SECTION 2 THE CEMENT MANUFACTURING PROCESS

The following section discusses the cement manufacturing process in detail, with specific reference to the PPC De Hoek factory, including process flow diagrams and photographs of the De Hoek kiln system and operational equipment.

2.1 A DETAILED DESCRIPTION OF THE CEMENT MAKING PROCESS AT DE HOEK

De Hoek has two kilns currently in operation, both kilns are equipped with 4-stage preheaters, conditioning towers and planetary clinker coolers. The limestone for De Hoek is mined at the adjacent Zoutkloof Quarry.

- Kiln 5 (DHK5) was commissioned in 1974 and is equipped with a 4-stage preheater. The kiln is 66m long and 4.35m in diameter; and
- Kiln 6 (DHK6) was commissioned in 1980, and is also equipped with a 4-stage preheater. DHK6 is 4.2m in diameter and 72m long.

De Hoek has two raw mills (RM), used to grind raw materials into “raw meal” as well as two finishing mills (FM) which are used to grind clinker into cement. The De Hoek kilns are also equipped with planetary clinker coolers and both are fitted with conditioning towers for cooling of the hot exit gases. The kilns and finishing mills are equipped with electrostatic precipitators (ESP’s). An ESP is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge.

Cement clinker is made by crushing, blending and fine milling of limestone (calcium carbonate) and other materials containing silica, alumina and iron oxides, which are then heated to temperatures as high as 1,450°C in a kiln where the compounds react chemically to form clinker. The clinker is then cooled and ground with small quantities of gypsum and other additives to produce cement. The heating process is performed in a rotary kiln, which is inclined at 3 - 4^{o} to the horizontal. The length and diameter of the kiln is dependent on the type of manufacturing process.

2.1.1 Primary Raw Materials

The primary raw material for cement manufacture is limestone (predominantly calcium carbonate). Limestone used at De Hoek is mined at the adjacent Zoutkloof Quarry. PPC will start mining limestone at the Vondeling Quarry located towards the southeast of the plant.

Figure 1-4: Photographs of the quarry at Zoutkloof.

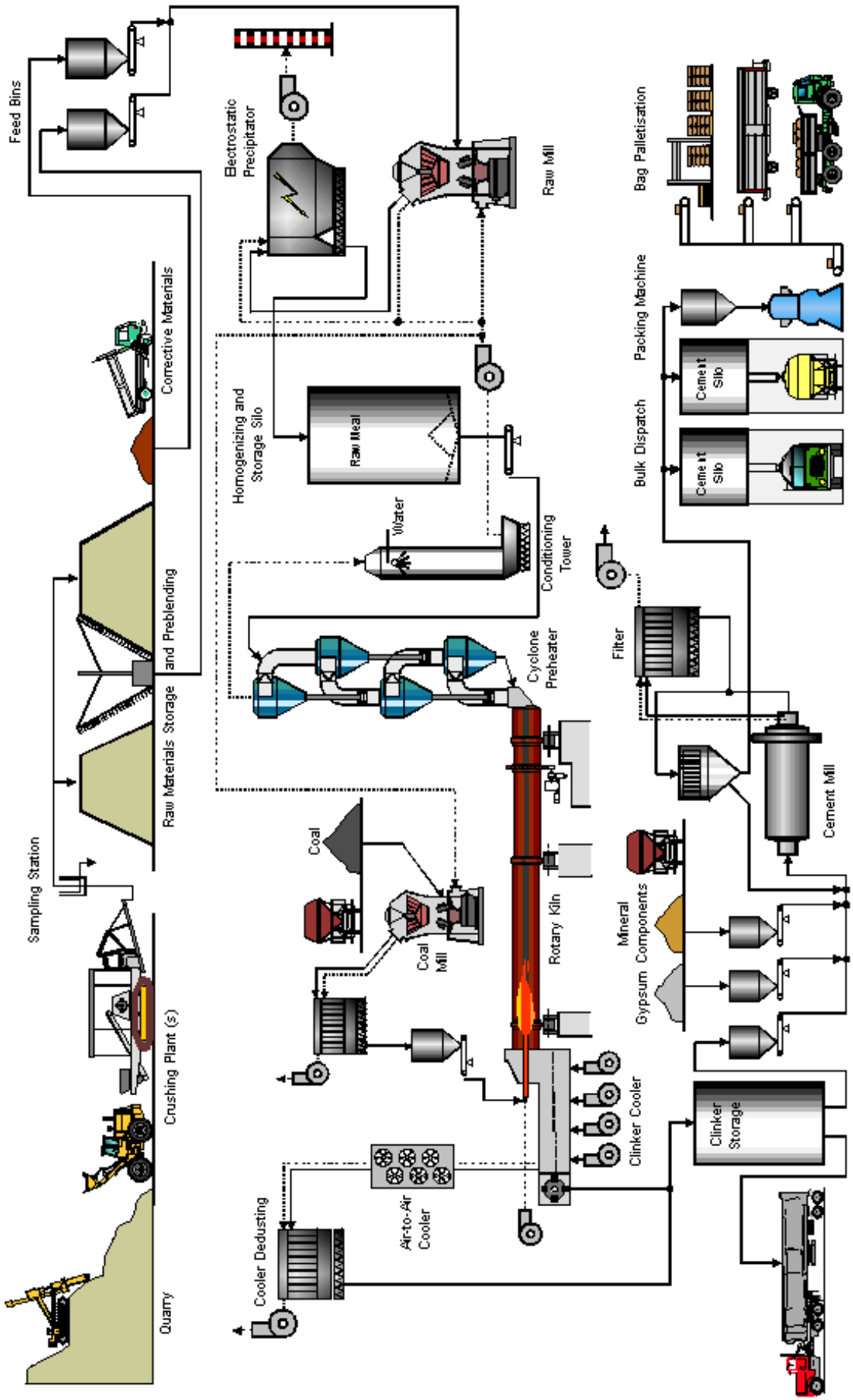

Figure 1-5: Process Flow diagram of the cement manufacturing process.

The limestone is passed through multiple-stage crushers at the quarry, where it is reduced to less than 19mm in diameter. Shale and sand are also used as raw materials. The raw materials are milled together in a raw mill, to a fine powder and sent to the blending silo for homogenisation. The homogenised powder, known as kiln feed, is stored in silos prior to use. Approximately 1.5 – 1.6 tons of kiln feed is required to produce one ton of clinker.

The primary fuel used in South African cement kilns is coal. It is transported to De Hoek by rail, where it is ground to fine dust in a coal mill, and stored in a silo. The fine coal dust is accurately metered into the kiln firing system. The coal has a calorific value of 24-26MJ/kg, hence to produce 100 tons of clinker; 15-18 tons of coal is burned per 100 tons of clinker.

2.1.2 Secondary Raw Materials

Depending on availability and chemical composition, additional components may be added to the raw mix. These are referred to as “Secondary” raw materials. Examples are coal fly ash from power stations, steel slag, foundry sand, lime sludge, FCC catalysts from oil refineries, and many more.

2.1.3 Clinker burning

The rotary kiln is a cylindrical steel vessel, which is inclined to the horizontal at 2.5% to 4.5%. The kiln slowly rotates at 0.5 – 4.5 revolutions per minute to allow the material to tumble through the kiln to ensure sufficient residence time in the kiln to achieve the required thermal conversion processes.

Figure 1-6: Photograph of the De Hoek factory showing the kiln.

The finely ground coal is fed to the firing end of the kiln where it is burned to produce a gas temperature of approximately 2,000°C. The gases flow through the kiln and into the pre-heater where the cold kiln feed is introduced. The preheater consists of several stages contained in a tall preheater tower, which uses the heat produced by the kiln to preheat the raw materials as they move through the various stages of the tower. Kiln systems with preheaters are more fuel efficient than long kilns, using up to 50% less energy. DHK 5 and 6 both have 4-stage cyclone pre-heaters.

Figure 1-7: Photograph of a preheater at De Hoek.

The prepared raw mix, now referred to as kiln feed, is fed to the kiln system, DHK5 and DHK6, into the preheaters.

- DHK5 and DHK6: Preheater Kilns

  The hot gas produced from the combustion of coal enters the preheater and heats the kiln feed, such that the temperature entering the kiln is between 900°C and 1,000°C, at which point all moisture has been removed and the initial chemical reactions have begun. The counter current heat exchange in the preheater improves heat exchange between gas and material and reduces the total heat consumption of the burning process. For a typical 4-stage preheater, the overall heat consumption is <4MJ/kg of clinker.

As the raw meal is transported through the kiln system, it is heated through 4 thermal zones:

a) First the Calcining zone, where limestone is chemically converted to lime as the temperature of the material is raised to approximately 900ºC. This causes the liberation of

carbon dioxide from the limestone and is known as calcination. This stage occurs in the preheater in the case of the De Hoek kilns.

b) The second thermal zone is the Upper-Transition zone, where the temperature of the material increases to approximately 1,200ºC.

c) The third is the Sintering or Burning zone where the temperature of the material increases to approximately 1,450ºC, and clinker nodules, with a diameter of 3 – 20mm, are formed.

d) The final zone is the Cooling or Lower-Transition zone: in the last few metres of the kiln, the clinker is cooled to approximately 1,250ºC.

The reaction zones in the kiln are represented graphically in Figure 2-5.

Exhaust gas from the kiln system is used to dry raw materials, solid fuels or mineral additions in the mills. Exhaust gases are de-dusted in either electrostatic precipitators or bag filter systems before being released to the atmosphere. At De Hoek, exhaust gases exit through the two stacks. Gases from the two kiln and raw mills are dedusted in an ESP and exit through two separate stacks.

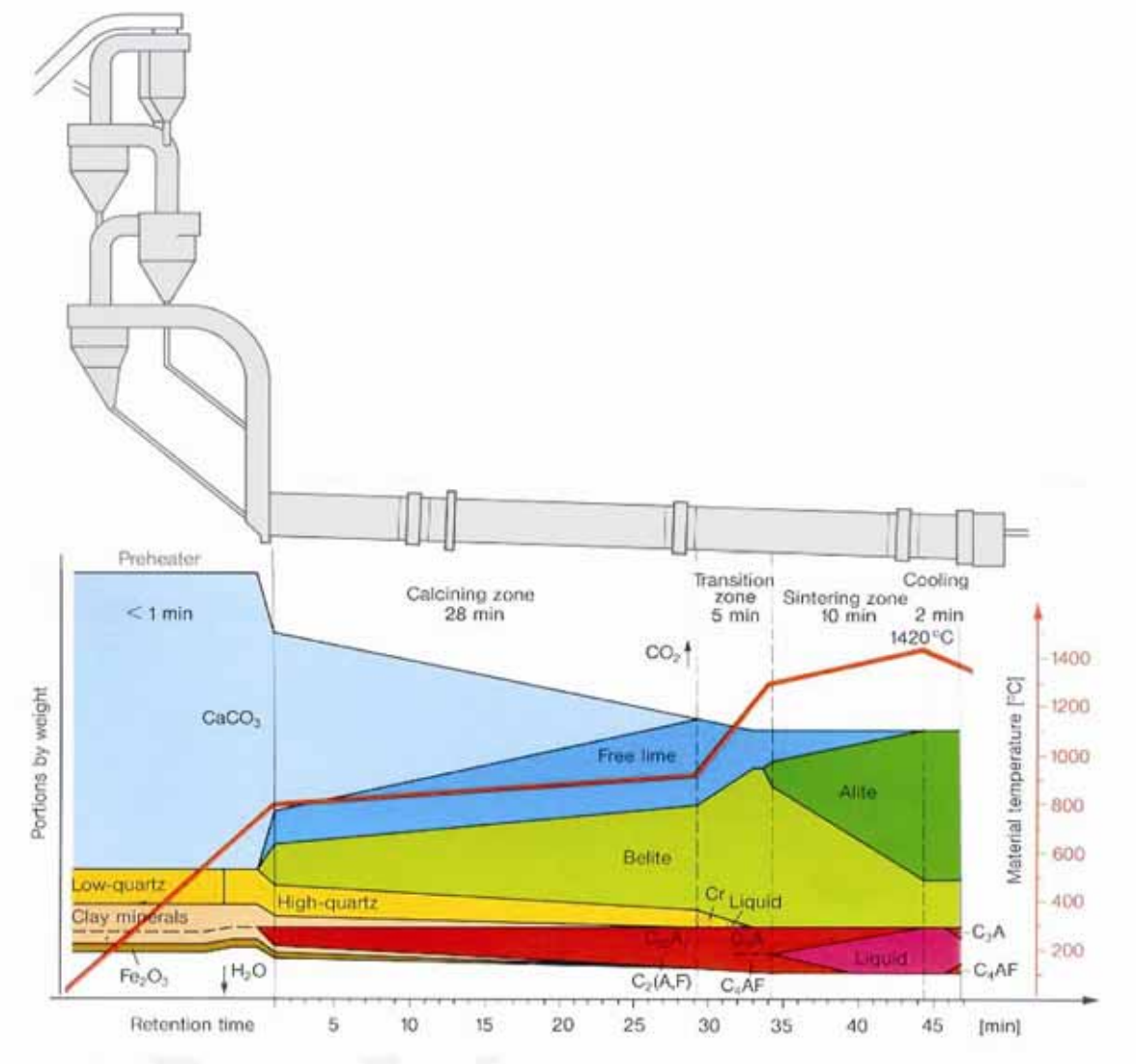

Figure 1-8: Kiln reaction profile[9].

[9] *Technical data, KHD, Cologne, Germany*

2.1.4 Clinker

Once the clinker has formed, and has arrived at the firing end of the kiln, it drops into a planetary cooler, where the clinker is cooled to approximately 100°C above ambient. It is then transported to the clinker storage silos.

Figure 1-9: Photograph of cooled Clinker

The properties of clinker (and thus, of the cement produced from it) are mainly determined by its mineral composition and its structure (silicates, aluminates and ferrites of the element calcium). Some elements in the raw materials such as the alkalis, sulphur and chlorides are volatilized at high temperature in the kiln system resulting in a permanent internal cycle of vaporization and condensation ("circulating elements"). A large part of these elements will remain in the kiln system and will finally leave the kiln incorporated in the clinker. A small component will be carried with the kiln exhaust gases and will mainly be precipitated with the particulates in the dedusting system.

2.1.5 Milling and Final Product (Cement)

Portland cement is produced by grinding clinker, with a small proportion of gypsum (or calcium sulphate di-hydrite) and an extender, such as limestone, slag or fly ash. Gypsum is used to control the setting times of the final cement products. The materials are milled together in a finishing mill. The final cement product is stored in silos by product type.

De Hoek manufactures several types of cement which are defined by the proportion of materials added during the above milling process.

2.1.6 Cement dispatch

Cement is dispatched either in bulk or in 50kg bags and distributed from the manufacturing plant via rail or road. The 50kg bags are palletised, with 40 bags per pallet and loaded via forklifts onto road trucks.

2.1.7 Summary of inputs and outputs

The cement manufacturing process has several inputs and outputs. Raw materials and fuel products (inputs) are converted to clinker (product), emissions and Cement Kiln Dust (CKD) (outputs) in the cement kiln.

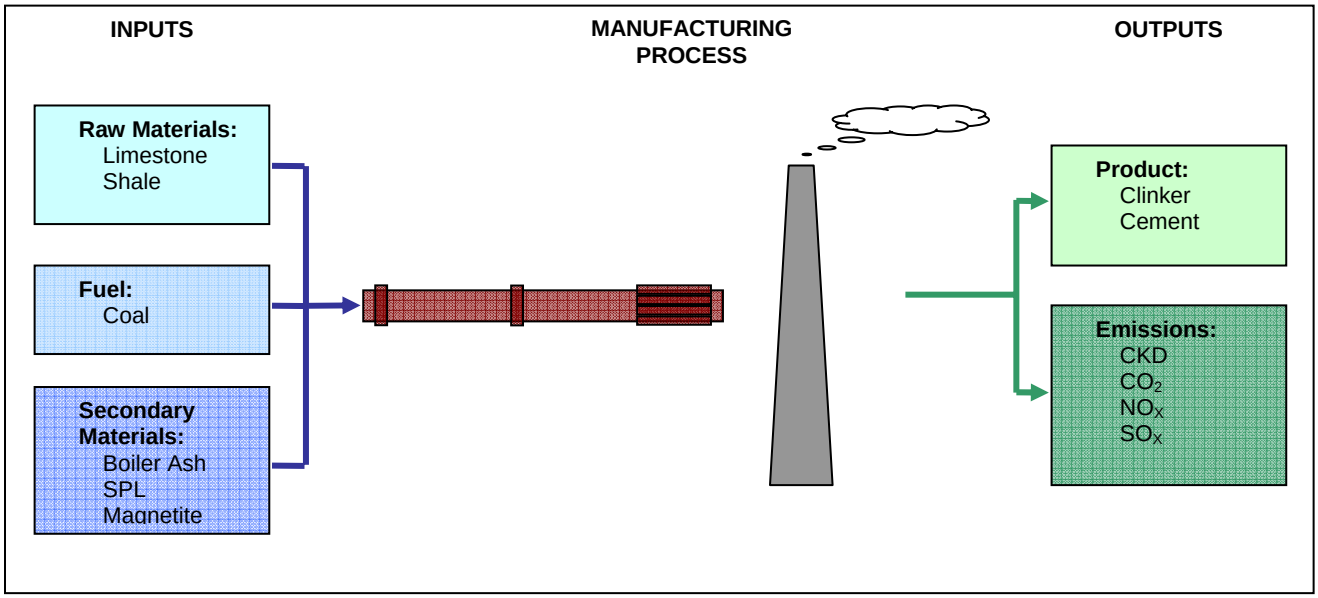

Figure 1-10: Flow diagram showing inputs and outputs in the cement manufacturing process

It should be noted that there is no continuous process waste generated from the cement manufacturing process.

The main constituents of fuel ash are silica and alumina compounds which combine with the raw materials to become part of the clinker. As the cement manufacturing process is a thermal process, there are resultant pollutants emitted through the stack. Under normal operating conditions, emissions that can be expected from the stack include:

a) Cement Kiln Dust (CKD).

b) Sulphur Dioxides (particularly SO_2).

c) Nitrogen Oxides.

d) Carbon Dioxide and Carbon Monoxide.

e) Trace Metals.