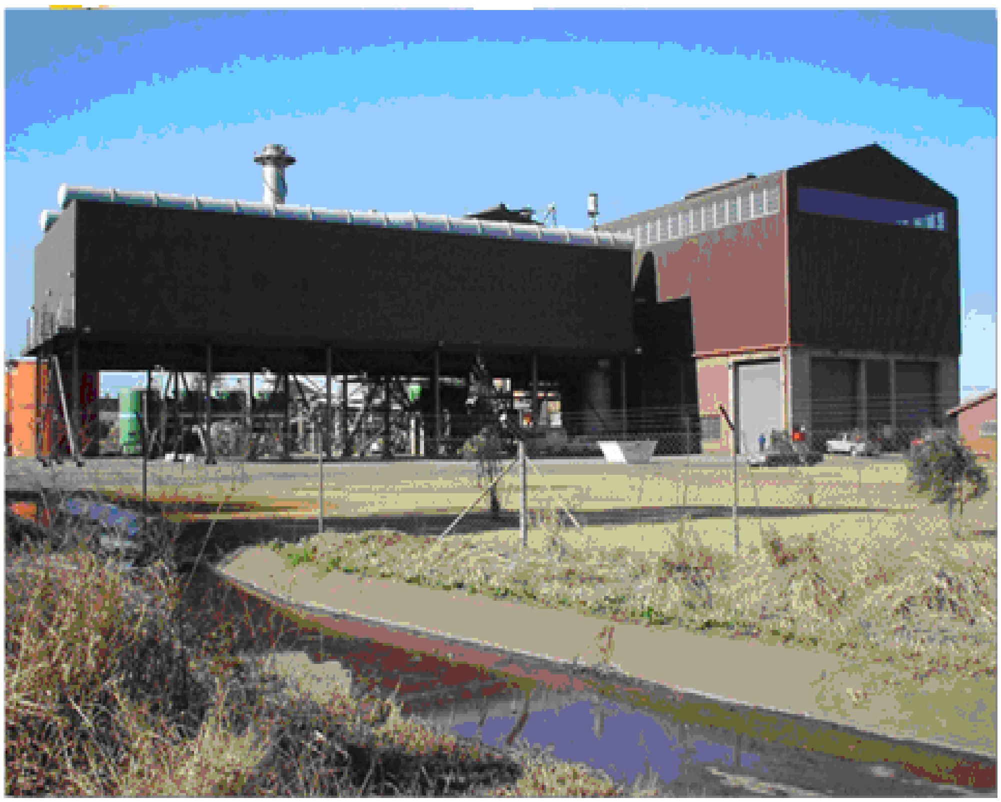
Report R66/2007

AN OVERVIEW OF VALUE SYSTEMS OF SELECTED FERROUS MINERAL COMMODITIES 2007

DIRECTORATE: MINERAL ECONOMICS



mineral resources

Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

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AN OVERVIEW OF VALUE SYSTEMS OF SELECTED FERROUS MINERAL COMMODITIES 2007

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Compiled by: Mr M.W Bonga

mpumzi.bonga@dme.co.za

Issued by and obtainable from
The Director: Mineral Economics, Mineralia Centre,
234 Visagie Street, Pretoria 0001, Private Bag X59, Pretoria 0001
Telephone (012) 317-8538, Telefax (012) 320-4327
Website: http://www.dme.gov.za

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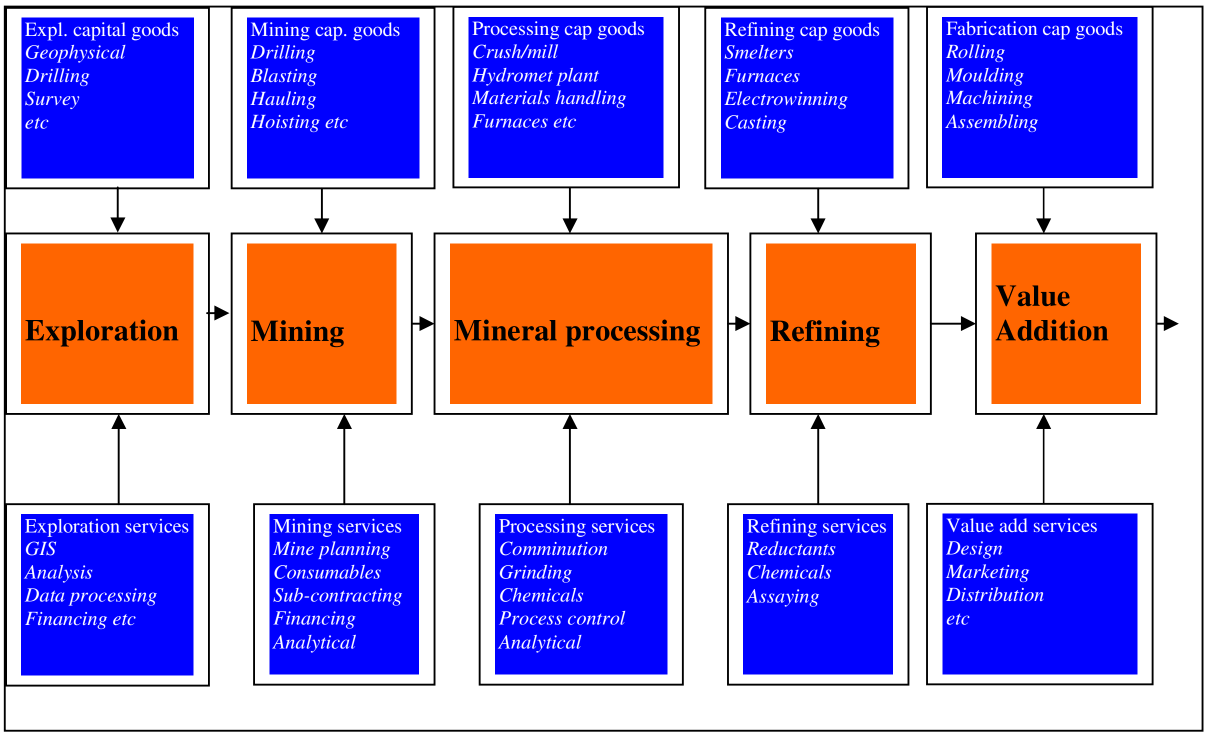
1. Introduction

Mineral beneficiation involves the transformation of raw materials using capital and human resources to produce a finished product that has a value higher than that of the raw material. The full value chain which includes beneficiation also includes both upstream and downstream value addition. Upstream value addition refers to inputs into the mining sector while downstream value addition involves large scale capital intensive activities such as smelting and refining as well as labour intensive activities such as craft jewellery and metal fabrication (Fig 1.1).

Fig 1.1: Mineral Value Chain



Source: Paul Jourdan, 2003

Beneficiation Stages

Figure 1.1 illustrates the four stages involved in downstream beneficiation:

- The labour intensive primary stage of mining and producing ore concentrate.
- Converting the concentrate into an intermediate product such as a metal or alloy
- Refining or semi-fabricating to a product suitable for use by both small and sophisticated industries.
- Fabrication- the metal is transformed into a finished product for use in different applications. Since this stage includes small and medium enterprises as well as large manufacturers, it offers significantly greater employment opportunities.

It is due to the increased employment opportunities and the possibility of higher revenues generated through downstream value addition activities that South Africa insists on increased local beneficiation of ores. This ensures not only optimal exploitation of the country's depleting resource but also maximal value extraction as well as increased local community benefits. This report focuses only on selected ferrous mineral commodity value chains.

2. Manganese Value System Overview

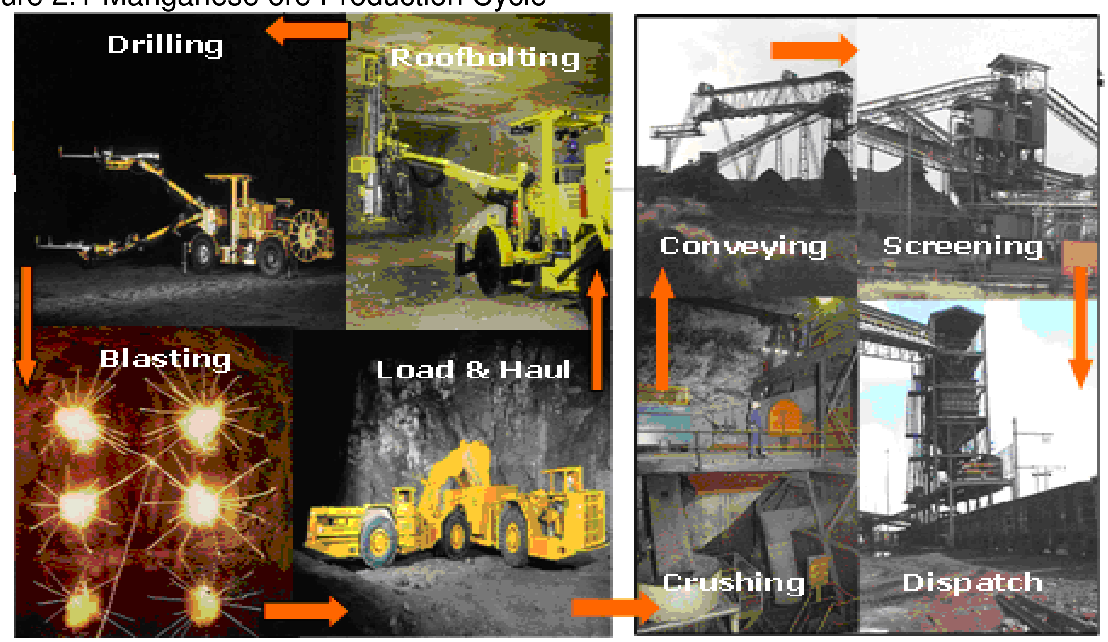
The manganese industry consists of three value system components which collectively describe the structure and dynamics of the industry.

a) Ore Producers

- Industry segmented by ore characteristics:
  - High grade ore (> 35% Mn) (60% of Mn units)
  - Low grade ore (< 35% Mn) (40% of Mn units)

Manganese ores of various grades are produced from various mines following the general manganese ore production cycle shown in Fig 2.1.

Figure 2.1 Manganese ore Production Cycle



b) Alloy Producers

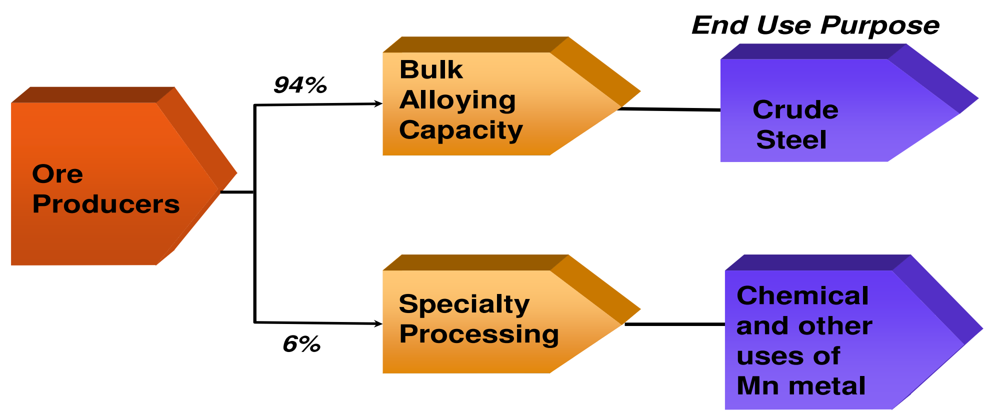
- Integrated alloy smelters account for 30 percent of production which translates to 3.0 Mtpa
- Independent alloy smelters account for 70 percent of production which amounts to 7.0 Mtpa)
- Products:
  - High Carbon Ferromanganese (HCFeMn)
  - Medium Carbon Ferromanganese (MCFeMn)
  - Silicomanganese (SiMn)

c) End Use Customers (Fig 2.2)

- Primarily crude steel producers (94% of demand)
  - Integrated Mills
  - Minimill Flat Producers
  - Minimill Long Producers
  - Speciality Mills
- Also chemical and specialist metallurgical segments (6% of demand)

The manganese value system has evolved over time leading to a partial integration between ore and alloy producers. This involved both backward integration by steelmakers and forward integration by ore producers which led to integrated alloyers and integrated steel producers.

2.2 Manganese End Use Markets



Source: Roskill

2.1 The Manganese Value Chain

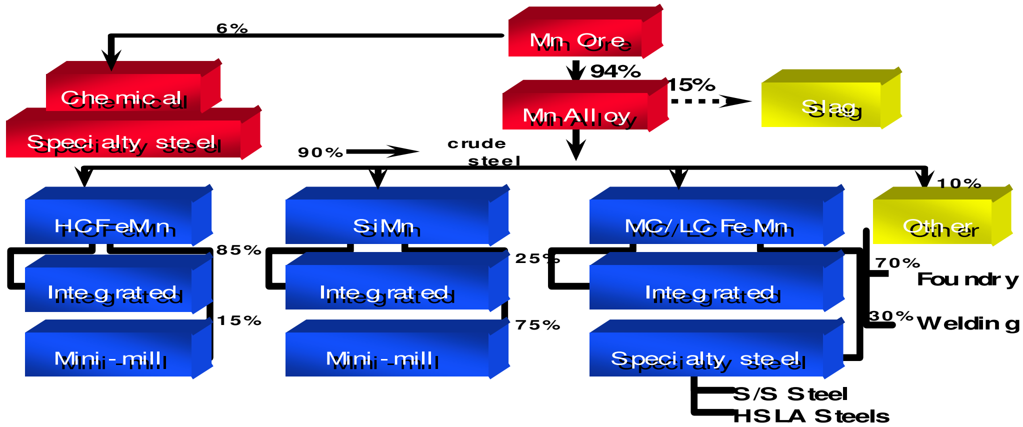
The following processes make up the manganese value chain:

- Exploration
- Mining
- Crushing and screening - (sizing, lumpy & fines)
- Dense Media Separation - (mineral from gangue)
- Sintering - (increase manganese (Mn) unit value per ton)
- Reductive smelting (alloying) & casting- (increase Mn unit value per ton further)
- Any one or more of these steps may be bypassed if the grade is high enough
- Processing-value addition
- End use

2.2 Manganese End Use Markets

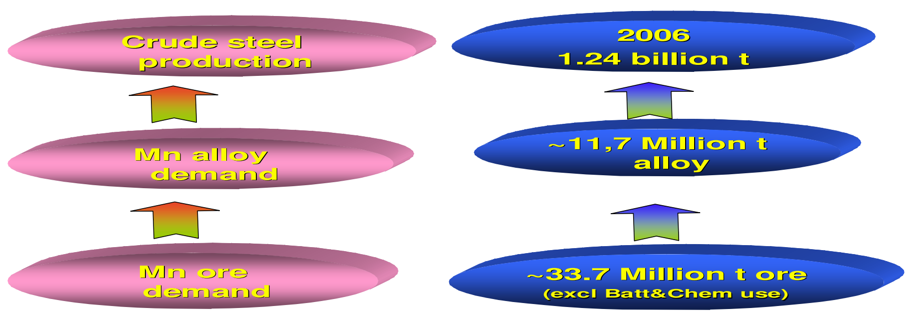
More than ninety percent of manganese is consumed in crude steel production (Fig 2.2) and the remainder is used in other applications. Figures 2.3 and 2.4 re-emphasizes the dependence of manganese ore demand on steel production.

Fig 2.3 Manganese Flowchart



Source: Roskill

Fig 2.4 Manganese Demand Chain



3. Chrome Value System Overview

The chrome industry consists of three value system components which collectively describe the structure and dynamics of the industry.

a) **Ore Producers**

- Industry segmented by ore characteristics:
  - Refractory grade ore (> 60% Cr)
  - Metallurgical grade ore (>46%Cr)
  - Chemical grade ore (40 <Cr <46)

b) **Alloyers**

- Integrated alloy smelters (30% of production; 3.0 Mtpa)
- Independent alloy smelters (70% of production; 7.0 Mtpa)
- Products:
  - MCFeCr

    - HCFeCr
    - LCFeCr

c) **End Use Customers (Fig 3.1)**

- Primarily Stainless steel producers
    - Stainless Steel (91%)
    - Alloy Steels
    - Nonferrous alloys
    - Speciality Mills
- Refractories and foundries (3.5%)
- Chemicals (5.5%)

The chrome value system has evolved over time leading to a partial integration between ore and alloy producers. This involved both the forward integration by ore producers and backward integration by stainless steelmakers.

3.1 The Chrome Value Chain

- Exploration
- Mining
- Crushing and screening - (sizing, lumpy & fines)
- Milling - (mineral from gangue)
- Screening - (increase Cr unit value per ton)
- Pelletizing
- Reductive smelting (alloying) & casting- (increase Cr unit value per ton further)
- Any one or more of these steps may be bypassed if the grade is high enough
- Logistics

- Value Chain Interactions
    - Ore producers
    - Logistics
    - Local and export sales of ore to independent and intergrated alloyers
    - Logistics
    - Marketing
    - End use markets (export sales of alloys to overseas producers

3.2 Chrome End Use Markets

Ninety one percent of chrome is consumed in stainless steel making in a form of chrome alloys while the remaining 9 percent is used in other applications (Fig 3.1). The chrome demand chain (Fig 3.2) re-emphasizes the dependence of chrome demand on stainless steel production.

Fig 3.1 Chrome End-Use Market

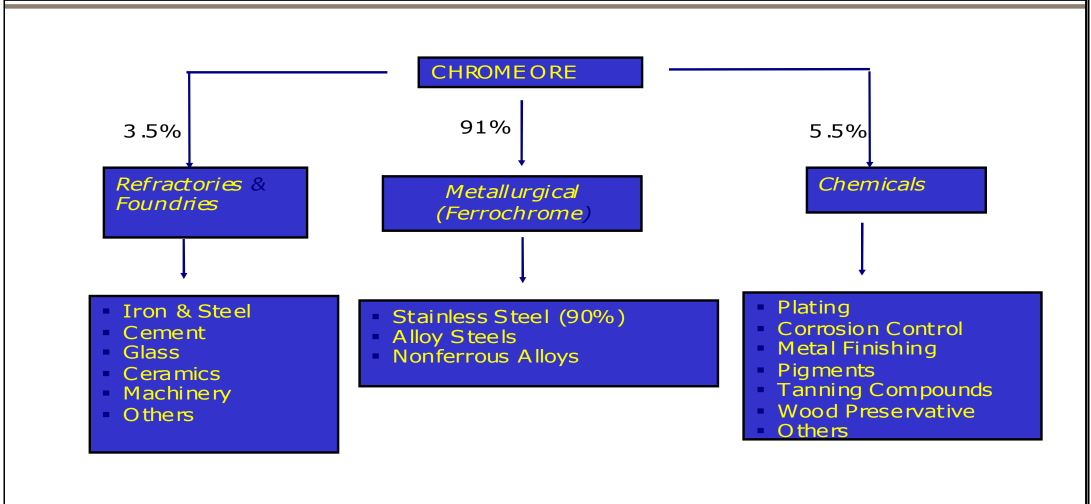
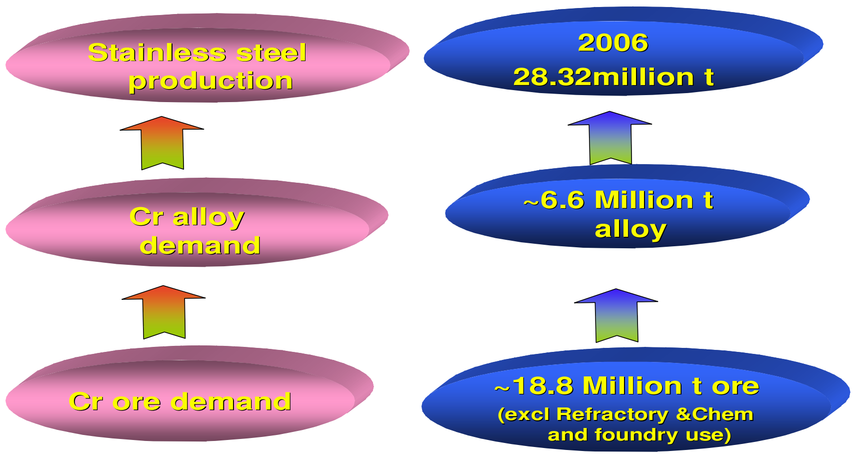


Fig 3.2 Chrome Demand Chain



3.3 Chrome Alloy Production

Ferrochrome is used as raw material for Stainless Steel production as well as other specialist steels. Stainless steel accounts for about 91 percent of the world's FeCr consumption. Ferrochrome is also used as an alloy in grinding media.

Raw materials

About 2.5 tons of chromite ore are consumed for every ton of FeCr produced. The ore is sourced from the mining operations which supply the smelting operations. Other important raw materials contributing to the production of ferrochrome include reductants (Coal, Coke, Char) with a consumption of about 0.7 ton of reductant per ton of FeCr produced. Coal, coke and char are sourced locally and abroad. Fluxing agents are also used in the production process. Fluxes include Sillica, which are sourced from silica mines and Dolomite is sourced locally. Chrome ore, reductants and fluxes are distributed via a highly automated materials handling system to four furnaces. A brief summary of the raw materials in use are:

- **Ore**

Chrome mines, supply quality lumpy ore and concentrate

- **Reductants**

Metallurgical coke and retort char (gas coke) supply is sourced from local producers. Coal is purchased from local collieries.

- **Flux**

Quartz and limestone are supplied under contract by local quarries

Pelletizing

Metallurgical concentrate together with recycled baghouse dust is pelletised using Outokumpu technology.

Furnaces

Using computer-based mass balances and automated batching systems, the raw materials are blended into a charge suitable for each of the furnaces. The blend varies depending on the ferrochrome specification required. The furnace operations consists of open 33 mega-volts amperes (MVA) Submerged Arc Furnaces (SAF), one open 30 MVA SAF (all of Tagliaferri design) and one closed 54 MVA SAF (Titaco) with pre-heater (Outokumpu). Slag-free ferrochrome ingots are produced by bottom ladle teeming. All slag and ladle skulls are cooled and sent to the Metal Recovery Plant to produce saleable ferrochrome products.

- **Metal Recovery Plant (MRP)**

Ferrochrome production results in a discard slag, which contains entrapped ferrochrome metal, causing low superheat and high slag viscosities. Ferrochrome is also lost due to freezing in the ladles and launders. This ferrochrome can, however, be recovered in the metal recovery plant with an installed capacity of about 20 000 tons of saleable product per annum.

The slag and skulls are recovered by excavator and front end loader and, after tramp iron removal, are crushed and screened into 25 x 10, 10 x 3, 3 x 1 and -1mm size fractions. Batig and Delkor jigs are used to separate the metal from the slag in the coarser fractions while spirals are used to separate the -1mm material. The waste slag is returned to the slag dump after hexavalent chromium neutralization.

- **Crushing, Screening & Dispatch**

The three stage crushing and screening plant is automated and closely controlled to ensure that the ferrochrome complies with customer size requirements. The plant is operated in campaigns to crush products with different silicon specifications. All products are weighed and stockpiled according to size and silicon specification. Finished products are then weighed and analysed, before being transported to local and international customers.

Products

Furnaces		MRP	
Size:	To customer specification	Sizes:	25 x 10 mm, 10 x 3 mm, 3 x 1 mm, -1 mm
Si:	3 % to 6 %	Chemistry:	Not guaranteed, typical only
Cr:	51.5 % to 52.5 % typical	Slag:	2.5% max for 25 x 10 mm and 10 x 3 mm, 10% max for 3 x 1 mm and 15% max for -1 mm. There is also a 15% max 10 x 3 mm middlings product.
S:	0.060 max (0.04 typical)		
P:	0.020 max (0.012 typical)		
C:	6.3 % to 8 %		

4. Iron Ore Value System Overview

4.1 Iron ore Beneficiation

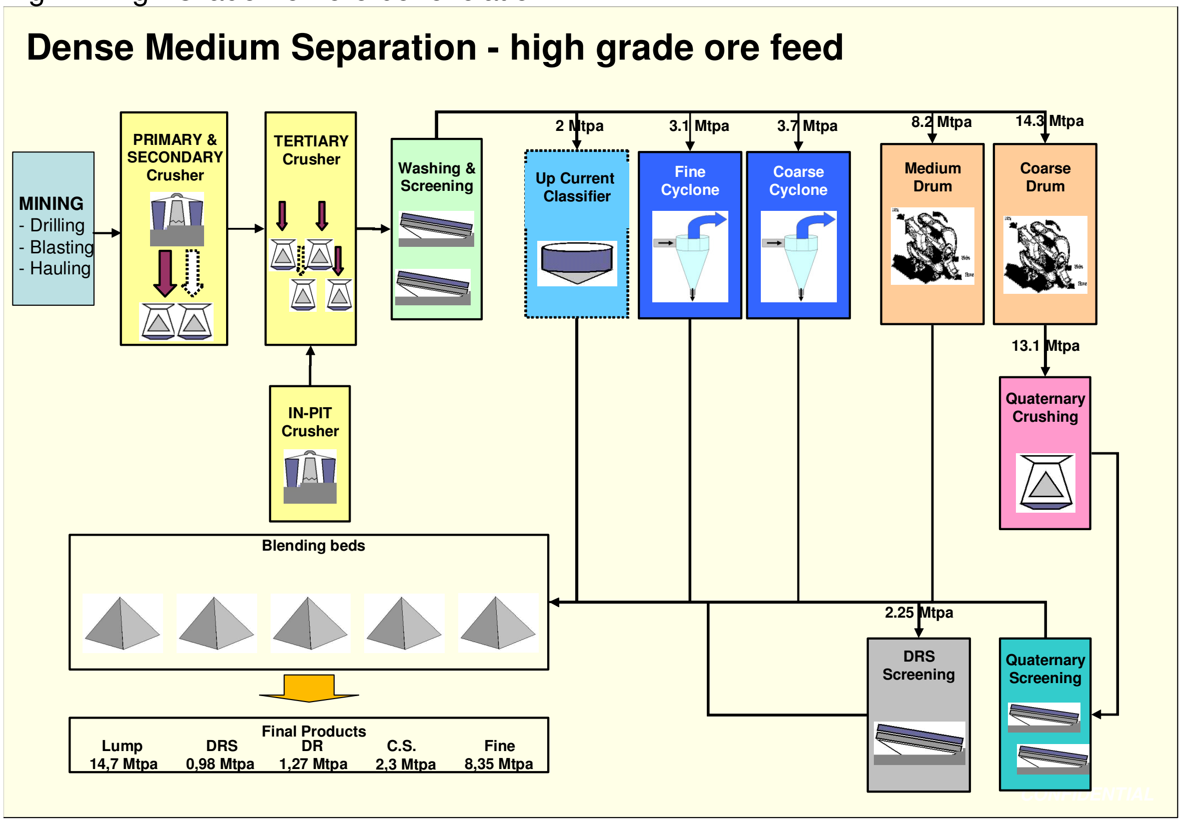
Mining

Drilling-Blasting-Hauling

Ore beneficiation Process

- Three stages of ore crushing initially (Fig 4.1)
- Followed by dense media separation in up current classifiers, fine and coarse cyclones and medium and coarse drums
- Followed by a fourth stage of crushing
- Followed by careful blending to customers' specifications in terms of size, quality and chemical and physical properties

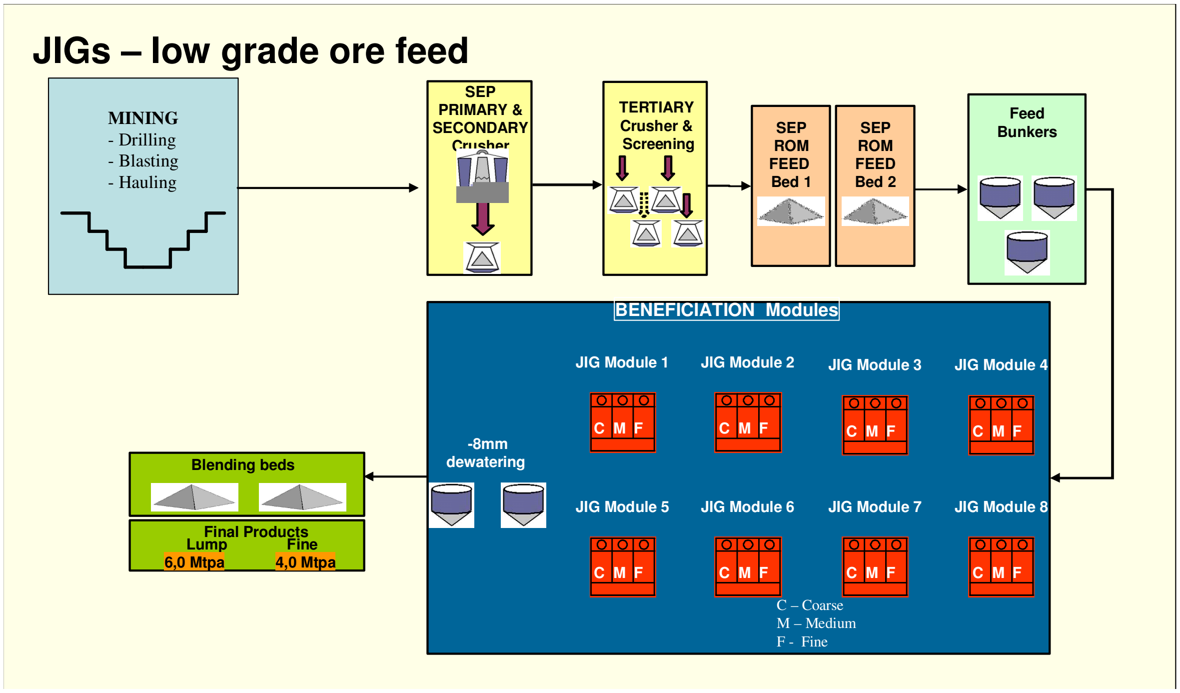
Fig 4.1 High Grade Iron ore beneficiation



Although this process takes place in a facility which could cost R8bn to replace and adds around R20/t of ore to the cost of the iron ore shipped the additional revenue generated far outweighs the costs. Figure 4.1 shows the additional beneficiation steps that may be put in place particularly for low grade ores:

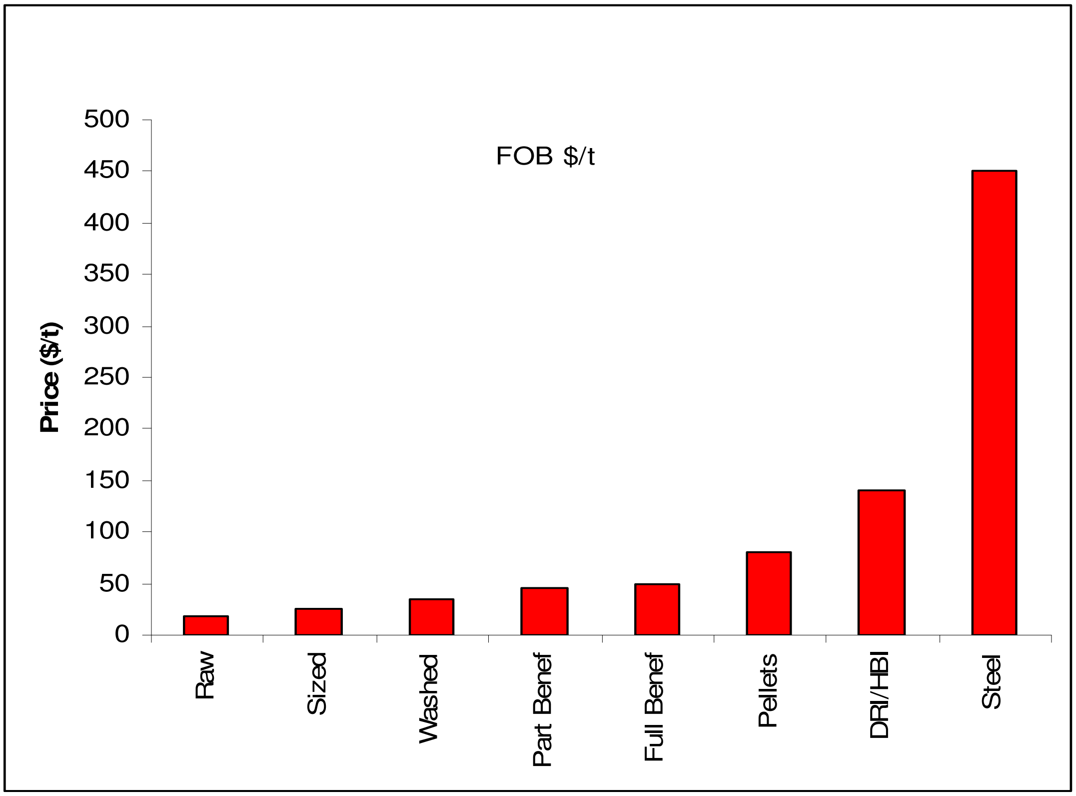
In addition to this complex beneficiation process for high grade ore, low grade ore could be *beneficiated, through the use of new technology (Fig 4.2).*

Figure 4.2: Low Grade Iron ore Beneficiation



- In addition to the usual three stages of crushing, low grade ore is fed through JIG modules to upgrade it to saleable iron ore grade
- JIG technology, in the way utilised in the Sishen Expansion Project (SEP) project, is unique to Kumba specifically with the computerised process control technology not easily replicable by other iron ore producers

Fig 4.3 Iron Ore Value Chain



A lot of value is created through further downstream beneficiation of ores (Fig 4.3). To ensure maximum value extraction and shareholder value growth increased local beneficiation of ore is encouraged as is required by the Mineral and Petroleum Resources Development Act (2002).

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