Appendix A: Alumina Refining Process Description

The principal stages in the Bayer alumina refining process are described below.

Bauxite pre-treatment: In preparation for digestion, bauxite is conveyed from an open stockpile to a series of grinding mills where the bauxite is ground from approx. 10mm particle size to 1mm. Fresh aqueous caustic solution is mixed with the bauxite in a number of grinding mills.

Digestion: The ground bauxite/ caustic mixture then enters the digestion vessels along with the recycled spent caustic liquor coming from the Evaporator unit. In the Digestors, the aluminium in the aluminium oxide in the bauxite ore is fully dissolved in the caustic liquor under conditions of high temperature and high pressure (280 ˚C and 6,000 kPa) to form sodium aluminate according to the following reaction:

$$Al_2O_3 + 2\ NaOH + 3\ H_2O \rightarrow 2\ NaAl(OH)_4$$

To reach this elevated temperature, the bauxite/ caustic slurry is first heated to approx. 200 ˚C via heat exchange with low pressure steam coming from the Flash Train. The bauxite/ caustic slurry is then further heated to approx. 280 ˚C via heat exchange with high pressure steam (approx. 310 ˚C) produced in the on-site gas-fired Boiler. Flashed steam condensate leaves the Digestor and reports to the Mud Washing plant. The high-pressure steam condensate returns to the boiler.

Flash Train: The digested slurry from the Digestors then enters the Flash Train where the mixture is cooled in a series of flash vessels, operating at successively lower pressures. As the slurry enters each flash tank, steam is flashed off and sent back to the Digestor to preheat the bauxite/ caustic slurry. At the end of the Flash Train, there is a final Blow-off tank where the flashed steam is vented to atmosphere. The bauxite/ caustic slurry exits the Flash Train at approximately 100 ˚C before entering the Clarification unit.

Clarification & Filtration: The cooled bauxite/ caustic slurry is pumped to a series of Clarifiers or open thickening tanks operating at atmospheric pressure. Here, the mud and solids settle and separate from the caustic-alumina solution. The pregnant liquor overflows the clarifier and is pumped to a series of filters to remove any remaining solids. The filtered liquor is then sent to the Precipitation unit. The solids removed in the filters join the Clarifier underflow to go to the Mud Washing circuit.

Mud Washing: The solids from the Clarifier and Filtration unit enter the Mud Washing plant where the mud is washed with fresh process water to remove entrained caustic-alumina solution. The washed 'red mud', so named because of its red bauxite colour, is then pumped to off-site, storage dams. The dirty wash water is recycled back to the Clarifiers.

Precipitation: The filtered, pregnant liquor exiting the Clarifier unit enters the Precipitation unit where crystals of alumina trihydrate $Al_2O_3.3H_2O$ drop out of solution in a series of agitated, open-top tanks, according to the following reaction:

$$2\ NaAl(OH)_4 \rightarrow Al_2O_3.3H_2O + 2\ NaOH$$

The spent caustic solution from the Precipitation tanks is then sent to the Evaporator.

Evaporation: The spent caustic solution from the Precipitation unit enters a steam-fired Evaporator where a fraction of the water in the feed is evaporated. The steam condensate is returned in closed

circuit to the boiler and the evaporated water is returned to the Mud Washing plant. The concentrated caustic liquor is then recycled back to the Digestors.

Alumina Filtration: The crystals of alumina trihydrate (ATH) from the Precipitation unit are then sent to the Alumina Filtration unit where most of the free water in the feed is removed. This recovered water is directed back to the Mud Washing plant and the ATH crystals, containing some residual free water (and caustic and alumina), are then sent to the Calcination unit.

Calcination: The filtered ATH crystals from the Precipitation unit are then conveyed to the gas-fired Calcination unit. In the Calciner, the feed crystals are subjected to extremely high temperatures (approx. 1000 ˚C) to produce alumina, according to the following reaction:

$$Al_2O_3.3H_2O \rightarrow Al_2O_3 + 3H_2O$$

The dry alumina powder falls and exits from the base of the Calciner. The other components (free and bound water, alumina and caustic) exit the Calciner in the flue gases.

Alumina Storage & Shipping: Finally, dry alumina powder is conveyed from the Calciner to an on-site covered storage building before being transported to domestic or offshore smelters which produce aluminium.

Boiler: A gas-fired boiler produces high pressure steam for the Digestor and the Evaporator. The boiler operates in closed circuit where condensate from the Digestor and the Evaporator returns to the boiler.

Appendix B: Alumina Refinery Process Data

Stream	**Flowrate (t/h)**	**Temp. (˚C)**	**Pressure (bar)**	**Enthalpy * (kJ/kg)**
Digestor slurry before high pressure steam heating	750	220	40	760
Digestor slurry after high pressure steam heating	750	280	60	975
Spent caustic liquor to Evaporator	410	25		0
Concentrated caustic liquor ex Evaporator	320	100		324
Water leaving the Evaporator (saturated steam)	90	100		
Boiler superheated steam		325	80	
Boiler feed water		80	1	
Boiler inlet methane		25	1	
Boiler inlet air		25	1	
Boiler stack gases		120	1	
Calciner feed (alumina trihydrate ATH and water)	280	25	1	
Calciner inlet methane		25	1	
Calciner inlet air		25	1	
Calciner stack gases		200	1	
Calciner exit alumina product	145	200	1	
Other				
% Excess air feed to Boiler	25%			
% Excess air feed to Calciner	30%			
Heat of reaction for ATH -> alumina + water	196 kJ/mol			
Heat capacity of alumina	130 J/mol.K			

Note: * Enthalpy values quoted relative to 25 ˚C and 1 atm