Iron Facts

Atomic number: 26

Symbol: Fe

Atomic weight: 55,847

Discovery: Known since prehistoric time

Electron configuration: [Ar]$4s^2 3d^6$

Word origin: Latin *ferrum*; Anglo-Saxon *iron*

26
Fe
Iron

- **Isotopes:** There are 14 known isotopes of iron. Common iron consists of a mixture of 4 isotopes.
- **Properties:** The melting point of iron is 1535°C, boiling point is 2750°C, specific gravity is 7.874 (20°C), with a valence of 2, 3, 4, or 6. Pure iron is chemically reactive and corrodes rapidly, especially in moist air or at elevated temperatures. Four allotropic forms, or ferrites, are known: a, b, g, and d, with transition points at 770, 928, and 1530°C. The 'a' form is magnetic, but when iron is transformed into the 'b' form, the magnetism disappears, although the lattice remains unchanged.
- **Uses:** Iron is vital to plant and animal life. In humans, it appears in the haemoglobin molecule in blood. Iron metal is usually alloyed with other metals and carbon for commercial uses. Pig iron is an alloy containing about 3% carbon, with varying quantities of Si, S, P, and Mn. Pig iron is brittle, hard, and fairly fusible and is used to produce other iron alloys, including steel. Wrought iron contains only a few tenths of a percent of carbon and is malleable, tough, and less fusible than pig iron. Wrought iron typically has a fibrous structure. Carbon steel is an iron alloy with carbon and small amounts of S, Si, Mn, and P. Alloy steels are carbon steels that contain additives such as chromium, nickel and vanadium. Iron is the least expensive, most abundant, and most used of all metals.
- **Sources:** Iron is a relatively abundant element in the Universe. The Sun and many types of stars contain iron. Iron is found native in a class of meteorites called siderites and it is a minor constituent of the other two classes of meteorites. The Earth's core is thought to be composed mainly of iron, with about 10% occluded hydrogen. Iron is the fourth-most abundant element in the Earth's crust. The most common iron ore is haematite (Fe_2O_3), from which iron metal is obtained by reduction with carbon. Iron is also found in minerals such as taconite and magnetite, which is commonly seen as black sands along beaches and stream banks.

Some Facts about Iron:

Sources of iron: haematite, magnetite (iron oxide)

Oxide(s): FeO, Fe_3O_4, Fe_2O_3

Chloride(s): $FeCl_2$, $FeCl_3$

Reaction with air: mild reaction, forms Fe_3O_4

Reaction with 6M HCl: mild reaction, forms H_2 and $FeCl_2$

Magnetic ordering: ferromagnetic

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The Background of Iron

Iron is one of the most common elements on Earth. Nearly every construction of man contains at least a little iron. It is also one of the oldest metals and was first fashioned into useful and ornamental objects at least 3 500 years ago.

Pure iron is a soft, greyish-white metal. Although

Iron is one of the seven metals of alchemy. The symbol for the planet Mars was sometimes used to represent iron. It is also the symbol for 'male'.

iron is a common element, pure iron is almost never found in nature. The only pure iron known to exist naturally comes from fallen meteorites. Most iron is found in minerals formed by the combination of iron with other elements. Iron oxides are the most common. Those minerals near the surface of the Earth that have the highest iron content are mined commercially.

Iron ore is converted into various types of iron through several processes. The most common process is the use of a blast furnace to produce pig iron, which is about 92–94% iron and 3–5% carbon with smaller amounts of other elements. Pig iron has only limited uses, and most of this iron goes on to a steel mill where it is converted into various steel alloys by further reducing the carbon content and adding other elements such as manganese and nickel to give the steel specific properties.

History

Historians believe that the Egyptians were the first people to work with small amounts of iron, some five or six thousand years ago. The metal they used was apparently extracted from meteorites. Evidence of what is believed to be the first example of iron mining and smelting points to the ancient Hittite culture in what is now Turkey. Because iron was a far superior material for the manufacture of weapons and tools than any other known metal, its production was a closely-guarded secret. However, the basic technique was simple, and the use of iron gradually spread. As useful as it was compared to other materials, iron had disadvantages. The quality of the tools made from it was highly variable, depending on the region from which the iron ore was taken and the method used to extract the iron. The chemical nature of the changes taking place during the extraction were not understood; in particular, the importance of carbon to the metal's hardness.

Natural iron oxides (haematites)

Practices varied widely in different parts of the world. There is evidence, for example, that the Chinese were able to melt and cast iron implements very early, and that the Japanese produced amazing results with steel in small amounts, as evidenced by heirloom swords dating back centuries. Similar breakthroughs were made in the Middle East and India, but the processes never emerged into the rest of the world. For centuries the Europeans lacked methods for heating iron to the melting point at all. To produce iron, they slowly burned iron ore with wood in a clay-lined oven. The iron separated from the surrounding rock but never quite melted. Instead, it formed a crusty slag, which was removed by hammering. This repeated heating and hammering process mixed oxygen with the iron oxide to produce iron, and removed the carbon from the metal. The result was nearly pure iron, easily shaped with hammers and tongs but too soft to take and keep a good edge. Because the metal was shaped, or wrought, by hammering, it came to be called wrought iron.

Tools and weapons brought back to Europe from the East were made of an iron that had been melted and cast into shape. Retaining more carbon, cast iron is harder than wrought iron and will hold a cutting edge. However, it is also more brittle than wrought iron. The European ironworkers knew the Easterners had better iron, but not the processes involved in fashioning stronger iron products. Entire nations launched efforts to discover the process.

The first known European breakthrough in the production of cast iron, which led quickly to the first practical steel, did not come until 1740. In that year, Benjamin Huntsman took out a patent for the melting of material for the production of steel springs to be used in clock making. Over the next twenty years or so, the procedure became more widely adopted. Huntsman used a blast furnace to melt wrought iron in a clay crucible. He then added carefully measured amounts of pure charcoal to the melted metal. The resulting alloy was both strong and flexible when cast into springs. Since Huntsman was originally interested only in making better clocks, his crucible steel led directly to the development of nautical chronometers, which, in turn, made global navigation possible by allowing mariners to precisely determine their east/west position. The fact that he had also invented modern metallurgy was a side effect, which he apparently failed to notice.

Raw Materials

The raw materials used to produce pig iron in a blast furnace are iron ore, coke, and limestone. Iron ores are mainly iron oxides and include magnetite, haematite and limonite. The iron content of these ores ranges between 60% and 70%. Coke is a substance made by heating coal until it becomes almost pure carbon. Limestone occurs naturally and is a source of calcium carbonate.

Other metals are sometimes mixed with iron in the production of various forms of steel, such as chromium, nickel, manganese, molybdenum and tungsten.

The Ore Extraction and Refining Process

Before iron ore can be used in a blast furnace, it must be extracted from the ground and partially refined to remove most of the impurities.

Historically, iron was produced by the hot-blast method, or later, the anthracite furnace. Either way, the fundamental activity in iron making involved a worker stirring small batches of pig iron and cinder until the iron separated from the slag. Called 'puddling,' this was highly-skilled work, but was also hot, strenuous, and dangerous. It required a lot of experience as well as a hearty constitution. Puddlers were proud, independent and highly paid.

Puddlers founded the first trade union in the iron and steel industry, the Sons of Vulcan, in Pittsburgh in 1858. In 1876, this union merged with three other labour organizations to form the Amalgamated Association of Iron and Steel Workers. This was the union that Andrew Carnegie defeated in the Homestead Strike of 1892, leaving the union in shambles and the industry essentially unorganized until the 1930s.

What About the Environment?

There are a great many possible environmental effects from the iron industry. The first and most obvious is the process of open pit mining. Huge tracts of land are stripped to bare rock. Today, depleted mining sites are commonly used as landfills, then covered over and landscaped. Some of these landfills themselves become environmental problems, as in the recent past, some were used for the disposal of highly toxic substances which leached into soil and water.

An iron landfill site

The process of extracting iron from ore produces great quantities of poisonous and corrosive gases. In practice, these gases are scrubbed and recycled. Inevitably, however, some small amounts of toxic gases escape to the atmosphere.

A by-product of iron purification is slag, which is produced in huge amounts. This material is largely inert, but must still be disposed of in landfills. Large quantities of slag are processed into a low strength cement.

Iron making uses up huge amounts of coal. The coal is not used directly, but is first reduced to coke which consists of almost pure carbon. The many chemical by-products of coking are almost all toxic, but they are also commercially useful. These products include ammonia, which is used in a vast number of products; phenol, which is used to make plastics, cutting oils, and antiseptics; cresols, which go into herbicides, pesticides, pharmaceuticals and photographic chemicals; and toluene, which is an ingredient in many complex chemical products such as solvents and explosives.

Scrap iron and steel—in the form of old cars, appliances and even entire steel-girdered buildings—are also a visual environmental concern. Most of this material is recycled, however, since steel scrap is an essential resource in steel making. Scrap, which is not recycled, eventually turns into iron oxide, or rust, and returns to the ground.

Source: Mineral Information Institute www.mii.org

Limestone is crushed and then used as a fluxing agent in a blast furnace to make iron from iron ore.

Coal is burned to form coke before it is used in a blast furnace to make iron.

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Iron: The Process

Iron Ore

Iron ores are rocks and minerals from which metallic iron can be economically extracted. The ores are usually rich in iron oxides and vary in colour from dark grey, bright yellow, deep purple, to rusty red.

The iron itself is usually found in the form of haematite (Fe_2O_3), magnetite (Fe_3O_4), goethite, limonite or siderite. Haematite is also known as 'natural ore'. The name refers to the early years of mining, when certain haematite ores contained 66% iron and could be fed directly into iron-making blast furnaces. Iron ore is the raw material used to make pig iron, which is one of the main raw materials used to make steel. 98% of the mined iron ore is used to make steel.

Banded iron formations (BIF) are fine-grained metamorphosed sedimentary rocks composed predominantly of magnetite, haematite and silica (as quartz). Banded iron formations are locally known as taconite within North America. Mining of BIF formations involves coarse crushing and screening, followed by rough crushing and fine grinding to comminute the ore to the point where the crystallized magnetite, haematite and quartz are fine enough that the quartz is left behind when the resultant powder is passed through a magnetic separator.

The BIF mining involves moving tremendous amounts of ore and waste. The waste comes in two forms, bedrock in the mine (mullock) that isn't ore, and unwanted minerals which are an intrinsic part of the ore rock itself (gangue). The mullock is mined and piled in waste dumps, and the gangue is separated during the beneficiation process and is removed as tailings. Tailings are mostly the mineral quartz, which is chemically inert (does not react with other

chemicals). This material is stored in large, regulated water settling ponds.

Haematite iron is typically rarer than magnetite bearing BIF or other rocks which form its main source or protolith rock, but it is considerably cheaper and easier to beneficiate the haematite ores and requires considerably less energy to crush and grind. Haematite ores however can contain significantly higher concentrations of penalty elements, typically being higher in phosphorus, water content and aluminium.

Iron is the world's most commonly-used metal. It is used primarily in structural engineering applications and in maritime purposes, automobiles and general industrial applications (machinery).

Iron-rich rocks are common worldwide, but ore-grade commercial mining operations are dominated by a few countries. The major constraint to economics for iron ore deposits is not necessarily the grade or size of the deposits, because it is not particularly hard to geologically prove enough tonnage of the rocks exist. The main constraint is the position of the iron ore relative to market, the cost of rail infrastructure to get it to market and the energy cost required to do so.

World production averages one billion tonnes of raw ore annually. The world's largest producer of iron ore is the Brazilian mining corporation Vale, followed by Australian companies BHP Billiton and Rio Tinto Group. World consumption of iron ore grows 10% per annum on average with the main consumers being China, Japan, Korea, the United States and the European Union. China is currently the largest consumer of iron ore, which translates into the world's largest steel producing country. China is followed by Japan and Korea, which consume a significant amount of raw iron ore and metallurgical coal. In 2006, China produced 588 million tonnes of iron ore, with an annual growth of 38%.

Processed iron ore pellets used in the steel making industry, with an RSA 5c coin, shown to scale

Smelting

Iron ore consists of oxygen and iron atoms bonded together into a compound. To convert it to metallic iron it must be sent through a reduction process to remove the oxygen. Oxygen-iron bonds are strong, and to remove the iron from the oxygen, a stronger elemental bond must be presented to attach to the oxygen. Carbon is used because the strength of a carbon-oxygen bond is greater than that of the iron-oxygen bond, at high temperatures.

The water in this river in Spain is discoloured because of the high iron content in the rocks. Source: NASA

Thus, the iron ore must be mixed with coke (which contains carbon), to be burnt in the smelting process.

However, it is not entirely as simple as that; carbon monoxide is needed instead of pure carbon to remove the oxygen from the iron. Thus, the iron and carbon smelting must be kept at an oxygen deficient reduced state to promote burning of carbon to produce CO not CO_2.

Air blast and charcoal (coke): $2C + O_2 \longrightarrow 2CO$.

Carbon monoxide (CO) is the principal reducing agent.

Stage one: $3Fe_2O_3 + CO \longrightarrow 2Fe_3O_4 + CO_2$

Stage two: $Fe_3O_4 + CO \longrightarrow 3FeO + CO_2$

Stage three: $FeO + CO \longrightarrow Fe + CO_2$

Limestone fluxing chemistry: $CaCO_3 \longrightarrow CaO + CO_2$

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The Blast Furnace

A blast furnace is a type of metallurgical furnace used for smelting to produce metals, generally iron. In a blast furnace, fuel and ore are continuously supplied through the top of the furnace, while air (or pure oxygen) is blown into the bottom of the chamber, so that the chemical reactions take place throughout the furnace as the material moves downward. The end products are usually molten metal and slag phase tapped from the bottom of the furnace, and flue gases exiting from the top of the furnace.

The blast furnace is to be distinguished from the bloomery in that the object of the blast furnace is to produce molten metal that can be tapped from the furnace, whereas the intention in the bloomery is to avoid it melting so that carbon does not become dissolved in the iron. Bloomeries were also artificially blown using bellows, but the term 'blast furnace' is normally reserved for furnaces where iron (or other metal) are refined from ore.

The blast furnace remains an important part of modern iron production. Modern furnaces are highly efficient, including Cowper stoves to pre-heat the blast air and employ recovery systems to extract the heat from the hot gases exiting the furnace. Due to competition in industry higher production rates need to be obtained. The largest blast furnaces have a volume of 5 500 m^3, which could hold the water from two standard swimming pools and can produce around 80 000 tonnes of iron per week. This is a great increase from the typical 18th century furnaces, which averaged about 400 tonnes per year.

A blast furnace and surroundings. The blast furnace is inside the central girderwork.

Modern furnaces are equipped with an array of supporting facilities to increase efficiency, such as ore storage yards where barges are unloaded. The raw materials are transferred to the stockhouse complex using ore bridges, or rail hoppers and 'ore transfer cars'. Rail-mounted scale cars or computer-controlled weigh hoppers weigh out the various raw materials to yield the desired hot metal and slag chemistry. A 'skip car' powered by winches brings these to the top of the furnace or it is fed into the furnace via a large conveyor belt system.

The iron-making blast furnace itself is built in the form of a tall chimney-like structure lined with refractory brick. Coke, fluxing agents like limestone and dolomite and iron ore (iron oxide) are charged into the top of the furnace in a precise filling order which helps control gas flow and the chemical reactions inside the furnace. Four 'uptakes' allow the hot, dirty gas to exit the furnace dome, while 'bleeder valves' protect the top of the furnace from sudden gas pressure surges. The coarse particles in the gas settle in the 'dustcatcher' and are dumped into a railroad car or truck for disposal, while the gas itself flows through a Venturi scrubber and a gas cooler to reduce the temperature of the cleaned gas.

The hot blast temperature can be from 900 ºC to 1 300 ºC depending on the stove design and condition. The hot blast is directed into the furnace through water-cooled copper nozzles called 'tuyères' near the base. The temperatures they deal with may be 1 700 ºC to 1 800 ºC. Oil, tar, natural gas, powdered coal and oxygen can also be injected into the furnace at tuyère level to combine with the coke to release additional energy which is necessary to increase productivity.

The 'casthouse' at the bottom half of the furnace contains the bustle pipe, tuyères and the equipment for casting the liquid iron and slag. Once a 'taphole' is drilled through the refractory clay plug, liquid iron, and slag flow down a trough through a 'skimmer'

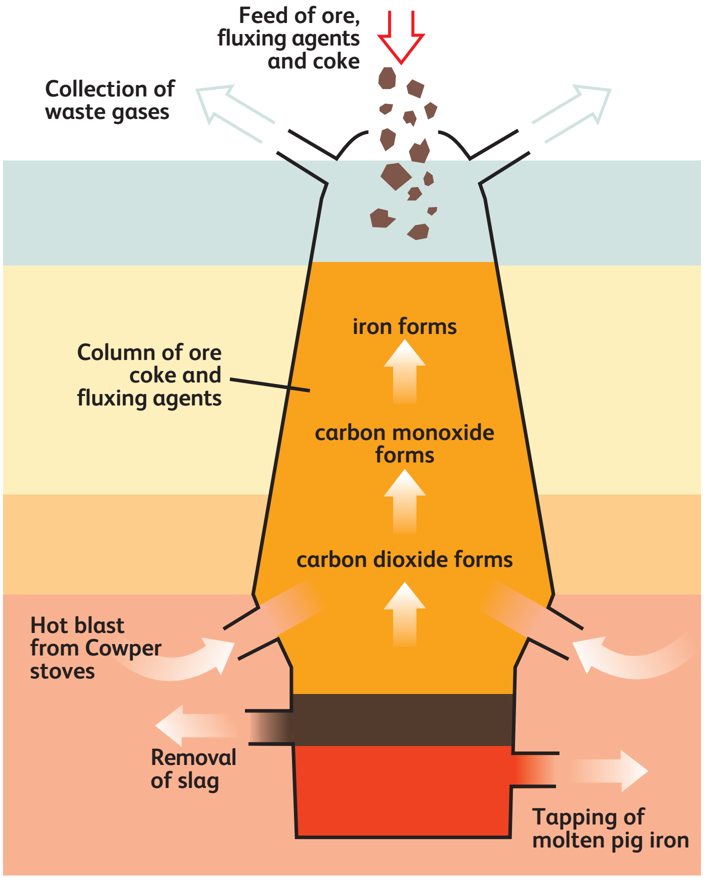

Figure 1: Diagram of a blast furnace

opening, separating the iron and slag. Modern, larger blast furnaces may have as many as four tapholes and two casthouses.

The overall chemical reaction producing the molten iron is:

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

Preheated blast air blown into the furnace reacts with the carbon in the form of coke to produce carbon monoxide and heat. The carbon monoxide then reacts with the iron oxide to produce molten iron and carbon dioxide. Hot carbon dioxide, unreacted carbon monoxide and nitrogen from the air pass up through the furnace as fresh feed material travels down into the reaction zone. As the material travels downward, the counter-current gases both preheat the feed charge, decompose the limestone to calcium oxide and carbon dioxide, and begin to reduce the iron oxides in the solid state. The main reaction controlling the gas atmosphere in the furnace is called the Boudouard reaction:

$$C + O_2 \longrightarrow CO_2$$

$$CO_2 + C \longrightarrow 2CO$$

The decomposition of fluxing agents, for example limestone, in the middle zones of the furnace proceeds according to the following reaction:

$$CaCO_3 \longrightarrow CaO + CO_2$$

The calcium oxide formed by decomposition reacts with various acidic impurities in the iron (notably silica), to form the slag which is essentially calcium silicate, $CaSiO_3$ and $Al_2O_3 \bullet SiO_2$.

The 'pig' iron produced by the blast furnace has a relatively high carbon content of around 4–5%, making it very brittle, and of little commercial use. Some pig iron is used to make cast iron. The majority of pig iron produced by blast furnaces undergoes further processing to reduce the carbon content and produce various grades of steel used for tools and construction materials.

Although the efficiency of blast furnaces is constantly evolving, the chemical process inside the blast furnace remains the same. According to the American Iron and Steel Institute, 'Blast furnaces will survive into the next millennium because the larger, efficient furnaces can produce hot metal at costs competitive with other iron making technologies.' One of the biggest drawbacks of the iron making process is the inevitable carbon dioxide production as iron is reduced from iron oxides by carbon and there is no economical substitute – steelmaking is one of the major industrial contributors of the CO_2 emissions in the world.

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The Ore Extraction and Refining Process

Extraction of Iron

Much of the world's iron ore is extracted through open-pit mining in which the surface of the ground is removed by heavy machines, often over a very large area, to expose the ore beneath.

In cases where it is not economical to remove the surface, shafts are dug into the earth, with side tunnels to follow the layer of ore.

Refining

The mined ore is crushed and sorted. The best grades of ore contain over 64% iron. Lesser grades are treated, or refined, to remove various contaminants before the ore is shipped to the blast furnace. Collectively, these refining methods are called beneficiation and include further crushing, washing with water to float sand and clay away, magnetic separation, pelletizing and sintering. As more of the world's known supply of high iron content ore is depleted, these refining techniques have become increasingly important.

The refined ore is then loaded on trains or ships and transported to the blast furnace site or to harbours for export.

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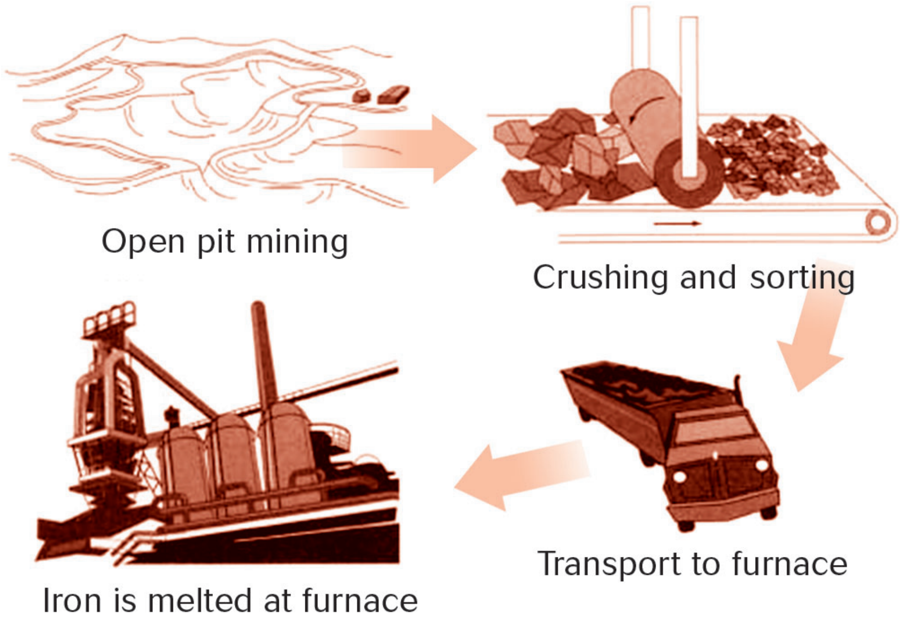


Pure iron is a soft, greyish-white metal. Although iron is a common element, pure iron is almost never found in nature. Minerals near the surface of the Earth that have the highest iron content are known as iron ores and are mined commercially.

Learner Information Sheet

Extraction And Refining

3

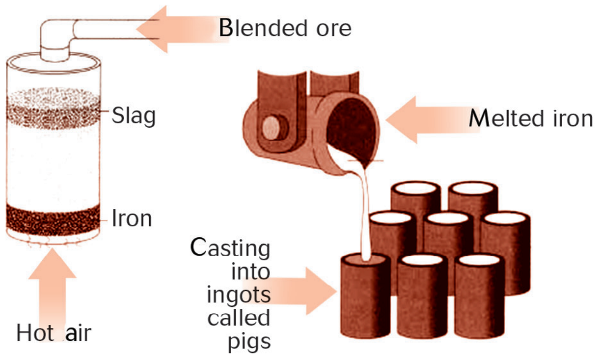
The Manufacturing Process

Charging the blast furnace

After processing, the ore is blended with other ore and goes to the blast furnace. A blast furnace is a tower-shaped structure made of steel and lined with refractory, heat-resistant bricks. The mixture of raw material, or charge, enters at the top of the blast furnace. At the bottom of the furnace, very hot air is blown in through nozzles called tuyères. The coke burns in the presence of the hot air. The oxygen in the air reacts with the carbon in the coke to form carbon monoxide. The carbon monoxide then reacts with the iron ore to form carbon dioxide and pure iron.

Separating the Iron from the Slag

The melted iron sinks to the bottom of the furnace.



The limestone combines with the rock and other impurities in the ore to form a slag which is lighter than the iron and floats on top of the iron. As the volume of the charge is reduced, more raw materials are added at the top of the furnace. The iron and slag are drawn off separately from the furnace. The melted iron might go to a further alloying process, or might be cast into ingots called pigs. The slag is carried away for disposal or cement manufacturing.

Treating the Gases

The hot gases produced in the chemical reactions are drawn off at the top and routed to a gas cleaning plant where the solids are removed. The cleaned offgas is then used to heat the air used at the tuyères.

A blast furnace normally runs day and night for several years. Eventually the brick lining begins to crumble, and the furnace is then shut down for maintenance.

Quality Control

The blast furnace operation is highly instrumented and is monitored continuously. Times and temperatures are checked and recorded. The chemical content of the iron ores received from the various mines is checked, and the ore is blended with other iron ore to achieve the desired charge. Samples are taken from each pour and checked for chemical content.

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Magnetite

Haematite

Goethite

Limonite

Source: Mineral Information Institute www.mii.org

The Advantages of Iron

Iron is an incredibly useful substance for several reasons:

- Relatively speaking, and especially when compared to wood or copper, iron is extremely strong.
- By heating it, iron is relatively easy to bend and shape using simple tools.
- Unlike wood, iron can handle heat, so you can build things like engines from it.
- Unlike most substances, you can magnetize iron, making it useful in the creation of electric motors and generators.
- Iron is plentiful – 5 % of the Earth's crust is iron, and in some areas it concentrates in ores that contain as much as 70 % iron.
- It is relatively easy to refine iron using simple tools.

When you compare iron and steel with something like aluminium, you can see why it was so important historically. To refine aluminium, you must have access to huge amounts of electricity. To shape aluminium, you must either cast it or extrude it. Iron is much easier to deal with. Iron has been useful to man for thousands of years, while aluminium really did not exist in any meaningful way until the 20th century.

Iron can be created relatively easily with tools that were available to primitive societies. There will likely come a day when we become so technologically advanced that iron is completely replaced by aluminium, plastics and things like carbon and glass fibres. But right now, the economic equation gives inexpensive iron and steel a huge advantage over these much more expensive alternatives.

The only real problem with iron and steel is rust. But you can control rust with paint, galvanizing, chrome plating alloying it with Cr or Ni or sacrificial anodes.

Iron Ore

To make iron, you start with iron ore. Iron ore is simply rock that happens to contain a high concentration of iron.

One thing that gave certain countries an edge between the 15th and 20th centuries was the availability of iron ore deposits. For example, England, the United States, France, Germany, Spain, Russia and South Africa all have good iron ore deposits.

Common iron ore minerals include:

- Haematite – Fe_2O_3 – 70% iron
- Magnetite – Fe_3O_4 – 72% iron
- Limonite – $Fe_2O_3 + H_2O$ – 50% to 66% iron
- Siderite – $FeCO_3$ – 48% iron

Usually, you find these minerals mixed into rocks containing silica and alumina.

Source: http://upload.wikimedia.org/wikipedia/commons/9/9e/Castingiron.jpg

Creating Iron

You can see in the previous section that all of the iron ores contain iron combined with oxygen. To make iron from iron ore, you need to eliminate the oxygen to create pure iron.

The most primitive facility used to refine iron from iron ore is called a bloomery. In a bloomery, you burn charcoal with iron ore and a good supply of oxygen (provided by a bellows or blower). Charcoal is essentially pure carbon. The carbon combines with oxygen to create carbon dioxide and carbon monoxide (releasing lots of heat in the process). Carbon and carbon monoxide combine with the oxygen in the iron ore and carry it away, leaving iron metal.

In a bloomery, the fire does not get hot enough to melt the iron completely, so you are left with a spongy mass containing iron and silicates from the ore (the bloom). By heating and hammering the bloom, the iron metal is welded into wrought iron. Wrought iron is tough and easy to work, making it perfect for creating tools in a blacksmith shop.

The more advanced way to smelt iron is in a blast furnace. A blast furnace is charged with iron ore, charcoal or coke (coke is charcoal made from coal) and fluxing agents like limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$). Huge quantities of air blast in at the bottom of the furnace. The calcium or magnesium in the fluxing agents combines with the silicates to form slag. At the bottom of the blast furnace, liquid iron collects along with a layer of slag on top. Periodically, you let the liquid iron flow out and cool.

The liquid iron typically flows into a channel and indentations in a bed of sand. Once it cools, this metal is known as pig iron.

To create a tonne of pig iron, you start with 1,5 tonnes of ore, 1 tonne of coke and a half-tonne of limestone. The fire consumes 5 tonnes of air. The temperature reaches almost 3 000 ºF (about 1 700 ºC) at the core of the blast furnace!

Pig iron contains 4 – 5 % carbon and is so hard and brittle that it is almost useless. You do one of two things with pig iron:

- You melt it, mix it with slag and hammer it to eliminate some of the carbon (down to 0,3 percent) and create wrought iron. Wrought iron is used by a blacksmith to create tools, horseshoes and so on. When you heat wrought iron, it is malleable, bendable, weldable and very easy to work with.
- You create steel.

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From Iron To Steel

What is Steel?

Steel is an alloy of iron and carbon containing less than 2% carbon and 1% manganese and small amounts of silicon, phosphorus and sulfur. Steel is the most important engineering and construction material in the world. It is used in every aspect of our lives, from automotive manufacture to construction products, from steel toecaps for protective footwear to refrigerators and washing machines and from cargo ships to the finest scalpel for hospital surgery.

How is Steel Made?

Most steel is made via one of two basic routes:

- Integrated (blast furnace and basic oxygen furnace)
- Electric arc furnace (EAF)

The integrated route uses raw materials (that is, iron ore, limestone and coke) and scrap to create steel. The EAF method uses scrap as its principal input.

The EAF method is much easier and faster since it only requires scrap steel. Recycled steel is introduced into a furnace and re-melted along with some other additions to produce the end product.

Steel used to be produced by other methods such as open hearth. However, the amount of steel produced by these methods decreases every year.

Of the steel produced in 2005, 65,4% was produced via the integrated route, 31,7% via EAF and 2,9% via the open hearth and other methods. (Source: World Steel in Figures 2006)

Can Steel Rust?

Many elements and materials go through chemical reactions with other elements. When steel comes into contact with water and oxygen there is a chemical reaction and the steel begins to change to its original form – iron oxide. In most modern steel applications this problem is easily overcome by coating. Many different coating materials can be applied to steel. Paint is used to coat automobiles, and enamel is used on refrigerators and other domestic appliances. In other cases, elements such as nickel and chromium are added to make stainless steel, which can help prevent rust, but is costly.

How Many Different Types of Steel are Available?

Steel is not a single product. There are currently more than 3 500 different grades of steel with many different physical, chemical, and environmental properties. Approximately 75% of modern steels have been developed in the last 20 years. If the Eiffel Tower were to be rebuilt today the engineers would only need one-third of the amount of steel. Modern cars are built with new steels that are stronger, but up to 25% lighter than in the past.

Is Steel Environmentally Friendly and Sustainable?

Steel is very friendly to the environment. It is completely recyclable, possesses great durability, and, compared to other materials, requires relatively low amounts of energy to produce. Innovative lightweight steel construction (such as in automobile and rail vehicle construction) help to save energy and resources. The steel industry has made immense efforts to limit environmental pollution in the last decades. Energy consumption and carbon dioxide emissions have decreased by one-half of what they were in the 1960s. Dust emissions have been reduced by even more.

Learner Information Sheet

Steel A New Era

4

Who Invented Steel?

It is not known who produced the first steel. Since 200BC, many cultures have produced steel in one form or another. A British inventor, Henry Bessemer, is generally credited with the invention of the first technique to mass produce steel in the mid 1850s. Steel is still produced using technology based on the Bessemer Process of blowing air through molten pig iron to oxidise the material and separate impurities.

Raw Materials

Supply of raw materials is a key issue for the world steel industry. The World Steel Association (formerly known as the International Iron and Steel Institute (IISI)) manages projects which look at the availability of raw materials such as iron ore, coking coal, freight and scrap.

Scrap iron is mainly used in electric arc furnace steelmaking. As well as scrap arising in the making and using of steel, obsolete scrap from demolished structures and end-of-life vehicles and machinery is recycled to make new steel. About 500 million tonnes of scrap are melted each year.

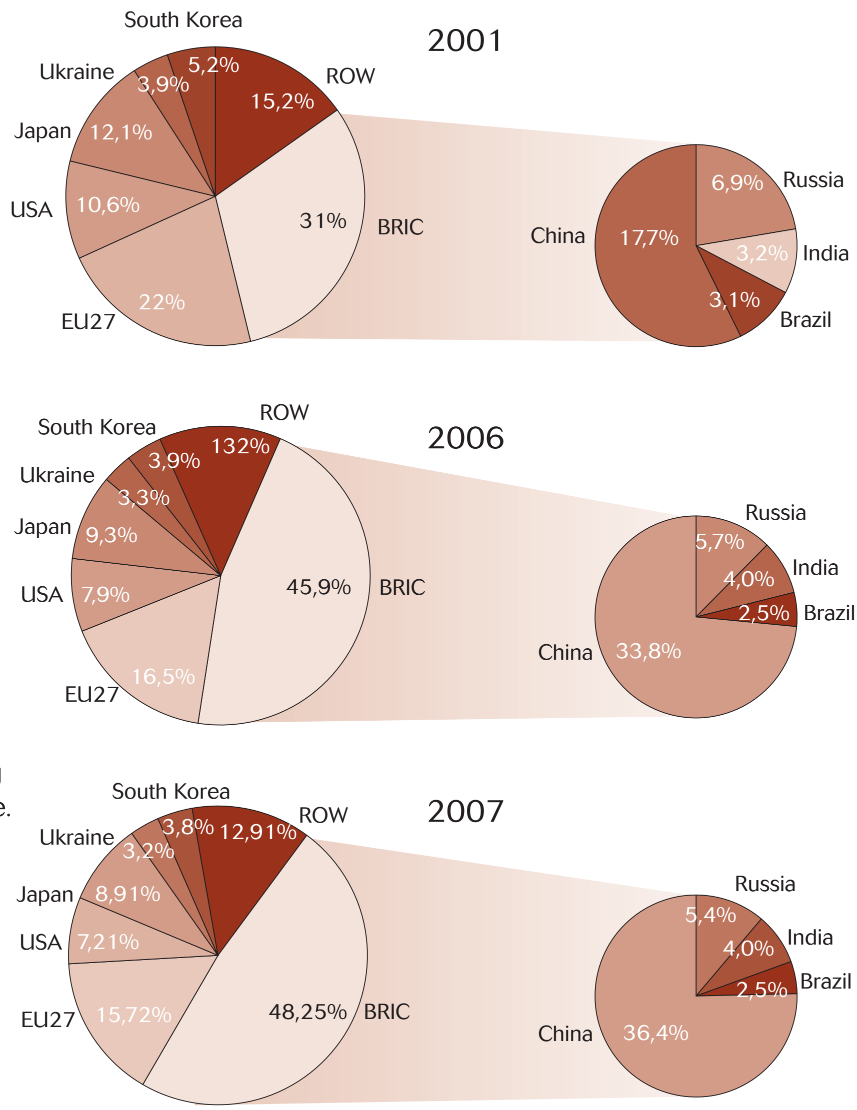
Iron ore and coking coal are used mainly in the blast furnace process of ironmaking. For this process, coking coal is turned into coke, an almost pure form of carbon which is used as the main fuel and reductant in a blast furnace.

Typically, it takes 1,5 tonnes of iron ore and about 450 kilograms of coke to produce a tonne of pig iron, the raw iron that comes out of a blast furnace. Some of the coke can be replaced by injecting pulverised coal into the blast furnace.

Iron is a common mineral on the Earth's surface. Most iron ore is extracted in opencast mines, carried to dedicated ports by rail, and then shipped to steel plants in other parts of the world.

Iron ore and coking coal are primarily shipped in capesize vessels, huge bulk carriers that can hold a cargo of 140 000 tonnes or more. Sea freight is an area of major concern for steelmakers today, as the high demand for raw materials is causing backlogs at ports, with vessels delayed in queues.

Which Country Makes the Most Steel?



Source: www.worldsteel.org

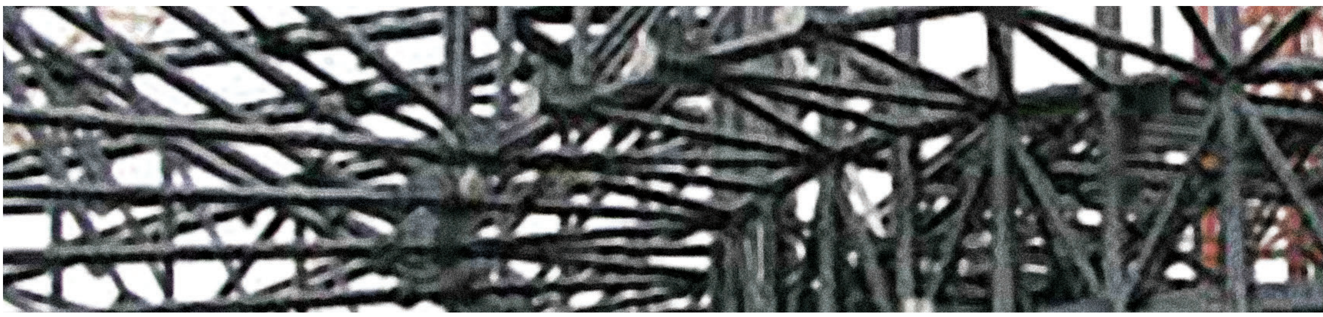
The Future of Stainless Steel

Use of stainless and super stainless steels is expanding in a variety of markets. To meet the requirements of the new Clean Air Act, coal-fired power plants are installing stainless steel stack liners. Other new industrial applications include secondary heat exchangers for high-efficiency home furnaces, service-water piping in nuclear power plants, ballast tanks and fire-suppression systems for offshore drilling platforms, flexible pipe for oil and gas distribution systems, and heliostats for solar-energy plants.

Environmental legislation is also forcing the petrochemical and refinery industries to recycle secondary cooling water in closed systems rather than simply discharge it. Reuse results in cooling water with elevated levels of chloride, resulting in pitting-corrosion problems. Duplex stainless steel tubing will play an increasingly important role in solving such industrial corrosion problems, since it costs less than other materials. Manufacturers are developing highly corrosion-resistant steels in respond to this demand.

In the automotive industry, one steel manufacturer has estimated that stainless steel usage per vehicle will increase from 25 to 30 kilograms to more than 45 kilograms in the next decade. New applications include metallic substrates for catalytic converters, airbag components, composite bumpers, fuel line and other fuel-system parts compatible with alternate fuels, brake lines, and long-life exhaust systems.

With improvements in process technology, superaustenitic stainless steels (with nitrogen contents up to 0,5%) are being developed. These steels are used in pulp-mill bleach plants, seawater and phosphoric-acid handling systems, scrubbers, offshore platforms and other highly corrosive applications. A number of manufacturers have begun marketing such materials in sheet, plate and other forms. Other new compositions are being developed: ferritic iron-base alloys containing 8 and 12% Cr for magnetic applications, and austenitic stainless with extra-low sulfur content for parts used in the manufacture of semiconductors and pharmaceuticals.



Steel
A New Era

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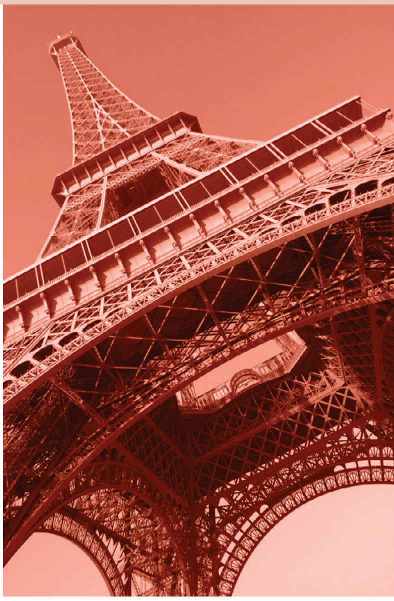
Research will continue to develop improved and unique materials. For instance, Japanese researchers have recently developed several. One is a corrosion-resistant stainless steel that displays the shape-memory effect. This type of material returns to its original shape upon heating after being plastically deformed. Potential applications include assembly components (pipe fittings, clips, fasteners and clamps), temperature sensing (circuit breakers and fire alarms), and springs. An improved martensitic stainless steel has also been developed for precision miniature and instrument rolling-contact bearings, which has reduced vibration levels, improved life expectancy, and better surface finish compared to conventional materials.



Stainless Steel

Stainless steel is an iron-containing alloy made up of two or more chemical elements used in a wide range of applications.

It has excellent resistance to stain or rust due to its chromium content, usually from 12 to 20% of the alloy. There are more than 57 stainless steels recognized as standard alloys, in addition to many proprietary alloys produced by different stainless steel producers. These many types of steel are used in an almost endless number of applications and industries: bulk materials handling equipment, building exteriors and roofing, automobile components (exhaust, trim/decorative, engine, chassis, fasteners, tubing for fuel lines), chemical processing plants (scrubbers and heat exchangers), pulp and paper manufacturing, petroleum refining, water supply piping, consumer products, marine and shipbuilding, pollution control, sporting goods and transportation, to name just a few.

About 200 000 tonnes of nickel-containing stainless steel is used each year by the food processing industry in North America. It is used in a variety of food handling, storing, cooking and serving equipment—from the beginning of the food collection process through to the end. Beverages such as milk, wine, beer, soft drinks and fruit juice are processed in stainless steel equipment. Stainless steel is also used in commercial cookers, pasteurizers, transfer bins and other specialized equipment. Advantages include easy cleaning, good corrosion resistance, durability, economy, food flavour protection and sanitary design.

Stainless steels come in several types depending on their microstructure. Austenitic stainless steels contain at least 6% nickel and austenite—carbon-containing iron with a face-centered cubic structure—and have good corrosion resistance and high ductility (the ability of the material to bend without breaking). Ferritic stainless steels (ferrite has a body-centered cubic structure) have better resistance to stress corrosion than austenitic, but they are difficult to weld. Martensitic stainless steels contain iron having a needle-like structure.

Duplex stainless steels, which generally contain equal amounts of ferrite and austenite, provide better resistance to pitting and crevice corrosion in most environments. They also have superior resistance to cracking due to chloride stress corrosion, and they are about twice as strong as the common austenitics. Therefore, duplex stainless steels are widely-used in the chemical industry in refineries, gas-processing plants, pulp and paper plants, and sea water piping installations.

Raw Materials

Stainless steels are made of some of the basic elements found in the earth: iron ore, chromium, silicon, nickel, carbon, nitrogen and manganese. Properties of the final alloy are tailored by varying the amounts of these elements. Nitrogen, for instance, improves tensile properties like ductility. It also improves corrosion resistance, which makes it valuable for use in duplex stainless steels.

Stainless Steel

The Manufacturing Process

To make stainless steel, the raw materials—iron ore, chromium, silicon, nickel, etc.—are melted together in an electric furnace. This step usually involves 1,5 to 2 hours of intense heat. Next, the mixture is cast into one of several shapes, including blooms, billets and slabs.

The manufacture of stainless steel involves a series of processes. First, the steel is melted, and then it is cast into solid form. After various forming steps, the steel is heat treated and then cleaned and polished to give it the desired finish. Next, it is packaged and sent to manufacturers, who weld and join the steel to produce the desired shapes.

Melting and Casting

The raw materials are first melted together in an electric furnace. This step usually requires 1,5 to 2 hours of intense heat. When the melting is finished, the molten steel is cast into semi-finished forms. These include blooms (rectangular shapes), billets (round or square shapes 3,8 centimetres in thickness), slabs, rods and tube rounds.

Forming

Next, the semi-finished steel goes through forming operations, beginning with hot rolling, in which the steel is heated and passed through huge rolls. Blooms and billets are formed into bar and wire, while slabs are formed into plate, strip, and sheet. Bars are available in all grades and come in rounds, squares, octagons, or hexagons 0,63 cm in diameter or size. Wire is usually available up to 1,27 cm in diameter or size. Plate is more than 0,47 cm thick and over 25,4 cm wide. Strip is less than 0,47 cm thick and less than 61 cm wide. Sheet is less than 0,47 cm thick and more than 61 cm wide.

Heat Treatment

After the stainless steel is formed, most types must go through an annealing step. Annealing is a heat treatment in which the steel is heated and cooled under controlled conditions to relieve internal stresses and soften the metal. Some steels are heat treated for higher strength. However, such a heat treatment—also known as age hardening—requires careful control, for even small changes from the recommended temperature, time or cooling rate can seriously affect the properties. Lower ageing temperatures produce high strength with low fracture toughness, while

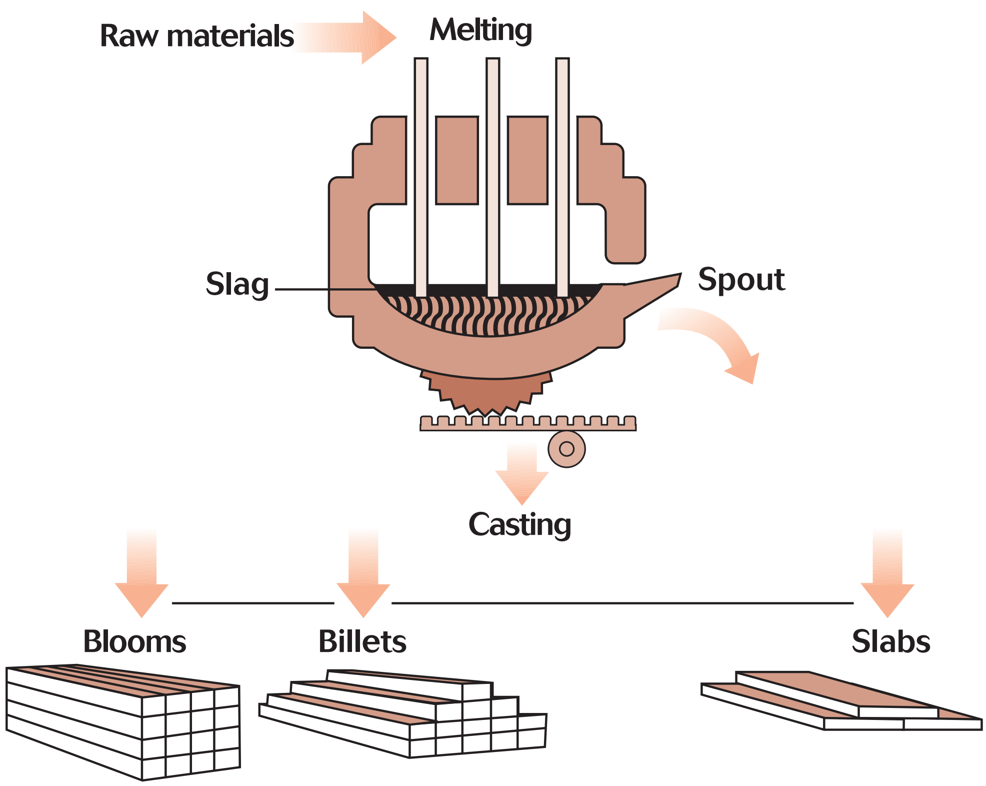


Figure 1: Melting and casting

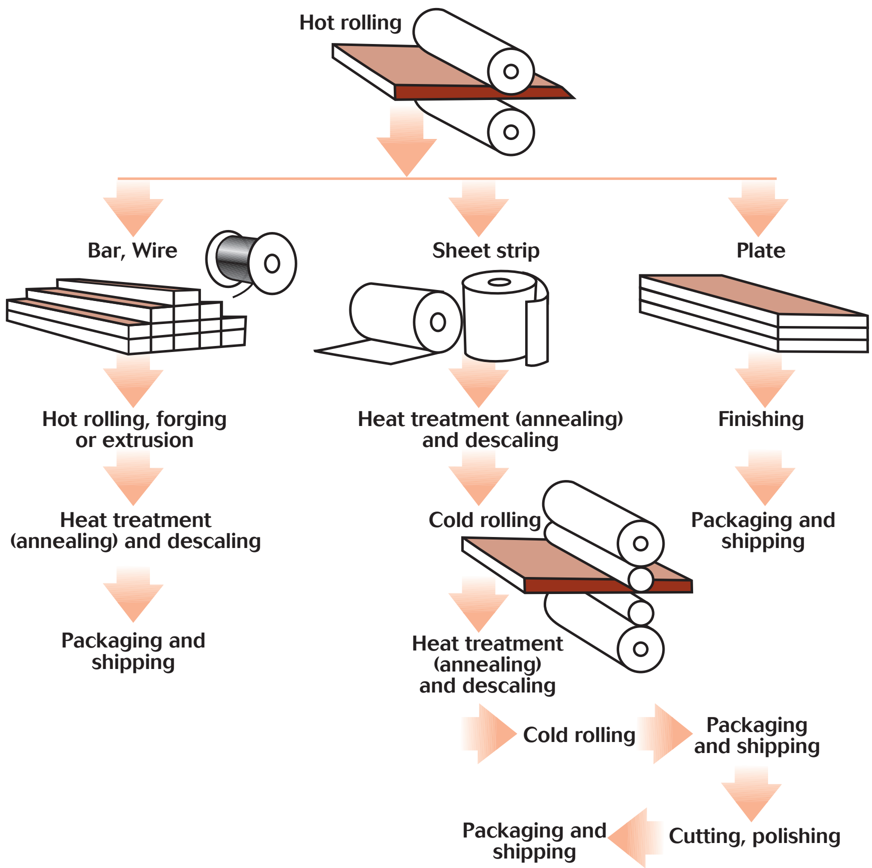


Figure 2: The forming process for steel

higher-temperature ageing produces a lower strength, tougher material.

Though the heating rate to reach the aging temperature (900 to 1 000 ºF or 482 to 537 ºC) does not affect the properties, the cooling rate does. A post-ageing quenching (rapid cooling) treatment can increase the toughness without a significant loss in strength. One such process involves water quenching the material in a 35 ºF (1,6 ºC) ice-water bath for a minimum of two hours.

The type of heat treatment depends on the type of steel; in other words, whether it is austenitic, ferritic or martensitic. Austenitic steels are heated to above 1 900 ºF (1037 ºC) for a time depending on the thickness. Water quenching is used for thick sections, whereas air cooling or air blasting is used for thin sections. If cooled too slowly, carbide precipitation can occur. This build-up can be eliminated by thermal stabilization. In this method, the steel is held for several hours at 1 500 to 1 600 ºF (815 to 871 ºC). Cleaning part surfaces of contaminants before heat treatment is sometimes also necessary to achieve proper heat treatment.

Descaling

Annealing causes a scale or build-up to form on the steel. The scale can be removed using several processes. One of the most common methods, pickling, uses a nitric-hydrofluoric acid bath to de-scale the steel. In another method, electro-cleaning, an electric current is applied to the surface using a cathode and phosphoric acid, and the scale is removed. The annealing and de-scaling steps occur at different stages depending on the type of steel being worked. Bar and wire, for instance, go through further forming steps (more hot rolling, forging, or extruding) after the initial hot rolling before being annealed and de-scaled. Sheet and strip, on the other hand, go through an initial annealing and de-scaling step immediately after hot rolling. After cold rolling (passing through rolls at a relatively low temperature), which produces a further reduction in thickness, sheet and strip are annealed and de-scaled again. A final cold rolling step then prepares the steel for final processing.

Cutting

Cutting operations are usually necessary to obtain the desired blank shape or size to trim the part to final size. Mechanical cutting is accomplished by a variety of methods, including straight shearing using guillotine knives, circle shearing using circular knives horizontally and vertically positioned, sawing using high speed steel blades, blanking, and nibbling. Blanking uses metal punches and dies to punch out the shape by shearing. Nibbling is a process of cutting by blanking out a series of overlapping holes and is ideally suited for irregular shapes.

Stainless steel can also be cut using flame cutting, which involves a flame-fired torch using oxygen and propane. Another cutting method is known as plasma jet cutting, in which an ionized gas column in conjunction with an electric arc through a small orifice makes the cut. The gas produces extremely high temperatures to melt the metal.

Finishing

Surface finish is an important specification for stainless steel products and is critical in applications where appearance is also important. Certain surface finishes also make stainless steel easier to clean, which is obviously important for sanitary applications. A smooth surface as obtained by polishing also provides better corrosion resistance. On the other hand, rough finishes are often required for lubrication applications, as well as to facilitate further manufacturing steps.

Surface finishes are the result of processes used in fabricating the various forms or are the result of further processing. There are a variety of methods used for finishing. Hot rolling, annealing and descaling produce a dull finish. First hot rolling and then cold rolling on polished rolls obtains a bright finish. A highly reflective finish is produced by cold rolling in combination with annealing in a controlled atmosphere furnace, by grinding with abrasives, or by buffing a finely ground surface. Polishing with progressively finer abrasives, followed by extensive buffing, produces a mirror finish. For grinding or polishing, grinding wheels or abrasive belts are normally used. Buffing uses cloth wheels in combination with cutting compounds containing very fine abrasive particles in bar or stick forms. Other finishing methods include tumbling, which forces movement of a tumbling material against surfaces of parts, dry etching (sandblasting), wet etching using acid solutions and surface dulling. The latter uses sandblasting, wire brushing or pickling techniques.

The initial steel shapes—blooms, billets, slabs, etc.—are hot rolled into bar, wire, sheet, strip and plate. Depending on the form, the steel then undergoes further rolling steps (both hot and cold rolling), heat treatment (annealing), de-scaling (to remove build-up), and polishing to produce the finished stainless steel. The steel is then sent the end user.

Manufacturing at the Fabricator or End User

After the stainless steel in its various forms is packed and shipped to the fabricator or end user, a variety of other processes are needed. Further shaping is accomplished using a variety of methods, such as roll forming, press forming, forging, press drawing and extrusion. Additional heat treating (annealing), machining and cleaning processes are also often required.

There are a variety of methods for joining stainless steel, with welding being the most common. Fusion and resistance welding are the two basic methods generally used with many variations for both. In fusion welding, heat is provided by an electric arc struck between an electrode and the metal to be welded. In resistance welding, bonding is the result of heat and pressure. Heat is produced by the resistance to the flow of electric current through the parts to be welded, and the electrodes apply pressure. After parts are welded together, they must be cleaned around the joined area.

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Iron In South Africa

Map of Iron Operations in South Africa
Source: Kumba Iron Ore

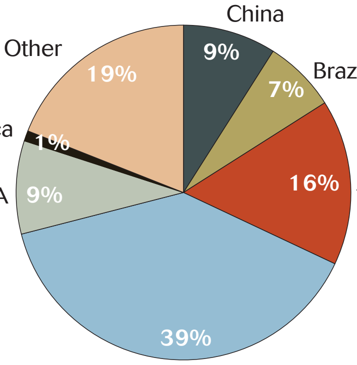
This map was obtained from Kumba Iron Ore. Learners– if you use it you need to include "Source: Kumba Iron Ore" next to the map and add the following to your reference list: Kumba Iron Ore. 2008. Map of Operations. [Online] Available: http://www.kumba.co.za/ops_maps.php [29 September 2008]

South African Iron Ore Production

South African iron ore resources, an estimated nearly 5 370 megatonnes, are ranked the 9th largest in the world (2003). If the Bushveld Complexs lower-grade potential resources are included, the resource base increases by 26 400 megatonnes, which would then rank South Africas iron ore resources as the 6th largest in the world (see Figure 1). In terms of export of iron ore, South Africa is ranked 4th in the world (see Figure 2).

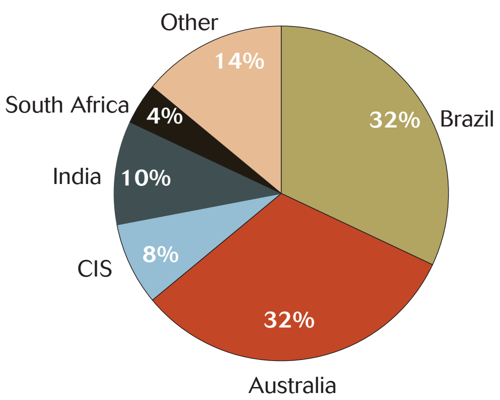
The principal deposits of iron ore in South Africa are the Superior-type banded iron formations of the Transvaal Supergroup in the Northern Cape, which can be traced as a prominent, bow-shaped range of hills for some 400 kilometres from Pomfret in the

Figure 1
World iron ore reserves



*The Commonwealth of Independant States (Russia and the former Soviet Republics)

Figure 2
World Iron ore production 2003



north to Prieska in the south. The most significant deposits occur in the vicinity of Postmasburg and Sishen.

An additional 900 megatonnes is estimated to occur as haematite concentrations along the northern rim of the Bushveld Complex near Thabazimbi in Limpopo.

The Bushveld Igneous Complex also contains approximately 26 400 megatonnes of iron ore resources in the form of titaniferous magnetite, titanium dioxide and vanadium pentoxide: 50–67% Fe; 8–22% TiO_2; 0–2% V_2O_5.

The Main Producers

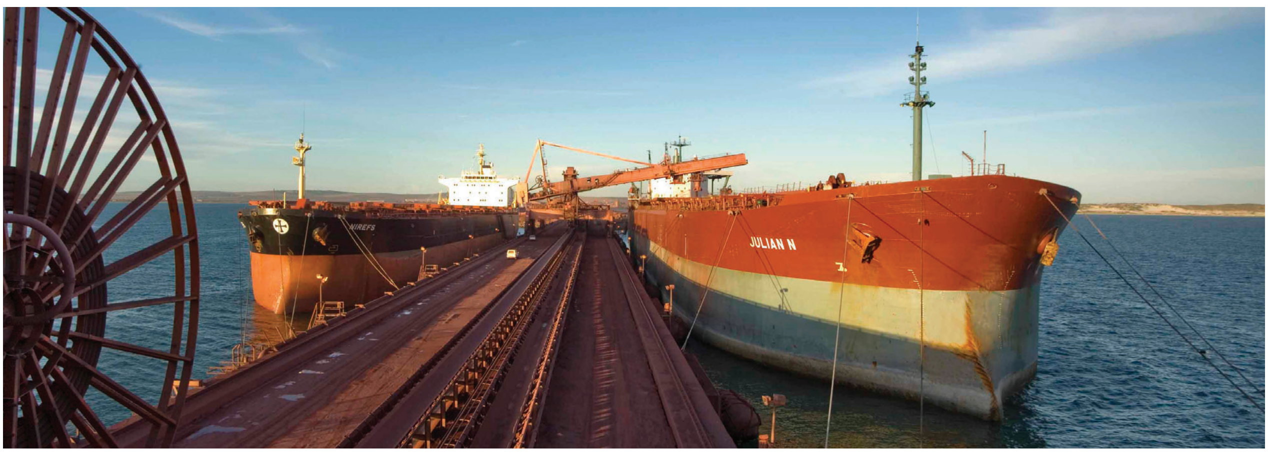
The four major players in the industry are BHP Billiton, Rio Tinto, CVRD and Kumba Resources.

Kumba came into being as a result of the separation of the mining and the steel-making components of Iscor Ltd in 2001. This separation came at a price for Kumba, as the separation agreement requires that Kumba provides Iscor, since globalised and renamed Arcelor Mittal SA (AMSA), with its iron ore requirements at cost. Its main sources of ore are Thabazimbi mine and the Sishen mine.

The two major players in the Northern Cape Iron ore fields are Kumba and Assmang - a subsidiary of African Rainbow Minerals (ARM).

Market Share

Kumba accounts for 80% of South Africa's iron ore exports and Assmang accounts for the bulk of the remaining 20%. Kumba is one of the world's premier suppliers of high quality lump-iron ore to the international steel industry and owns a large proportion of the known lump-ore reserves in the world. Kumba also sells 6,5 megatonnes per annum to AMSA. The group annually produces 40 megatonnes of iron ore from Sishen and some 2,5 megatonnes from Thabazimbi. 80% of ore from Sishen is exported and the remainder sold locally.



Exports

The two producers use the Saldanha Bay harbour (See Figure 3) to export their iron ore. Ore is transported from the Northern Cape by means of rail on the Transnet line.

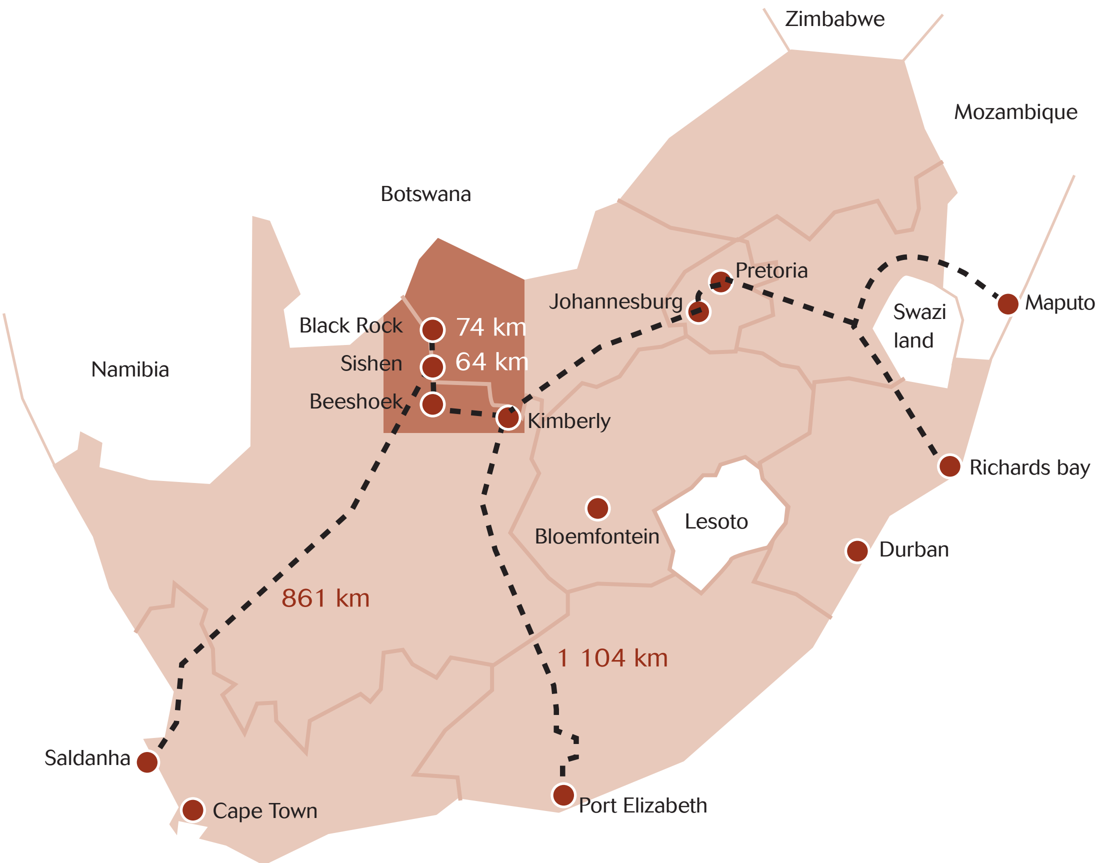


Figure 3
South African export facilities

Iron In South Africa

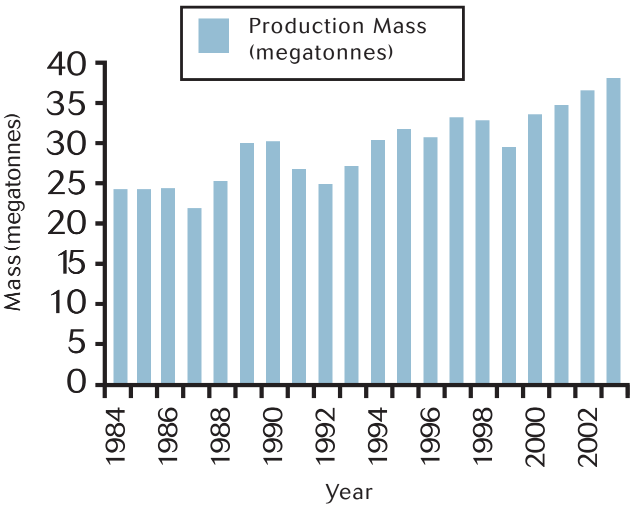


Figure 4: South African Production of Iron Ore. 1984–2003

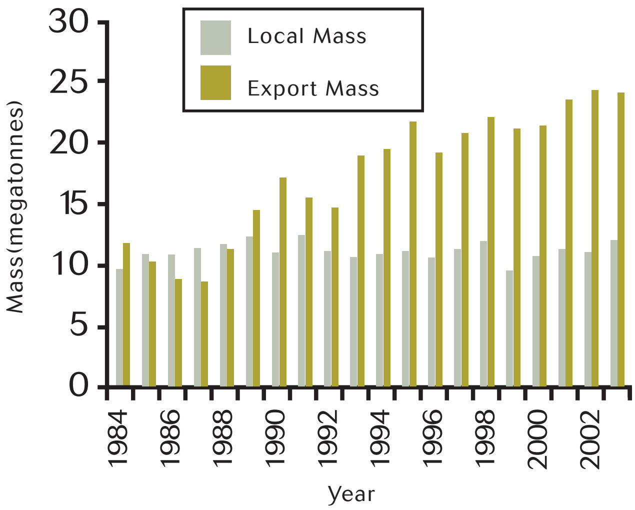


Figure 5 South African Iron ore Consumption and Exports, 1984–2003

Iron Ore Production, 1984–2003

At the beginning of the period under study, a far larger proportion of the ore produced was consumed locally (see Figure 5). This is a period during which sanctions were still in force and as the sanctions eased towards the end of the 1980s, export sales overtook local consumption. The low export figures can also be attributed to the severe recession of the 1980s during which the United States steel industry permanently closed mills with a combined annual capacity of 40 million tonnes. The situation elsewhere in the world was no better. South African mines produced a total of 592,47 million tons of iron ore over this period.

Consumption of Iron Ore, 1984-2003

A total of 592 mega tonnes has been produced in SA over the past 20 years. Within this period the local market consumed only 37% of the ore produced while 60% went to satisfy global demand. 43% of the total tonnes was produced during the first half of the 20-year period while 57% was produced during the second half.

Growth in the steel industry has resulted in a rise in demand for iron ore units locally and globally. Since the end of the 1990s most of this demand has stemmed from the developing world, especially China. China's steel industry has been growing at an alarming rate to the extent that its government recently attempted to limit growth to avoid overheating in the economy.

This material was obtained from a publication from the Department of Minerals and Energy. Learners – if you use it you need to write it in your own words and add the following to your reference list: Bonga, M. W. 2003. An Overview of the South African Iron, Manganese and Steel Industry during the period 1984–2003 [Online] Available: http://www.dme.gov.za/pdfs/minerals/R45%20-%20update%202007.pdf [29 September 2008]

Sishen Mine

KUMBA IRON ORE

Kumba to invest R8,5 billion in new Sishen South Mine

31 July 2008

Kumba Iron Ore Limited (Kumba) is pleased to announce the approval of an R8,5billion investment in the new Sishen South mine.

Sishen South mine is located 80km south of the Sishen mine, near Postmasburg in the Northern Cape. The new mine is scheduled to start production in the first half of 2012, ramping up to full capacity of 9 magetonnes per annum in 2013.

It will have in excess of 20 years life and produce Direct Shipping Ore (DSO) with product qualities of 64% Fe lump and 63,5% Fe fine ore for the export market. The ore will be transported on the main Sishen-Saldanha rail line to the port of Saldanha Bay via a rail link to be built from Sishen South mine.

Chris Griffith, CEO of Kumba, said:

'This is another exciting achievement for Kumba, and one that demonstrates our commitment to deliver on a strong project pipeline. The development forms part of Kumba's expansion strategy to grow Iron Ore Export Channel (IOEC) volumes to 44 megatonnes per annum by 2013. Including current domestic production of 9 megatonnes per annum, this increases Kumbas total production to well over 50 megatonnes per annum.

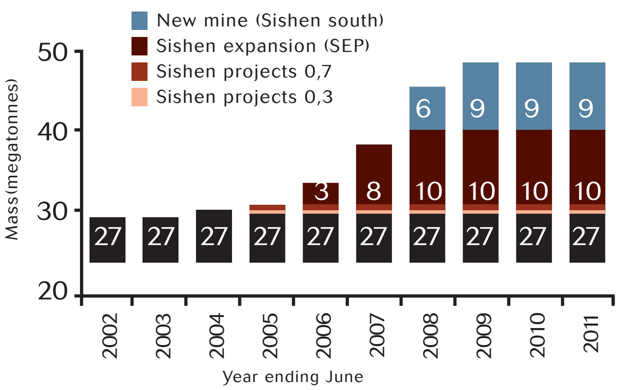


Figure 1: Kumba Iron Ore expansion plans in the Northern Cape

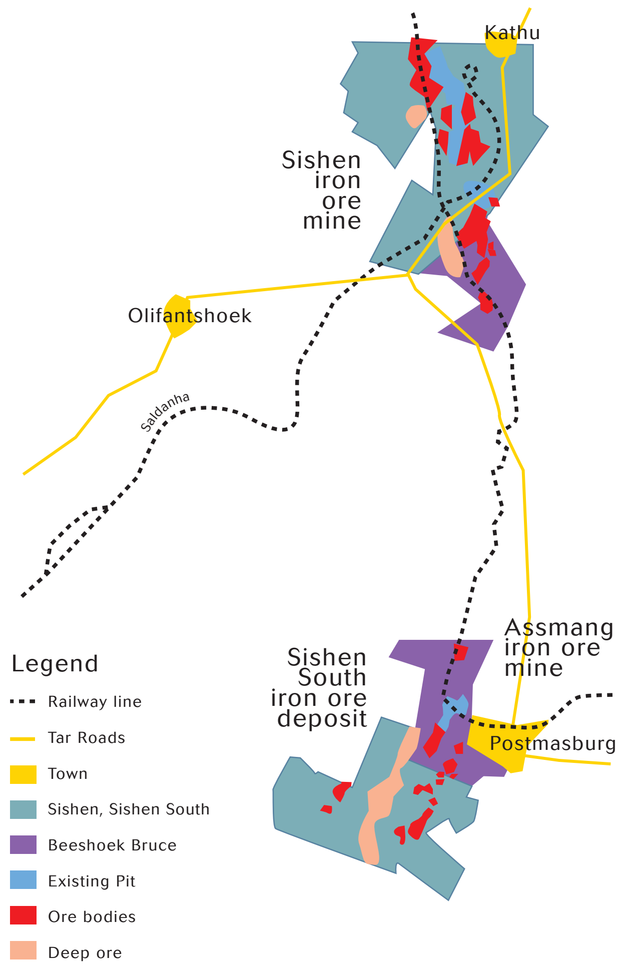


Figure 2: Northern Cape iron ore deposits

This milestone has been made possible by the recent granting of Sishen Souths new order mining rights, the issuing of its Integrated Water Use Licence, and the positive conclusion to the negotiations with Transnet regarding the additional capacity on the Sishen-Saldana iron ore export channel. Eskom has also committed to honour the supply contract for electricity to the Sishen South mine.

SA Iron Mines

An experienced project team has been secured and we have ensured that the people and skills deployed in the Sishen Expansion Project (SEP) were retained for the development of the Sishen South mine. Orders have also been placed on long lead equipment, which means that we are in a strong position to ramp up swiftly to full capacity."

Approximately 750 people will be employed by the mine, with a further 2 000 jobs created at the peak of the construction phase. Indirect job creation is estimated to be in the region of 4 000 jobs. The mine will have a positive impact on the economy of the Northern Cape.

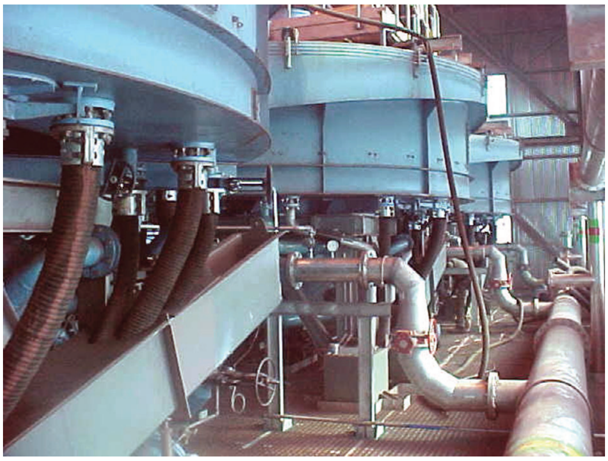
Kumba is committed to its high standards of environmental responsibility and safety in the development of this mine. An Environmental Impact Assessment, Environmental Management Plan and Social and Labour Plan were submitted to and accepted by the Department of Minerals and Energy. This will result in the immediate implementation of the local economic development projects as agreed to with key stakeholders.

Kumba expects the iron ore market to remain attractive for some time and customers are very excited about Sishen South coming on line.

This material was obtained from Kumba Iron Ore. Learners– if you use any part of it you must write it in your own words and include the following in your reference list: Kumba Iron Ore, 2008. Kumba to invest R8,5 billion in new Sishen South Mine [Online]. Available http://www.kumba.co.za/pr_310708.php [4 December 2008]

Stockpiling

View of the Sishen pit, the largest pit mine in South Africa



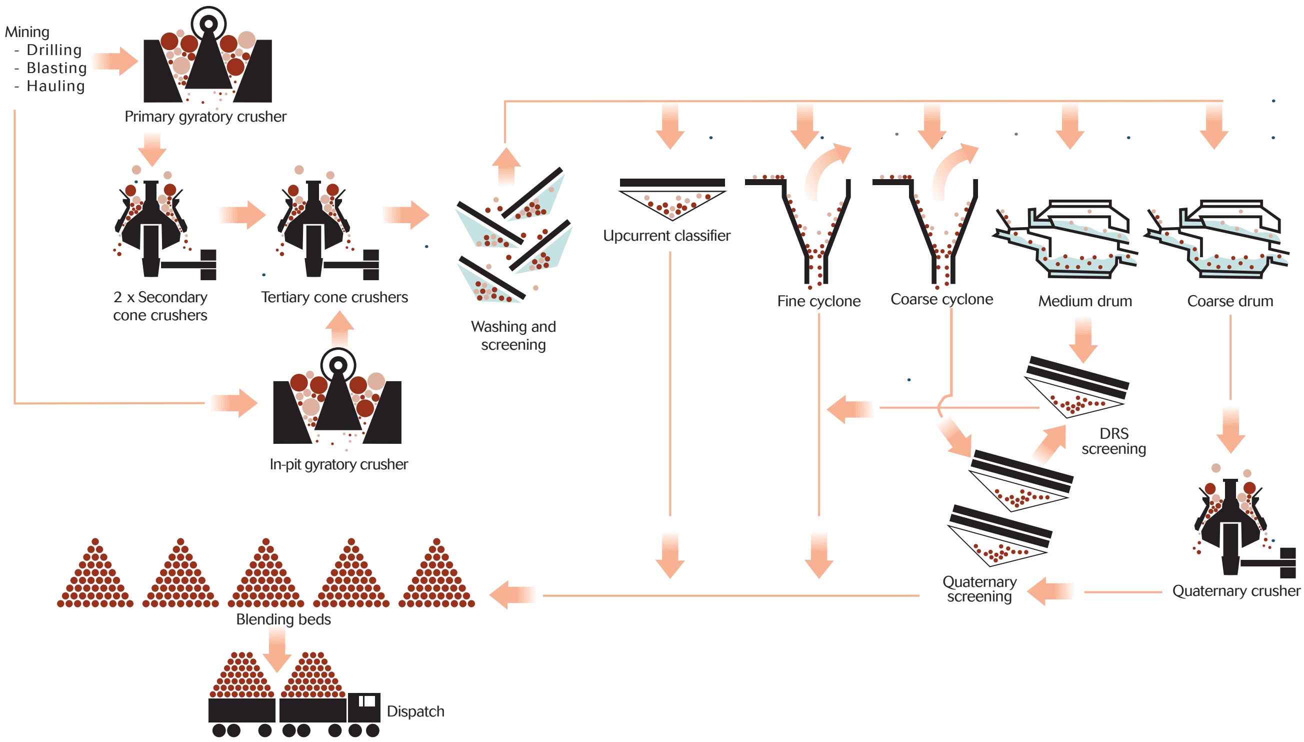
Up-current classifier at Sishen

Thabazimbi Iron Ore Mine

- Location: The Thabazimbi Iron Ore Mine is located 220 km north-west of Johannesburg and 200 km north-west of Pretoria, in the Northern Province.
- Brief history: Exploration, development and production history dates from 1919. However, large-scale exploration began only in the early 1930s when Iscor acquired the mineral rights. Substantive mining operations began in 1934, primarily providing ore for consumption at domestic steel mills. Mining activities started underground and then with surface mining in 1942. The Thabazimbi plant was the template for the first beneficiation plant of its big brother Sishen, situated in the Northern Cape. Underground mining was stopped in 1998, with surface mining being the current method of operation.
- Brief description: Thabazimbi is an opencast iron-ore mine, with five pits and 950 employees.
- 2,5 million tonnes a year are mined.
- Products: Fine product and lump product haematite iron ore.
- Mining method: The mine is operated through conventional opencast methods, including blasting, drilling, loading and hauling.
- Reserves to sustain the curent production could last up to 2014.
- Geology: Thabazimbi mine is located on the northern margin of the lower proterozoic Transvaal basin that strikes approximately east-north-east and dips steeply to the south in this area. The iron ore deposits are located on three thrust blocks within the penge formation, named the northern, middle and the southern ranges. The northern range hosts the majority of the deposits, namely the Kwaggashoek-East, East Mine, Vanderbijl, Donkerpoort, Donkerpoort-Nek and Donkerpoort-West ore bodies. The Buffelshoek-East, Buffelshoek-West and Meyer Mine ore bodies are located on the southern range and Bobbejaanwater ore body on the central range.
- Major infrastructure and equipment: Rotating drills, haul-trucks and rope shovels, as well as supportive equipment.
- Future prospects: Thabazimbis iron ore reserves are estimated to run out in seven years, but processing stockpiled and yet-to-be-mined banded-ironstone reserves will extend the mine's operating life by more than 20 years.
- Controlling company: Kumba Resources
- Unique features: Thabazimbis ore is low in contaminants and high in reducibility, making it valuable on the steel value chain.

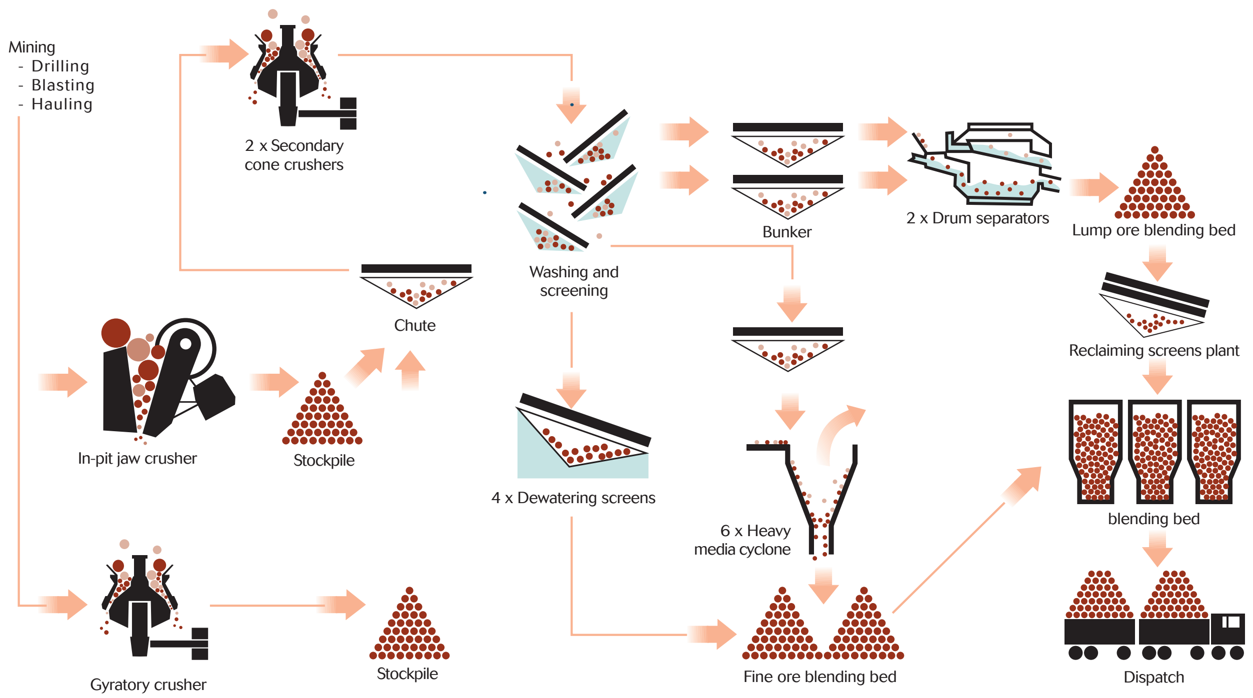
This news article was published by Cramer Media's Mining Weekly at www.miningweekly.com. Learners – if you use any part of it you must write it in your own words and include the following in your reference list: Fernandes, C. 1 July 2005. Thabazimbi Iron Ore [Online]. Available http://www.miningweekly.com/article.php?a_id=69197 [4 December 2008]

SA Iron Mines



Sishen Mines beneficiation process flow

Source: www.kumba.co.za

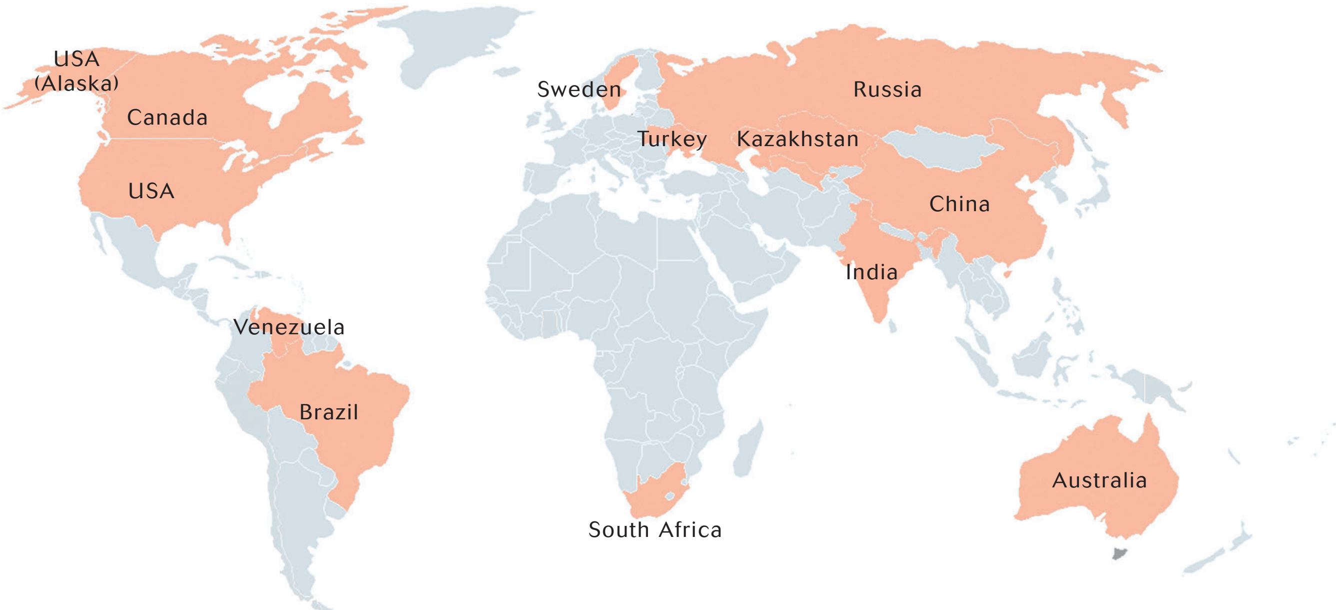


Thabazimbi Mine's beneficiation process flow

Source: www.kumba.co.za

The flow diagrams shown were obtained from Kumba Iron Ore. Learners – if you use any part of it you must write it in your own words and include the following in your reference list: Kumba Iron Ore, 2008. Kumba Iron Ore Annual Report 2007 [Online]. Available http://www.kumba.co.za/reports/kumba_ar07/pdf/full.pdf [4 December 2008]

World Production of Iron Ore



Characteristics of Iron Ore

In its pure form, iron is a lustrous silver metal with a greyish tinge. It readily oxidizes in air and is only very rarely found as native metal. As a ferromagnetic element it has magnetic properties. Iron is abundant (around 5%) in the Earth's crust and its minerals vary greatly in their composition and appearance. The most common ore minerals are the oxides, which can vary in colour from gray to yellow or red, particularly magnetite (Fe_3O_4) and haematite (Fe_2O_3). Other common ores include the hydrated oxides, goethite (FeO(OH)) and limonite (FeO(OH) • nH2O), and the carbonate mineral siderite ($FeCO_3$). The most economically important iron ore deposits are known as banded iron formations (BIF). These are found in Proterozoic rocks (2 500–524 million years old) formed by deposition of iron oxides on the sea bed. Economic deposits are usually those that have been secondarily enriched by natural processes to grades of around 64% iron. Magmatic deposits can also be the source of large quantities of magnetite where the mineral is segregated in a large magma chamber; the largest magmatic iron ore deposit is at Kiruna in Sweden. World reserves of iron ore are 150 000 million tonnes of ore containing 73 million tonnes of iron. Ukraine holds the worlds largest reserves of ore with 30 000 million tonnes (19% of the world total). Russia is the second largest and China the third with 25 000 and 21 000 tonnes respectively (USGS 2008).

Uses

Around 98% of iron ore is used to make steel and goes directly to primary steel plants. The ore is first smelted to iron , known as pig iron, before it is processed into steel. The iron product can be in the

form of blast furnace iron (BFI) where the ore is smelted with limestone and coke to produce liquid iron or direct reduced iron (DRI). Here the ore is heated and reduced using natural gas to produce iron. Scrap iron and steel is melted in an electric arc furnace. To produce steel, liquid iron is treated in a converter to reduce its carbon content and adjust the alloy composition. Steel has numerous varied uses and, depending on the alloy, many different properties. The most common steel alloys are plain-carbon steel (up to 2,1% carbon), stainless steel (alloyed with chromium and nickel), high-strength low-alloy steel (HSLA) with low levels of carbon, and tool steel, which is very hard due to heat-treatment.

Pig iron can also be re-melted, reducing the carbon and silicon contents, to produce cast iron; this is more brittle than steel but is suitable for many engineering uses such as machine and car parts (such as engine blocks), street furniture and pipes. The remaining 2% has many other minor uses

including use as a pigment, as an additive to cement, as magnets, in industrial processes, as an ingredient in fertilizers, in catalysts or as a radioactive tracer for use in medicine or biochemical research.

World Production in 2006

World production of iron ore rose to 1 810 million tonnes in 2006, a 16% increase on 2005. Increase in production was driven by high demand from China and to a lesser extent India. The consequent price increases have led to operators increasing production capacity and investing in new mines. Production still struggles to catch up with world demand. The highest iron ore production rates ever were recorded in 2006 for the fifth consecutive year with production rising by 62% since 2002. China was once again the world's highest producer with a 40% increase in production, increasing by 153% in the last five years. This increase has mainly been achieved by heavy investment at existing operations by big companies and a very fast expansion by small producers as well as technological breakthroughs leading to development of new low-grade mines; the increase could slow in future years however, due to new regulations leading to the phasing out of many smaller less efficient operations.

Brazil, the world's second-largest producer increased production by 13%, mainly due to Vale (formerly CVRD), the country's biggest producer, increasing production at existing mines, expanding the Carajás mine and to the startup of the Fábrica Nova and Brucutu Mines.

Australia, the worlds third-largest producer, increased its production by 5% in 2006 compared to 2005, however this is a slowdown compared to the increase of 12% seen in 2004–2005. Unprecedented bad weather in Australia, with five cyclones, caused damage, flooding and delays to many operations early in the year. These problems were further compounded by labour shortages. BHP Billiton and Rio Tinto both increased their production levels in Australia with both companies expanding several mines.

Only modest increases were seen in African production. In South Africa, the world's eighth-largest producer, production rose by five per cent compared to 2005. This figure was mirrored by most other African producers except Algeria, which rose by 25 %, and Zimbabwe, which fell by 53% due to increasing political instability.

The growth in European production was below the world average with an 11% increase during 2002–2006, this is due largely to competition from increased production in Russia and Ukraine. Here production levels at existing sites have been increased

Worldwide Production of Iron Ore 2002–2006 (tonnes)

Country	2002	2003	2004	2005	2006
China	232 619 000	261 084 600	310 104 800	420 492 700	588 171 400
Brazil	214 560 000	234 478 000	261 696 128	281 462 088	317 800 229
Australia	188 760 000	212 881 000	234 002 000	261 796 000	275 042 000
India	99 072 000	122 838 000	145 942 000	154 436 000	173 976 000
Russia	85 964 300	92 604 600	94 894 600	96 828 000	104 000 000
Ukrane	59 300 000	62 500 000	66 000 000	69 456 000	74 000 000
USA	51 570 000	48 554 000	54 724 000	54 300 000	52 900 000
South Africa	36 484 015	38 085 855	39 322 048	39 542 072	41 326 036
Canada	28 704 000	33 013 000	28 596 000	28 343 000	34 094 000
Sweden	20 281 000	21 498 000	22 272 000	13 255 000	23 302 000
World Total	**1 117 000 000**	**1 237 000 000**	**1 371 000 000**	**1 554 000 000**	**1 810 000 000**

but it is predicted that they have now reached capacity and big investments in new sites will be required to maintain their growth. Production in North America fell by 3%. However Canada, the worlds ninth-largest producer, increased production by 20% due to record production from the Carol mine in Labrador.

Prices

Iron ore is trade is characterised by consumers having fixed contracts with producers negotiated annually. Rarely will iron ore be traded with spot prices on the open market. The price of iron ore remained relatively constant for the last decade until 2004, when prices rose by 19% price. In 2005, this increased again by 70%, prices stabilised in 2006 and rose again by 30% in 2007, rising throughout the year. This rise, mainly driven by Chinese demand, pushed spot iron ore prices so high above contract prices by the end of 2007 (around £50 per tonne according to Rio Tinto) that major producers Rio Tinto and BHP Billiton made plans to sell considerably more iron on the spot market.

Industry Events in 2007

This was a very positive year for iron ore production where growth was almost worldwide. This was coupled with large price increases in the last half of the year, as Chinese demand drove up the share price of almost all major iron ore mining companies despite problems with the American economy. The three major iron ore producers, Vale (formerly CVRD), Rio Tinto and BHP Billiton, all announced significant production capacity increases. Vale announced plans to increase capacity by 50% over the next four years by fast-tracking expansion plans from 300 million tonnes per year to 450 million tonnes per year by 2011. BHP Billiton and Rio Tinto have similar plans, investing larger amounts in their Western Australia operations. Rio Tinto announced two changes to their production targets this year: the first, in June, was an increase in production from 220 million tonnes a year to between 300 and 320 million tonnes a year by 2009; and the second, in November, a longer term increase to a total of 600 million tonnes a year in the next two decades. This is to be done mainly by increasing production and opening new mines in the Pilbara region of Australia, where production rates could reach 420 million tonnes per year. Many dormant operations are being revived; the year saw the start of iron ore exports from

Australia's Northern Territory for the first time in 13 years.

Chinese producers began a significant programme of foreign investments, with several of the nation's top steel mills forming overseas joint ventures, notably in Australia, USA, Asia and Africa. One of the largest was an investment in a northern Cambodian iron ore mine with 200 million tonnes of reserves. In Australia, Baotou and Shenyang Orient iron and steel have agreed to buy 1 million tonnes of ore from the Wilgerup haematite deposit, South Australia.

In early 2007, the imbalance in supply and demand of iron ore production was predicted to end by 2009, possibly with iron ore production outstripping demand. However, now it is thought that project delays could maintain the current iron ore boom until 2011.

High demand has resulted in prices on the spot market being almost twice the value of contract prices, leading to more ore being sold on the spot market. Rio Tinto has announced plans to sell 15 million tons of ore on the spot market in 2008, although contract prices are predicted to rise next year by between 30% and 50%. Increased shipping cost from Brazil to China has also led to substantial differences in the prices of Brazilian ore and Australian ore at Chinese ports.

BHP Billiton and Rio Tinto have attempted to alter the pricing system as a result but have met with strong resistance from the Chinese. Vale has ordered four new very large ore carriers to try to reduce costs. Consolidation in the iron ore industry grew in 2007, promoted by price increases and positive forecasts, with the 15 largest companies controlling almost 60% of production. Vale took over several smaller Brazilian companies. Brazilian producer MMX sold stakes in two major projects to Cleveland-Cliffs (in late 2006) and Anglo American. Many steel companies tried to buy into iron ore as a hedge against increasingly high prices, Arcelor Mittal making the biggest move by buying into the Wabush mine in Canada. The company aims to be 75% self-sufficient eventually and has begun to invest heavily in Africa. Another Indian Steel maker, Jindal Steel, has signed a £1, 05 billion contract to develop the El Mutan deposit in Bolivia, which is estimated to contain 40 billion tonnes of ore.

This material was obtained from the publication World Mineral Production 2002–2006 as found on the Natural Environment Research Council NERC Open Research Archive (NORA) website: http://nora.nerc.ac.uk/. Learners – if you use any part of this document you need to write it in your own words and include the following in your reference list: British Geological Survey. 2008. World Mineral Production 2002–6. Keyworth, Nottingham: British Geological Survey. p. 42–44.

Social Responsibility

Healthcare at Sishen Mine

Sishen Mine is a partner in several healthcare initiatives in the Gamagara area.

1. **Ulysses Gogi Modise Wellness Clinic.** The Northern Cape premier, Dipuo Peters, opened this facility in December 2007. It will address the need for testing a huge number of contractors working at the mine and will relieve the burden currently experienced by the local clinic. The clinic was built next to the local hospital, which has doctors and other medical services. The location offers easy access from the taxi rank and is within a short walking distance to all other medical services, which include dentists and other doctors. Sishen Mine financed the construction of the clinic, and is responsible for its operating costs (excluding medicines) for the next three years.
2. **Soup Kitchen.** In Dingleton, Kumba supports a soup kitchen that supplies nutritious, hot meals to 150 patients per day, five days per week. When patients need to be transported to the local clinic or provincial hospital in Kuruman, the soup kitchen ensures food parcels are provided to them on that day. Other services provided by the kitchen health workers include referrals to medical facilities, social welfare services, house visits and emotional support.

This material was obtained from Kumba Iron Ore. Learners– if you use any part of it you must write it in your own words and include the following in your reference list: Kumba Iron Ore, 2008. Community Engagement and Development [Online]. Available: http://www.kumba.co.za/profile_suscomm.php [4 December 2008]

Acacia Mellifera, the black thorn tree

Sishen Mine's Small Development Enterprise

Sishen Mine's LED programme has three primary focus areas: healthcare, education and enterprise development. Key projects are discussed below.

1. **Wood and Charcoal Project.** The black thorn tree, *Acacia mellifera*, is classified as an indigenous invader – it occupies valuable land and reduces grazing. The wood and charcoal project was conceived in response to the need to clear the area of this pest. Trees on farms are cut down and processed into marketable firewood. Teams are deployed on these infested farms that trim and cut down the trees using Boscut machines. This project employs 15 people as well as two teams of four people each on the farms. A storeroom is being built and will be used to store buffer stock to ensure continuous supply to customers.
2. **Compost Project.** This project was initiated as a second phase of the wood and charcoal project at Deben. Only 80% of the black thorn tree is used for firewood and 15% left behind on farms to prevent land erosion. Of the 80%, 45–60% is used to produce wood products and the rest disposed of as waste. The waste product is being used to produce compost for rehabilitating mine dumps.
3. **Boitirello Jewellery.** Unique and exquisite silver, gold and other metal jewellery is manufactured by the Boitirello jewellery project, which was founded through the Anglo Zimele programme. The project comprises six women from Kathu. The staff designs all jewellery manufactured through the project. These designers have all completed the NQF 3 qualification – production of jewellery, and are awaiting external moderation

of their portfolios of evidence. A portfolio compiled by Boitirello Jewellery, consisting of a range of designed jewellery and corporate gift items, was sent to Anglo Zimele for display overseas. Through the project, skills transfer and craftsmanship are ensured in the production of high-quality products.

4. **Carwash Project.** Any visitor to Sishen Mine is instantly reminded that mining is a dusty business. All mine vehicles are coated with brick-red mud in the rains and a similar coloured powder in the dry season. This presented an opportunity – the space for a local entrepreneur to deliver a cleaning service to the mine. Currently, the service includes cleaning parts at workshops before they are refitted into vehicles or equipment, as well as sandblasting parts. With regular and thorough cleaning, and this level of attention, the lifespan of the mine's vehicles is prolonged. In addition to cleaning parts, an opportunity to wash employee cars was identified. An outside carwash facility is being built to enable mine employees to leave their vehicles for cleaning. Proper and safe detergents will be used at the car wash. Fifteen people are currently employed at the parts wash bays.

5. **New Horizon Entrepreneurial Project.** The New Horizon Entrepreneurial Project was launched in Kimberley in 2007 under the custodianship of the premier of the Northern Cape. Grade 10 learners from all high schools in the province were invited to submit business plans to be evaluated by a skilled panel for possible implementation. In 2007, the project attracted 75 submissions of which 24 business plans were successful and subsequently funded with start-up capital of R5 000, donated by the mine. These businesses will be given an opportunity to grow and be evaluated against each other. Businesses established vary from a scrap metal dealer, a florist and a school tuck shop to catering services and sandblasted glass to sell to tourists. When learners leave school, they will have the option to continue with their businesses or sell them back to their school.

6. **Tyre Recycling Project.** Part of the waste recycling strategy at Sishen Mine includes recycling tyres. Research was done and, through the Anglo Zimele programme, a joint venture concluded with a company called ART (Alternative Recycling Technology). ART has the necessary rights for various methods of tyre recycling. The second part of the project saw advertisements placed to recruit HDSA candidates to partner the initiative. The project will have three shareholders: Anglo Zimele, ART and an HDSA company. Tyres will be bought from the mine and processed into different products. Extracting the rubber is done using a stripping machine. One of the products that will be produced and sold back to the mine will be rubber granules, which are used as part of the blasting process. This initiative will produce many other spin-offs, which will allow for more job creation and empowerment.

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Jewellery manufacture

Industry Related Risks

Risks Relating to Kumba Iron Ore's Business and the Mining Industry in South Africa

Mining Exploration and Projects

In order to expand its operations and mineral resources and reserve base, Kumba Iron Ore relies on its exploration programme and its ability to develop mining projects. Resource exploration and development are speculative in nature, characterised by a number of significant risks.

Further exploration on, and development of, mines and exploration projects will require additional capital which will need to be sourced as required. The current buoyant construction market in South Africa may see an increase in the cost of capital required for major construction projects.

Mining Operations

The mining operations of Kumba Iron Ore are subject to the risks and hazards that are normally encountered in such opencast mining operations. These risks include environmental hazards, such as unexpected geological pressures and ground subsidence, and operational risks relating to materials handling, industrial accidents, blasting and removing material from an opencast pit. If any of these risks should materialise, such event could delay production, increase production costs and result in an increase in the liabilities of Kumba Iron Ore.

Mining operations, development and exploration activities are further subject to extensive legislation and regulations. Changes in this regulatory environment could increase Kumba Iron Ores cost of production and, as in most other businesses, its failure to adhere thereto, could result in the revocation of the consents, licences and rights that it requires to conduct its business.

Growth Prospects

Sishen mine is under a contractual obligation to deliver up to 6,25 megatonnes per annum of iron ore to Mittal Steel at a price which recovers the cost of production plus 3%. Mittal Steel may, with proper notice, procure iron ore for use within South Africa in excess of 6,25 megatonnes per annum at a price and on terms and conditions to be negotiated. The contract with Mittal Steel runs to the end of the life the of mine, currently expected to be 2028.

Labour

Kumba Iron Ore is, to a great extent, reliant on the large number of persons employed in its operations. The availability of skills in the mining industry, especially artisans, may have an impact on current production and future growth in the industry. Unionised operations are exposed to the risks posed by organised labour disruption and disputes. The company's production costs may also be increased as a result of increases in wages and employee benefits.

The incidence of AIDS in South Africa is high and may adversely impact the operations of Kumba Iron Ore through potentially reduced productivity and increased medical and other costs.

Environmental Risks

The operations of Kumba Iron Ore are subject to environmental legislation and regulations. If any of the legislation or regulations should be changed, Kumba Iron Ores production costs could be increased.

Commodity Price Fluctuations

Iron ore prices typically lag the steel commodity cycle by approximately 18 months. Iron ore prices are negotiated annually with the major international steel producers. Kumba Iron Ore normally follows the international price settlements in its annual price negotiations with its clients.

Currency Fluctuations

Iron ore prices are normally determined in US$ terms and Kumba Iron Ore negotiates iron ore prices in US$ terms with its customers. Strengthening or weakening of the US$ therefore could have a significant effect on the financial position and financial results of Kumba Iron Ore.

Risks Related to the Mining Industry in South Africa

South Africa has enacted legislation that promotes the ownership and control of mining companies by HDSAs as set out in the Mining Charter. The legislation enacted in South Africa at present, requires all mining companies to convert the rights that they held under the previous legislation into rights under the new legislation. Kumba Iron Ore has commenced application for conversion of its old order mineral rights to new order mining rights. The Kumba Resources empowerment transaction referred to in this pre-listing statement has been structured to satisfy the equity ownership requirements of the Mining Charter.

Rail and Port

Kumba Iron Ore does not own or operate any of its logistical chain assets and exports its iron ore to its international customers through a single channel rail and port. Labour and other operational risks associated with the management of the rail operators' assets fall outside the scope of Kumba Iron Ore's direct control.

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Resource Management and the Environment

In this section we focus on water and energy consumption. Energy efficiency in South Africa is of utmost importance and an issue that requires commitment and attention.

Water Management

Sishen and Thabazimbi mines are in semi-arid regions. This implies that Kumba needs to be extra efficient at managing water usage, quality and control of discharges and groundwater resources impact management.

Although Kumba achieved an overall water saving of 3,7% in 2007 compared to 2005 and 2006, the target of 0,223m^3 per tonne was not met. This was due mainly to the full-scale construction of a new processing plant for the Sishen Expansion Project (SEP) and increased production. Two major water reduction projects were implemented at Sishen Mine, namely the construction of a new return water dam and a new slimes handling process. The new slimes handling process involves increasing the density of the discarded slurry, which reduces the amount of water 'wasted' through slimes deposition, and reducing the surface area of the slimes dam ponds, thus reducing evaporation.

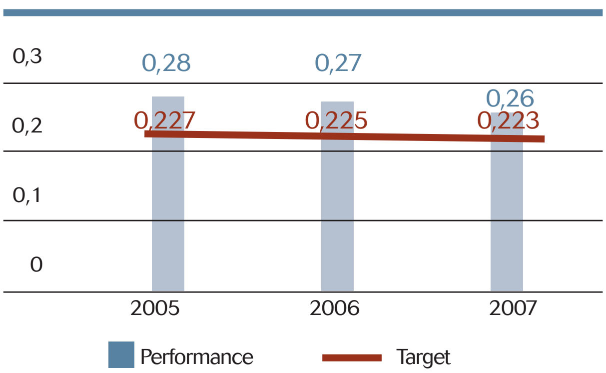


Figure 1: Water consumption (m^3/tonne)

Sishen Mine also uses treated effluent from the Kathu sewage treatment plant. Approximately 20% of the mine's water requirements are provided by this treatment plant, thus reducing reliance on external sources. Another important management action that has decreased water use is the treatment of permanent roads using a chemical dust suppressant instead of water. A trial was undertaken in 2007 to identify a suitable chemical suppressant for use on non-permanent roads.

A water and energy efficiency task team was established in 2007. This team is responsible for developing water and energy policies, strategies, goals and savings initiatives. Several savings initiatives were identified at the end of 2007 for further investigation. A modified baseline will be used in future for reporting progress against targets. The target for water reduction will be revised in 2008 in consideration of secondary factors affecting water consumption at the mines.

Groundwater Management

The health of underground aquifers at both Sishen and Thabazimbi mines is vital to the sustainability of the mines and neighbouring communities. The mines obtain 57% of their supply from groundwater reserves.

At Sishen Mine, farmers surrounding the operations have alleged that the mine's dewatering activity has affected their water supplies and their ability to water their livestock. Formations of swallets (similar to sinkholes) were also visible in the banks of the Gamagara River near the mine. Specialists appointed by the mine to determine the impact of dewatering on neighbouring farmers conducted several studies. After some farmers disputed the findings of the study, the University of the Western Cape was appointed by the Department of Water Affairs and Forestry (DWAF) to review the study. A peer review raised doubts on the boundaries of the impact zone as defined by previous investigations. Consultations with affected farmers and DWAF have been ongoing to determine the scope of additional work. In the meantime, the mine is providing water to affected farmers. Agreements to provide assistance for grazing were also reached with the majority of downstream farmers.

In addition to these actions, the mine undertook a project to backfill the swallets to re-establish the normal path of the river.

A formal river diversion to channel water around the backfilled portions will be investigated in 2008.

Sishen Mine Water Conservation Initiatives

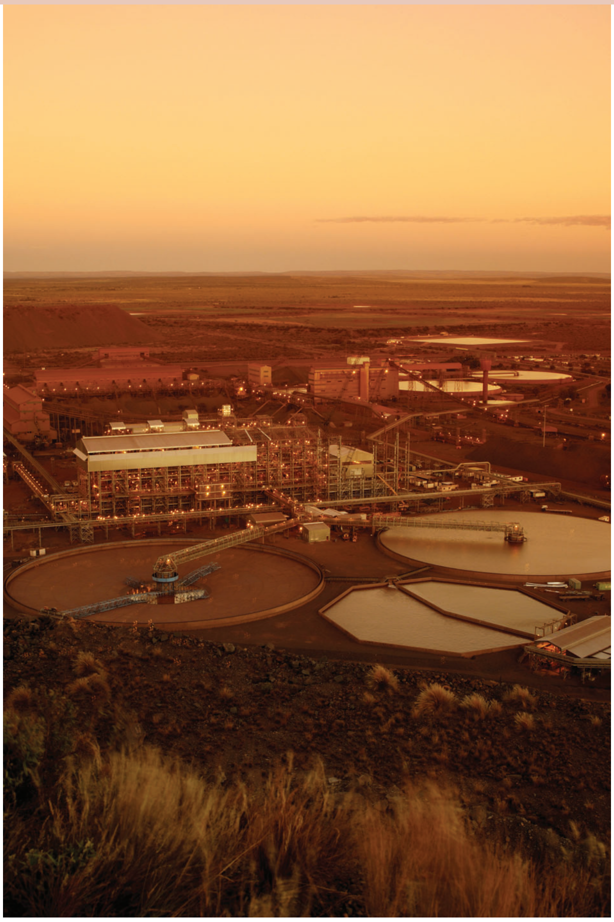
Sishen Mine is in a semi-arid area. The mean annual rainfall is 349 mm while the average annual evaporation rate is 2 026 mm. Low rainfall coupled with high evaporation requires all water users in the region to apply strict measures to reduce evaporation, as well as stringent water conservation measures. Through its environmental management system, the mine is committed to using its water resources efficiently.

The existing beneficiation plant at the mine, which produces about 29 megatonnes of ore per annum, uses a wet process in which run-of-mine ore is washed, separated, sieved and sorted. At the end of the beneficiation process, all process water is sent to sludge thickener dams where the sludge settles out.

From these dams, the separated clean water is returned to the beneficiation process and the sludge is pumped to four individual slimes dams. In the slimes dams, the remaining solids settle out and water is recovered.

The slimes dams were historically a major source of water loss. A large volume of water was stored in the dams to allow sufficient retention time for sludge to settle out. Water was lost from this pool through evaporation and seepage. To improve water conservation, the mine has recently optimised slimes dam management and constructed a return water dam as a part of the Sishen Expansion Project (SEP).

In 2006, the new return water dam was constructed adjacent to the existing slimes dams at a cost of approximately R6 million. Instead of returning recovered water directly from the slimes dams to the beneficiation plant as in the past, recovered water



now flows from the slimes dams via a silt trap to the return water dam. From this dam, water is pumped to the beneficiation plant. The advantages of the silt trap and return water dam include:

- A shorter retention time for water on the slimes dams
- Smaller water pool area on the slimes dams
- The return water dam is lined and allows for a deeper pool with a smaller surface area.

These advantages result in no seepage and lower evaporation losses. An intensive engineering redesign was initiated to increase sludge density for the new SEP plant. By increasing the density of sludge sent to the slimes dams, more water is effectively extracted at the thickener dams and returned to the beneficiation process, resulting in less water being sent to the slimes dams, where it can evaporate.

Other practical measures implemented by Sishen Mine to conserve water include separating the clean and dirty water systems. Now all dirty water on the mine is collected via a series of drains, treated and used in the plant and other processes.

Waste and Emissions

In 2007, Sishen Mine began developing an air quality management plan to monitor dust pollution. The project will be completed in April 2008. The adequacy of the monitoring network will be reviewed against proposed legislative amendments to ensure the mine complies with all legal requirements.

In line with sector targets, Kumba is committed to a 10% reduction in CO_2 emissions by 2014. The largest component of our CO_2 emissions results from direct and indirect energy consumption; it follows that we are addressing emissions by tackling our energy consumption through energy-efficiency initiatives.

Waste

Kumba is guided by the ‘reduce, reuse, recycle, and recover’ approach (4Rs). The companys waste management standard and business unit waste management procedures guide the application of this approach.

In 2007, the attention was drawn to the Polokwane declaration in terms of waste management. Considering the limited amount of space left for landfill sites and the amount of waste generated by operations, the need to review the current waste management practices was critical.

The mines have on-site waste management systems to ensure that minimal environmental impacts occur. The system consists of various service points equipped with a number of waste skips. Different skips are provided for different types of waste, and some separation takes place at source. The temporary accumulation areas are managed appropriately to reduce risks such as spills. Currently, recyclable items and hazardous waste are taken to a temporary storage yard for removal by recycling companies. The remainder is disposed of at authorised landfill sites.

Land Management

Land management involves several aspects: rehabilitation of mined-out areas, biodiversity conservation, land management and closure planning. Kumba owns 40 895 hectares of land. Land management plans are being developed at both operations to ensure that all land is responsibly managed.

The Rehabilitation of Thabazimbi Mine

Thabazimbi Mine is rehabilitating its waste rock dumps according to commitments made in its approved environmental management plan. The process of rehabilitation started in the 1990s. Several experiments have been undertaken in conjunction with the University of North-West to find the most effective rehabilitation method. Over the years, several improvements and much progress has been made on rehabilitation work at the mine.

The dump rehabilitation process consists of the following steps:

- The crown of the waste rock dump is levelled with an excavator and a bulldozer to a safe slope angle of between 18–20°; this is a safe angle at which to work.
- After levelling, a bulldozer makes indentations in a process called ‘moonscaping’. The indentations are about 20 m apart on the downward slope and staggered to ensure they do not form continuous lines. The function of the moonscape is to retard run-off water and prevent erosion of the slopes.
- Two indigenous trees and two clumps of grass are planted per indentation.
- After vegetation has been planted, a mixture of fertilizer is applied. The area is watered three times a week until rains have fallen.
- All flat surface areas on the waste rock dumps

are ripped with a bulldozer; trees and clumps of grass are planted 5 m apart in the ripped furrows, fertilized and watered in the same manner as moonscape areas.

- Vegetation planted the previous year is fertilized every new year.

Remaining challenges include:

- Identifying a process whereby indigenous grasses can be more rapidly established and on a larger scale.
- Identifying a process whereby vegetation establishment can be hastened on longer slopes. The mine has begun experiments using indigenous grasses to overcome these challenges.

Rehablitation at Sishen Mine

The disturbed mining area at Sishen Mine comprises 6 193 hectares. Rehabilitation of mine rock dumps first started in 1985, and one of the initial problems encountered was how to stabilise and vegetate the slopes of mine dumps.

To establish the most effective and efficient way of achieving this, the mine, in collaboration with the University of North-West, researched and tested different combinations of soil, slope and vegetation as part of the move to stabilise the slopes of mine waste rock dumps, vegetate them and improve the scenic quality of the pit in the long term. The difficulties in making this a successful endeavour include the steepness of the rock dump slope, the ability of indigenous vegetation to colonise the slopes permanently as well as soil factors that would affect this colonisation.

The process began in 2003. Trials involved numerous plots on a range of slopes to which various seeding, fertilization and care regimes were applied.

The results of this study, as well as earlier trials, indicate the following:

- Sustainable vegetation cover can be achieved at a fairly gradual slope angle on the western and southern slopes.
- Application of organic material such as compost to increase water-holding capacity as well as bacterial activity in the growing medium per hectare is vital for vegetation success.
- All 'banks' should be back-sloped and surface water flow on these well-managed through contouring.
- A seed mixture of several grass species proved most successful. *Cenchrus ciliaris* (Malopo) (Blue buffalo grass) seems to be the species that will dominate, while *Heteropogon contortus* (spear grass), *Digitaria eriantha* (finger grass), *Anthephora pubescens* (wool grass) and *Fingerhuthia africana* (thimble grass) are perennial grasses that will play an important role in determining rehabilitation success. *Melinis repens* (Natal red top), *Enneapogon cenchroides* (nine-awned grass) and *Aristida adscensiones* (annual three-awn) are the annual species found to perform very well.

It is recommended that tree/shrub species should be planted on the slopes and banks to break straight lines and increase the biodiversity of the site.

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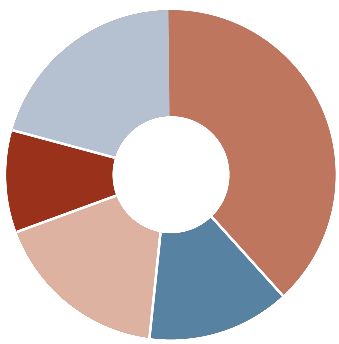
Safety, Health and Wellness

Safety

Regrettably, Kumba recorded one fatality during the year. On 24 February 2007, Samuel Marutle, a truck driver employed by a contractor at Sishen Mine, was fatally injured when his haul truck collided with the foot of a berm and crashed through a sidewall. Operator fatigue was identified as the most probable cause of the accident. Sishen Mine embarked on a renewed roll-out of a complete fatigue management programme for both employees and contractors at the mine, drawing on Thabazimbi Mine's well-established programme.

While we are extremely disappointed to have missed our average lost-time injury frequency rate (LTIFR) target for the year, and saddened by the fatality, we can report the following exceptional safety performances:

- Thabazimbi Mine had reached five years without a fatality by the end of 2007.
- Thabazimbi Mine LTIFR improved by over 40% compared to the previous year (only two lost-time injuries (LTIs) against five reported in 2006).



- 11 lifting and material handling
- 4 energy and machinery isolation
- 5 working at heights
- 3 vehicle safety
- 6 other

Figure 1: Kumba LTI, 2007
Source: Kumba LTI:2007

- In August 2007, Sishen Mine worked 4,4 million man-hours without an LTI. The mine has also achieved 3 million LTI-free man-hours on four separate occasions.
- At all head office sites, including Saldanha Port Operations, explorations and the research and development plant, no fatalities or lost-time injuries were recorded in 2007.

The average LTIFR for Kumba for the 12 months to 31 December 2007 was 0,22 against the target of 0,18. The lack of progress was mainly due to increased injuries, particularly in February and March, with the construction of the Sishen Extension Project (SEP).

The majority of injuries suffered in 2007 were from lifting and materials handling. Managing this risk is incorporated in our road map to zero harm, and the focus will be on reviewing training material and the proper identification and management of risks related to lifting and material handling.

On 4 December 2007, the South African National Union of Mineworkers (NUM) went on a nationwide strike to protest against what it views as the unacceptable number of injuries and fatalities occurring on South African mines. The NUM website (www.num.org.za) stated that the NUM agrees with the Chamber of Mines that it is our collective responsibility to change the status quo, however employers need to take a leadership role and invest in safety in the same manner they invest in production. Though Kumba has a good safety record, we endorse the collective responsibility emphasised by NUM and will continue to invest in the safety of our employees and contractors.

During 2007, we responded actively to address safety as our number one priority. Several workshops were held with leadership across the group to develop our three-year safety action plan, road map to zero harm, which is aimed at improving our safety performance. In addition to ongoing initiatives

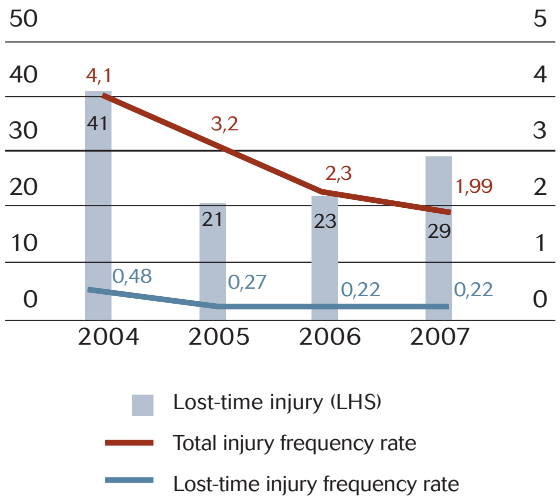


Figure 2: Kumba safety performance (2004 to 2007) LTI, LTIFR, TIFR

Source: Kumba LTI:2007

documented in our safety improvement plans, our safety management focus over the next three years (October 2007 to October 2010), as outlined in our road map, will address the prevention and minimization of major occupational risks identified at our operations and summarised as follows:

- Risk and change management
- Culture, leadership and communication
- Training and competency
- Empowerment of first-line managers
- Contractor management
- Transport management
- Lifting and materials handling.

Kumba was part of the Anglo American-wide review of safety standards during 2007. For Kumba, this has resulted in a code that guides our daily behaviour.

A major initiative during the year was the successful launch of the ONE Campaign at all operations, including head office. The campaign strongly emphasized the theme one injury is one too many. It also included the implementation of leading indicators and the revamped I Care Rules, which were renamed the Golden Rules. The Golden Rules, which prescribe expected behaviour, are non-negotiable and focus on vehicle safety, confined spaces, working at heights, energy and machinery isolation, lifting and mechanical handling, open-pit mining, stockpile management, dams and water storage, chemicals and hazardous substances, and conveyor belts.

Occupational Health and Wellness

We are committed to eliminating all occupational illnesses and injuries from our operations. Our SHE policy outlines the commitment to develop, communicate and review responsible and innovative policies, programmes and guidelines that provide safeguards for employees and contractors.

Our occupational health and hygiene standard calls for the identification and control of occupational health and hygiene hazards through practical measures to eliminate work-related illnesses and injuries. Attention has been directed at reducing risk and implementing indicators to support the elimination of key occupational health and hygiene risks.

During 2007, we compensated an employee who suffered irritant contact dermatitis at Thabazimbi Mine. The disease was treated and cleared successfully and the employee was transferred to a non-exposure area. Sishen Mine reported one suspected case of noise-induced hearing loss (NIHL).

Health and Wellness Objectives and Targets for 2008	
Objective	**Target**
Elimination of silicosis (Thabazimbi Mine)	By December 2008, 95% of all exposure measurement results must be below occupational exposure limit for respirable crystalline silica of 0,1 mg/m^3.
To prevent new employees from contracting silicosis	No new cases to be reported from end December 2008.
Hearing conservation	Fully implemented programmes by end December 2008.
Elimination of all equipment exceeding 110 dB	50% reduction by end December 2008.
Voluntary Counselling and Testing (VCT)	80% of all employees to be tested by end 2008.

This case was reported to the Medical Bureau for Occupational Diseases and we await feedback.

No new or suspected cases of pneumoconiosis, asbestosis, chronic obstructive airways disease, hand-arm vibration syndrome and occupational asthma were recorded for the period.

To manage NIHL cases proactively, employees who have shown a 5% deterioration from baseline are identified and management actions taken including retraining, transfer to a quieter working environment, reducing noise at source, identification and engineering control of high-noise zones. Sishen Mine also installed 'warning systems' in which a red warning light goes on when noise levels reach 82 dB. Working towards minimising exposure to noise, the mine's objective is to move all homogeneous exposure groups falling into category B (86–105 dB) to category C (82–85 dB). Ongoing campaigns are also conducted on exposure to noise and dust.

Improving hygiene systems and the interface between occupational health and hygiene has been a focus during the year. Revising homogeneous exposure groups resulted in a new baseline monitoring exercise. The 2008 risk classification will be based on the results of this study. One of the key benefits of revised homogeneous exposure groups is accurate risk profiling for different designations which will assist in effectively managing occupational health risks and protecting employees against potential occupational diseases.

HIV and Aids

Kumba has a comprehensive HIV and AIDS strategy in place, guided by our HIV and AIDS policy. It is built on preventing employees from becoming infected with HIV, extending the lives of those infected and ensuring the impact on the company is managed. The company extends its assistance to the families of infected employees.

Key HIV and Aids Statistics		
	2007	2006
Infected with HIV (% of workforce)*	5,82	4,86
% of workforce participating in VCT	75	73
Number of new cases	142	122
Number on ART	92	82
Number of employees on wellness programme	314	219

* The basis of calculation of the infected rate reported is the number of HIV infected employee as a percentage of the total Kumba workforce as at the end of the 2007 reporting period. It excludes the potential HIV infection rate present in the percentage of the workforce who do not know their status.

The following features are part of our HIV and AIDS programme:

- Condoms and femidoms are distributed widely.
- Voluntary counselling and testing is available for employees and families.
- Wellness programme is in place and assistance provided for emotional support, co-ordinating medical aid for access to nutritional supplements and antiretroviral treatment and co-ordinating access to hospice care in advanced stages.
- Presently the internal HIV programme does not extend to customers or suppliers. The mine is considering extending a full programme to contractors. Contractors already have access to ARVs and VCT voluntarily.
- Peer educators are active in local communities. Advice is given on how to access government-provided services, and condoms are supplied.

Case study: Thabazimbi Mine HIV programme

Thabazimbi Mine launched Re Tlo Lwana (*we will fight*) community HIV programme in 2003. In the company's view, HIV is effectively combated by combining efforts with non-governmental organisations (NGOs), faith-based groups, the government health department, the communities themselves and other stakeholders.

Re Tlo Lwana is a community-driven project that aims to strengthen and extend the group's HIV programme to host communities. Among other activities, the programme:

- Conducts prevention campaigns in and around the mining community
- Conducts voluntary counselling and testing (VCT)
- Conducts HIV-awareness and education programmes
- Promotes comprehensive community home-based care programmes for families whose members are already infected
- Promotes income-generating projects for indigent communities around Thabazimbi Mine's operations.

Substantial amounts were invested in training and capacity building during the inception of the project.

In addition to sponsored training, the mine provides office space and facilities to Re Tlo Lwana and local NGOs.

As part of the community home-based care programme, the mine regularly provides transport for delivering food parcels to the community and transporting caregivers for the awareness campaigns.

This information was obtained from Kumba Iron Ore. Learners– if you use any part of it you must write it in your own words and include the following in your reference list: Kumba Iron Ore, 2008. Safety, Health and Wellness [Online]. Available: http://www.kumba.co.za/profile_susshw.php [4 December 2008]

News

Bleak Medium- to Long-term for Steel and Iron ore

26 November 2008

SAO PAULO (Reuters)

A quick recovery for world steel and iron ore producers looks more remote every day as the global financial crisis weighs on economic growth, analysts said on Tuesday.

Stuart Reynolds, manager at Global Steel Consultants, presented a bleak revised medium- to long-term outlook for the steel sector on the first day of the three-day America's Iron Ore Conference in Rio de Janeiro.

The conference's proceedings were largely drowned out by news across the world earlier in the day that BHP Billiton abandoned its hostile takeover bid of Rio Tinto.

Participants in Rio were widely tight-lipped about the deal as many were restricted legally from making public statements about it. Others were simply reluctant to comment.

"It's a much less rosy picture today than it was just a few months ago," said Reynolds before a room full of steel and iron ore representatives who were still openly confident in demand projections from emerging markets like China.

"As each day passes it appears this slowdown will be longer and deeper in the developed countries of the United States, Europe and Japan and growth will be slower in the emerging world," he said.

The broad study on world steel demand presented by Reynolds suggested the most likely scenario would be for "no growth in steel demand through 2012" and a similar fate is seen for demand of iron ore, the sole purpose for which is steel.

"There is, of course, the chance that the world could snap out of this and we could recover faster than expected but that looks much more remote now," Reynolds said.

The global construction sector consumes over half of all the steel produced in the world, followed by the mechanical engineering sector. Growth in demand for steel from these sectors requires investments, which have become much harder to come by in the current credit climate, Reynolds said.

Equity research analyst Roger Downey at Credit Suisse said that steel output grew by nearly 6% annually from 2001 through 2007 and "I see China steel output growth growing 5,5% through 2012."

But China's expected increase in capacity that is set to come online through 2012 and beyond may not find sufficient demand at home.

While world supply and demand for steel was nearly balanced in 2007 and 2008, Downey's model showed an oversupply growing to 3% in 2009, 7% in 2010 and to 15% by 2015.

However, he was more modest in his view that iron ore prices would fall significantly in 2009.

"I think maybe term prices may move $5 per tonne up or down in 2009," he said, adding that a lot of marginal, high-cost iron ore producers would fold under the current market conditions, limiting production capacity.

But Reynolds was much more pessimistic, suggesting that Japan may have to retire one-third of its steel-making capacity over the next five to ten years as prices fall to $600 a tonne for hot rolled coil and rebar and less competitive mills get squeezed out of the market.

"China is still a big unknown for us," said Reynolds. "You could see that something was going to break when they announced budgetary investments of roughly half of their GDP. That is unsustainable. No country in history has done that."

Reynolds expects China, where the world has been exporting much of its excess steel, to become a net exporter over the coming years.

"Chinese demand for steel will probably grow but not so much that it will keep China from exporting steel because of the new capacity it will be pushing through by 2012. And that is what will hurt Japanese mills," he added.

"And iron ore prices look like they won't recover until after 2012," he added.

This article was published by MineWeb. Learners– if you use any part of it you need to write it in your own words and include the following in your reference list: Ewing, R. 26 November 2008. Bleak medium- to long-term for steel and iron ore [Online] Available: http://www.miningweb.co.za/mineweb/view/mineweb/en/page39?oid=73814&sn=Detail [5 December 2008

Proposed Relocation of the Dingleton Township and Community

15 December 2007

The Township of Dingleton was constructed to serve Sishen Mine in the Northern Cape at the time of mine development in the 1950s.The state-owned mining company, Iscor, built the town. Kumba Iron Ore, a subsidiary of the Anglo American plc group, now owns the mine. The town is now, by modern standards, located too close to the current mine. This has been compounded by rising environmental awareness and the expansion of mining activities at both Sishen Mine and a new, neighbouring mine.

Although independent tests have demonstrated that noise, dust and vibration impacts from mining are within legal limits, recent public consultations by Kumba with the Dingleton residents indicated a strong desire by the residents to relocate. While Kumba will pay for the resettlement, the resettlement will only proceed if:

- the resettlement can be planned collaboratively by the residents, Kumba and the appropriate public authorities;
- the overwhelming majority of residents support both the principle of resettlement and the detailed proposals for rehousing residents;
- international best practice requirements, as set out in the World Bank's resettlement guidelines and the International Finance Corporation's Performance Standards, can be met;
- all relevant South African legislation is adhered to; and
- the resettlement leads to an improvement in both the standard of living and the sustainability of the affected communities;
- the viability of the resettlement can be accommodated.

In addition to re-housing affected residents, Kumba is willing to provide through SIOC, in consultation with the community and relevant authorities but at SIOC's own cost, replacement community infrastructure. Any existing businesses or livelihoods directly affected by the resettlement will also be addressed as a part of the resettlement process.

This press release was published by Kumba Iron Ore. Learners– if you use any part of it you must write it in your own words and include the following in your reference list: Kumba Iron Ore, 15 December 2008. Proposed relocation of the Dingleton Township and Community [Online]. Available: http://www.kumba.co.za/pr_151207.php [4 December 2008]

Rio Tinto Notes Scrapping of BHP Billiton Takeover Bid

London, England

27 November 2008

The Boards of Rio Tinto plc and Rio Tinto Limited – which together form the Rio Tinto group, the worlds third-largest mining company – have noted the announcement by BHP Billiton that it will not pursue its pre-conditional offers for the acquisition of Rio Tinto.
In making this announcement here, Rio Tinto confirmed that it would continue with its strategy of operating and developing large-scale, long-life, low-cost assets to generate significant value for shareholders. It pointed out that the group had an exceptional portfolio of cash-generative assets and significant stand-alone growth opportunities.

Earlier this week, BHP Billiton Limited – the world's largest mining company – abandoned its more than year-long pursuit of the Rio Tinto Group, blaming the rout in commodities prices and the credit-market squeeze for the derailment of what could have been the world's biggest hostile takeover.

It said BHP Billiton intended to write off the costs of approximately US$450 million (R4,7 billion) incurred in progressing this matter over the past eighteen months in its December 2008 half-year results.

Rio Tinto is a leading international mining group headquartered in the UK, combining Rio Tinto plc – a London and NYSE listed company – and Rio Tinto Limited, which is listed on the Australian Securities Exchange.

Rio Tinto's business is finding, mining, and processing mineral resources. Major products are aluminium, copper, diamonds, energy (coal and uranium), gold, industrial minerals (borax, titanium dioxide, salt, talc) and iron ore. Activities span the world but are strongly represented in Australia and North America with significant businesses in South America, Asia, Europe and southern Africa.

This article was published by Miningreview.com. Learners – if you use any part of it you need to write it in your own words and include the following in your reference list: Miningreview.com. 27 November 2008. Rio Tinto notes scrapping of BHB Billiton takeover bid [Online] Available: http://beta.miningreview.com/Rio/Tinto/notes/scrapping/BHP/Billiton/takeover/bid [5 December 2008]

SA to Take on Mining Industry Over Safety Record

The South African government plans to deal severely with mining companies operating in the country if their safety records do not improve, Minerals and Energy Minister Buyelwa Sonjica said on Friday.

She said the CEOs of mining firms needed to commit more to the safety of their work force, and urged top executives to show more 'visible leadership'.

This comes after the industry's safety performance has not improved 'an inch' since a 20% target was agreed upon in 2003.

The mining sector had committed itself to zero occupational diseases, injuries and fatalities in 2003. Part of this commitment was to shrink the fatality rate by at least 20% a year, but the industry had failed to achieve its target, killing 199 workers in 2006.

And, between January and May this year, 93 mineworkers had already lost their lives. More than half of the fatalities occurred in the gold mining sector.

Sonjica said that mining companies could not put profits and productivity before the lives of their workers.

'There is a haste to make profits because of the mining boom, but CEOs need to take the lead in safety."

However, she also admitted that the Department of Minerals and Energy had not played its part in implementing safety legislation and vowed that her department would monitor safety more closely.

Labour unions have lashed out at mining companies, arguing that not enough is being done to improve the safety of the mining industry, which killed 199 workers in 2006.

For mining companies to now meet the 20% reduction target, the industry would have to reduce the fatality rate by at least 35% a year to compensate for the lost ground.

This article was published by Cramer Media's Mining Weekly at miningweekly.com. Learners– if you use any part of it you need to write it in your own words and include the following in your reference list: Webb, M. 22 June 2008. SA to take on mining industry over safety record [Online] Available: http://www.miningweekly.com/article.sa-to-ale-on-mining-industry-over-safety-record-2007-06-22 [5 December 2008]

Wireless Technologies Improve Mine Safety

Information and communications technology company GijimaAsts' mining division (GMSI) and Tronimex Data Technologies have partnered to develop a locally innovated radio-frequency identification (RFID) based management system that is currently being implemented at iron-ore-miner Kumba's Sishen mine, in the Northern Cape.

The Wireless Event Management System (Wems) can be used, besides other applications, for the access control or key control of operators to mining and manufacturing equipment.

Wems enables the mine to operate in accordance with the required safety acts pertaining to moving machinery. Each operator wears an active RFID personnel tag. When entering through the mine's turnstiles, the operators licences on the tag are updated wirelessly. Prior to an operator starting equipment, the system checks that the operator has the required qualifications and up-to-date licences to operate the equipment.

If any of the requirements are missing or have expired, the operator is unable to start the equipment. The hardware in the equipment logs and time-stamps all the events, and forwards it to the Wems database through Wems radio frequency or wireless local area network (LAN). Biometric options, such as fingerprint and vein readers, can be incorporated as well.

The software can operate in standalone mode, or can be integrated with a clients enterprise resource planning system to automatically import operator details and qualifications. Forepersons are informed in advance, by email, that an operator's licence is about to expire. The system will also inform the foreperson if an operator has not operated equipment for a preset period.

Because licences are stored on the personnel tags and data is buffered, mining operations can continue even when the local area network (LAN) is down.

	Mine Production		Crude Ore		Iron Content	
	2006	2007e	Reserves	Reserves base	Reserves	Reserves base
United States	53	52	6 900	15 000	2 100	4 600
Australia	275	320	16 000	45 000	10 000	28 000
Brazil	318	360	16 000	27 000	8 900	14 000
Canada	34	33	1 700	3 900	1 100	2 500
China	588	600	21 000	46 000	7 000	15 000
India	140	160	6 600	9 800	4 200	6 200
Iran	20	20	1 800	2 500	1 000	1 500
Kazakhstan	19	23	8 300	19 000	3 300	7 400
Mauritania	11	11	700	1 500	400	1 000
Mexico	11	12	700	1 500	400	900
Russia	102	110	25 000	56 000	14 000	31 000
South Africa	41	40	1 000	2 300	650	1 500
Sweden	23	24	3 500	7 800	2 200	5 000
Ukraine	74	76	30 000	68 000	9 000	20 000
Venezuela	23	20	4 000	6 000	2 400	3 600
Other countries	67	70	11 000	30 000	6 200	17 000
World total (rounded)	**1 800**	**1 900**	**150 000**	**340 000**	**73 000**	**160 000**

Source: U.S. Geological Survey, Mineral Commodity Summaries, January 2008 Key: e: Estimated. All quantities reported in million tonnes ('000 000 t)

The system has a wide variety of additional applications, such as the management of site access, time and attendance, the tracking of products during manufacturing processes and the tracking of goods.

In South African conditions, this has been demonstrated at 1 400 m. It has been installed in over 150 coal and metalliferous mines around the world.

GMSI provides new technology- based solutions to the mining, minerals and metals market. One of its business areas focuses on the provision of solutions in the operations management space.

This article was published by Cramer Media's Mining Weekly at www.miningweekly.com. If you use any part of it you need to write it in your own words and include the following in your reference list: Gabru, F. 12 September 2008. Wireless technologies improve mine safety [Online] Available: http://www.miningweekly.com/wireless-technologies-improve-mine-safety-2008-09-12 [5 December 2008]

World Mine Production, Reserves, and Reserve Base

The mine production estimates for China are based on crude ore, rather than usable ore, which is reported for the other countries. The iron ore reserve estimates for Australia and Brazil and the reserve base estimate for Brazil have been revised based on new information from those countries.

World Resources

World resources are estimated to exceed 800 billion tonnes of crude ore containing more than 230 billion tonnes of iron. U.S. resources are estimated to be about 110 billion tons of ore containing about 27 billion tons of iron. U.S. resources are mainly low-grade taconite-type ores from the Lake Superior district that require beneficiation and agglomeration for commercial use.