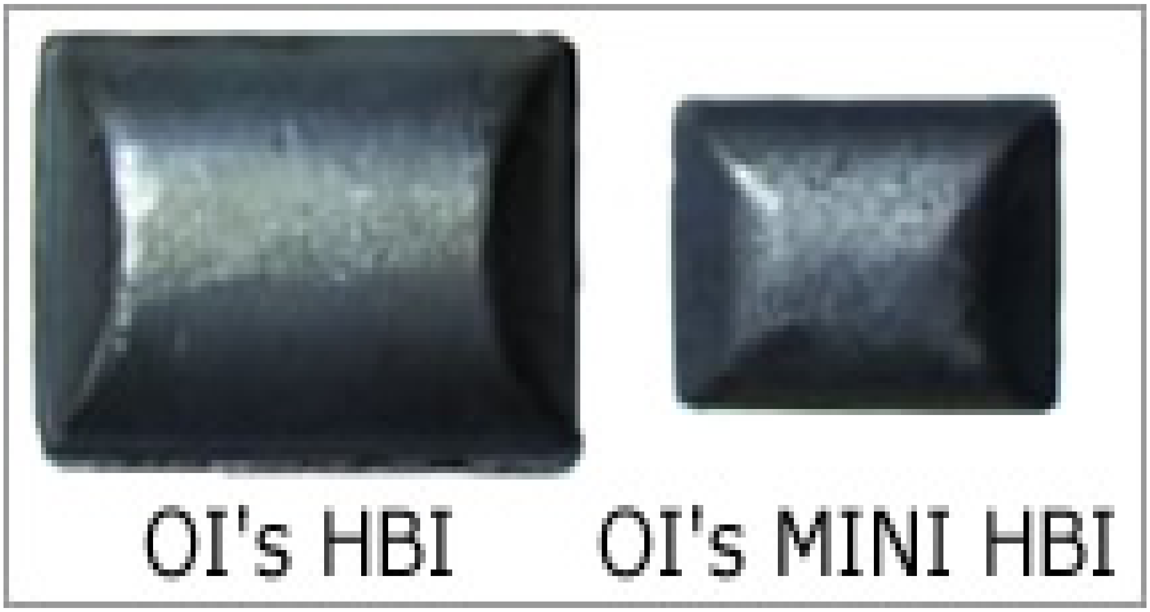
OI's HBI
OI's MINI HBI