“DR Grade Pellet Quality, Supply and Prices”

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Direct Reduction Pellet Quality

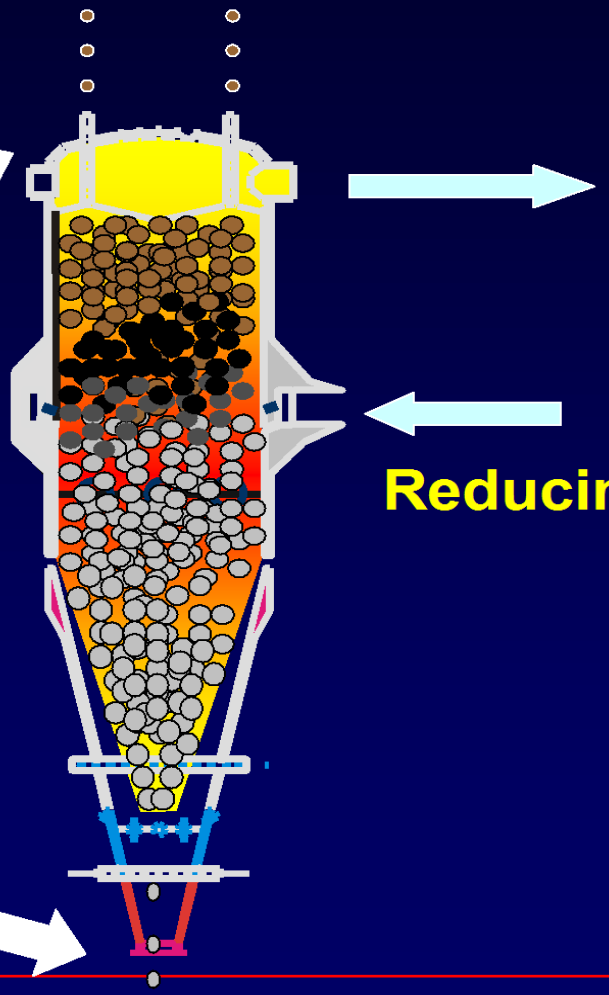
HBIA
HOT BRIQUETTED IRON ASSOCIATION

Available Processes

Lump ore & pellet based processes (HyL, Midrex)

Lump iron ore, pellet feed

Shaft furnace



Reducing gas

Hot metallized product to briquetters

Chemistry Considerations

- direct reduction processes:
  - chemical change is removal of oxygen from ore
  - remaining constituents stay with direct reduced iron product but increase in concentration due to the removal of oxygen
  - these affect process economics of subsequent EAF melting vessel
- Blast furnace, smelting reduction processes
  - formation of refining slag allows modification of hot metal product to meet requirements of subsequent steelmaking process

REQUIRED CHEMICAL PROPERTIES

Direct Reduction Processes - Shaft Furnace Rotary Kiln, Fluidized Bed, Rotary Hearth processes :

Maximize: Fe, total iron > 67%.

Minimize: gangue, impurities, residual elements, moisture, LOI

REQUIRED CHEMICAL PROPERTIES

Minimize: gangue

SiO_2 + Al_2O_3 + TiO_2, acid gangue

prefer < 2% but accept < 3%.

CaO + MgO, basic oxides

basic oxides (< 3.0 %) displace purchased flux in steelmaking;

REQUIRED PHYSICAL PROPERTIES

shaft furnaces: pellets, lump ore

key physical properties are size consist, mechanical strength:

economic importance

(a) yield of pellet, lump ore converted to DRI

(b) performance of the shaft reduction furnace

unlike blast furnace, pellets (and lump ore) are only solid materials and so determine gas distribution, permeability, reduction behavior

DR Pellet Size Exceeds BF Pellet Size

- **DR pellets: >50 % + 12.5 mm vs.**
- **BF: 9.5 x 12.5 mm target**

- **Benefits of larger pellets :**

  Increase in permeability, increased yield (fewer smaller pellets degrading into fines), reduced clustering tendency (with a decrease in contacting surface area)

- **Drawbacks of larger pellets :**

  Decreased reduction & heat transfer efficiency and pellet strength (as larger pellets are more difficult to indurate).

REQUIRED METALLURGICAL PROPERTIES

key pellet metallurgical properties are reducibility, sticking tendency, and metallization

sticking of pellets minimized by

additives, such as limestone or dolomite in pelletizing, or

oxide coatings after the pelletizing process.

reducibility, sticking tendency determine DR furnace productivity, fuel consumption

Physical vs. Metallurgical Properties

metallurgical properties, such as reducibility, are important but the physical characteristics will dominate the behavior and performance of the pellets:

a highly reducible but weak and/or poorly sized pellet will impair permeability and gas-solid contacting effectiveness and minimize the benefit of inherent excellent pellet reducibility

Direct Reduction Pellet Chemical Properties

- Merchant Pellets

	AMMC BBS	Samarco	LKAB KPRS	VALE Tubarao	VALE Oman	IOC	CAP (Chile)
Chemistry, %							
Fe	67.70	67.90	67.90	67.75	67.75	67.00	67.33
SiO2	1.60	1.23	0.75	1.40	1.40	1.20	1.40
Al2O3	0.40	0.49	0.16	0.55	0.55	0.45	0.23
TiO2	0.15	0.04	0.16	-		0.040	0.10
Mn	0.030	0.04	0.06	0.10		0.12	-
P	0.010	0.053	0.025	0.035	0.030	0.009	0.033
S	0.002	0.002	0.002	0.007	0.003	0.003	0.005
V	0.005	0.003	0.110	-		<0.01	-
Cu	0.0002	0.003	0.001	-		<0.001	-
Pb	0.001	0.05	-	-		<0.002	-
Zn	0.0015	0.002	0.004	-		<0.002	-
Cr	0.018	0.05	0.002	-		0.012	-

NAFTA Pellet Production

North America Pellet Production						
Company	**Plant**	**Annual Capacity (KT)**	**2013 Production KT**	**Equity KT**	**Market KT**	**DR Pellet Capacity**
Cliffs	Northshore	5,200	3,800	0	3,800	2,600
	United Taconite	5,000	5,100	0	5,100	
	Hibbing	8,000	7,700	6,100	1,600	
	Empire	6,000	1,300	1,300	0	
	Tilden	8,000	7,500	1,200	6,300	
	Wabush	6,000	1,200	0	1,200	
AK Magnetation	Reynolds	3,500				
USSteel	Minntac	14,500	14,200	14,200	0	
	KeeTac	6,000	5,000	5,000	0	
ArcelorMittal	Minorca	2,700	2,800	2,800	0	
	Mines Canada QCM	9,200	9,200	6,200	3,000	4,600
	Lazaro Cardenas 1	3,500	3,500	3,500	0	3,500
	Lazaro Cardenas 2	2,100	2,100	2,100	0	
Rio Tinto	IOC Lab City	12,500	9,000	0	9,000	12,500
Ternium	Las Ecinsas	2,000	2,000	2,000	0	2,000
JV AM/Ternium	Pena Colarada	4,000	4,000	4,000	0	4,000
totals, MTPY		98.2	78.4	48.4	30.0	29.2

Brazil Pellet Production

Brazil Pellet Production							
Company	Plant	Annual Capacity (KT)	Production 2013 KT	Equity KT	Market KT	DR Pellet Capacity KT	Comment
VALE	Tubarao No 1	2,100	0	0	0	2,100	idled by VALE
	Tubarao No 2	3,100	0	0	0	3,100	idled by VALE
	Itabrasco No 3	3,300	4,400	2,200	2,200	1,650	
	Hispanobras No 4	3,800	3,900	1,950	1,950	1,900	
	Nibrasco No 5	4,800	4,500	2,250	2,250	2,400	
	Nibrasco No 6	4,800	4,500	2,250	2,250	2,400	
	Kobrasco No 7	4,300	4,300	2,150	2,150	2,150	
	Tubarao No 8	7,500	0	0	0	7,500	2014 startup
	Vargem Grande	7,000	5,300	0	5,300	7,000	
	Fabrica	3,600	3,800	0	3,800	0	
	San Luis (Carajas)	6,000		0	0	0	idled by VALE
Samarco	Pont Ubu No 1	7,000	7,000	0	7,000	7,000	
	Pont Ubu No 2	7,000	7,000	0	7,000	7,000	
	Pont Ubu No 3	7,600	7,100	0	7,600	7,600	
	Pont Ubu No 4	7,600		0	0	7,600	2014 startup
Vallourec	Pau Branco	1,600	1,000	1,000	0	0	captive
totals, MTPY		81.1	52.8	11.8	41.5	59.4	

South American Pellet Feed, Concentrates

Chemistry	VALE Tubarao--→ PF		Samarco PF Oman	VALE Guaba	Hierro Peru PF	Romeral pellet feed	CVG nat. feed	CasaDePedra Pellet feed		Namisa Namisa Feed	DR PF	Anglo American Minas DR PF	Rio BF PF
	PFFT	PFPT		PFFG									
Fe	66.5	68.0	66.9	64.7	69.0	67.0	67.3	67.0	66.0	67.3		68.4	67.2
SiO_2	2.50	0.95	1.27	4.30	2.00	1.90	1.10	1.90	3.50	1.60		1.00	2.50
Al_2O_3	0.70	0.50	0.39	1.30	0.50	0.45	0.70	0.70	0.60	0.70		0.30	0.65
TiO_2	0.05		0.03	0.04	-	0.15	0.03						
Mn	0.150	0.050	0.054	0.300	0.020	-	0.11	0.40	0.20	0.40			
P	0.045	0.032	0.043	0.060	0.020	0.040	0.045	0.045	0.055	0.035		0.040	0.043
S	0.003		0.004	0.005	0.135	0.045	0.020						
V	-		-	0.006	-	0.750	0.020						
Cu	-		-	-	0.008	-	0.030						

Sweden Pellet Production

Sweden Pellet Production							
Company	**Plant**	**Annual Capacity (KT)**	**Production 2013 KT**	**Equity KT**	**Market KT**	**DR Pellet Capacity KT**	**Comments**
LKAB	Kiruna No 1	3,800	3,000	0	3,000	3,800	
	Kiruna No 2	5,000	4,900	0	4,900	5,000	
	Kiruna No 3	5,000	4,900	0	4,900	5,000	
	Malmberget No 1	4,300	4,000	0	4,000		Supply BF's in
	Malmberget No 2	2,500	2,500	0	2,500		Sweden, Finland
	Svappavaara No 1	3,800	3,800	0	3,800		
totals, MTPY		24.4	23.1	0	23.1	13.8	

Russia Pellet Production

Russia Pellet Production						
Company	**Plant**	**Annual Capacity (KT)**	**Production 2013 KT**	**Equity KT**	**Market KT**	**Comments**
Kachkanarsky	No 1	3,000	3,150	2,650	500	
	No 2	3,000	3,150	2,650	500	
Kostomuksha	No 1	3,000	3,500	1,750	1,750	
	No 2	3,000	3,500	1,750	1,750	
	No 3	3,000	3,456	1,750	1,706	
Lebedinsky GOK	No 1	2,500	2,225	1,225	1,000	DR grade pellets
	No 2	2,500	2,225	1,225	1,000	to LGOK plants
	No 3	2,500	2,225	1,225	1,000	
	No 4	2,500	2,225	1,225	1,000	
Mikhailvoski GOK	No 1	4,500	4,500	0	4,500	
	No. 2	5,000	5,000	5,000	0	
OEMK	No 1	3,750	3,750	3,750	0	DR grade pellets
						to OEMK DRI
totals, MTPY		38.3	38.9	24.2	14.7	

Middle East Pellet Production

MENA Pellet Production							
Country	Company	Plant	Annual Capacity (KT)	Production 2013 KT	Equity KT	Market KT	DR Pellet Capacity KT
Bahrain	GIIC	No1	5,000	1,500	1,200	300	5,000
		No2	6,000	2,000	0	2,000	6,000
							0
Oman	VALE	No 1	4,500	4,150	0	4,500	4,500
		No 2	4,500	4,150	0	4,500	4,500
Iran							0
	NISCO-Ahwaz	No 1-2	4,400	4,400	4,400	0	4,400
	NISCO-Mobarekeh	No 1	3,400	3,400	3,400	0	3,400
		No 2	4,500	4,500	4,500	0	4,500
	Gol-e-Gohar Mining	No 1	5,000	5,000	0	5,000	5,000
		No 2	5,000	0	0	0	5,000
	Chador Malu		3,400	3,400	0	3,400	3,400
totals, MTPY			45.7	32.5	13.5	19.7	45.7

World Pellet Supply

World Pellet Supply						
Region		Annual Capacity MT	Production 2013 MT	Equity MT	Market MT	DR Pellet Capacity MT
North America		98.2	78.4	48.4	30.0	29.2
Brazil		81.1	52.8	11.8	41.5	59.4
Latin America ex Brazil		17.5	5.9	4.8	1.1	11.9
Sweden		24.4	23.1	0	23.1	13.8
MENA		45.7	32.5	13.5	19.7	45.7
Other Europe						
Netherlands		4.4	4.0	4.0	0	0
Turkey		1.5	1.5	1.5	0	0
Russia		38.3	38.9	24.2	14.7	13.7
Ukraine		26.0	23.8	7.5	16.3	0
Kazachstan		8.4	6.7	0	6.7	0
India		65.5	32.6	28	4.4	20.0
Japan		3.0	3.0	3.0	0	0
China		216.9	170.1	146.1	24.0	0
Australia		4.3	4.0	1.7	2.3	0
Totals		**635**	**477**	**295**	**184**	**194**

Impact of Samarco Tailings Dam Disaster

- **Loss of Samarco mine/Concentrator for 6-18 months,**
- **Pellet plants still operational but can logistic/technical issues be overcome to use external pellet feed (VALE, others)?,**
- **Samarco currently supplies about 15 MTPY of DR grade pellets: key supplier to Nucor, Antara and MENA region,**
- **DR pellet premium will almost certainly increase**

Overcoming Impact of Samarco Tailings Dam Disaster

- **Increased production from:**
  - **VALE Oman,**
  - **GIIC Bahrain (AngloAmerican Minas Rio PF),**
  - **Kudremukh (")**
  - **new sources: Cliffs Northshore**
  - **IOC**
  - **VALE (Tubarao, Vargem Grande), LKAB, AMMC**
- **Samarco DR pellet production with external PF**
- **Alternate feed materials:**
  - **DR lump ore (Sishen)**
  - **BF pellets (impact on EAF only)**

DR Pellet Pricing

Pellet Pricing Formula:

- **China CFR Fines Price @62% Fe**
- **+ Fe adjustments**
- **- Freight netback (Brazil-China)**
- **+ Pellet premium**

= $ 48 x (67/62) – 12 + 35 = $ 75/ton

Pellet premium ➔ negotiable; higher for DR pellets

Pellet sales into China are frequently distressed at very low pellet premiums

DR Pellet Pricing

- **Pellet pricing highly dependent upon world iron ore price; dependent upon sintering ore fines price**
- **Sintering ore fines are in oversupply; pellets are not in oversupply; lump ore, pellet feed also not really in oversupply,**
- **Near and intermediate term sintering ore fines pricing projected very low: actions of "Big Three", oversupply (Roy Hill, Carajas 11D)**
- **Current pellet pricing not high enough to justify pellet plant construction**

Slowdown in China pig iron production combined with increased supply made iron ore prices fall to historic low levels throughout 2014 and into 2015

DEMAND

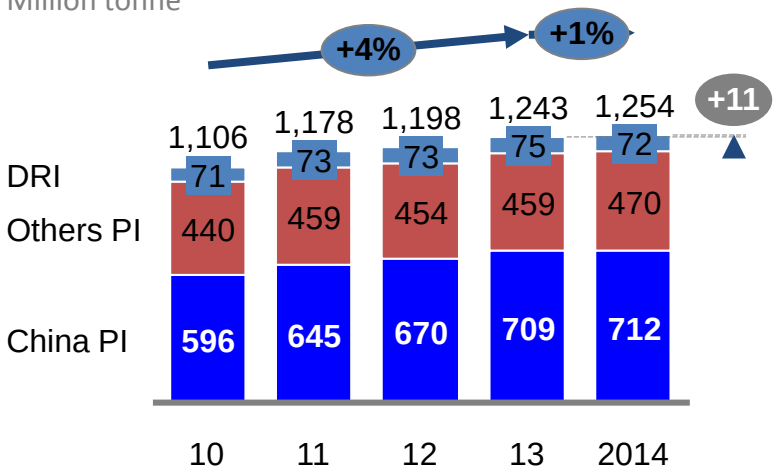
Overall slowdown or iron ore demand especially in China

Continued increase of iron ore supply, especially from Australia (FMG, Rio, BHPB)

SUPPLY

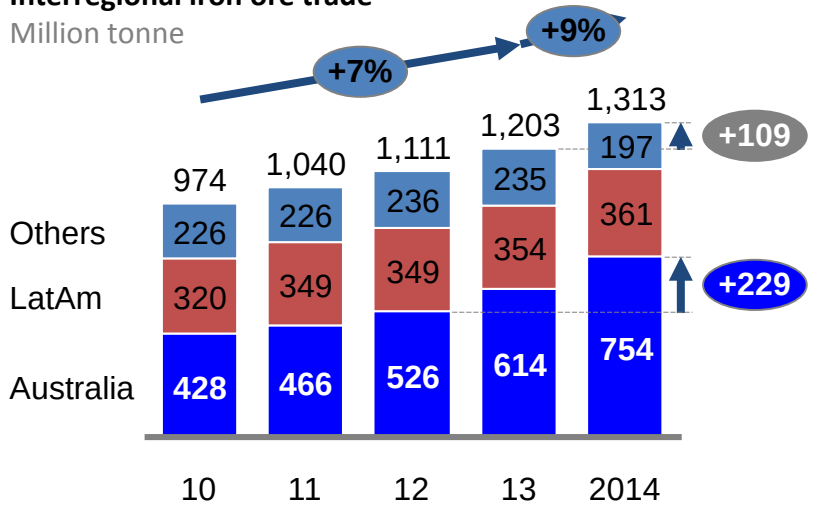
Pig iron and DRI production

Million tonne



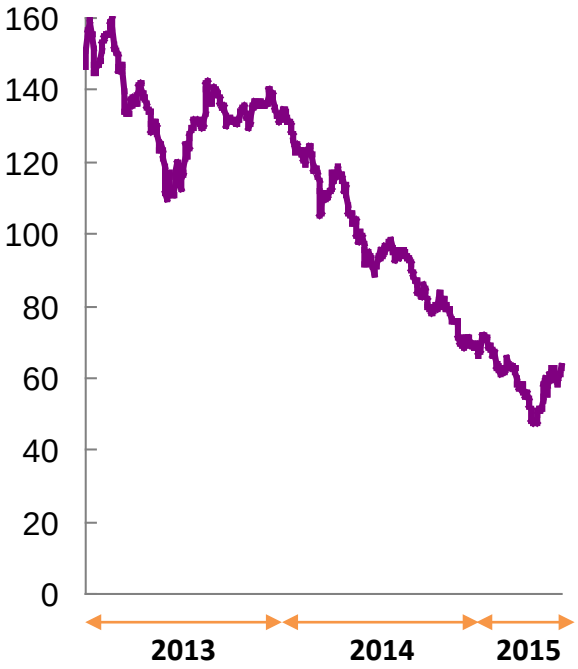
Interregional iron ore trade

Million tonne



Iron ore IODEX

USD/tonne



SOURCE: McKinsey, WorldSteel; ISSB; Platts

Current Strategy of "Big Three": Rio Tinto, BHPB and VALE

- **Big 3 Continue to Maximize Iron Ore Production, Exports to Minimize Unit Costs; thereby maintaining margins even at < 50 $/ton price while driving out competitors:**
  - **Countries not normally in seaborne iron ore trade: Malaysia, Mexico, western USA, Myammar, Thailand, Honduras, Finland, Argentina, Turkey**
  - **junior miners in Australia**
  - **ill conceived Atlantic basin projects: Northland Resources, Bloom Lake, Marampa, others**
  - **small, private, high cost coastal mines in China: larger mines, state owned or not, independent or steel company affiliated, located inland, continue to operate even in loss position now some being shut down**

Conclusions – DR Pellet Quality

- **DR grade pellets differ from BF pellets most importantly in the requirement to minimize the acidic gangue content as such acidic gangue needs to be removed in EAF slag phase .**
- **DR pellet reducibility needs to be high as high metallization needs to be achieved in the DRI process since reduction of unreduced iron oxide also is difficult in the EAF.**
- **Required physical properties, fines level, tumbler and compression strength and the metallurgical property, LTB (Low Temperature Breakdown) are comparable for both shaft furnace processes, BF and DR.**
- **The DR process does favor larger pellets to maximize permeability and minimize sticking surfaces.**

Conclusions – DR Pellet Supply

- **Merchant DR pellet supply is concentrated in Canada, Brazil, Sweden and the MENA region**
- **Considerable captive DR pellet capacity exists in Mexico, Venezuela, Iran, India and Russia.**
- **Captive capacity being added in Iran, India and Russia**
- **Considerable BF pellet capacity can be switched to DR pellet capacity in Brazil and Canada, at least in the short and intermediate term.**
- **Long term, any major increase in DRI capacity in the Atlantic Basin will require new DR pellet capacity**

Conclusions – DR Pellet Pricing

- **Pellet pricing formula starts with global (China) sintering ore fines price, depends on Fe content, freight rates and negotiated pellet premium,**
- **DR pellet premium is higher than BF pellet premium,**
- **Even with today's very low pellet prices, the production of DRI is not favorable when scrap prices are very low:**
- **1.5 x 75 + gas (40) +conversion (30) = $ 182/ton**

Thank You

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Direct Reduction Pellet Physical Properties - Merchant Pellets

	AMMC BBS	Samarco	LKAB KPRS	VALE Tubarao	VALE Oman	IOC	CAP
Sizing, mm							
+ 16.0	2.5	8.0	2.0	0.7			
+ 12.5	24.7		63.0	52.9		15.0	
+ 11.2	33.6						
+ 9.5	29.2					75.0	
+ 9.0	6.0		32.0				
+ 8.0				43.2			
+ 6.3	3.0					8.5	
- 6.3	1.0	1.1				1.5	
+ 5.0			2.0	1.9			
- 5.0			1.0	1.0	1.5		
9 x 16	93.5		95.0				
8 x 16		94.2					
8 x 18				96.0	95.0		
Tumbler,							
+6.3 mm	96.0	93.6	94.0	94.5	93.5	95.1	
-0.5 mm	4.0	5.8	5.0	5.0	5.5	4.0	3.5
Compression, kg	280	307	260	290	260	250	260

Direct Reduction Pellet Metallurgical Properties - Merchant Pellets

	AMMC *BBS*	Samarco	LKAB *KPD-1*	VALE *Tubarao*	VALE *Oman*	IOC
Metallurgical						
Degree of Metallization				94.0	94.0	
Reducibility,						
R180	93.8	97.2	97.0	94.4		
ISO R40	-	1.99		1.10		
DR90 11258						95
Metalliz., ISO 11257		96		94.0		
Clustering,						
CRM test	11.2	32.6	14.4			
ISO 11256		12				20
HyL Testing						
LTB, > 6.3 mm		94.2	90.4			
LTB, < 3.2 mm		2.1				
LTB, < 0.5 mm			3.8			
HyL Reducibility,						
@ 800 C		4.5	4.0			
@ 950 C		5.8	5.5			
degree of red.						
HyL Sticking Index			30-35	36		
@ 950 C w/o drops		6-12%				
Metallization,						
@ 950 C %		94.0				
@ 800 C		93.0				
Swelling, @ 950 C		8.5				
" , @ 800 C		10.0				