How Aluminium is Made

NEW ZEALAND ALUMINIUM SMELTERS LIMITED
NZAS uses the Hall-Heroult process to reduce alumina to aluminium metal. The basic inputs are alumina, electricity and carbon.

In this process, alumina undergoes an electro-chemical reaction in individual reduction cells. These cells are long steel shells lined with refractory bricks and carbon and are connected electrically in series. The carbon lining of the cell forms the cathode.

Alumina (Al₂O₃) is fed into the cells at regular intervals where it is dissolved in a bath of molten cryolite (sodium aluminium fluoride).

NZAS has four reduction lines: Lines 1, 2 & 3 each containing 208 individual cells and Line 4 containing 48 cells.

An electric current, of approximately 196,000 amps for Lines 1, 2 & 3 and 225,000 amps for Line 4, flows into the cells through carbon anodes which form the positive electrode and also supply the carbon for the reduction reaction. The current passing through the alumina/bath solution reduces the alumina to aluminium and oxygen. The aluminium is deposited at the cathode, while the oxygen is attracted to the carbon anode. The cells operate at temperatures of around 960°C.

There are 18 carbon anodes in Lines 1, 2 & 3 cells and 20 carbon anodes in Line 4 cells. Aluminium rods are attached to suspend them in the reduction cells. The anodes, which are largely consumed in the reaction, are replaced by rota after around 26 days in the cell. Used anodes called butts, are crushed and used in the production of new anodes which are manufactured using petroleum coke, liquid pitch and the recycled carbon material.

The Process

The equation for the basic reaction is

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2\text{Al}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Al} + 3\text{CO}_2
\]
Molten aluminium, which collects in the bottom of the cell, is siphoned off and transported to the cast house. Each cell in Line 1, 2 & 3 produces approximately 1,450 kg of molten aluminium and each cell in Line 4 produces approximately 1,730 kg of molten aluminium every 24 hours.

Gases generated in the process are collected and filtered through fluoride scrubbing equipment before being released to the atmosphere.

Apart from alumina, the primary requirement in the smelting of aluminium is a constant availability of electricity at a competitive price. Around 14,500 DCkWh of electricity, two tonnes of alumina and 425 kgs of carbon are required to produce one tonne of aluminium.

**Metal Casting:**

Molten aluminium is transported to the Metal Products cast house in lined crucibles carried by special purpose crucible transport vehicles. Each crucible holds about five tonnes of molten metal.

The metal is tipped into the holding furnaces. The holding furnaces are heated and hold the aluminium at 730°C, the desired casting temperature.

Aluminium is cast as 23 kg ingot, rolling block and T bar lengths, or alloyed with other metals to produce billet.

Two ingot casting machines, each capable of casting up to 21.5 tonnes per hour, cast, stack, strap and weigh the ingots into one tonne bundles, ready for transport.

Billet, rolling block and T bar are cast using a vertical direct chill casting process producing up to seven metre lengths. Billet can be cast in a variety of diameters. After casting, billet is placed in a homogenising furnace for reheating and cooling under controlled conditions. This ensures a uniform crystalline structure throughout.

| 4 Tonnes Bauxite | = | 2 Tonnes Alumina | = | 1 Tonne Aluminium |
Raw Materials

1. Bauxite is the ore from which aluminium metal is acquired. Bauxite is mined at Weipa on Cape York Peninsula in north Queensland. It is shipped to Rio Tinto Alcan Yarwun and Queensland Alumina Limited, in Gladstone on the central Queensland coast for refining.

2. The fine white alumina powder (Al₂O₃) is transported by ship to NZAS from the alumina refineries. Four tonnes of bauxite produce two tonnes of alumina, which produces one tonne of aluminium.

3. The electrical current required for the smelting process flows in the reduction cell through carbon blocks (anodes) to the cathodes in the bottom of the reduction cells. The anodes are made from petroleum coke, liquid pitch and recycled carbon anodes which are returned from the reduction process.

4. The raw materials are mixed and formed into carbon anodes weighing approximately 1,125 kg for all Lines. They are then baked at temperatures of up to 1,100°C for up to 16 days. This baking process improves the strength and conductivity of the anode. Pitch volatiles are released and burnt to provide extra heat.

5. The carbon anodes are attached to aluminium rods using molten cast iron to enable them to be suspended from cell superstructures. They are then sprayed with approximately 8 kg of molten aluminium to reduce airburn in the cell. They are distributed by an overhead conveyor to a distribution point where they are trucked to the cells via an Anode Transport Vehicle (ATV).

6. The smelter’s main emission control equipment are the Dry Scrubbers, where dust particles and fluoride gases are removed from cell emissions. There are 13 dry scrubbers at NZAS which collect more than 99 per cent of the fluoride gases from process emissions.

7. Chemical reduction of alumina to aluminium takes place in individual reduction cells connected in an electrical circuit. The smelter has four reduction lines. Reduction Lines 1, 2 & 3 are housed in buildings 600 metres long and all contain 208 reduction cells. Lines 1, 2 & 3 are Kaiser P69 technology.

8. Reduction Line 4 comprises more recent CD200 technology and is 300 metres in length, connected in an electric circuit. Line 4 contains 48 reduction cells.
Electricity is supplied to the smelter by two transmission towers each carrying two 3 phase power circuits which supply 610 MW to the plant. Rectifiers convert the electricity from AC to DC to feed the P69 Reduction Lines at approximately 920 volts. Reduction Lines 1, 2 & 3 operate at around 196,000 amps and Reduction Line 4 operates at around 225,000 amps. Each cell in Lines 1, 2 & 3 contains 18 anodes which are partly consumed during the smelting process. Line 4 cells contain 20 anodes. The anode remains (or butts) are replaced on a daily rota system and transported to the carbon plant for recycling of the carbon material.

Crucibles suspended from overhead cell tending machines are used to siphon molten aluminium from the cells.

Purpose-built crucible transport vehicles transport the molten aluminium from the cells to furnaces in the Metal Products cast house, where the metal is held and alloyed (where required) prior to being cast.

Around 70 per cent of the aluminium produced at NZAS is cast as ingots using automatic casting machines. The smelter has two ingot casting machines, served by four holding furnaces. The remaining metal is either cast as extrusion billet, rolling block or T bar.

Molten metal is poured into 23 kg ingot moulds which are quenched by travelling in a water trough. Ingots are automatically stacked, strapped and weighed into one tonne bundles for shipment.

Extrusion billet is cast using vertical direct chill technology. The metal is chilled instantly, first using air and then water. Billet is cast up to seven metres in length with diameters ranging from 155 mm to 339 mm. Rolling block and T bar are also cast using vertical direct chill technology.

Aluminium is transported throughout New Zealand and overseas by road, rail and ship. Metal is trucked to the smelter wharf and then loaded onto the ship. Most of the aluminium produced at the smelter is exported to Japan and other Asian countries, the United States and Europe. Approximately 10 per cent of the product is consumed by the domestic market.
The main by-product of smelting is the gas generated within the cell during the reduction process.

The cells are enclosed to minimise the escape of untreated gases and fans maintain a constant negative pressure inside, ensuring a flow of fresh air into the cells. Fluoride gases are generated from the molten bath in the cells. This molten bath has a similar composition to the naturally occurring mineral, cryolite, or sodium aluminium fluoride. Sometimes naturally occurring cryolite is used. Sulphur dioxide and carbon oxides from carbon anode consumption are also generated during the smelting process. Fine dust is carried in the exhaust gas streams.

These gases are drawn through a system of ducts to the 13 dry scrubbers to treat the emissions.

In these dry scrubbers, alumina is mixed with the gas stream, absorbing the fluorides at more than 99 per cent effectiveness. The fluoride enriched alumina and particulate matter are collected on bag filters and then returned to the reduction cells, while the cleaned gases are released into the atmosphere.

In addition to benefits for the environment, this recovery of fluoride in the dry scrubbers for recycling also results in significant savings in raw materials.
NZAS, through its operating company Rio Tinto Alcan, entered into a voluntary carbon dioxide reduction programme with the New Zealand government. In addition, improved process control has already led to a significant reduction in PFCs (perfluorinated carbons) released from the smelter’s reduction lines.

Monitoring of air, water and vegetation is an important part of environmental management. Five ambient air monitoring sites maintained in the local area measure fluoride and particulate emissions, confirming the effectiveness of the gas containment and dry scrubber operations. NZAS reuses or sends for recycling many of its wastes and by-products. Further reuse or recycling options are continually being sought. Some wastes are disposed of at the NZAS landfill, a controlled and monitored operation. Considerable effort was put into identifying a recycling option for spent cell lining (SCL). An on site crushing plant, designed to operate at 30 tonnes per hour eliminates the build up of SCL material at NZAS. The processed material is then sent to other facilities throughout the world for further processing.

NZAS conducts an extensive on-site monitoring programme to assess its effects on the environment. In addition, specialist consultants have conducted studies on specific aspects of the environment.

The environmental monitoring data is regularly reported to Environment Southland and is reviewed by other regulatory agencies at the Interdepartmental Committee, which meets annually.
The key reasons that Tiwai Point was chosen as the location for the smelter are as follows:

- the availability of continuous, substantial quantities of hydro electricity from the Manapouri Power Scheme, which is part of New Zealand’s national electricity grid;
- close to the deep water harbour of Bluff;
- well established infrastructure offered by the City of Invercargill in terms of smelter housing needs, services and supplies; and
- favourable environmental and climatic conditions that exist at Tiwai Point.

NZAS recognises that excellence in managing health, safety and environmental responsibilities is essential to long term success. Through effective and efficient management practices, NZAS aims to ensure the health and safety of its 750 employees and 120 contractors, to minimise any impacts its activities may have on the environment and to make a positive contribution to local community life.