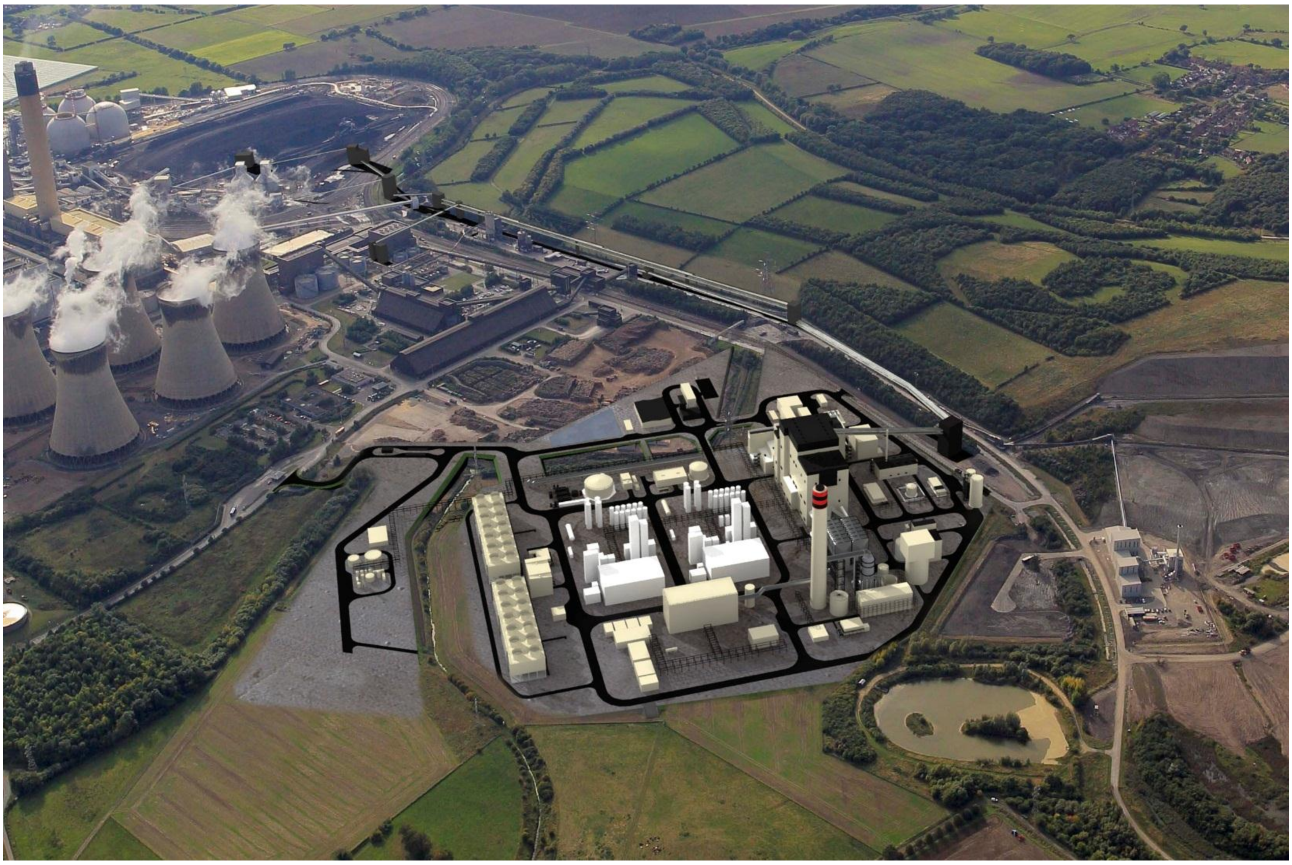
White Rose Carbon Capture and Storage (CCS) Project

Land adjacent to and within the Drax Power Station site, Drax, near Selby, North Yorkshire

Environmental Permit
Chapter IV – Technical Description of CCS Plant



Applicant: Drax Power Limited
Date: April 2015

Document History

Document Number	1		
Revision	0.1		
Author	Luke Jenkins		
Signed	Jim Doyle	**Date**	31/03/2015
Approved By			
Signed		**Date**	
Document Owner	Drax Power Plc		

Revision History			
Revision No.	**Date**	**Reason for Revision**	**Authorised By**

Glossary of Abbreviations and Definitions	
AOD	Above Ordinance Datum
ASU	Air Separation Unit
BS	British Standard
CCS	Carbon Capture and Storage
CEMP	Construction Environmental Management Plan
CPL	Capture Power Limited
dB	Decibel
EA	Environment Agency
EIA	Environmental Impact Assessment
ES	Environmental Statement
FGD	Flue Gas Desulphurisation
FRA	Flood Risk Assessment
GPU	Gas Processing Unit
HGV	Heavy Goods Vehicle
LWS	Local Wildlife Site
MWe	Megawatt
NERC	Natural Environment and Rural Communities (Act 2006)
NSIP	Nationally Significant Infrastructure Project
PEIR	Preliminary Environmental Information Report
SAC	Special Area of Conservation
SINC	Site of Importance for Nature Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive
WHO	World Health Organisation
WSI	Written Scheme of Investigation

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1.0 INTRODUCTION

The application of Carbon Capture and Storage (CCS) from the power generation sector is an emerging technology. CCS has thus far been demonstrated by a small number of projects which have looked at either relatively small scale plants or have utilised a side stream process to capture a portion of flue gas which may then be simply released to atmosphere rather than transported and stored. Currently there are three generic CCS technologies for the power sector which are believed to represented the best options for commercial deployment; pre-combustion capture, post combustion capture and Oxyfuel which is a hybrid technology. The White Rose CCS project is an Oxyfuel derivative. Oxyfuel technology provides some inherent benefits:

1. Generation of a relatively pure CO_2 stream for transport and storage
2. Significant reduction in NOx generation through nitrogen removal
3. No significant increase in use of chemicals for CO_2 capture
4. No requirement for energy input for recovery of solvents
5. Flexible operation with the ability to meet the future demands of National Grid

It would be incorrect to suggest that Oxyfuel technology in terms of CCS is BAT, until there are a number of plants which have been operating for a reasonable amount of time it is not possible to demonstrate which technology may be most suitable for CCS. Indeed, there may be a number of specific considerations which may favour one CCS technology over another for a given installation with respect to location, fuel type and flexibility of operation.

Currently there is no BAT guidance available against which CCS technologies can be appraised, The Environment Agency (the EA) have stated that CCS plants will be permitted under the existing regime and that there is no need to amend or modify the way in which applications involving CCS plants are determined.

The White Rose CCS plant will be located to the North of the existing Drax power station on an area of land which is almost identical to the area permitted for the Ouse Renewable Energy Plant (Ouse REP). In this sense the area of land has previously been appraised in terms of the risks associated with the addition of large combustion plant onsite, albeit a different technology for generating electricity and capturing the carbon dioxide. Operating in ‘Oxy-mode’ or capture mode, the plant is a more benign plant that the Ouse REP when considering emissions to atmosphere, this is due to the significant reduction in nitrogen entering the boiler as well as the iterative cycling of flue gas through the boiler hence resulting in the flue gas passing through the abatement systems multiple times. In addition, the flue gas condenser removes moisture from the flue gas which comprises a sulphur and nitrogen load prior to CO_2 processing and compression.

The White Rose CCS plant will benefit from a number of interconnections with the existing power station including fuel, water and process effluents, raw materials such as limestone and certain waste management facilities. In addition data and communications provision.

Water for a number of purposes will be abstracted from the existing station’s abstraction facility and discharged through the existing stations purge facilities hence there is no requirement for modification of the abstraction and discharge facilities. The current station’s abstraction licence is capable of meeting the demands of the White Rose CCS plant. Previous discussions with the Environment Agency identified this point and specifically the issue of the use of the abstraction licence for the White Rose CCS plant. Where necessary and in order to meet the current permit’s discharge limits, White Rose CCS will treat some of its process effluents in order to ensure compliance.

Raw materials including fuel will be conveyed to the White Rose plant with interconnections into the existing station’s limestone and gypsum storage facilities. Conveyors will run adjacent to the haulage roads to the White Rose CCS plant.

Waste will be managed according to the types and volumes of wastes generated, the generation of ash from White Rose CCS will result in ash either being transported from the station by truck or by rail or disposed of on Barlow mound.

2.0 TECHNICAL DESCRIPTION OF THE PLANT

2.1 Boiler

The boiler will consist of a balanced draft, sliding pressure, ultra-supercritical once through boiler. The purposes of the boiler is to raise steam (both high pressure and reheat pressure) to then pass through the turbines at specified flow rates and temperatures and pressures.

The steam generator will be designed to produce a continuous steam flow to the turbine generator. The nominal boiler maximum continuous rating (BMCR) outlet conditions, for both air and oxy mode of operation, are:

- Around 300 kg/s, 600ºC and 260 bar at the super-heater outlet; and
- Around 260 kg/s, 620ºC and 50 bar at the re-heater outlet.

The system is characterised by its unique arrangement of the evaporator sections in the flue system ad by the water separator that is placed at the end of the evaporator sections. In this type of system, the water and steam flow only once through the evaporator circuit sand converted to a steam. At the outlet of the evaporator walls, the steam produced is slightly superheated. In the load range between the minimum once-through load and the maximum load, the medium is always in a superheated condition and the water separator operates in a dry mode. The advantage of the once-through systems is that there is no fixed point at which the evaporator wall system ends and the super heater system starts. This system can operate with a very wide range of fuels and at different states of furnace cleanliness.

The boiler proper consists of all the feed water, super-heater and re-heater heat transfer surfaces along with their connecting piping headers, de-super-heater systems, support attachments, enclosures and casings, start-up system vessels, valves, and piping. The basic concept of oxy firing is to replace the ambient air with a mixture of pure oxygen and recirculated flue gas. Flue gas is recirculated to maintain the temperatures and oxygen concentrations in the boiler.

2.2 Turbo-generator

The turbo generator set consists of a single shaft turbine rotating at 3000 rpm with one single flow High pressure module, one double flow intermediate pressure module and 2 double flow low pressure modules plus the generator. The low pressure module’s exhaust steam is condensed in a water cooled, open circuit condenser. The generator design consists of a stator core and rotor which are hydrogen cooled and the stator winding is cooled directly by high purity water.

2.3 Water Steam cycle

The water steam cycle (WSC) provides water to the boiler and to bring steam generated by the boiler through to the turbine and then to condense the steam at the turbine exhaust. The WSC consist of the following key elements

- Condenser
- Feed water Tank
- Condensate extraction pumps
- Feed Water Pumps
- Low pressure and High pressure Heaters
- Condensate vacuum pumps
- WSC piping system

Water following the condenser is fed back from the condenser hot well to the boiler economiser inlet. The live steam produced by the boiler moves through the High pressure turbine module, the exhaust steam from the HP module then returns to the boiler to reheat the steam flow. The boiler reheated steam is sent to the intermediate pressure turbine module, exhaust steam then feeds the low pressure turbine. The Steam exhaust is then condensed and collected in the hot well for return to the boiler. The condenser is maintained under a vacuum to increase plant efficiency.

2.4 Flue Gas Abatement

The air and fuel gas systems are designed to provide combustion air, cooling air, sealing air, and to remove the flue gases resulting from the combustion in a balanced draft manner.

One Forced Draft Fan supplies the secondary air for combustion. In air combustion mode, the secondary air comes from the atmosphere through the steam coil air pre-heater. In oxy-combustion mode, the secondary air is sucked up to the downstream wet flue gas desulphurisation system to keep SO_x concentrations low, the O_2 is mixed with the flue gas upstream of the Forced Draft Fan. The secondary air is heated in the gas heat exchanger and led to the wind boxes for combustion. Secondary air represents the bulk of the flow to the firing system.

One Primary Air Fan provides primary air for drying and transporting of coal. In air combustion mode, the primary air comes from the atmosphere. In oxy-combustion mode the primary air is sucked up downstream of the flue gas condenser in order to limit the water concentration, where the O_2 is mixed with the flue gas upstream of the Primary Air Fan. The primary air is heated in the gas heat exchanger and led to the mills. From the mills, the primary air transports the coal up to the burners.

One Induced Draft Fan removes the flue gasses from the furnace while controlling a furnace pressure to slightly below atmospheric levels. The Induced Draft Fan is located downstream of the electrostatic precipitator and upstream of the wet flue gas desulphurisation.

Oxygen is injected in the flue gas circuits in 3 different ways;

- In the Primary Recycle Loop, upstream of the fan
- In the Secondary Recycle Loop, upstream of the fan
- In the Secondary Oxidant ducts between the rotary preheater and burners

The concentration of oxygen in the air secondary is limited to around 25% to allow fabrication with carbon steel material based upon Compressed Gas Association (CGA) guidelines. Oxygen concentration in the primary air is limited to around 20% to maintain the same concentrations as air to the pulveriser to minimise potential hazards. Seal gas is extracted from the primary air before oxygen is added.

As flue gas produced from oxy-firing has different properties than air-firing, the quantity of Flue Gas Recirculation to achieve boiler thermal performance is not sufficient to allow all of the oxygen needed for combustion to be injected with the Flue Gas Recirculation streams, and still maintain the oxygen concentration of around 25% O_2. Therefore, additional oxygen is required for combustion.

Operation of the firing system using oxygen with Flue Gas Recirculation is the key boiler operating change associated with oxy-firing. Other boiler systems and Air Quality Control Systems can be operated in the same manner as during normal air firing. Additional valves and dampers, instrumentation and controls are required to isolate as well as control the Flue Gas Recirculation and oxygen flows at desired values. The same primary gas and forced draft fan are used to provide air stream for start-up on air firing as well as to recirculate flue gas during oxy0firing.

Dampers are used to transition and provide isolation between air and Flue Gas Recirculation intakes to the primary and forced draft fans. Overall oxygen demand from the Air Separation Unit is driven by the overall combustion requirement to maintain the targeted oxygen concentration in the flue gas leaving the economiser section.

2.5 Air Separation Unit

The Air Separation Unit (ASU) produces the oxygen necessary for the boiler to operate in oxy mode at full load. The ASU process is composed of the following successive steps;

- First Air Compression: the air to be processed is compressed in the Min Air Compressor (MAC). The MAC includes inlet guide vanes to modulate air flow.
- Air Purification: water and CO_2 are removed from the air using an adsorption process based on a molecular sieve adsorbent. This is a batch process with 2 adsorbers. 1 is regenerated while the other is in the adsorption phased. The regeneration is achieved by sending dry nitrogen gas produced from the ASU. The nitrogen is heated up by a steam gas heat exchanger.

- Second Air Compression: After water ad CO_2 removal process, the air is again compressed by a booster air compressor before it enters the cryogenic process
- Cryogenic Process: This section includes cryogenic heat exchangers, with 2 distillation columns and a refrigeration cycle using a cryogenic expander. Oxygen is produced from the bottom of the column, then vaporised and warmed up in the main exchanger

The ASU is designed to provide a Gaseous Oxygen during nominal operation and also Liquid Oxygen thanks to integrated liquefiers when the power plant is at minimum load. Common Gaseous Oxygen buffers are used to control the oxygen pressure in transient regimes.

2.6 Gas Processing Unit

The purpose of the Gas Processing Unit (GPU) is to compress and purify the CO_2 rich flue gas and to provide a CO_2 product that meets the specification defined for storage. The GRU operates during boiler oxy-mode operation only.

The technical concepts of the GPU has been developed with the objective of minimising the energy consumption. The GPU can be divided into the following main sub-systems;

- Flue Gas Compression
- Conditioning and Drying
- Regeneration Gas System
- CO_2 Chilling and Separation
- Off Gas Handling
- CO_2 Recompression

The GPU process is based on the condensation of CO_2 at low temperatures and elevated pressure. It is designed for a CO_2 recovery rate of around 90%.

The CO_2 rich flue gas leaves the Direct Contact Cooler at a low temperature and saturated with water, it then enters the Flue Gas Compression section. Trace components that may harm the mechanical integrity of the equipment downstream of the compression, e.g. Mercury, which may condense and leads to the brazed aluminium exchanges becoming brittle, will be removed in dedicated adsorbers.

To reach low enough water content in the CO_2 product and prevent freezing in the system, moisture has to be removed down to ppm levels before further processing can take place. A fixed bed dehydrator is selected with an alumina or molecular sieve filler, which absorbs practically all of the remaining moisture. The dehydration unit is located after the compression states, which is advantageous for 2 reasons: efficiency is improved at higher pressure and size is decreased due to the reduced gas volume. The gas hydration system is of the regenerative type with one unit in service while the other one is being regenerated. The regeneration requires heat which is provided by an electrical heater. The vent gas from the subsequent low temperature purification stage, which is dry, is typically used as regeneration medium for this purpose.

The gas stream leaves the dehydration unit, Is further cooled and during this cooling CO_2 starts condensing the cooling is carried out in several steps and at different temperature leaves and from different cooling sources.

After cooling, the condensed or partially condensed flue gas continues to the low temperature purification stage, where CO_2 is separated in a flash drum. The vent gas leaving the purification unit is dry, clean, and pressurised. Possible usages of this stream are power recovery in an expansion turbine and as a regeneration gas for the dehydrators. After leaving the separation section, the pressure of the C02 product streams is raised to a pipeline pressure of around 135 bar. The pressure increase is carried out by a combination of a compressor and a liquid pump. The gas compressor has normally multiple compression stages because of the high end pressure and will be equipped with coolers after each stage.

2.7 Fuel Use, Storage, Processing and Handling

2.7.1 Coal

Coal for the Capture Power facility will be delivered to site by Rail and will be unloaded at the existing Drax coal rail unloading facility. From this point, a series of existing Drax coal conveyors are utilised to convey the coal to either the existing Drax coal yard or to a new ground hopper provided for exclusive use of the new Oxy Power Plant.

A new 350m^3 ground level hopper has been designed to accept coal from either the existing emergency stock-out conveyors, or to be loaded from the Drax coal yard by vehicles of various sizes, up to and including a coal yard scraper. The hopper design will allow additional coal to be piled up to accommodate variations in the delivery rate to site. To support this, the existing high level trip switches will be retained to prevent over stacking of the pile

2.7.2 Biomass

The Biomass conveying system draws biomass fuel from the existing biomass storage facility at Drax. It should be noted that Drax has two independent biomass storage and distribution systems on site; the selected interface is with the road delivery and storage system only. This system has a total of 6 biomass storage silos, 4 of which are available for supplying the Capture Power facility

Biomass is delivered to site by road and then screened for oversize objects and the presence of ferrous materials before being stored in either or all of silos. When required, the Biomass pellets are reclaimed from the silos using the existing screw conveyor reclaim system and then conveyed by the existing conveyors before arriving at the new conveyor system to supply the Oxy Power Plant.

2.7.3 Limestone

Limestone is delivered to site by either Rail or by Road and is stored on the Drax site in the limestone store. From here, an ‘A-frame’ portal reclaimer which will reclaim the limestone and conveys the material to the Drax FGD plant for processing. The new limestone conveyor system intercepts the existing feed of limestone to the Drax FGD plant, and diverts it to Capture Power instead. This has been achieved by the addition of two new pneumatically operated diverter chutes fitted in the discharge chutes of existing limestone conveyors in Limestone junction house, either of which will deposit the limestone onto the new conveyor.

The new conveyor will then transfer the limestone to new transfer tower which will be sited at the side of Limestone junction house JH2 and next to the existing site roadway. From here, the new conveyor continues on an unhindered run to join the main conveyor gantry between transfer towers. A smaller tower is located on the main conveyor run to allow the limestone to be transferred from the new conveyor to the tail of conveyor which would then run parallel to the coal and biomass conveyor lines.

Belt weighing rollers are included in the system immediately before the tower. The weighing system will comply with the required commercial accuracy. From here the limestone will be conveyed to tower TT5, then on to tower TT6 and from there to the tops of the limestone storage silos. A pneumatically operated diverter chute located above the limestone silos has been included to divert material to either of the silos as required. The design for the limestone interconnection has been based on standard 600mm wide trough belt conveyors, sized for a flow rate of 60T/hr.

2.7.4 Gypsum

A new conveyor will transfer Gypsum from the Oxy Power Plant Gypsum silo to a new transfer tower TT6. From here, a single gypsum conveyor GC04 will run to the adjacent transfer TT5 and subsequently on to TT4 and TT3A which will be situated in the main gantry line between tower TT3 and TT4. From this point the gypsum will be transported to Gypsum junction house JH2 by new conveyor GC01 and then new chutes and pneumatically operated divert chutes will be provided to allow the gypsum to be deposited onto either of shuttle conveyors C11 or C12. Conveyors C11 or C12 will then transfer the gypsum onto the main stockpile and the gypsum will ultimately be removed from site by either Rail or Road transportation.

2.7.4 *Pulverised Fuel Ash*

Pulverised fuel ash will to be conveyed pneumatically from the Capture Power facility to Drax's existing 2000T PFA storage silo. The system selected for this interconnection utilises dense phase pneumatic conveying, as dense phase conveying has lower overall air consumption and causes less wear on the conveying pipe due to the lower conveying velocities. The proposed system begins from the outlet of the new Oxy Power Plant intermediate ash silo. From here, PFA will enter one of two pressure vessels where compressed air will be injected to fluidise the PFA. From here, motive air will empty the pressure vessels and convey the PFA through the conveyor pipework to Drax's 2000T PFA silo.

2.7.5 *Cooling Water*

Cooling water make-up for the Capture Power facility will be taken from the existing CW Makeup distribution tower located on the east side of the existing Drax Facility. Following a detailed analysis of the current CW make-up system, enough spare capacity has been found to be available in the system to support the new Oxy Power Plant.

The make-up water required by the Drax generating station is abstracted from the River Ouse. The water is fed to four make-up water pumps via two intake screens and supplied to four sedimentation tanks via two pipelines. The treated water from the sedimentation tanks is taken to the distribution tower via two pipelines. To supply water to the Capture Power facility, a connection is to be made on the outlet pipeline which supplies make-up water to the North generation units. The make-up water is pumped via two new 100% VSD driven centrifugal pumps (one in operation and one standby) to the Capture Power tie-in point via a single buried GRP pipeline.

The purge water from the Capture Power facility is gravity fed into a new connection to an existing access chamber (74) located on the 1050mm diameter North cooling towers purge water pipeline in the Drax cooling water purge network. This existing northern purge pipeline feeds purge water to the north-west chamber in the purge pump station. Two existing purge pumps are then used to discharge the purge water from the chamber back to the River Ouse via the purge outfall chamber.

2.8 **Energy Efficiency**

High efficiency systems have been selected throughout the plant:

- Ultra super critical boiler design with reheat
- High efficiency steam turbine designed for high pressures and temperatures to improve efficiency
- BFW Variable frequency drives (VFD) have been fitted to the boiler feed water pumps in order to reduce feed water pumps electrical consumption at partial load.
- Water (rather than air) cooled condenser to achieve a lower pressure (higher power recovery) at the steam turbine exit
- Mechanical draft cooling towers to minimise cooling water temperature
    - Higher power from Steam Turbine
    - Lower power for large compressors in ASU & GPU
- Hydrogen cooling in generator to minimise windage losses and thereby improve efficiency of the generator
- ASU cycle selection and machine selection for minimum power consumption
- Selection of high efficiency centrifugal compressors in GPU
- ASU & GPU cold boxes design to minimise heat losses from cryogenic processes
- Liquid oxygen is contained in highly insulated storage vessels in order to minimise heat in leak and thus minimise product boil off and loss.
- ASU is located as close as possible to boiler to minimise pressure drop on high gas flows.

The water and steam cycle is the central element between the steam generator and the turbo-generator. The purpose of the water and steam cycle is to heat the water and feed this to the boiler, to transfer the steam produced by the Boiler to the Steam Turbine and to condense the steam in a condenser at the turbine exhaust to enable re-start of a new cycle. A number of features are aimed to maximise efficiency:

In order to increase the plant efficiency, the condensate stream (excluding the portion heated in the ASU) is heated-up through six low pressure heaters by steam from the low pressure turbine section.

Reheating of high pressure turbine exhaust - the "cold reheat steam" returns to the boiler re-heater to reheat the steam to maximise efficiency in the later stages of expansion.

In the turbine, the steam expansion provides mechanical energy to the Steam Turbine shaft, which is coupled (on the same shaft) with the turbo-generator. Directly coupling means there are no gearbox losses.

The steam from the low pressure turbine section is then directed to the condenser where it condenses at vacuum conditions. To obtain the maximum of expansion in the turbine, the main driver for the steam cycle efficiency, non-condensable gases that collect in the condenser are removed using the vacuum pumps, to ensure highest achievable vacuum level is maintained.

The fundamental concept of oxy-firing is to use oxygen instead of air (as per conventional coal combustion) for the combustion process in order to obtain a CO_2 rich flue gas mainly composed of CO_2 + H_2O (and some inert gases) more "easily" cleaned and compressed to the required pipeline CO_2 specification for onward transport and storage.

As a result oxy-firing requires the addition of two units to the conventional coal fired power plant:

- the Air Separation Unit (ASU) to provide the oxygen; and
- the Gas Processing Unit (GPU) where the CO2 is purified and compressed.

In addition, some modifications of the power plant itself are necessary, mainly:

- Partial recirculation of the flue gas in order to maintain appropriate temperature and heat absorption in the furnace and convection pass;
- Removal of the water from the flue gas before treatment in the GPU in the Flue Gas Condenser;
- Minimisation of leakage of air into flue gas ducts and equipment (e.g. Boiler, Flue Gas Desulphurisation (FGD), Electrostatic Precipitator (ESP));
- Sizing of auxiliary equipment, taking into account the additional needs of ASU and GPU; and
- Injection/mixing of oxygen in the flue gas path.

While the additional and modified units increase the parasitic load versus an unabated plant, as a new build plant White Rose benefits from being able to select modern high efficiency boiler technology and auxiliary units as well as design for heat integration between the components in order to reduce the impact of CO_2 capture on overall efficiency.

2.9 Hybrid Cooling Towers

The cooling tower is a counter-flow wet-dry type, mechanical induced draft. The cooling tower is split in two blocks of 14 cells. Each cell is isolated by means of partition walls. Each cell is equipped with its own hot water riser pipe, wet section, dry section and mechanical equipment. The wet section of each cell includes the water distribution system with spray nozzles, the fill and the drift eliminators. The dry section of each cell includes air dampers (depending on supplier design), finned tube bundles, air mixers. The tube bundles of each cooling tower block are connected to a common vacuum skid (2 x 100% vacuum pumps) to prevent air accumulation in their upper part.

The mechanical equipment of each cell consists of a right angle gearbox connected to an electrical motor via a drive shaft. The complete drive train comprising motor, gearbox, shaft and fan is mounted on a rigid support torque tube. Air is drawn vertically from the wet air inlet in the lower part of the tower, travels across the fill against the stream of water and is discharged in the atmosphere at high velocity.

2.10 Air Flows

The air and fuel gas systems are designed to provide combustion air, cooling air, sealing air, and to remove the flue gases resulting from the combustion. One primary air fan provides the primary oxidant stream to the mills for drying and transporting the coal or biomass to the furnace. A portion of the primary oxidant stream is heated in a rotary GGH against the boiler exhaust flue gas. From the mills, the primary oxidant stream transports the pulverized coal to the furnace. In air mode, the primary oxidant stream is the air coming from the atmosphere, and damper no.6 is open and damper no. 5 is closed.

In oxy mode, the flue gas stream is recirculated from downstream of the direct contact cooler (DCC) in order to limit the water concentration. Damper no.5 is open and damper no.6 is closed. Oxygen is mixed with the recirculated flue gas upstream of the PA Fan. This mix of recirculated flue gas and oxygen constitutes the primary oxidant stream.

Raw coal, fed to coal mills, is dried and transported to the furnace by the heated primary oxidant stream. The raw coal flow to the mills is about 140 t/h. The total primary oxidant stream flow used to dry the coal is around 395 t/h. One FD fan supplies the secondary oxidant stream for combustion. In air mode, the secondary oxidant stream comes from the atmosphere through the steam coil air pre-heater; damper no.4 is open while damper no.3 is closed.

In oxy mode, the secondary oxidant stream is drawn from downstream of the FGD system to keep SO3 concentration as low as possible. The pure oxygen is mixed with the recirculated flue gas upstream of the fan. The secondary oxidant stream is heated in the GGH and led to the boiler firing system. The total secondary oxidant stream entering the windbox is approximately 755 t/h.

About a third of the total oxygen need is introduced directly in the windbox. This is done in order to keep oxygen content in the primary and secondary streams below a threshold value, above which would require the use of more costly alloys for the ducts and other equipment downstream of the oxygen mixing locations. The total oxygen flow to the boiler is about 270 t/h. For both air and oxy mode the flue gas stream leaving the boiler is cleaned by reducing the NOx content in the SCR system and by reducing the SO3 in the flue gas by the use of an SO3 mitigation system. The flue gas, transported by the induced draft fan is cooled in the GGH, cleaned of particulate matter in the ESP, and cleaned of sulphur compounds in the FGD. In air mode the flue gas is discharged through the stack; damper no.1 is open and damper no.2 is closed. A Control Emission Monitoring System (CEMS) is installed to monitor the emission level.

The flue gas leaving the FGD system is saturated with water which needs to be reduced before entering the GPU. This is accomplished in the DCC flue gas condenser. Cooling water is distributed through the incoming flue gas thanks to multiple stages of sprays. The water condensed is partly recirculated and cooled by main cooling water from cooling towers. The main part of the excess condensate is discharged to the FGD as make-up water with the remaining part discharged to the Waste Water Treatment Plant.

The flue gas flow at the inlet of the DCC is about 866 t/h. At the outlet of the DCC, after the water condensation, the flue gas flow is about 742t/h. Part of the flue gas is recirculated to the boiler via the primary air fan while the rest is sent to the GPU. This stream named “CO2 rich flue gas” has a flow of about 354 t/h.