Introduction

Padeswood Cement Works is located to the south of Buckley, near Mold, Flintshire, CH7 4HB. The cement works is owned and operated by Castle Cement Limited (the Applicant), trading as Heidelberg Materials UK Cement (from now on referred to as Heidelberg Materials). Heidelberg Materials is one of the largest building materials manufacturers in the world and the global market leader in aggregates, with leading positions in asphalt, cement, concrete, and other downstream activities.

Heidelberg Materials operates a cement production works at Padeswood, Flintshire, under Environmental Permit **EPR/BL1096IB**. The cement produced at the Padeswood Cement Works is sold primarily in bulk for ready-mix concrete and the production of concrete products. Bagged cement is also produced and distributed through builders' merchants. The Applicant is a national supplier, and Padeswood Cement Works is connected to the rail network, enabling cement to be delivered to rail depots located in London, Glasgow, and Avonmouth. Bulk and packed cements are also delivered to regional customers by road. The plant currently employs 117 people.

Manufacturing of cement at Padeswood involves three main steps:

Step 1: Crushing and blending of raw materials and additives to produce "raw meal".

Limestone brought from the nearby Cefn Mawr quarry is delivered to a reception hopper in a purpose-built enclosure, from where it is transferred to the Crane Store using a system of conveyor belts. The other raw materials are also stored here. From the Crane Store, all the raw materials (except gypsum) are taken by conveyor to the dry raw milling equipment to produce raw meal.

Step 2: Clinker Manufacture.

The raw meal is transported to the top of the pre-heater tower cyclones. The mixture descends through the cyclones, where it is heated to a temperature of about 850ºC and is then calcined (calcining involves breaking down the carbonates in the limestone to produce oxides). The calcinated material is further heated in the rotating kiln to produce clinker at a temperature of 1450ºC. The clinker is cooled to about 100ºC and discharged from the kiln's cooler and conveyed to a storage building.

The calciner can be heated using Waste Derived Fuels (WDFs), including but not limited to Profuel (made from paper, plastic, fibre, and textiles), Solid Recovered Fuel (SRF, which is similar to Profuel but reclaimed from 'black bag' waste), meat and bone meal (MBM), shredded tyres, or coal/petcoke. In addition, hot gas from the kiln and the clinker cooler is recovered to assist combustion and reduce overall energy requirements. The burner for kiln 4 can be fuelled by WDFs, including but not limited to Cemfuel, SRF, Profuel, MBM, and the coal/petcoke mix.

Combustion gases pass from the pre-heater tower and are used for drying raw materials in the mill or are cooled and then cleaned in the bag filter prior to release at the stack. Dust collected at the bag filter is returned to the pre-heater tower and is mixed with the raw meal. Continuous gas analysis at the stack monitors emissions to air for permit compliance.

Step 3: Cement Milling

Conveyor belts transfer the clinker from the storage facility to the feed hoppers on the cement mills, where it is mixed with gypsum and may be ground with additives such as fillers, grinding aids, and strength enhancers to make the final cement product. The five cement mills each have fabric filters to minimise releases of dust to air. The cement produced is pneumatically conveyed to the bulk silos fitted with dust filters on the vents. From these storage silos, cement is extracted either directly to bulk road and rail tankers or to the bagging plant.

Variation

Heidelberg Materials is committed to reducing carbon emissions in every area of its business and has already made significant progress, with annual carbon emissions less than half the level they were in 1990. The ambition of reaching net zero carbon emissions by 2050 can only be achieved by utilising carbon capture and storage (CCS) technology. Padeswood Carbon Capture and Storage could deliver the first net zero carbon capture cement works in the United Kingdom.

The Padeswood CCS project is a post-combustion carbon capture and compression (PCCC) plant with natural gas-fired combined heat and power (CHP) to supply the heat and power requirements of the PCCC plant. The carbon dioxide (CO_2) arising from the CHP will be treated in the PCCC as well. In addition, waste heat recovery units (WHRU) are included in the scope to harvest waste heat from the cement process and complement the heat supply from the CHP.

The kiln gas cleaning will be enhanced with lime injection to control Hydrogen Chloride (HCl) and Sulphur Dioxide (SO_2) entering the capture plant. To protect the integrity of process equipment, in particular aluminium heat exchangers, activated carbon injection will be used to control the mercury concentration entering the capture plant.

A selective catalytic reduction and oxidation unit (SCR/O) will be integrated with the CHP to pre-treat the gases from the cement plant to reduce carbon monoxide (CO), ammonia (NH_3), oxides of nitrogen (NOx), and volatile organic compounds (VOC) content to ensure the PCCC is operated efficiently and emissions are minimised.

The combined gases from the cement kiln and CHP are cooled in a gas/gas heat exchanger and quencher, and then pass through the absorber. The absorber, which is the ‘capture’ part of the process, can be described as a giant washing machine that removes to CO_2 from the gas and traps it in the liquid. This liquid, is mixture of water and amines (like the detergent in the washing machine), grabs onto the CO_2 and holds it tight, removing it from the flue gas.

Amines are organic compounds derived from ammonia, that readily react with CO_2. Amines are particularly effective for this purpose because they have a high affinity for CO_2, allowing for efficient absorption even at low concentrations. This technology is relatively mature in the petrochemical and gas industries, however, it is considered new technology for the cement industry. Amine based carbon capture can be integrated into existing industrial processes for large-scale CO_2 reduction. Amine solutions for the carbon capture process have been in development for many years and are ever evolving.

Heidelberg Materials have selected KS21^{TM} amine developed by Mitsubishi solution for the Padeswood project. Compared with generic amines and its predecessors, KS-21 provides energy-saving performance, reduces operating costs, and lower amine emissions.

With the CO_2 removed, the remaining gases pass through the wash tower to remove any carried-over amine droplets from the gas. The clean gas is then reheated at the gas/gas heat exchanger prior to being released at the stack. The emissions from the new stack will be reduced in comparison to the existing plant.

The amine solution combined with CO_2 is transferred to the regenerator column, where it is heated to release the CO_2. The amine is recycled back to the absorber. The CO_2 is compressed, dried, and purified to meet the pipeline and storage specifications. The CO_2 then flows through the CO_2 pipeline to storage.

The carbon capture system requires clean water to operate and therefore requires a water treatment plant to produce demineralised water. The mineral-rich wastewater stream will be used in the cement plant for cooling purposes instead of borehole or surface water used at present. The overall scope of this project is for zero process liquid discharge.

Given the above, the proposed development aims to capture approximately 800,000 tonnes of carbon dioxide (CO_2) per year from the cement works and will comprise the following main project components:

1. *Pre-Carbon Capture Plant modifications*

A new ducting from the existing bag filter will be installed to transfer the flue gas to the CHP. Continuous monitors for process control and asset protection will be installed on the ducting, including equipment such as gas analysers, mercury analysers, and particulate analysers. Activated carbon injection to the kiln bag filter will be installed to control the mercury concentration. Although this is an asset protection requirement, there is expected to be a reduction of mercury at the stack compared with current levels. There will also be lime injection to the bag filter for SO_2 and HCl control to limit the concentration in the flue gas entering the carbon capture process.

2. *Combined Heat and Power (CHP) and Selective Catalytic Reactor (SCR)*

The flue gas flows from the existing kiln bag filter to the CHP. Natural gas, kiln gases, and ambient air are combusted in the CHP. The use of kiln gas for combustion reduces the total gas flow from the CHP to the capture plant. The gas flow is treated in the selective catalytic reduction unit to reduce NOx, CO, TOC, and NH_3 entering the capture plant. Electrical energy from the steam turbine is used to power the plant, and the steam from the CHP is used to heat the carbon capture plant.

3. *Gas gas heat exchanger*

Flue gas must be cooled before entry to the quencher to enable efficient treatment. Clean gas post-CO_2 removal is reheated in this heat exchanger prior to release at the stack to improve dispersion.

4. *Quencher*

The quencher is the final flue gas pre-treatment stage prior to CO_2 capture. The flue gas enters the bottom of the quencher, where slaked lime is sprayed into the quencher to remove the remaining SOx from the flue gas. Further cooling of the flue gas occurs in the quencher prior to entering the wet electrostatic precipitator (ESP) at the top of the quencher. The wet ESP removes particulates from the flue gas.

5. *Absorber*

The gas stream flows up through the absorber whilst the amine solvent flows down. The CO_2 is absorbed into the solvent, creating a carbon rich amine stream which flows out of the bottom of the absorber to the regenerator. The flue gas exits from the top and flows to the wash tower.

6. *Wash tower*

The flue gas enters the wash tower for final treatment before returning back through the gas/gas heat exchanger. The wash tower uses water and acid to clean the flue gas of amine droplets. The amine captured re-enters the system via a makeup stream. Reclaiming amine at this stage not only helps to adhere to emission limits but also reduces the amount of fresh amine solution required.

7. *Stack*

The CCS stack is similar to the existing stack, albeit in a new location within the carbon capture plant. There will be a new emission point on the CCS stack with appropriate monitors installed.

8. *Regenerator*

The CO_2 is stripped from the solvent at this point in the process. The carbon-rich amine stream is heated up in a heat exchanger before entering the top of the regenerator column. A reboiler at the base of the regenerator column uses steam from the CHP to heat the amine to separate the CO_2.

With most of the CO_2 removed, the amine solution enters the reboiler, where it is heated enough to remove any remaining CO_2. The CO_2 then re-enters the regenerator and joins the pure CO_2 gas stream travelling to the compressor system. The lean amine that has been regenerated is cooled and recycles back around, ready to capture more CO_2 from the flue gas in the absorber.

9. CO_2 compressor

This is the final stage before leaving the site. The CO_2 is compressed and purified to remove water and oxygen. The chemical composition is analysed before leaving the site through a pipeline. This pipeline transfers the CO_2 to storage.

10. Ancillary Tanks to support processes

11. Water emission point from the storage lagoon

Permitted Activities

As detailed above, this variation outlines the installation of a carbon capture plant with associated flue gas pretreatment for the site to achieve net zero CO_2 emissions. Equipment to be installed as part of the carbon capture process includes a combined heat and power plant (CHP), SCR catalyst, quencher tower, absorber column, wash tower, and regenerator.

New permitted activities to be added, or existing activities to be changed on the existing permit **(ref: EPR/BL1096IB)**, are as follows:

Primary and new activities

- C0_2 Capture Plant including flue gas pre-treatment.
    - **6.10 Part A (1) (a)** - Carbon capture and storage
        - Capture of carbon dioxide streams from an installation for the purposes of geological storage pursuant to Directive 2009/31/EC of the European Parliament and of the Council on the geological storage of carbon dioxide.
- Combined Heat and Power (CHP) Plant
    - **1.1 Part A (1) (a)** - Burning any fuel in an appliance with a rated thermal input of 50 or more megawatts.

Secondary and changed activities.

- Activated carbon system for mercury capture and injection to cement process
    - **3.1 Part A (1) (a) -** Producing cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or in other kilns with a production capacity exceeding 50 tonnes per day.
    - **3.1 Part A (2) (a)** - Grinding cement clinker