SECTION 2 THE CEMENT MANUFACTURING PROCESS

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

2.1 A DETAILED DESCRIPTION OF THE CEMENT MAKING PROCESS AT SLURRY

Slurry manufactures Ordinary Portland Cement (OPC), Surebuild and Rapid Hardening Cement (RHC). A portion of this is distributed to other plants such as Port Elizabeth, Jupiter or Hercules, to supplement their production and for further processing, and a portion is also exported to Botswana for further processing. A small amount of the raw materials mined at Slurry is also distributed to the plants, to supplement their raw material supply.

Slurry currently has 4 operating kilns:

- Kiln 5 (SK5) and Kiln 6 (SK6) were commissioned 1959 and 1960, respectively. Both are long dry kilns, which are not equipped with preheaters. Each kiln is 145m long and 3.45m in diameter;
- Kiln 7 (SK7) was commissioned in 1968, and has a 1-stage preheater. SK7 is 4.55m in diameter and 120m long ; and
- Kiln 8 was commissioned in 1976. SK8 has a diameter of 5.25m and is 83m long, and is fitted with a 4-stage preheater.

The Slurry kilns are all equipped with planetary clinker coolers. Kiln 8 is fitted with a conditioning tower for cooling of the hot exit gases. All the kilns and the raw mill are equipped with ESPs to limit dust emissions.

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

Limestone used at Slurry is mined from several quarries adjacent to the plant, two to three kilometres away.

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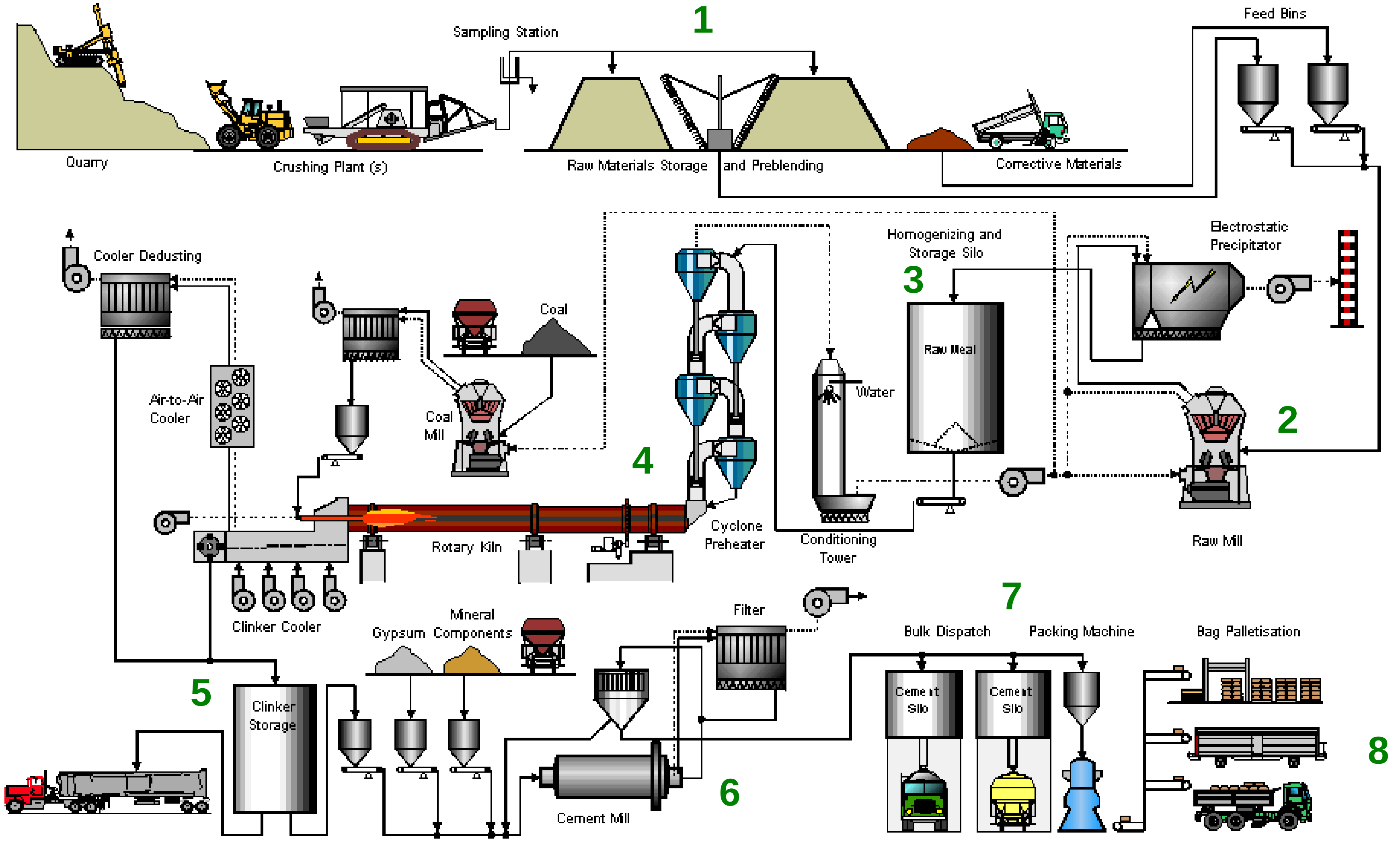

Figure 2-1: Process Flow diagram of the cement manufacturing process. The green numbers correspond with the numbers on the Slurry material flow diagram, which follows at the end of this section

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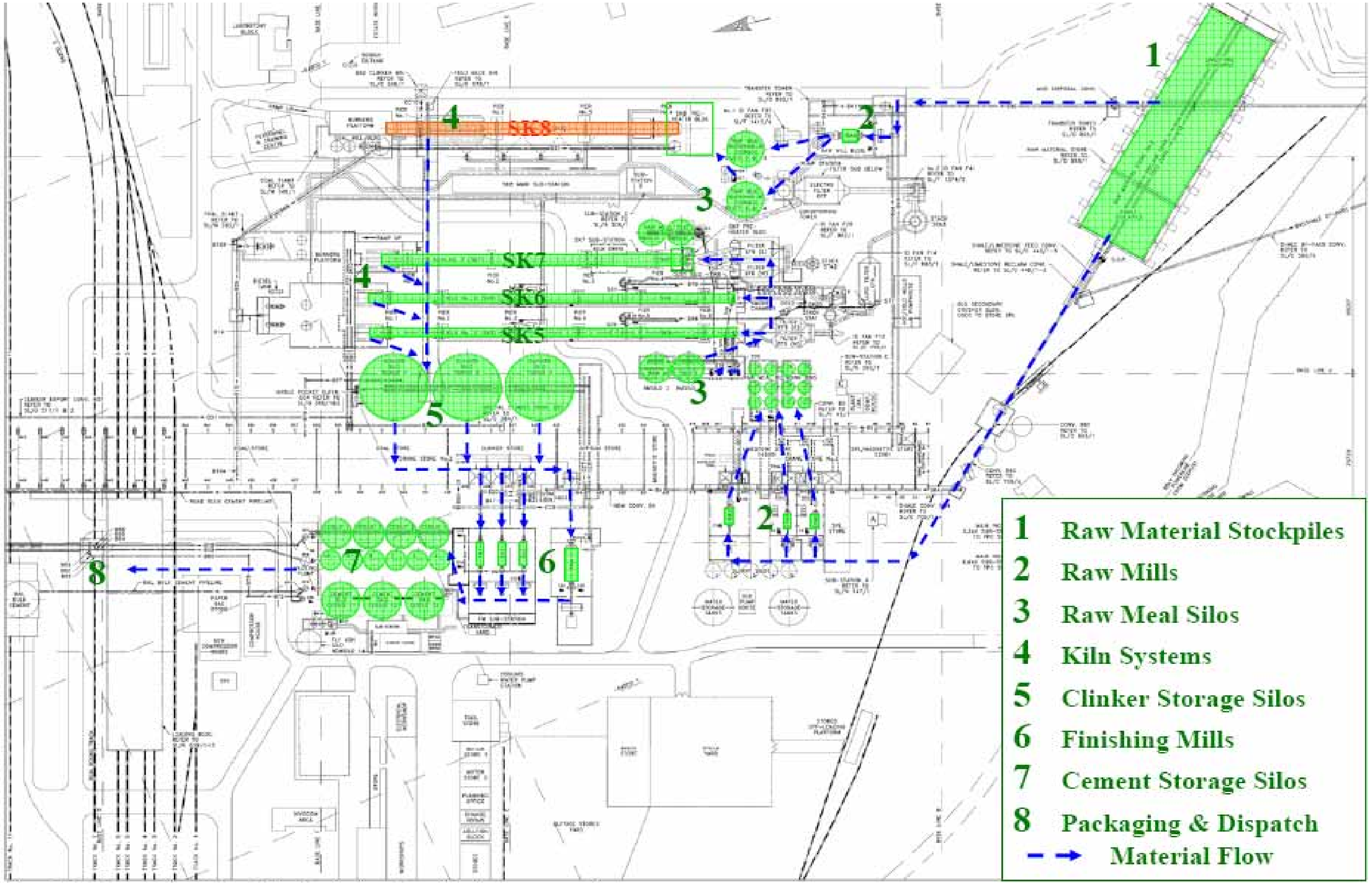

Figure 2-2: Site layout plan indicating the flow of materials in the cement making process

The limestone is mined and stored in stockpiles (1). The raw materials are sent to the raw mills to be finely milled (2), and stored and blended in the raw meal silos (3). The raw meal is fed to the kiln system (4); in the case of SK 7 and SK8, the raw meal is fed to the preheater and is heated prior to entering the kiln, and in the case of SK5 and SK6, the raw meal enters the kiln directly (4). The clinker formed in the kiln is cooled and sent via conveyers to the clinker storage silos (5). The clinker, together with extenders such as gypsum, are milled in the finishing mills (6) to form the final cement product, which is stored in cement storage silos (7). The cement is then sent to be packaged and dispatched (8). *SK 8 is highlighted in orange as secondary materials will be introduced to this kiln.*

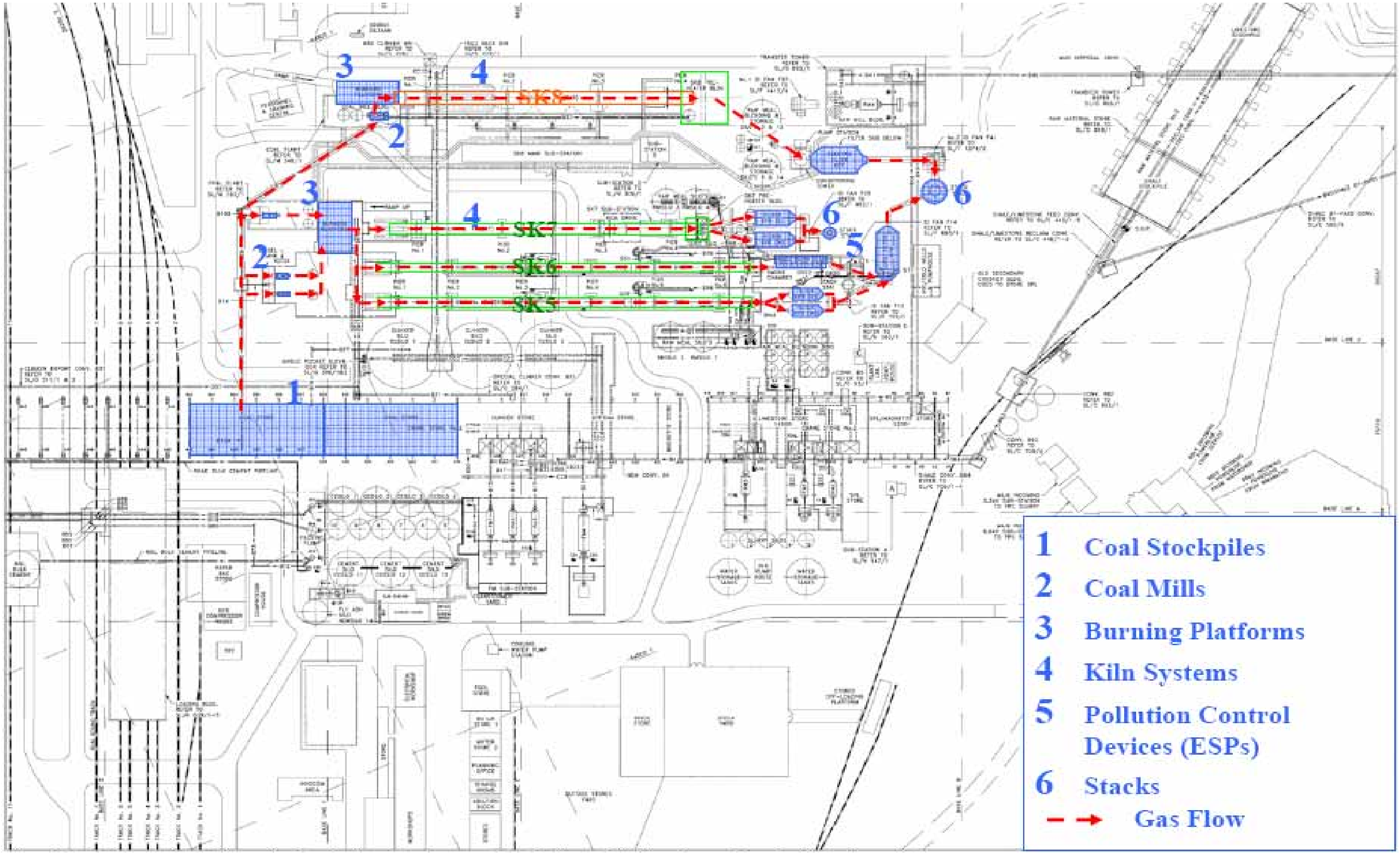

Figure 2-3: Site layout plan of Slurry showing the flow of fuel sources into the kiln and the flow of gases from the kiln to the stacks

The coal, used for firing the kiln, is stored in stockpiles (1). It is sent to the coal mills (2), where is finely milled, and then transferred to the burning platforms (3), where the amount of coal fed to the kiln firing system is carefully managed. The coal is burned at the firing end of the kiln (4), and the hot gases produced travel along the kiln to heat the material. In the case of SK7 and SK8, the gases leave the kiln and travel through the preheater. Once the gases leave the kiln system, they are sent through a pollution control device (5), or electrostatic precipitators (ESPs) at Slurry. The gas then exits the stacks (6). *SK 8 is highlighted in orange as secondary materials will be introduced to this kiln.*.

Figure 2-4: Photograph of the limestone stockpiles at Slurry. At the quarry, the limestone is crushed to particles approximately 25mm in size and stored on stockpiles, where the material is homogenised prior to milling.

The limestone is passed through multiple-stage crushers at the quarry, where it is reduced to less than 19mm in diameter. Shale and magnetite 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 Slurry 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 are burned per 100 tons of clinker.

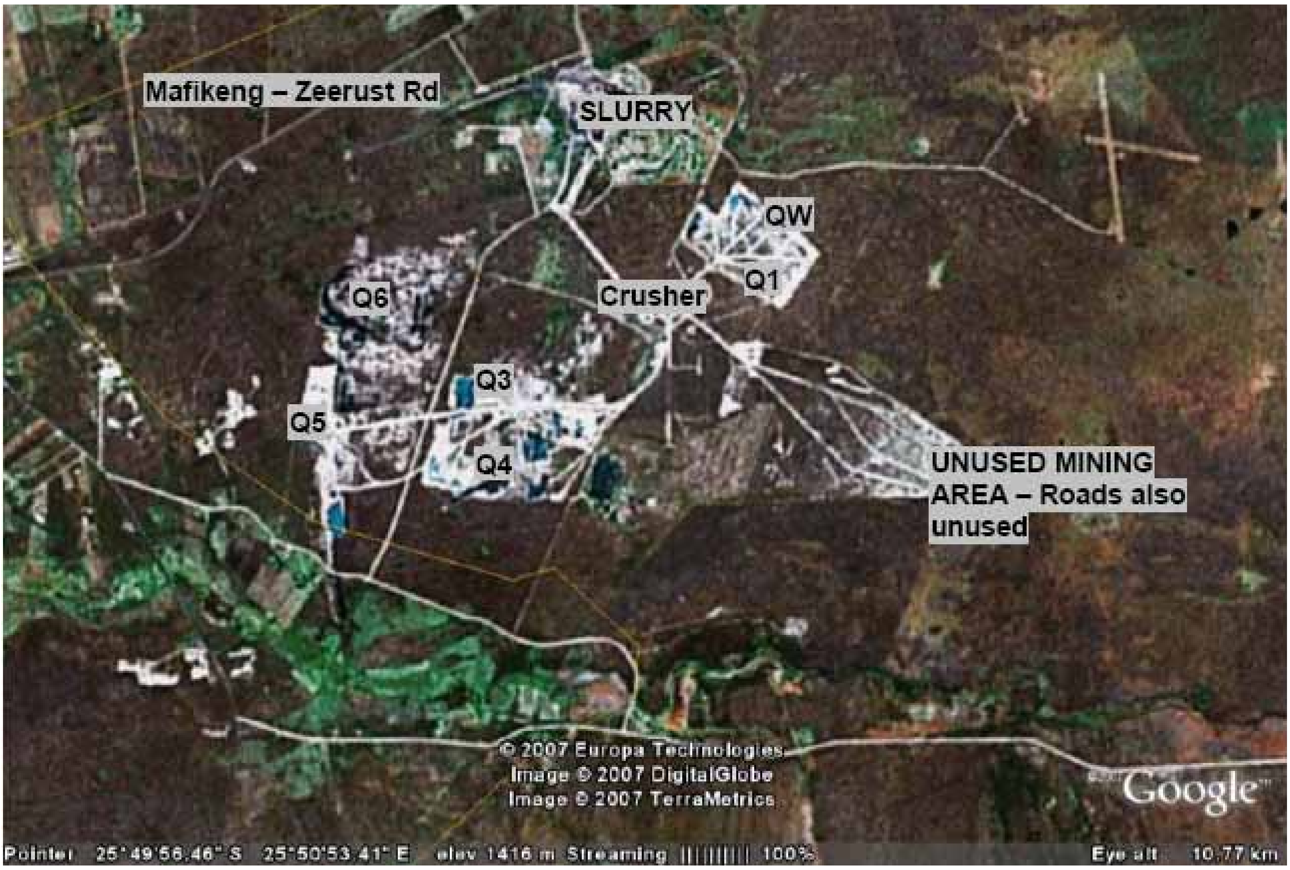

Figure 2-5: Google Image showing the location of the quarries and their proximity to the factory.

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. At Slurry, boiler ash, which is a by-product from power stations and a source of aluminium, and magnetite, which is a by-product from steel factories and a source of iron are also used as secondary raw materials.

Apart from raw materials, additional fuel sources may be added to the coal to fire the kiln. Examples include Spent Pot Lining (SPL) and tyres. SPL is used as a secondary fuel material only in Kiln 8 at Slurry (SK8). It is received from BHP Billiton, Richards Bay, and stored at the quarry. It is crushed and transported to the factory, where it is included with the coal for the firing of the kilns.

Synthetic gypsum is also used at Slurry, to replace natural gypsum. Synthetic gypsum is a by-product from the fertiliser industry, and contains primarily $CaSO_4$.

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 2-6: Photograph of the Slurry factory showing the four kilns, from left to right: SK5, SK6, SK7 (as indicated in green) and SK8 (indicated in orange).

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. SK 8 has a 4-stage cyclone pre-heater, and SK7 has a 1-stage pre-heater. SK5 and SK6 are long dry kilns and have no preheater.

Figure 2-7: Photograph of the preheater of Kiln 8 at Slurry. The raw meal silo is pictured to the right of the preheater.

The prepared raw mix, now referred to as kiln feed, is fed to the kiln system – directly into the long dry kilns, SK5 and SK6, and into the preheaters of SK7 and SK8.

a) SK7 and SK8: Preheater Kilns

The hot gas produced from the burning coal enters the preheater and heats the kiln feed, such that the temperature entering the kiln is between 900°C and 1,000°C (in the case of SK8), 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 (as in the case of SK8), the overall heat consumption is <4MJ/kg of clinker.

b) SK5 and SK6: Long Dry Kilns

Long dry kilns are not equipped with preheaters and as a result, the initial heating of the kiln feed occurs in the kiln itself. To ensure sufficient heating for the thermal processes, the kiln is designed to be much longer. Long dry kilns represent an older less energy efficient cement manufacturing technology, and are being phased out as more cement manufacturing plants change to the newer shorter kilns with multi-stage preheaters.

Figure 2-8: Photograph of Kiln 8, showing the planetary clinker cooler at the front of the kiln. Kiln 7 is visible in the left of the photograph.

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 SK8, and in the back end of SK5 and SK6.

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 2-7.

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 Slurry, exhaust gases exit through two stacks. Gases from SK7 are dedusted in an ESP and exit through a single stack. Exhaust gases from SK5, SK6 and SK8 are dedusted in ESPs for each kiln, and all exit through the second stack. In other words emissions from the second stack at Slurry are comprised of gases from SK5, SK6 and SK8.

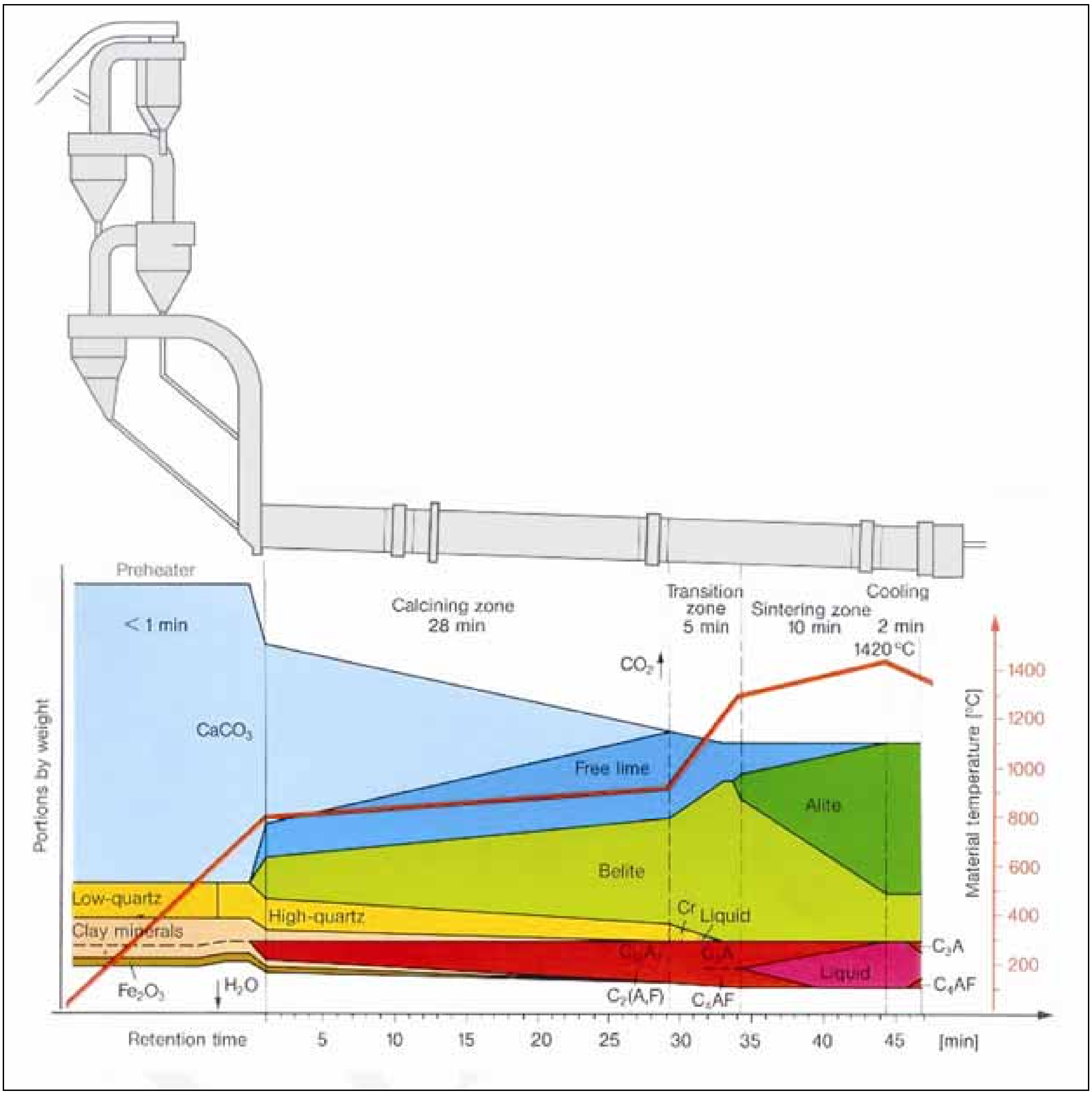

Figure 2-9: Kiln reaction profile for long dry kiln without calciner[5].

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 800°C. It is then transported to the clinker storage silos.

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

Figure 2-10: 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.

Slurry manufactures OPC, Surebuild and RHC; each cement type is 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.

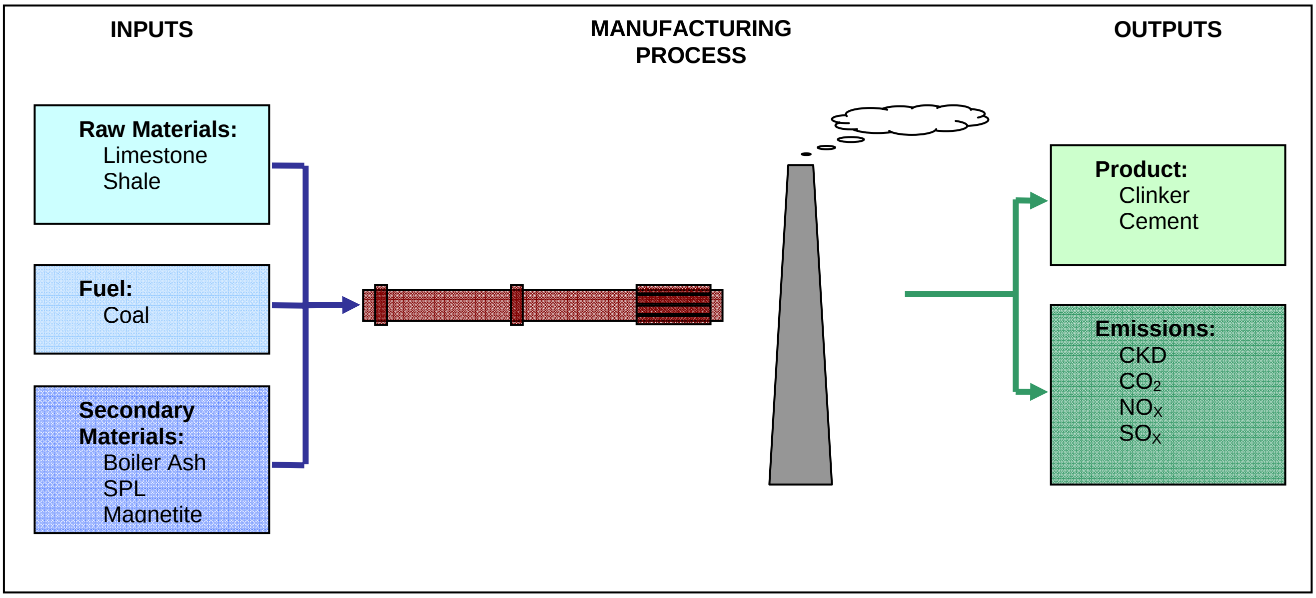

Figure 2-11: Flow diagram showing inputs and outputs in the cement manufacturing process

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