Making Steel

The Port Kembla Steelworks is an integrated steelworks, where all three of the major phases of production (ironmaking, steelmaking and shaping) are undertaken on one site. It is by far Australia’s biggest steelworks, capable of producing more than five million tonnes of steel per year, in the form of steel slabs, hot rolled coils, plate, tinplate and downstream value added products.

Raw materials
The basic raw materials for large-scale steelmaking are:

Iron ore (sourced mainly from the Pilbara region in Western Australia and brought to Port Kembla by sea in bulk carriers). Lump ore is crushed and sized before being fed into the blast furnace. Fine ore is agglomerated into sinter in the Sinter Plant, where it is mixed with small particles of coke (coke breeze), fine fluxes such as limestone, dolomite, quartzite and serpentine, and other iron-bearing wastes collected from air filtration units around the plant, and then fused together under extremely high temperatures (1300°C) to form sinter. The sinter is broken into lumps and fed to the blast furnace.

Coal (a high-bituminous grade mined in the Illawarra Escarpment west of the Steelworks): Before it is suitable for use in the blast furnace, coal must be treated by crushing, washing and baking to form metallurgical coke. This baking process is carried out in the Coke Ovens batteries, at 1200°C in the absence of air. Batteries have up to 100 narrow ovens separated by heating chambers. Each oven is charged with coal from the top and then sealed. After 17 to 20 hours of heating, the distillation of volatile compounds is complete and the coke that has been produced is pushed from the oven. It is then quenched with water, screened, and fed to the blast furnaces by conveyor belt.

Limestone: sourced from Marulan in the Southern Highlands and some from Japan.

The BOS Furnace
Fluxes: oxides used in the metallurgical processing to react with impurities to form a liquid slag, which allows the metal to be easily separated from the impurities.

The Ironmaking Process
Firstly, iron is extracted from iron ore in a blast furnace by a process known as reduction. A blast furnace is shaped like a giant bottle and is as tall as a 27-storey building. The furnace is lined with special bricks called refractories that can tolerate very hot temperatures. This process, called ironmaking, is continuous and operates 24 hours a day, seven days a week at the two blast furnaces at the Port Kembla Steelworks.

The raw materials - iron ore, coke and fluxes - are fed into the top of the furnace by conveyor. Air, which is heated to about 1200°C, is blown into the furnace through nozzles called tuyeres that are spaced around the lower section of the furnace. The air causes the coke to burn, producing carbon monoxide which creates the chemical reaction. The iron ore (iron oxide) is reduced to molten iron by removing the oxygen.

About every two hours a hole, called a taphole, at the bottom of the furnace is opened and the molten iron and slag is drained. There are three tapholes at each furnace. One of them at each furnace is always producing.

Slag is a by-product of ironmaking. It is made up of molten limestone which has absorbed the impurities from the process. It is removed from the blast furnace, with the iron, and allowed to cool. The slag is then crushed and used by other industries to make cement, as a soil substitute, and in the making of roadways.

Gases are also produced during the process. They are used elsewhere in the steelworks for heating processes, or as an energy source to produce steam and electricity.

The Steelmaking Process
At Port Kembla, steel is made using the Basic Oxygen Steelmaking (BOS) method in three furnaces.

The BOS furnace holds about 280 tonnes of steel. It is lined with refractories to tolerate the very hot temperatures.

1. The BOS furnace is one-fifth filled with steel scrap (around 40 tonnes), which aids temperature control and reduces energy costs. Around 200 tonnes of molten iron is added to the furnace, in a process called charging.

2. A water-cooled lance is then lowered into the furnace. The lance blows 98 percent pure oxygen onto the steel and iron, causing the temperature to rise to about 1700°C. This melts the scrap, lowers the carbon content of the molten iron and helps remove unwanted elements.

3. Fluxes (burnt lime or dolomite) are fed into the furnace to form slag which absorbs impurities of the steelmaking process. Near the end of the blowing cycle, which takes about 15 minutes, a temperature reading and samples are taken.
The samples are tested in a laboratory and a computer analysis of the steel given within six minutes.

4. The BOS furnace is tilted and the steel is poured into a large ladle. This process is called tapping the steel. In the ladle, the steel is further refined by adding alloying materials which give the steel special properties required by the customer, such as hardness, toughness, corrosion resistance and machinability.

5. After the steel is removed from the BOS furnace, the slag, filled with impurities, is poured off and cooled.

Casting
Liquid steel must be cast into shapes so that it can be handled more easily and rolled. This is done by continuous casting machines that mould the liquid steel into slabs. The process is continuous because liquid steel is continuously poured into a "bottomless" mould at the same rate as a continuous steel casting is extracted.

Rolling
Cast steel is a relatively weak mass of coarse, uneven metal crystals, or grains. Rolling causes this coarse grain structure to re-crystallize into a much finer grain structure, giving greater toughness, shock resistance and tensile (stress) strength.

Rolling is the main method used to shape steel into different products after it has been cast. There are two types of rolling - hot and cold. The rolling process (for both hot and cold) consists of passing the steel between two rolls revolving at the same speed but in opposite directions. The gap between the rolls is smaller than the steel being rolled, so that the steel is reduced in thickness and at the same time lengthened.

One set of rollers is called a stand, and in any one mill there can be a number of stands. One length of steel can pass through a stand a number of times so that it is gradually reduced in size and progressively rolled to the desired shape. A slab 230mm thick can end up only 1.5mm thick, but many times longer, after the hot rolling process.

Hot Rolling
Before hot rolling, slabs are heated in a furnace to about 1200°C. This makes it easier to roll the steel.

Cold Rolling
Certain types of steel are also cold rolled after hot rolling. Before cold rolling the steel is cleaned with acid (pickled) to remove scale or iron oxide. Cold rolling is carried out at room temperature and is rolled at very fast speeds using lubricants to reduce friction. Cold rolling increases strength, makes steel thinner and produces a bright smooth surface.

Coating and Painting
At our Springhill Works adjacent to the Port Kembla Steelworks, cold rolled steel is coated with other metals or paint to protect the steel surface or to give it special characteristics. ZINCALUME® steel is steel strip with a coating of 45 percent zinc and 55 percent aluminium. The coating makes the steel more corrosion resistant. The process involves cleaning, annealing and then coating the strip. Annealing is a general term that describes processes that clean and soften the steel and prepare it for further machining.

COLORBOND® steel is metallic coated steel which is painted. The steel strip is cleaned and a conversion coating is applied to ensure good paint adhesion. A corrosion inhibiting primer and finish coat are then applied.

Shaping
COLORBOND® steel and ZINCALUME® steel are most often shaped or roll-formed before being used by customers. Roll-forming is done by passing the flat strip through rolls that create different patterns, or profiles, in the steel.
Making Steel at the Port Kembla Steelworks

Iron Ore

Coal

Coke oven by-products

Pellets

Sinter

Dust and fume collection

Recycled scrap metal

Fume and dust collection

Fluxing materials

Bag house floor de-dusting processes

Hot Air Stoves

Iron Making

Blast Furnace

Molten Slag

Molten Iron

Slag product

Basic Oxygen Steelmaking

Molten Iron
Ironmaking

Iron is extracted from iron ore in a blast furnace by a thermochemical process known as reduction. Blast furnaces are bottle-shaped, and the latest No. 6 Blast Furnace at Port Kembla is 80 metres high and produces around 7300 tonnes of molten iron per day.

The furnace generates molten iron at temperatures around 1500°C and is lined with special bricks called refractories that can tolerate very high temperatures, and are up to a metre thick. Ironmaking is continuous and a furnace can usually operate for 15 years before new cooling stoves and refractory lining are required.

The raw materials - iron ore (in lump or pellet form and as sinter), coke and trimming fluxes such as limestone and quartzite to control slag chemistry - are fed into the top of the furnace by conveyor in a process called charging. They then take eight hours to work their way down through the furnace. Oxygen-enriched air heated to about 1200°C is blown into the furnace through nozzles called tuyeres that are spaced around the lower section of the furnace. The air causes the coke to burn, producing carbon monoxide which creates the chemical reaction. The iron ore (iron oxide) is reduced to molten iron by removing the oxygen.

Chemical reactions involving iron:

\[ 3\text{Fe}_2\text{O}_3 \text{ (iron ore)} + \text{C} \text{ (coke)} = 2\text{Fe}_3\text{O}_4 + \text{CO} \]

\[ \text{Fe}_3\text{O}_4 + \text{C} = 3\text{FeO} + \text{CO} \]

\[ \text{FeO} + \text{C} = \text{Fe} + \text{CO} \]

Powdered coal from the coal pulverising plant is also injected into the blast furnace through the tuyeres as a convenient and cheaper fuel and to ensure an even high temperature is maintained in the molten iron.

The molten iron is drained through tapholes in a process called casting. Special drilling machines drill the tapholes through the refractory clay at the base of the furnace, and after tapping the hole is plugged with a "mudgun" which inserts a plug of clay. Such is the temperature generated in the furnace that it takes about five minutes for the fresh clay to be baked into a solid plug capable of withstanding the pressure from inside the furnace.

The molten iron runs down a trough into torpedo ladles that are on rail tracks, while the slag is skimmed off into giant containers called slag pots. Slag is a by-product of ironmaking. It is made up of molten fluxes that have absorbed the impurities from the process. It is removed from the blast furnace and allowed to cool. The slag is then crushed and used by other industries to make cement, as a sand substitute and in the making of roadways.

The torpedo ladles can carry 250 tonnes of molten iron, and three ladles are filled in each cast. The ladles are lined with refractory bricks to keep the molten iron hot for the short rail trip to the steelmaking plant.

The blast furnace also produces gases which are captured and cleaned for use elsewhere in the Steelworks in heating processes, or to generate energy. The gas cleaning process collects fine dust which has a high iron content and is recycled as feed for the Sinter Plant.
The Sinter Plant (Continued)

The grate passes through a furnace with gas burners that ignite the coke within the mixture. Air is drawn down through the mixture as it travels along the moving grate generating temperatures up to 1350°C as the coke burns. This fuses the mixture into a solid mass of sinter, which is broken down into lumps as it leaves the strand.

The sinter spends an hour in the rotating cooler where a combination of air and water cooling systems reduces its temperature to 100°C, cool enough for the conveyor belt which takes it to be screened into a sinter product with a mean size of 23-26 mm which is fed to the blast furnaces.

The Blast Furnaces

The Control Room of the No. 6 Blast Furnace at Port Kembla Steelworks is a high-tech world of closed circuit television monitors and computer screens, where two process controllers closely monitor operations across the furnace site.

The furnace stands 30 m high and is like a giant cooking pot, into which ingredients (iron ore, coke, sinter and fluxes) are "charged" from the top. The ingredients work their way down through the furnace over eight hours, and it's the process controllers' job to make sure the 7300 tonnes of molten iron that is tapped from the bottom each day meets all the required standards.

To do this they monitor literally thousands of different sensors, controls and pumps, from pressure and flow transmitters to the all-important temperature controls that ensure optimum blast furnace efficiency. From the control room they ensure that the correct proportions of raw materials from the storage bins are fed into the top of the furnace, and they control the temperature by injecting oxygen-enriched air and powdered coal into the furnace via the tuyères near the bottom of the furnace.

Staff operating from two other control rooms at the base of the furnace manage the tapping operations which extract the molten iron and slag.
Steelmaking

BOS Method
At Port Kembla, steel is made using the Basic Oxygen Steelmaking (BOS) method in three very large barrel-shaped furnaces, or vessels, mounted on a tilting mechanism.

The vessels, which are also lined with refractory bricks, are charged with steel scrap, molten iron and a variety of additives. This mixture is then heated to extremely high temperatures to create molten steel, with each vessel producing up to 300 tonnes of steel in each "heat". The steps in the BOS process are:

1. The BOS vessel is tilted and one-fifth charged with around 50 tonnes of steel scrap, which aids temperature control and is an important part of the chemical makeup of the molten steel, then topped up with 250 tonnes of molten iron.

2. The vessel is then rotated to an upright position and a water-cooled lance is lowered into it. The lance blows 99 percent pure oxygen into the charge at extremely high pressure, causing the temperature to rise to about 1700°C. This blowing cycle melts the scrap, lowers the carbon content of the molten iron and helps remove unwanted elements, or impurities.
When Materials Engineer Brett Tarrant says he likes the grand scale of his job, he isn’t exaggerating.

Brett works at the heart of the steelmaking process at the Port Kembla Steelworks – the Basic Oxygen Steelmaking (BOS) plant which produces more than 16,000 tonnes of molten steel every day to feed the processing units further down the line.

Everything is done on a grand scale in the BOS plant – from the skips that tip up to 60 tonnes of scrap steel into the furnaces to the size of what is reputedly Australia’s largest industrial building.

Inside, three massive 300 tonne BOS vessels are filled with a mixture of scrap steel, molten iron and other additives. A lance is lowered into each vessel to inject oxygen at very high flow rates (twice the speed of sound) in a process called blowing, which takes the temperature up to 1700°C and produces molten steel in 16 minutes.

As Technical Coordinator of the BOS, Brett looks after the blowing and the metallurgy in the three furnaces which means he is responsible for blowing control and ensuring the chemistry and temperature of the molten steel is correct, with the right proportions of additives for the different grades of steel being made. He also controls the fluxes which remove impurities.

“This is no dull, mundane office job. We have got to get it right in the BOS because this is the hub where all the plant’s steel is made,” Brett says.

“It is really challenging and an exciting industry to work in. We produce five million tonnes of steel a year at Port Kembla and it is used around the world in all sorts of applications. Our product compares with anything produced overseas, and I am really proud to be able to say I contribute to that.”

“In fact, when I see a COLORBOND® steel roof or some other BlueScope Steel product I think ‘I helped make that’.”

Brett studied Materials Engineering at the University of Wollongong on a Steelworks cadetship, combining on-the-job training with his university studies. He was Cadet of the Year when he graduated in 2000 and says he “couldn’t think of a better way to go through uni”, thanks to the financial assistance, practical training and, most importantly, a great career.
3. Fluxes (burnt lime or dolomite) are fed into the vessel to absorb the impurities, forming slag. Near the end of the blowing cycle, which takes about 16 minutes, a temperature reading and samples are taken. The samples are tested and a computer analysis of the steel given within a few minutes.

4. The BOS vessel is tilted again and the molten steel is poured into a giant ladle. This process is called tapping the steel. In the ladle, the steel is further refined by the addition of alloying materials which give the steel special properties required by the customer. Argon or nitrogen gas may be bubbled into the ladle to ensure the alloys mix correctly. The steel now contains 0.1-1 percent carbon. The more carbon in the steel, the harder it is, but it is also more brittle and less flexible.

5. After the steel is removed from the BOS vessel, the slag is poured off and cooled. As with slag from the blast furnaces, it is recycled.
Ana Bran
Chemical Engineer

"Working here excites me. I wanted a job that combined hands on practical work with office work, and the Steelworks gives me that."

Ana Bran says it’s her workmates who make working in the steel industry so special. She likes the people, and the excitement of working in Australia’s largest industrial complex.

Ana joined the Port Kembla Steelworks after graduating from the University of Queensland with a degree in Chemical Engineering. She works as a process engineer in the BOS, helping ensure that the processes that turn molten iron into steel are running smoothly.

“I’ve been here two years and it’s been a very good working environment. It’s the people … I’ve received a lot of support, guidance and feedback from the senior engineer, who has been really involved in my development,” Ana says. “The people have taken me under their wings and I am learning from their experience.”

She said the fact she was a woman made no difference in what was traditionally a male-dominated industry. “There’s just no male-female issue,” she says.

Ana remembers being overwhelmed by the sheer scale of the Steelworks on her first day at work. “I was amazed at how big everything was,” she says. “It seems normal now that I am used to it, but my sister came for a family open day and all she could say was ‘Wow!’”

“Working here excites me. I wanted a job that combined hands-on practical work with office work, and the Steelworks gives me that. I like the work and have a wide range of jobs from project management and trouble shooting to training and team activities. Basically everything’s covered — people management, time management and technical work.”

Mark Visser
Process Controller

“It is very satisfying (to be) developing people to work as a team, valuing their opinions and ideas for improvement.”

Mark Visser is following a family tradition at the Port Kembla Steelworks. His father Bob was the Principle Export Officer working in the Export Department, and Mark heads one of the four 25-strong production crews that manage the flow of steel through the Slab Casters on shifts that operate around the clock.

All five million tonnes of Port Kembla steel pass from the BOS through the Slabmaking Department, where the three continuous casting machines produce slabs of steel at the rate of around 1.4 metres a minute.

On his shift, Mark, 35, manages that flow of steel through Slabmaking, and ensures it meets production standards as it passes through his jurisdiction.

He is in constant communication with the BOS operators who provide the feed of molten steel for the caster and the Production Control Centre which schedules the grades of steel to be made depending on customers’ requirements.

“This job is all about managing people, training and development,” says Mark. “It is very satisfying (to be) developing people to work as a team, valuing their opinions and ideas for improvement.”

Mark studied for his degree in Materials Engineering at the University of Wollongong under a Steelworks cadetship that offered a combination of full and part-time study and practical work on the plant. “When I was at school my father encouraged me to apply for a cadetship. He used to bring me on to the plant at weekends, and got me interested in the idea of earning money while I was studying.”
Shaping and Coating

Casting

Molten steel from the BOS ladle furnace is cast into slabs at Port Kembla using a continuous casting process.

The casting process:
1. Before casting begins a dummy bar is used to close the bottom of the mould.
2. A ladle of molten steel is positioned above a casting machine and a hole in the bottom of the ladle is opened, allowing the liquid steel to pour into the mould to form the required shape.
3. As the steel’s outer surface solidifies in the mould, the dummy bar is slowly withdrawn, pulling the steel with it.
4. The steel is cooled and solidified by water jets as it passes along the machine.
5. At the end of the machine, the steel is cut to the required length by computer-controlled gas torches. Typically, slabs are 1.25 m wide x 230 mm thick and 12 m long.

Slabs produced at Port Kembla are further processed in the Hot Strip Mill and Plate Mill, shipped to Western Port in Victoria for processing at its Hot Strip Mill, or exported to customers overseas.

Rolling

Compared with product steel, cast steel is a relatively weak mass of coarse, uneven metal crystals, or "grains". Rolling causes this coarse grain structure to re-crystallize into a much finer grain structure, giving the steel greater toughness, shock resistance and tensile (stress) strength.

Rolling is the main method used to shape steel slab into different products. There are two types of rolling - hot and cold. The rolling process (for both hot and cold) consists of passing the steel at great pressure between two rollers revolving at the same speed but in opposite directions. The gap between the rolls is smaller than the steel being rolled, so that the steel is reduced in thickness and at the same time lengthened.

Each set of rollers is called a stand, and in any one mill there can be a number of stands. One length of steel can pass through a stand a number of times so that it is gradually reduced in size and progressively rolled to the desired shape. A slab 230 mm thick can end up only 1.5 mm thick, but many times longer, after the hot rolling process.
Hot Strip Mill

The Hot Strip Mill at Port Kembla Steelworks is a big favourite with the thousands of visitors who tour the plant each year.

It’s not hard to see why, Australia’s longest industrial building houses one of the most spectacular sights in the steelmaking process, where glowing hot steel slabs up to 12m long emerge from a furnace which has re-heated them to 1200°C, then proceed along rollers through a series of six mill stands where they are cleaned, rolled and formed into coils.

The journey starts as each slab passes several times through the first mill, called theRoughing Mill. This mill reduces a 230 mm slab into a “transfer bar” of about 30 mm thickness. The transfer bar is then formed into a coil in the Coils Box machine in a process that ensures uniform rolling temperatures along the length of the coil in the subsequent finishing mill. The rolling operation is then reversed and the now heat and is fed into the mills’ finishing stands, to roll the steel to its final thickness.

Each coil resembles a glowing hot tongue of steel growing ever longer as it passes back and forth through the series of mill stands. Along the way its length will stretch from 10–12 m to up to 2000 m, while its thickness will correspondingly be reduced from 230 mm to as little as 1.48 mm.

Plate Mill

By the time it reaches the Finishing Mill at the end of the line where it is coiled, the rolling process and a final jet of water on the “run out” table will have reduced its temperature by half to around 600°C.

The poster of a Royal Australian Navy ANZAC class frigate on the wall at the entrance to the Plate Mill Department at the Port Kembla Steelworks is a simple statement of pride.

The Plate Mill supplied the steel for the hulls and superstructures of the frigates, as well as the highly specialised steel plates required for the RAN's new generation Collins Class submarines.

This is the home of heavy duty steel - where slabs are converted into steel plate for ship building, tanks, furnaces, bulk freight hoppers and a variety of other industrial uses where strength and durability are essential. Staff are justifiably proud of the role they have played in building Australia’s defence capabilities by providing steel to the exacting specifications of the Armed Forces.

Computers track each slab’s transformation into plate as it journeys through the Plate Mill, with special cameras called Plan View Monitors photographing the changing structure of the steel as it is rolled. These pictures are relayed back to a central computer that determines whether the steel is reaching its required tensile strength and density.

The hot rolling process in the Plate Mill is similar to the Hot Strip Mill, with each slab reheated...
Shaping and Coating

Hot Rolling

The slabs are heated in a furnace to about 1200°C, which makes it possible to roll the steel and remove the rough, flaky surface, or scale. The more steel is hot rolled, the denser and stronger it becomes.

Slabs are rolled in a Plate Mill or Hot Strip Mill to produce steel plate and strip. Plate is thicker than 5 mm and up to 3250 mm wide and flat for use in ship building, the manufacture of large pipes, boilers and tanks and steel girders. Hot strip is generally between 1.2 mm and 5 mm thick and produced as a coiled ribbon of thin steel ready for processing into a range of products including building materials such as roofing, fencing, whitegoods and automotive body panels.

Cold Rolling

After hot rolling, certain types of steel are also cold rolled in a Cold Reduction Mill to add strength, make the steel thinner and produce a smooth, bright surface suitable for coating.

Before cold rolling, steel strip is uncoiled and cleaned in a long tank containing acid. This process is called pickling, and removes the iron oxide (called scale) from the surface. Cold rolling is carried out at room temperature and the steel strip passes at speeds up to 80 km/hour through a series of rolling stands using lubricants to reduce friction.

By a combination of very high roll force and strip tension, the steel thickness is reduced progressively at each stand. Strip 2.5 mm thick and 1200 m long would typically be cold reduced to 0.5 mm and 6000 m long.