

## Introduction

This application to vary Padeswood Cement Works' existing environmental permit (ref: **EPR/BL1096IB**) includes the installation of a carbon capture plant with associated flue gas pretreatment for the site to achieve net zero CO<sub>2</sub> emissions.

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<sub>2</sub>) arising from cement kiln and the CHP will be treated in the PCCC. 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.

Key equipment to be installed as part of the carbon capture process includes a combined heat and power plant (CHP), Selective Catalytic Reduction (SCR), quencher tower, absorber column, wash tower and regenerator.

New permitted activities to be added, or existing activities to be changed on the existing are as follows:

### Primary and new activities

- CO<sub>2</sub> 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.

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## CCS C3-3a-2 Technical Description for Padeswood Cement Works CCS Plant

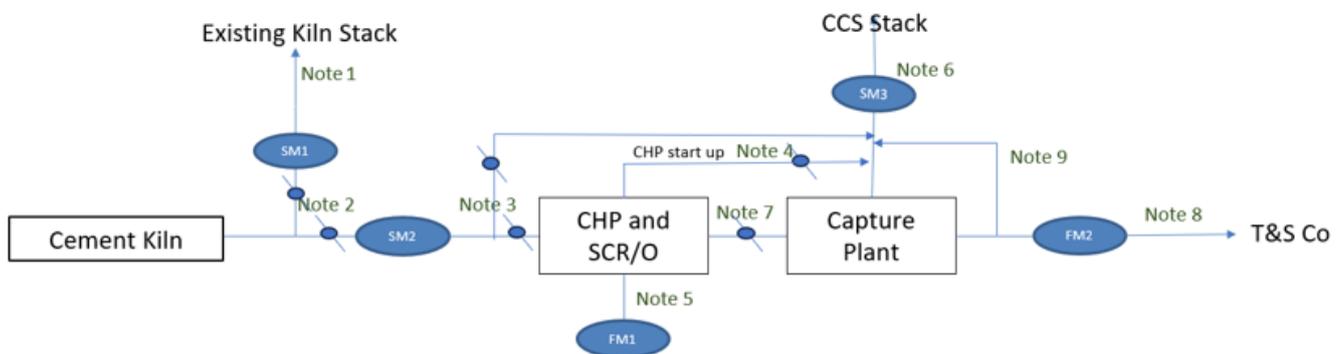
This Technical Description should be read in conjunction with the following documents:

- CCS-C2-5a-03 Carbon Capture Plant Block Plan
- CCS-C3-3b-01-01 Air Quality Assessment Report
- CCS-C3-2 Surface Drains layout and water emission points
- CCS-SUP-04 Site Drainage Technical Note
- CCS-SUP-02 Environmental Aspect and Impact Register
- CCS-SUP-06 Tank specification
- CCS-SUP-07 Block flow diagram
- CCS-SUP-08 Emission, waste and discharge schedule
- CCS-SUP-09 Effluent summary
- CCS-SUP-10 Environmental basis of design
- CCS-SUP-11 Environmental critical equipment identification procedure

All documents can be found accompanying this application and are referenced where possible throughout this document.

### 1. Pre-Carbon Capture Plant modifications

Flue gas from the Cement plant will be diverted from upstream of the existing blower to the new CHP Flue Gas Blower which will pressurise the flue gas to route to the CHP unit. All the gas from the kiln and any combustion air required for the CHP operation will then pass through the selective catalytic reduction and oxidation unit to clean the gas flow before entering the carbon capture unit.



1. Existing kiln stack CEMS cement kiln start up emissions and CCS plant outages duplicate (live and standby) CEMS
2. Changeover dampers for operation with or without CCS
3. Change over damper for operation with CCS or without CCS using new stack
4. CHP start up venting via the capture plant stack SM3.
5. Natural gas used in the CHP will be measured using a fiscal meter FM1.
6. Emission from capture plant absorber measured at SM3 duplicate stack CEMS (live and standby)
7. Changeover damper for CHP warm up process control instrumentation for CHP performance.
8. CO<sub>2</sub> compressed and sent to T&S Co measured by fiscal meter FM2.
9. Post compression venting out of specification CO<sub>2</sub> etc. (control valves not shown)

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 gas analyser, mercury analyser and particulate analyser. All gases from the combined processes will leave via the CCS stack.

Activated carbon injection to the kiln bag filter will be installed to control the mercury concentration entering the CCP. Although this is an asset protection requirement, there is expected to be a reduction of mercury emissions at the stack compared with existing operation.

Lime injection to the bag filter or kiln feed elevator will be used for SO<sub>2</sub> and HCl control; to limit the concentration in the flue gas entering the carbon capture process.

If CHP/SCR is not working flue gas can bypass the CHP by either diverting the flue gas to the new CCS stack or via the existing kiln chimney fan to the existing kiln stack.

If the Carbon Capture Plant (CCP) is not working, kiln flue gas can be routed through the CHP/SCR to produce steam and power to start up the capture plant any excess power can be used in the cement plant.

## 1.1 Process Description

Connection of the cement plant to the CCP will be via a pipe rack running east to west from the existing kiln stack to the inlet of the CHP. This pipe rack will carry the gas duct transporting the flue gas to the CHP, the pipework for the heat transfer fluid (HTF) to and from the waste heat recovery unit (WHRU), the water for the CCP, the ammonia water for the SCR from the existing ammonia tank, and the effluents from the CCP for use in the cement plant. The analysers for process control will be located on this section of flue gas duct. Further information on the monitors is detailed in section 1.3. Condition monitoring of pipework will be used as part of the planned preventative maintenance programme.

WHRU will be installed on both the clinker cooler and the preheater tower. HTF pipework will join directly from the pipe rack to the WHRUs.

The following effluents will be created whilst operating the CCP:

- Flue Gas Desulfurisation (FGD) waste water from the quencher
- Reclaimed waste from the amine reclaimer
- Waste water from the acid wash unit in the wash tower
- Waste from the amine filtration unit
- Condensate water from the CO<sub>2</sub> dehydration unit

Effluents containing trace organic compounds will be transferred to the calciner in the kiln preheater tower (PHT) and other water effluents will be utilised in other processes such as kiln Gas Conditioning Tower (GCT), raw milling or cement milling instead of abstracted/harvested water. There will be no point source emission to water from this process.

The table below details proposed European waste catalogue codes (EWC) for the effluents, all of which will need adding to table S2.2 of the permit if required.

Waste	Proposed EWC
FGD waste water from the quencher to be used in the raw mill, cement mills or GCT	10 01 19 wastes from gas cleaning other than those mentioned in 10 01 05, 10 01 07 and 10 01 18
Reclaimed waste from the reclaimer to be used in the calciner	14 06 03 other solvents and solvent mixtures
Waste water from the acid wash unit to be used in the calciner	10 01 19 wastes from gas cleaning other than those mentioned in 10 01 05, 10 01 07 and 10 01 18
Waste from filtration unit to be used in the calciner	14 06 05 sludges or solid wastes containing other solvents
Condensate water from the dehydration unit to be used in the calciner	10 01 19 wastes from gas cleaning other than those mentioned in 10 01 05, 10 01 07 and 10 01 18

If the above waste codes are added to table S2.2 the waste code of practice (WCoP) risk assessments will be completed.

## Mercury control

The proposed mercury concentration limit for the kiln flue gas set in the basis of design for the carbon capture plant is 0.01mg/Nm<sup>3</sup>, this is significantly below the emission limit value of 0.05 mg/Nm<sup>3</sup> defined in the permit. Castle Cement will install activated carbon injection 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.

Mercury abatement in the cement industry has been in use for many years. Activated carbon is injected at the main bag filter to adsorb the mercury from the gas stream. Over time, the mercury concentration increases within the kiln system (and raw mill circuit), and periodically, bag filter dust must be removed to reduce the mercury from circulation. Without breaking the cycle in this manner, the mercury would become saturated with in the system and the emission would start to rise.

The dust that is removed will be used in the cement milling process and added to finished product as a minor additional constituent (MAC). For the Padeswood project, the dust will be removed from the kiln main bag filter, stored in a silo, and then added to cement milling process. A storage silo is required to manage removal rates, the cement mill addition rate, and a buffer for when the cement mills are off for maintenance with the kiln still operational. This is common practice within Europe and described in EU Cement, Lime and Magnesium BAT (Best Available Technique) document section 1.3.4.7.1.

## SO<sub>2</sub> & HCl control

SO<sub>2</sub> and HCl can have a detrimental impact on the operation of the carbon capture plant and therefore these gases need to be controlled at the cement plant before the gas stream enters the CCP. The control of sulphur dioxide (SO<sub>2</sub>) and hydrogen chloride (HCl) emissions from cement flue gas can be effectively achieved through the injection of lime, specifically hydrated lime (Ca(OH)<sub>2</sub>). This process involves a chemical reaction where SO<sub>2</sub> reacts with hydrated lime to form calcium sulphite (CaSO<sub>3</sub>) and water (H<sub>2</sub>O). Similarly, the small amounts of HCl in the gas react with the lime to form calcium chloride (CaCl<sub>2</sub>). Castle cement will install lime injection on the existing cement plant to control SO<sub>2</sub> and HCl prior to the flue gas entering the CHP of the carbon capture plant.

The lime will be injected into the ducting from the preheater tower to the bag filter and/or the kiln feed elevator. The lime will mix with the flue gas, react with the SO<sub>2</sub> and HCl and be retained in the main bag filter. Dust from the main bag filter is returned to the kiln.

SO<sub>2</sub> and HCl within the flue gas is already a very low concentration. Low usage of lime is anticipated, and this system may therefore not be in use at all times. The presence of calcium sulphite and calcium chloride will react in the kiln system will not impact on emissions from the kiln process.

## 1.2 Infrastructure

### Tank/vessel specifications

Additional storage silos with suitable abatement systems are required for lime, activated carbon and filter dust. A transport and dosage system will also be required for conveying filter dust to the cement mill. There are no additional storage tanks or vessels directly associated with the pre capture section of the CCS Process.

## 1.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

Although there are to be no additional point source emissions to air or water from this stage of the process, the flue gas monitors will still be sourced to the MCERTS standard. Monitoring at this stage is for process control only.

A mercury CEMs analyser will be installed to monitor and manage the activated carbon injection to achieve design criteria.

A particulate monitor along with gas analysers and will be installed in the duct to measure typical combustion parameters. Again, as for the above compounds, monitoring at this stage is for process control only as there will be no point source emission to air.

## 2. General arrangement of the CCS plant area

The layout of the carbon capture plant site can be viewed in the accompanying block plan (CCS-C2-5a-03 Carbon Capture Plant Block Plan) and further supporting information within the drainage technical note (CCS-SUP-04 Site Drainage Technical Note) and the surface drain layout (CCS-C3-2 Surface Drains layout and water emission points).

General statements on the design of the site surfaces are below and the emission point to water from this design is detailed in section 12.

### Secondary containment and site surfacing

#### *External areas subject to potential contamination (amine or oil)*

In these areas a concrete slab laid to falls (min. 1:200, HPP +100.050, LPP +99.900) with an integrated (raised) kerb around their perimeter is to be constructed. Minimum slab thickness to be 200 mm. Slab to be made of reinforced concrete RC32/40. Any equipment located within slab's footprint to be sat on elevated plinth.

#### *External areas subject to potential contamination (secondary containment):*

In these areas concrete bunds comprising reinforced concrete slab and reinforced concrete walls are to be erected. Both slab and walls are to be designed as liquid retaining structures. A watertight joint, allowing for differential settlement needs to be formed between a bottom slab and a tank foundation. Minimum capacity of concrete bunds to be determined using the CIRIA C736 guidance.

#### *Remaining external process areas:*

In these areas a concrete slab laid to falls (min. 1:200, HPP +100.050, LPP +99.900) is to be constructed. Minimum slab thickness to be 200 mm. Slab to be made of reinforced concrete RC32/40. Any equipment located within slab's footprint to be sat on elevated plinth.

#### *Areas between concrete hardstandings/slabs/paving:*

Areas meant for foot traffic to be 150 mm thick concrete (PAV2) pavement with one layer of reinforcement. Infills between concrete slabs/bunds/pavements and roads to be to be covered with a min. 150 mm thick layer of gravel.

#### *Internal building floors:*

All internal floors to be constructed with reinforced concrete. These floors are to be laid flat and to be elevated 200 mm above the grade level.

## 3. Combined Heat and Power (CHP) and Selective Catalytic Reactor (SCR)

The flue gas flows from the existing kiln bag filter to 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 NO<sub>x</sub>, CO, TOC and NH<sub>3</sub> entering the capture plant. Electrical energy from the steam turbine is used to power the plant and the steam from the CHP boiler is used to heat the carbon capture plant.

### 3.1 Process Description

#### CHP

The Combined Heat and Power (CHP) plant provides the heat and power requirements for the Carbon Capture Plant (CCP). The combustion heat is utilised to produce high pressure (HP) Steam that is fed to a Steam Turbine Generator

(STG) for electrical power generation. Additionally, it is necessary to reduce NO<sub>x</sub> concentration in the kiln exit gas before it comes into contact with the solvent used in the CCU as NO<sub>2</sub> can cause amine degradation.

Atmospheric air from Combustion air Blower will be heated through the Combustion Air Preheater using Heat Transfer Fluid (HTF). Part of the flue gas from the cement plant via CHP Flue gas Blower will be diverted to the windbox and combined with air to provide combustion oxygen to the CHP boiler's burner. Natural gas will be mixed with the flue gas and air mixture before burning in the boiler. For a good combustion and minimising Methane slip in the CHP Boiler, the Oxygen to Natural Gas stoichiometric ratio needs to be maintained, while also minimising increase in flue gas flowrate to CCP.

The following information will be provided to the Burner management system for the boiler to control the firing in the boiler:

- Flue Gas flow
- Flue Gas O<sub>2</sub> content
- Air Flow
- O<sub>2</sub>, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub> composition of the flue gas from the boiler.
- Steam inlet pressure to the STG.

The Burner Management System (BMS) will control the Combustion air blower speed and natural gas flow rate. Flue gas from the boiler will be routed through Primary and Secondary steam superheater exchangers before entering SCR. High Pressure (HP) Boiler Feed Water pump will supply boiler feed water (BFW) to the boiler drum based on level control.

High pressure steam produced from the boiler will be superheated in the Primary HP Steam Superheater. Superheated steam temperature will be control by injecting BFW through the HP Steam Attemperator (before routing to the Secondary HP Steam Superheater).

Superheated HP steam will be used to generate power and low pressure (LP) steam through the Steam Turbine Generator. Back pressure Steam Turbine Generator will produce the electricity required for the CCP. A steam turbine generator was selected for the CHP as it produced a lower volume of exhaust gas (and hence higher CO<sub>2</sub> concentration in the gas) than other generators such as a gas turbine or combined cycle gas turbine. This reduces the total gas flow through the capture plant and enables a reduction in the size of the capture plant equipment and energy consumption. Low Pressure (LP) steam will be used for the plant operation, mainly amine regeneration and reclamation. .

Boiler blowdown will be controlled and the blow down flow rate set point will be adjusted based on the BFW quality. Blowdown will be routed to the Blowdown Vessel.

## SCR

SCR is integrated with CHP in a single equipment structure. All the flue gas (kiln and CHP), at approx. 300°C, pass through the SCR. The SCR reduces NO<sub>x</sub> emissions by converting the NO<sub>x</sub> to Nitrogen (N<sub>2</sub>) and water (H<sub>2</sub>O) by reacting the NO<sub>x</sub> with Ammonia (NH<sub>3</sub>). Several chemical reactions occur in the SCR system to reduce NO or NO<sub>2</sub> to N<sub>2</sub>, the most common reactions are expressed below in equations 1 and 2. Reference to ammonia within this document relates to ammonia water at 24.5% ammonia concentration.

- $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$  (1)
- $2\text{NO}_2 + 4\text{NH}_3 + \text{O}_2 \rightarrow 3\text{N}_2 + 6\text{H}_2\text{O}$  (2)

The SCR process requires precise control of the ammonia injection rate and reaction temperature, correct control can achieve NO<sub>x</sub> conversion efficiency rates as high as to 95%. Ammonia vapour is introduced into the main flue gas stream via an ammonia injection grid to maximize ammonia contact with the flue gas. The presence of a small amount (around 10 mg/Nm<sup>3</sup>) SO<sub>2</sub> can enhance SCR catalysis reactions.

The source of ammonia for injection is from the existing ammonia tank southeast of the works. The pipeline for this fluid transfer will be along the pipe rack described in section 1.2. Condition monitoring of pipework will be used as part of the planned preventative maintenance programme. Ammonia is used in vapour form, provided from the

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ammonia vaporisation skid. This skid is equipped with electrical vaporisation to vaporise the ammonia water. Manifold and headers are used to assure even distribution of the ammonia gas.

NH<sub>3</sub> can combine with SO<sub>3</sub> to form Ammonium sulphates ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> and NH<sub>4</sub>HSO<sub>4</sub>), Equations 3 and 4, which deposit on and foul the catalyst, as well as piping and equipment. At low exhaust temperatures, generally below 250°C, the fouling by ammonium sulfate may lead to a deactivation of the SCR catalyst.

- $\text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4\text{HSO}_4$  (3)
- $2\text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{HSO}_4$  (4)

Ammonium sulfates formation is greatly depending on the level of SO<sub>3</sub> presence in the flue gas stream and the ammonia slip. In addition to the SO<sub>3</sub> presence in the flue gas from the cement plant (typically less than 0.1mg/Nm<sup>3</sup>), there will be additional SO<sub>3</sub> generation in the boiler/ burners and SCR due to the conversion of SO<sub>2</sub> to SO<sub>3</sub>. Typical SO<sub>2</sub> to SO<sub>3</sub> conversion levels are between 5 - 8% in the burners and a further 1 - 5% in the SCR catalyst. Space has been reserved in the SCR design for CO catalysts, but this is not considered necessary at this stage. CO catalysts can also cause a similar SO<sub>2</sub> to SO<sub>3</sub> conversion. Ammonium sulfates and SO<sub>3</sub> can have a large impact to amine losses from the absorber. Therefore, Sodium Based Solution is injected at the outlet of the SCR to convert SO<sub>3</sub> to a benign sodium sulfate solid that is collected downstream in the Quencher 1<sup>st</sup> stage effluent and send to the Cement Plant.

- $\text{SO}_3 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4$  (solid particle) + H<sub>2</sub>O

The solution will be injected through Dual-Fluid Injection Nozzles to improve mixing with the flue gases.

Flue gas from SCR is used to preheat BFW in Economiser before routed to the Gas-Gas Heater (GGH) to cool the untreated flue gas to the Quencher and heating the treated flue gas routed to the stack to improve dispersion.

## 3.2 Infrastructure

### Tank/vessel specifications

Ammonia is required for injection in SCR. Ammonia water is stored in an existing ammonia storage tank on the Cement plant. Ammonia water injection pumps will route the required ammonia to the SCR.

Item No	Description	Service	Capacity (m <sup>3</sup> )	Operating Volume (m <sup>3</sup> )	Dimensions (mm)				Material Specification	
					ID	Width	Length	Height	Shell	Heads
720-TK-003	Caustic Soda Tank	50% Caustic Soda	16.7	14	2400			4000	Carbon Steel	Carbon Steel

Table 3.2.1 –tanks associated with CHP and SCR

## 3.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

There are to be no additional point source emissions to air or water from this process. Flue gas monitoring at this stage is to supply information to the burner management system. If the CHP/SCR is operating without the CCP (during start up of the CHP and CCP) the emissions are monitored at the new CCP stack.

## 4. Gas gas heat exchanger and waste heat recovery

Flue gas must be cooled before entry to the quencher to enable efficient treatment. Clean gas post CO<sub>2</sub> removal is reheated in this heat exchanger prior to release at the stack to improve dispersion. The gas gas heat exchanger is a plate design to minimise leakage from the untreated to treated gas flows.

### 4.1 Process Description

#### Waste Heat Recovery

Heat will be recovered from the kiln by two new heat exchangers: one recovering heat from flue gases out of the Pre-Heater Tower (PHT), and another recovering heat from the hot air leaving the clinker cooler. Heat Transfer Fluid (HTF) will be used to recover the heat, and to preheat combustion air in the Combustion Air Preheater and produce low pressure (LP) steam in the HTF Evaporator. The existing clinker cooler air to air heat exchanger will be retained for use during start ups and when the PCCC is shut down and the kiln is still required to operate.

Heated HTF from both the WHR exchangers will be combined and sent to the HTF Suction Drum. Combining the HTF flows reduces fluctuations in HTF temperature as a result changes in the kiln and cooler operation.

HTF Circulation Pump will draw from the HTF Suction Drum and circulate hot HTF to the users the Combustion Air Preheater the HTF Evaporator to produce LP steam by boiling BFW. Cooled HTF from both the users will be combined and recirculated to the cement plant heat exchangers via the two Waste Heat Recovery (WHR) loops to recover heat.

In the first HTF WHR loop, HTF to Clinker cooler excess air / HTF Heat Exchanger Feed Pump circulates a fixed flow rate of HTF via the Clinker cooler excess air / HTF Heat Exchanger. In the second WHR loop, HTF to PHT / HTF Heat Exchanger Feed Pump circulates a fixed flow rate of HTF via the PHT / HTF Heat Exchanger. Bypass lines for HTF and PHT flue gas are provided for the PHT / HTF Heat Exchanger, to allow continued kiln operation when cleaning the HTF / PHT Heat Exchanger due to buildup of kiln dust. A hot HTF recycle line is also provided to maintain the kiln flue gas temperature for raw mill operation if for example the raw material moisture is high and more drying capacity is needed.

The HTF Overhead Drum at the highest elevation in the system is used to vent any water vapour and non-condensables from the HTF circulation system during start-up, and to accommodate expansion/contraction of the HTF fluid due to temperature changes.

HTF Collection Sump is a start-up and maintenance drain sump and is designed to hold the full HTF inventory during any shutdown of the system. For system maintenance the HTF inventory will be controlled to the minimum practical level using the normal process connections to the downstream system. All the remaining HTF in the equipment will be drained using pressurized N<sub>2</sub>. Following maintenance, the HTF Transfer Pump will transfer fluid from the sump to the main HTF circuit low point to fill the system and expel any vapour. The HTF Collection Sump Drain Pump is provided to transfer off-specification HTF from the HTF Collection Sump to a tanker for disposal.

### 4.2 Infrastructure

#### Tank/vessel specifications

The only vessel associated with this process is the expansion tank of the WHRU located at the top of the unit adjacent to the PHT.

### 4.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

There are to be no additional point source emissions to air or water from this process.

## 5. Quencher

The Quencher is the final flue gas pre-treatment stage prior to CO<sub>2</sub> capture. The primary role of the quencher is cooling the flue gas to optimise the capture of CO<sub>2</sub> in the absorber. The quencher also removes SO<sub>x</sub> and particulates. The flue gas enters the bottom of the quencher, as it rises slaked lime is sprayed into the quencher to remove the remaining SO<sub>x</sub> from the flue gas. Direct contact with water is used to cool flue gas and then the wet electrostatic precipitator (ESP) at the top of the quencher removes particulates.

### 5.1 Process Description

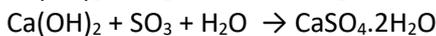
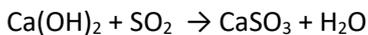
The Quencher is a rectangular tower with three important functions: (1) SO<sub>x</sub> removal (2) flue gas cooling (3) particulate matter removal.

#### DeSO<sub>x</sub> Section

Flue gas from the SCR enters the bottom of the quench tower, this is the desulphurisation section. SO<sub>x</sub> removal before contact with the amine solvent is important because it prevents the formation of heat stable salts in the Absorber. The Quencher FGD section reduces the concentration of SO<sub>x</sub>, and HCl, in the flue gas before flue gas entering to the Absorber. A Double Contact Flow Scrubber (DCFS) has been selected for SO<sub>x</sub> removal by reaction with calcium hydroxide (slaked lime).

Slaked Lime Powder is delivered by road tankers and unloaded to the Slaked Lime Silo, adjacent to the quench tower. The slaked lime silo will be fitted with a fabric filter for dedusting the conveying air from the delivery tanker. The Slaked Lime powder is fed from the Slaked Lime Silo to the Slaked Lime Slurry Tank by the Slaked Lime Feeder and Slaked Lime Conveyor. The slaked lime slurry is prepared by mixing with water in the tank. This slurry is pumped to the FGD section of the quencher when required.

The SO<sub>x</sub> in the flue gas reacts with the lime to produce calcium sulphite (CaSO<sub>3</sub>) and calcium sulphate (CaSO<sub>4</sub>) (gypsum) by the following reactions.



The calcium sulphite is then oxidised to calcium sulphate by the oxygen in the flue gas.



The lime/gypsum slurry circulated in the FGD section is predominately gypsum, a small quantity of the gypsum slurry is removed from the FGD section and transferred to the sump before being pumped to the cement plant. The gypsum slurry is maintained at the correct pH to ensure the SO<sub>2</sub> is removed from the gas stream. The pH of slurry is controlled by injecting Slaked Lime Slurry as required from the Slaked Lime Slurry Tank using the Slaked Lime Slurry Pump. Reverse Osmosis (RO) reject water from water treatment plant will be utilised as make up water for Quencher FGD section.

#### Flue Gas Cooling Section

The flue gas then moves upwards into the cooling section of the quench tower. The efficiency of CO<sub>2</sub> absorption increases with lower temperatures; therefore, the flue gas is cooled before it enters the Absorber. The flue gas is cooled by direct contact saturation with water on the surface of structured packing. The circulating water is fed to the top of the packing, recirculated through the system by the Quencher Circulation Pump, and cooled by the Quencher Cooler. The Quencher Cooler is a series of air fin coolers where ambient air is blown across the pipes to cool the water. The cooling of the flue gas generates large amounts of condensate that accumulates in the cooling section bottom. Excess process condensate is extracted and sent to water treatment plant to maintain a stable liquid level in the tower bottom.

## Wet ESP Section

The Wet ESP is installed at the top of Cooling Section. The primary purpose of the Wet ESP is to remove the filterable particulates and condensable particulates. These particulates arise from ammonium sulphate formation after the CHP/SCR, calcium sulphate from the FGD section and very fine particulates that have passed through the cement plant fabric filter.

At the Wet ESP, a high voltage is applied to the discharge electrode, generating a corona discharge that produces negative ions. The electrically charged dust is accumulated on the collecting electrode by the electrical field. The accumulated dust on the collecting electrode is washed continuously by circulating flush water. A portion of circulating water is discharged and sent to the Water Treatment Unit to avoid concentrating the particulate and other constituents in the circulating water and the same amount of makeup water is added to maintain the water balance. Flue gas condensate is used as make up for the Wet ESP wash water.

The CCU Flue Gas Blower draws the flue gas from the CHP through the Gas:Gas heater (untreated gas flow) and quencher, and overcome the pressure drop across the Absorber, Treated Gas Wash Tower and Gas:Gas Heater (post capture treated flow). The CCU Flue Gas Blower is installed downstream of Quencher.

## 5.2 Infrastructure

### Tank/vessel specifications

Item No	Description	Service	Capacity (m <sup>3</sup> )	Operating Volume (m <sup>3</sup> )	Dimensions (mm)				Material Specification	
					ID	Width	Length	Height	Shell	Heads
720-TK-002	Quencher FGD Section Area Tank	Gypsum Slurry	64	56	4000			4000	Concrete + Resin Lining	Concrete + Resin Lining
740-TK-003	Flue Gas Condensate Tank	Flue Gas Condensate	377	285	8000			7500	Carbon Steel with internal Lining	Carbon Steel with internal Lining
740-TK-004	RO Reject Tank	RO Reject	226	174	6000			8000	Carbon Steel with internal Lining	Carbon Steel with internal Lining
740-TK-010	CCP Effluent Tank	CCP Effluent (2% Slurry Water)	707	563	10000			9000	Fine grade steel plate	Fine grade steel plate
720-TK-011	Slaked Lime Slurry Tank	30wt% Slaked Lime Slurry	5.9	5.1	1800			2300	Carbon Steel + Resin Lining	Carbon Steel + Resin Lining
720-TK-012	Quencher FGD Section Drain Tank	Gypsum Slurry	478	462	8000			9500	Carbon Steel + Resin Lining	Carbon Steel + Resin Lining

Table 5.2.1 –tanks associated with the quencher

## 5.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

There are to be no additional point source emissions to air or water from this process.

## 6. Absorber

The gas stream flows up through the absorber whilst the amine solvent flows down. The CO<sub>2</sub> 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.

Amines are organic compounds derived from ammonia, that readily react with CO<sub>2</sub>. Amines are particularly effective for this purpose because they have a high affinity for CO<sub>2</sub>, allowing for efficient absorption even at low concentrations. This technology is relatively mature in the petrochemical and gas industries; it is considered new technology for the cement industry. Amine based carbon capture can be integrated into existing industrial processes for large-scale CO<sub>2</sub> reduction. Amine solutions for the carbon capture process have been in development for many years and are ever evolving.

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

### 6.1 Process Description

The Absorber is a rectangular tower with dimensionally configured structured packing. The Absorber uses structured packing to reduce the pressure drop of flue gas inside the tower.

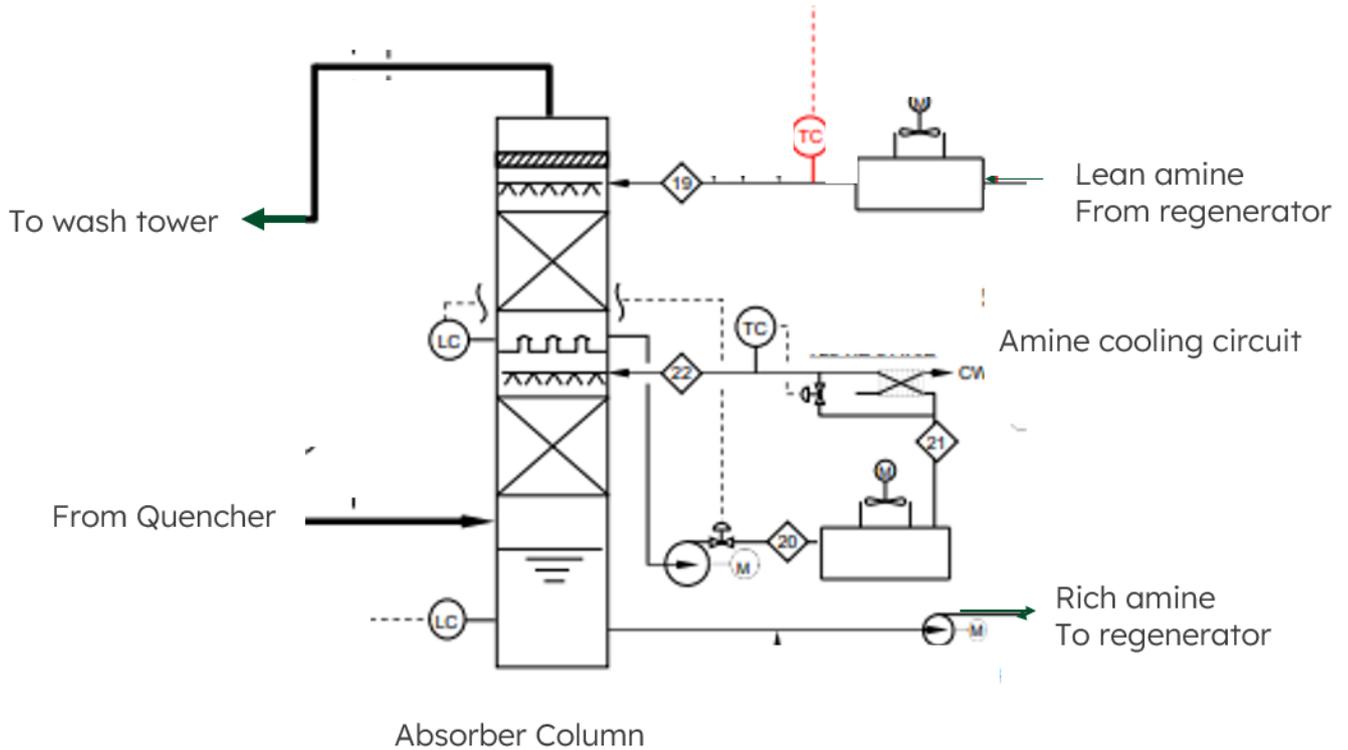
The flue gas from the Wet ESP is introduced into the bottom of the Absorber. The flue gas moves upward through the packing while the CO<sub>2</sub> lean solvent is supplied at the top of the Absorber packing. The flue gas contacts with the solvent on the surface of the packing where approximately 95% of the CO<sub>2</sub> in the flue gas is absorbed by the solvent. The flue gas then passes through a demister, to remove droplets, before continuing into the Treated Gas Wash Tower.

A simplified solvent CO<sub>2</sub> reaction using MEA as an example solvent is below:



CO<sub>2</sub> absorption is an exothermic reaction, so cooling the KS-21™ in the intermediate section is necessary to improve the CO<sub>2</sub> absorption capacity and efficiency. Additionally, cooling the KS-21™ aids in reducing volatile organic compound (VOC) emissions from the top of Treated Gas Wash Tower. The solvent is drawn from the chimney tray below the upper CO<sub>2</sub> absorption packing bed by the Intercooling Pump. Then it is cooled by the Intercooler and the Air Fin Intercooler and returned to the top of the lower CO<sub>2</sub> absorption packing bed. The rich solvent from the bottom of the Absorber is sent through the Lean Rich Exchanger by the Rich Pump to the Regenerator for CO<sub>2</sub> removal.

The illustrative schematic below shows the solvent and gas movement through the absorber:



## 6.2 Infrastructure

### Tank/vessel specifications

There are no additional storage tanks or vessels directly associated with this section of the CCS Process.

## 6.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

There are to be no additional point source emissions to air or water from this process.

## 7. Wash tower

The flue gas from the absorber 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 reduces amine emissions to air and hence reduces the amount of fresh amine solution required.

### 7.1 Process Description

The Treated Gas Wash Tower is a rectangular tower with dimensionally configured structured packing. The Treated Gas Wash Tower uses structured packing to reduce the pressure drop of flue gas inside the tower.

As the flue gas exits the Absorber, it continues into The Treated Gas Wash Tower. The Treated Gas Wash Tower consists of three sections.

The lower 1<sup>st</sup> washing section is similar to the Quencher Cooling Section, where cooled water comes into direct contact with the flue gas. The purpose of this section is to recover amine content in the flue gas and to cool the flue gas and maintain the water balance within the system. The 1<sup>st</sup> Wash Water Pump transfers water from the bottom of tower

through the Wash Water Cooler and the Wash Water Air Cooler before returning the cooled water to the top of the packing. An MHI proprietary demister is installed at the outlet of the 1<sup>st</sup> washing section to maximize recovery of amine mist from the treated gas. Excess water is diverted to the top of the Upper Absorption Section, blending with the Lean Solvent coming from the Regenerator.

The middle 2<sup>nd</sup> washing section also circulates water to recover amine vapour and mist. The 2<sup>nd</sup> Wash Water Pump transfers wash water from the bottom of the chimney tray of the 2<sup>nd</sup> washing section back to the top of the packing of the 2<sup>nd</sup> washing section. Another MHI proprietary demister is installed at the outlet of the 2<sup>nd</sup> washing section to catch amine mist remaining in the gas after the 2<sup>nd</sup> wash stage.

The upper 3<sup>rd</sup> washing section is the final amine emission reduction system to minimize amine emission from the Treated Gas Wash Tower top. The 3<sup>rd</sup> Wash Water Circulation Pump transfers water from the bottom of the chimney tray of the 3<sup>rd</sup> washing section back to the top of the packing of the 3<sup>rd</sup> washing section.

Another MHI proprietary demister is installed at the outlet of the 3<sup>rd</sup> washing section for catching amine mist in the treated flue gas. At the outlet of the flue gas washing section, the treated gas flows to the new stack after being heated in Gas:Gas Heater. Based on operational tests, each demister will remove approximately 90% of amines

Sulphuric acid and / or demineralized water are injected in 3<sup>rd</sup> washing section to thoroughly reduce the amine emission. The pH of circulating water is controlled by injection sulphuric acid from Sulphuric Acid Tank using the Sulphuric Acid Make-Up Pump. To maintain a stable liquid level in the chimney tray and pH level of washing water, the excess water is discharged from the washing section as blowdown. This blowdown water contains acid and amine degradation products and is sent to Acid Wash Water Tank. The blowdown water is transferred to the Acid Wash unit to concentrate amine degradation products then sent to the Cement Plant.

## 7.2 Infrastructure

### Tank/vessel specifications

Item No	Description	Service	Capacity (m <sup>3</sup> )	Operating Volume (m <sup>3</sup> )	Dimensions (mm)				Material Specification	
					ID	Width	Length	Height	Shell	Heads
720-TK-009	Acid Wash Tank	<1% Sulphuric Acid Solution	113.1	106	4000			9500	Stainless Steel	Stainless Steel
720-TK-010	Sulphuric Acid Tank	98% Sulphuric Acid	6.9	5.3	1800			3000	Carbon Steel	Carbon Steel
740-TK-002	Demineralised Water Tank	Demineralised Water	94	71	4000			7500	Stainless Steel or Carbon Steel with internal Lining	Stainless Steel or Carbon Steel with internal Lining

Table 7.2.1 –tanks associated with the wash tower

## 7.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

There are no additional point source emissions to air or water from this process.

## 8. 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 release point on the CCS stack with appropriate monitors installed.

### 8.1 Process Description

The CCS stack will be located centrally within the development due to the various scenarios from which the flue gas can enter the stack. Under normal operation conditions, kiln, CHP & CCS in operation, the flue gas will enter the stack after the gas:gas heat exchanger. Normal operating conditions are forecast to be 95% of the available operating time of the kiln. Alternative scenarios are kiln only operation, kiln and CHP, and CHP only (CHP warmup). Although there are various operating scenarios, the flue gas always enters the stack at the same point.

The stack height will be 117m from the ground with an internal diameter of 3.1m. Ground level of the CCP area is approx. 5 metres below that of the kiln. A stack height of 117m achieves an identical top of stack level for the existing and new stacks. This has been designed to avoid the plume of the new stack passing through the kiln preheater tower. A lift will be installed to access the measurement platform and ladders to the inspection platforms further up the stack. The measurement platform will be designed to the relevant section of BS EN 15259.

As CEMS require calibration by periodic monitoring, additional sample ports around the circumference of the stack will be installed to allow for isokinetic extractive sampling and calibration of the sampling and analysis equipment.

### 8.2 Infrastructure

#### Tank/vessel specifications

There are no additional storage tanks or vessels directly associated with this section of the CCS Process.

### 8.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

The new stack will be equipped with CEMS equipment that is certified by UK Monitoring Certification Scheme (MCERTS). MCERTS is the UK certification scheme for instruments, monitoring, and analytical services. The scheme is built on proven international standards and provides industry with a framework for choosing monitoring systems and services that meet acceptable performance specifications.

Laboratories carrying out measurements, calibrations, and relevant equipment assessments for CEMS shall be accredited in accordance with EN ISO/IEC 17025 for the relevant analytical methods or calibration activities.

All equipment shall be certified by MCERT. Laboratory testing shall be used to determine performance characteristics of the CEMS equipment, and such testing will require highly controlled environment and competent personnel. Competency of the personnel shall be certified by MCERT. The test laboratory shall evaluate the performance of the CEMS equipment at the lowest certifiable range of measurements possible for the intended application chosen by the manufacturer.

Calibrations shall be conducted in line with BS EN 14181 and the manufacturers recommendations and collected data shall be audited as part of the Heidelberg Materials audit program.

Comparing existing operation with proposed, the table below shows the calculated mass emission of each parameter based on Emission Limit Value (ELV) and the processes operating for 7400 hours per annum.

CCS C3-3a-2 Technical Description for Padeswood Cement Works CCS Plant

Parameter	Kiln 4 current		CCS (Mode 1) proposed		% of current ELV	% change of current mass emission
	ELV mg/Nm <sup>3</sup> 10%O <sub>2</sub>	kg/yr	ELV mg/Nm <sup>3</sup> 10%O <sub>2</sub>	kg/yr		
Particulate	10	20546	10	23600	100%	115%
TOC	50	102732	30	70801	60%	69%
HCl	10	20546	10	23600	100%	115%
CO	1200	2465568	400	944012	33%	38%
SO <sub>x</sub>	200	410928	50	118002	25%	29%
NO <sub>x</sub>	450	924588	200	472006	44%	51%
NH <sub>3</sub>	70	143825	30	70801	43%	49%
HF	1	2055	1	2360	100%	115%
Hg	0.05	103	0.05	118	100%	115%

Table 8.3.1 – comparison of mass emissions between existing process and proposed.

BAT-AELs for cement manufacture have been maintained for particulates, HCl, HF and Hg with lower ELVs proposed for the remaining parameters. Combustion of natural gas with air in the CHP increases the volume of gas released at the CCS stack and when considering the worst-case scenario, it appears that the emissions will increase for those parameters maintaining the BAT-AELs. Although theoretically possible, the likelihood of ELV emissions are low due to the additional process controls in place. For example, as detailed in section 1.1., lime injection and activated carbon injection will be installed at the fabric filter to control SO<sub>2</sub>, HCl and Hg and there are no additional inputs that could result in an increase of HF or particulates.

The air quality report (CCS-C3-3b-01-01 Air Quality Assessment Report) accompanying this application uses the proposed ELVs of each parameter. The report should be read in conjunction with this technical description.

Metal emissions for the kiln process are summarised below. The information used in the table is 2023 data submitted for pollution inventory reporting. This table has been compiled to demonstrate that, even before additional flue gas conditioning, the metal emissions are only 4.5% of the ELV.

Parameter	mg/Nm <sup>3</sup>	%
Antimony	0.00035	1.6%
Arsenic	0.0002	0.9%
Lead	0.0023	10.2%
Chromium	0.00235	10.4%
Cobalt	0.00025	1.1%
Copper	0.00935	41.6%
Manganese	0.00535	23.8%
Nickel	0.00205	9.1%
Vanadium	0.0003	1.3%
<hr/>		
Total metals	0.0225	
<hr/>		
% of ELV (ELV 0.5mg/Nm <sup>3</sup> )	4.5%	
<hr/>		

Table 8.3.2 – actual metal emissions split and proportion of ELV

Based on the above information, the proposed ELVs for the CCS process at A17 (emission point reference for CCS stack. A17 to be confirmed in determination process) are detailed in the table below.

### Schedule 3 – Emissions and monitoring

**Table S3.1 CCS Exhaust Emissions to air – emission limits and monitoring requirements**

Emission point ref. & location	Source	Parameter	Limit (including unit)	Reference period	Monitoring frequency	Monitoring standard or method
A17 – CCS stack on site plan in schedule 7	CCS Stack	Particulate matter	10 mg/Nm <sup>3</sup>	Daily average	Continuous measurement	BS EN 14181
		Total Organic Carbon (TOC)	30 mg/Nm <sup>3</sup>			
		Hydrogen chloride	10 mg/ Nm <sup>3</sup>			
		Carbon monoxide	400 mg/Nm <sup>3</sup>			
		Oxides of Sulphur expressed as SO <sub>2</sub>	50 mg/Nm <sup>3</sup>			
		Oxides of nitrogen (NO and NO <sub>2</sub> expressed as NO <sub>2</sub> )	200 mg/Nm <sup>3</sup>			
		Ammonia	30 mg/Nm <sup>3</sup>			
		Hydrogen fluoride	1 mg/Nm <sup>3</sup>	Periodic over minimum 30 minute, maximum 8-hour period	6 monthly	ISO 15713
		Cadmium & thallium and their compounds (total)	0.05 mg/Nm <sup>3</sup>			BS EN 14385
		Amine (total)	tbc	tbc	tbc	tbc
		Mercury and its compounds	0.05 mg/Nm <sup>3</sup>			BS EN 13211
		Sb, As, Pb, Cr, Co, Cu, Mn, Ni and V and their compounds (total)	0.5 mg/Nm <sup>3</sup>			BS EN 14385
		Dioxins / furans (I-TEQ)	0.1 ng/Nm <sup>3</sup>	Periodic average value over minimum 6 hours, maximum 8 hour period.		BS EN 1948 Parts 1, 2 and 3
		Dioxins / furans (WHO-TEQ Humans / Mammals / fish / birds)	No limit set	Periodic average value over sample period of between 6 and 8 hours.		BS EN 1948 Parts 1, 2 and 3

## 9. Regenerator and Reclaimer

The CO<sub>2</sub> is stripped from the solvent here. The carbon rich amine stream is heated in a heat exchanger before entering the top of regenerator column. A reboiler at the base of the regenerator column uses steam from the CHP to heat the amine to separate the CO<sub>2</sub>. These reactions are the same as shown in section 6 above but the increase in temperature moves the reaction to the right and the CO<sub>2</sub> is released.

With most of the CO<sub>2</sub> removed, the amine solution enters the reboiler where it is heated enough to release any remaining CO<sub>2</sub>. The CO<sub>2</sub> then re-enters the regenerator and joins the pure CO<sub>2</sub> 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<sub>2</sub> from the flue gas in the absorber.

### 9.1 Process Description

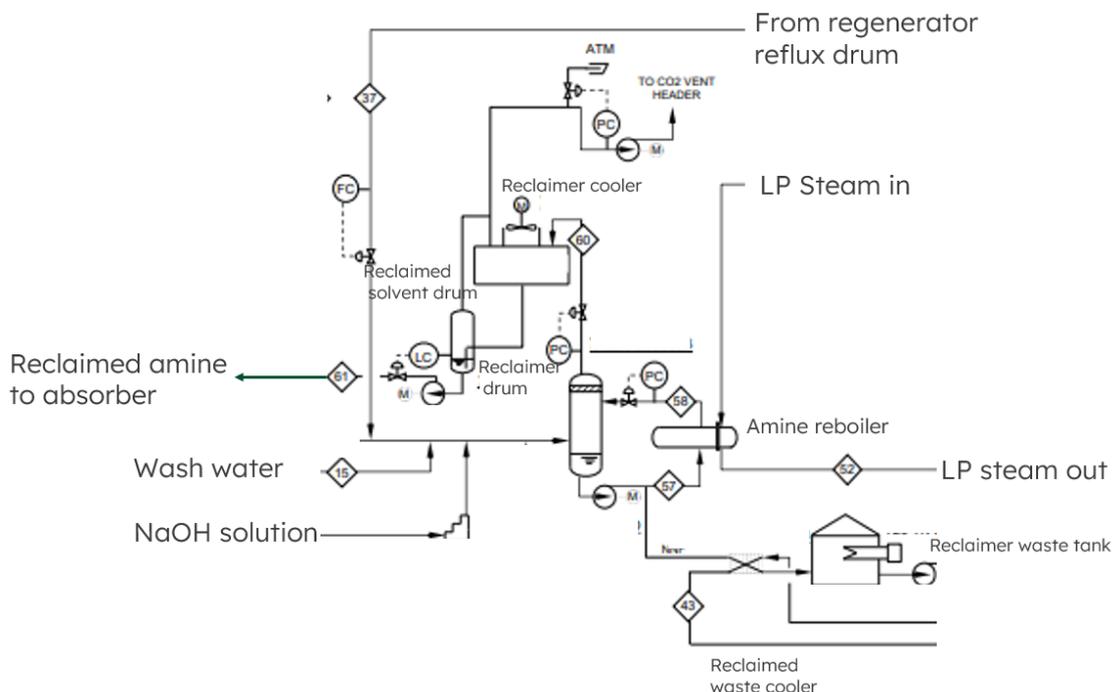
The Regenerator is a cylindrical column with structured packing. The purpose of the Regenerator is to recover the KS-21™ by removing the CO<sub>2</sub> using steam-stripping.

The rich solvent from the bottom of the Absorber is heated by the lean solvent from the bottom of the Regenerator in the Lean Rich Heat Exchanger. The preheated rich solvent is introduced at the top of the packing in the Regenerator. As the rich solvent flows down through the packing, it contacts with water vapour, which desorbs CO<sub>2</sub> from the solvent. The hot vapour (water and CO<sub>2</sub>) in the Regenerator is produced by the Regenerator Reboiler which use LP steam to boil the lean solvent.

The CO<sub>2</sub> and water vapour from the top of the Regenerator is sent to the Reflux Drum where it is cooled by direct contact with water on the surface of structure packing. This removes the water vapour from the CO<sub>2</sub>, increasing the quantity of water circulating in the reflux drum. The condensed water is distributed to the top of the regenerator to recover the amine and any excess transferred to the wash tower.

During operation SO<sub>2</sub>, NO<sub>2</sub> and O<sub>2</sub> react with the solvent in the Absorber forming heat stable salts (HSSs). These solids bind-in the solvent and have other negative effects. A small portion of the amine from the regenerator is sent to the reclaimer where caustic soda is injected to break down the HSS and release the solvent for re-use. The waste from the reclaimer containing the HSS is used in the calciner as fuel due to its energy content.

The illustrative schematic below shows the solvent and gas movement through the reclaimer:



## 9.2 Infrastructure

### Tank/vessel specifications

The Solvent Tank are designed to hold KS-21™ solvent from Absorber. The Fresh Solvent Tank is dedicated to store fresh KS-21™ Solvent for make-up. The fresh solvent is fed to the Fresh Solvent Tank by the Solvent Unloading Pump. No dilution of fresh solvent is necessary during normal operation. KS-21™ does not easily oxidise, so N<sub>2</sub> blanketing is not necessary.

Item No	Description	Service	Capacity (m <sup>3</sup> )	Operating Volume (m <sup>3</sup> )	Dimensions (mm)				Material Specification	
					ID	Width	Length	Height	Shell	Heads
720-TK-001	Solvent Tank	≤56% KS-21 Solvent Solution	427.3	397	8000			9000	Carbon Steel	Carbon Steel
720-TK-002	Solvent Sump Tank	≤56% KS-21 Solvent Solution	11.3	6.8	3000			3000	Carbon Steel	Carbon Steel
720-TK-003	Caustic Soda Tank	50% Caustic Soda	16.7	14	2400			4000	Carbon Steel	Carbon Steel
720-TK-004	Reclaimed Waste Tank	Reclaimed Waste	38.2	34	2800			6500	Stainless Steel	Stainless Steel
720-TK-007	Fresh Solvent Tank	70%wt KS-21 Solvent	86.6	81	3500			9500	Carbon Steel	Carbon Steel

Table 9.2.1 –tanks associated with the regenerator

## 9.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

There are to be no additional point source emissions to air or water from this process.

## 10. CO<sub>2</sub> compressor

This is the final stage of the process before the captured CO<sub>2</sub> leaves the site. The CO<sub>2</sub> is compressed and purified to remove water and oxygen. The chemical composition analysed before leaving site through a pipeline. This pipeline transfers the CO<sub>2</sub> to storage.

### 10.1 Process Description

The product CO<sub>2</sub> is supplied to the CO<sub>2</sub> Compressor through the Compressor Suction Scrubber. The CO<sub>2</sub> Compressor consists of the compressor and its interstage coolers. The CO<sub>2</sub> Compressor is an electric motor driven compressor with multiple stages of compression. The compressor stages have a common anti-surge line. The O<sub>2</sub> Removal Reactor and the Dehydration Unit are located at the outlet of the compressor. The O<sub>2</sub> Removal Reactor is followed by the Dehydration Unit where moisture in the CO<sub>2</sub> is removed. TSA (Thermal Swing Adsorption) is applied as dehydration method. This is a method to separate and refine the gas through repeated adsorption and desorption by means of swinging the temperature of the gas. The H<sub>2</sub> Generation Unit uses demineralized water and electricity to produce high purity hydrogen by electrolysis that is fed to the Compressor Suction Scrubber for adequate mixing prior to the O<sub>2</sub> Removal Reactor for oxygen removal. Hydrogen reacts with oxygen to produce water which is then condensed by the dehydration unit. Waste generated from dehydration is sent for use in the cement plant.

After compression, the CO<sub>2</sub> is cooled by the CO<sub>2</sub> Compressor Aftercooler before it is transported to the pipeline. CO<sub>2</sub> Compressor Aftercooler is included in CO<sub>2</sub> Compressor Unit.

A further heat exchanger after the dehydration unit may be required to meet the CO<sub>2</sub> transport and storage company's system entry temperature requirements. This will use hot CO<sub>2</sub> from upstream of the dehydrator to reheat the CO<sub>2</sub> after the dehydration unit to the required temperature. A flow meter and CO<sub>2</sub> analyser after the compressor will

measure the volume of CO<sub>2</sub> entering the pipeline to storage. If the CO<sub>2</sub> is found to be outside the specification it will be vented before the fiscal CO<sub>2</sub> metering to the CCS stack. If it is necessary to vent, depressurise or purge the short length pipeline between the last shutdown valve of the CCP and the first shutdown valve of the AGI this will be through a separate vent line which is also connect to the CCS stack.

After the metering, the CO<sub>2</sub> enters the ENI AGI (above ground installation) which is located on the west of the CCS plant. The AGI provides a transition point from the CCS plant to the underground CO<sub>2</sub> pipeline.

AGIs allow for the safe and efficient operation of a pipeline, as well as for routine inspections and maintenance. An AGI typically includes a control kiosk, which provides electrical equipment and instruments for distributing power to control and monitor the system, and a PIG (Pipeline Inspection Gauge) trap, to carry out pipeline inspection and cleaning. In addition, associated infrastructure for connecting the carbon dioxide pipelines includes above and below ground auxiliary pipework and valves, instrumentation and sensors and cable trays.

## 10.2 Infrastructure

### Tank/vessel specifications

There are no additional storage tanks or vessels directly associated with this section of the CCS Process.

## 10.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

Although there are to be no additional point source emissions to air or water from this process, there is a CO<sub>2</sub> specification that must be achieved before CO<sub>2</sub> can enter the pipeline. Failure to meet the specification results in the CO<sub>2</sub> being redirected to the stack where the flue gas is monitored (described earlier in this document).

## 11. Ancillary Tanks to support processes

### 11.1 Process Description

The Wash Water Tank and the Dilute Wash Water Tank are installed for storage of the wash water from 1<sup>st</sup>/2<sup>nd</sup> washing section of the Treated Gas Wash Tower. The wash water has a higher possibility of freezing than KS-21<sup>TM</sup> Solvent due to its low solvent concentration. To prevent the wash water from freezing, the wash water is to be drained out when the plant is shutdown during cold weather. CCP shutdowns will be in line with the annual kiln maintenance, i.e. one planned stop during the winter and a second in the summer.

Equipment containing KS-21<sup>TM</sup> can be easily drained anywhere in the plant through the underground drain collection system connected to the Solvent Sump Tank. Collected KS-21<sup>TM</sup> Solvent and wash water in the sump tank are transferred to either the Solvent Tank, the Wash Water Tank, or the Dilute Wash Water Tank depending on the solvent concentration. The KS-21<sup>TM</sup> solvent and wash water is transported by the Solvent Sump Pump and filtered by the Solvent Sump Filter.

## 11.2 Infrastructure

### Tank/vessel specifications

Item No	Description	Service	Capacity (m <sup>3</sup> )	Operating Volume (m <sup>3</sup> )	Dimensions (mm)				Material Specification	
					ID	Width	Length	Height	Shell	Heads
720-TK-005	Wash Water Tank	<10% KS-21 Solvent Solution	113.1	106	4000			9500	Carbon Steel	Carbon Steel
720-TK-006	Dilute Wash Water Tank	<1% KS-21 Solvent Solution	181	170	4800			10500	Carbon Steel	Carbon Steel
740-TK-001	Raw Water Buffer Tank	Raw Water	1473	1247	12500			12000	Carbon Steel with internal Lining	Carbon Steel with internal Lining
740-TK-009	Fire Water Tank	Fire Water	1227	879.5	12500			10000	Carbon Steel with internal Lining	Carbon Steel with internal Lining

Table 11.2.1 – tanks for support processes

## 12. Water emission point from the storage lagoon

### 12.1 Process Description

Potentially contaminated storm water collected in the various sumps and bunds will be tested locally for contamination. If no contamination is found the storm water will be sent to Balancing Pond via the Interceptor. Oil separated in the interceptor will be collected periodically by vacuum truck. Contaminated water in the sumps and bunds will be collected by vacuum truck and disposed of on site in the Cemfuel waste water handling system or sent to 3<sup>rd</sup> party for recycling.

An analyser is provided to check quality of water in balancing pond before pumping to the Raw water tank thus reducing the need for water abstraction at the Kinnerton borehole or discharging to environment.

### 12.2 Infrastructure

#### Tank/vessel specifications

There are no additional storage tanks or vessels directly associated with this section of the CCS Process.

Upstream of the lagoon inlet, there will be an interceptor sized accordingly for the storm water potential of the site.

The proposal is to install an interceptor with a catchment capacity area of 38,000m<sup>2</sup>, oil storage of 7000 litres and silt capacity of 70,000 litres.

### 12.3 Proposed monitoring of emissions – including frequency, location, methods, MCERTS compliance

Release Point	Name	Parameter	Current limit (W1)	Proposed limit (W4)	Proposed Reference Period	Proposed Monitoring Standard	Proposed Monitoring Frequency
W4	Surface water drainage via settlement lagoon	TSS	50 mg/l	50 mg/l	Spot Sample	BS EN 872	Monthly / when discharging
		pH	6 min 9 max	6 min 9 max	Instantaneous	MCERTS approved instrumentation	Continuous
		Temperature	23 °C	23 °C	Instantaneous	MCERTS approved instrumentation	Continuous
		Oil/Grease	None visible	None visible	Spot Sample	Visual check	Weekly
		COD	N/A	500 mg/l	Spot Sample	ISO 15705	Monthly / when discharging

### 13. Energy usage and efficiency

Carbon capture is energy intensive and will increase the power usage of the Padeswood Works once operational. The cement process power usage will remain relatively unchanged compared with existing operation.

The power for the CCP will be generated from burning natural gas, creating steam and operating a steam turbine generator (STG), collectively termed a combined heat and power plant (CHP). The CHP is sized for the power requirement of the CCP only and the heat required for operating the CCP, mainly re-boiling the amine.

Motors shall be designed & manufactured in accordance with BS EN standards. All Electrical equipment shall have UKCA marking.

The plant design includes many heat exchangers to manage thermal demand, redirect thermal energy where possible and minimise gas consumption. Low pressure steam from the CHP is the source of heat for the remainder of the plant.

Startup shutdown procedures will be used to achieve process efficiency.

A balance of water cooling and air cooling is within the design. Water cooling is more efficient than air however full water cooling is not possible due to the limited availability of fresh water and the capacity of the cement plant to accept waste water from the water treatment plant. The carbon capture plant has been designed to have zero liquid discharge with all mineral rich waste water from water treatment being used in the cement plant.