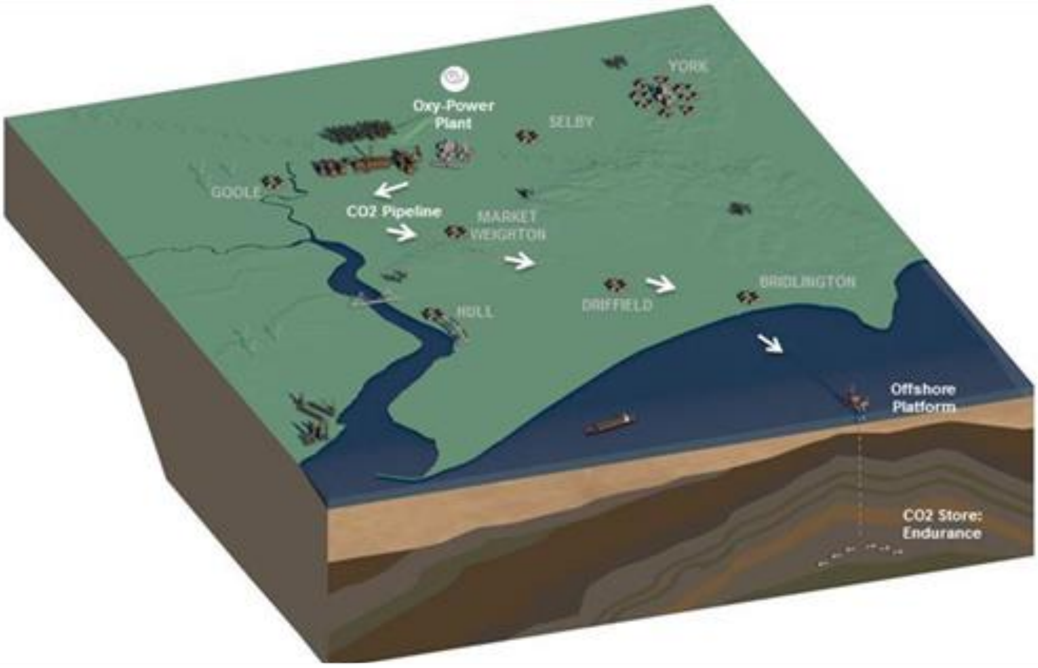
January 2016

K12: Full Chain Health and Safety Report

Category: Full Chain



Contents

Key Words

Key Words	Meaning or Explanation
Carbon Capture	Collection of carbon dioxide from power station combustion process or other facilities and its process ready for transportation
CCS	Carbon Capture and Storage
CDM	Construction (Design and Management) Regulations which govern health and safety in construction work and apply to the way projects are designed.
CO_2e	Equivalent carbon dioxide is the concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas
Co-fire Biomass	Co-firing is the combustion of two different types of materials at the same time. One of the advantages of co-firing is that an existing plant can be used to burn a new fuel, which may be cheaper or more environmentally friendly. In this case, biomass can be co-fired in existing coal plants instead of new biomass plants
COMAH	The Control of Major Accident Hazards (COMAH) Regulations ensuring that businesses: "Take all necessary measures to prevent major accidents involving dangerous substances Limit the consequences to people and the environment of any major accidents which do occur"
Dense Phase	The physical properties of CO_2 can vary according to temperature and pressure. It can be a gas, solid, liquid or can exist in a 'supercritical' state, where it behaves as a gas but has the viscosity of a liquid. The term 'dense phase' refers to CO_2 in either the supercritical or liquid stage
FEED	Front End Engineering Design
FEED Contract	CPL have entered into an agreement with the UK Government's DECC pursuant to which it will carry out, among other things, the engineering, cost estimation and risk assessment required to specify the budget required to develop and operate the White Rose assets
Full Chain	The complete process from the power generation and capture of the CO_2 at the emitter plant to its injection into the storage reservoir
Global Warming Potential (GWP)	Global Warming Potential. This is used to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to CO_2. It is measured using a standard unit called carbon dioxide equivalence (CO_2e) which is calculated by multiplying the amount of gas by its associated GWP factor. The global warming potential factors applied in emissions calculations are based on information available from the Intergovernmental Panel on Climate Change (IPCC)
HAZID Study	A safety assessment tool that can be used during the course of an engineering project or to review and identify the safety of a particular piece of plant or equipment. The content of Hazard Identification (HAZID) studies may overlap with that of other design-related safety activities, such as Hazard and Operability studies (HAZOP). It is possible to combine such activities. During a HAZID study, the proposed design is systematically examined, section by section, using guidewords to generate a free-ranging discussion. When a potential hazard is identified, a probable cause shall be established before the consequences of the hazard are examined and any remedial action recommended
HAZOP Study	A structured technique using guidewords to identify potential hazards and operability issues. During a HAZOP study the proposed design is systematically examined, section by section, using guidewords to generate a free ranging discussion. When a possible hazard or operability issue is identified, a probable cause should be identified and then the consequences of the hazard examined and any remedial action recommended
Inventory	An accounting of the amount of gas discharged into the atmosphere. An inventory usually contains the emission of one or more specific greenhouse gases or air pollutants within a specified time span in a specified place
Key Knowledge Deliverable	A series of reports (including this one) issued as public information to describe the flows and processes associated with the overall system. Also referred to as a KKD
Oxy-fuel Combustion	A process that burns fuel in a modified combustion environment with the resulting combustion gases being high in CO_2 concentration. This allows the CO_2 produced

Key Words	Meaning or Explanation
	to be captured without the need for additional chemical separation, before being compressed into dense phase and transported for storage
PIG operations	An essential maintenance activity that optimises the smooth operation of the pipeline using a Pipeline Inspection Gauge (PIG) to traverses the pipeline to inspect and clean it
Plateau Flow Rate	Occurs when the depressurisation rate plateaus from its initial peak flow rate and the system pressure reduces to a point where the CO_2 starts to vaporise and is released using the vent valve. The term is used in association with depressurisation valves
Storage	Containment in suitable pervious rock formations located under impervious rock formations usually under the seabed
Topsides	The upper half of the offshore platform structure, above sea level, outside the splash zone, on which equipment is installed
Transport	Removing processed CO_2 by pipeline from the capture and process unit to storage
White Rose Transport and Storage FEED Project	Is an integrated Full Chain CCS project comprising a new coal-fired Oxy Power Plant (OPP) and a Transport and Storage (T&S) network that will take the carbon dioxide (CO_2) from the OPP and transport it by pipeline for permanent storage under the southern North Sea

Executive Summary

The Full Chain Health and Safety was generated as part of the Front End Engineering Design (FEED) contract with the Department of Energy and Climate Change (DECC) for White Rose, an integrated Full Chain Carbon Capture and Storage (CCS) Project. This document is one of a series of Key Knowledge Deliverables (KKD) from White Rose to be issued by DECC for public information.

White Rose comprises a new coal-fired ultra-supercritical Oxy Power Plant (OPP) of up to 448 MW_e (gross) and a Transport and Storage (T&S) network that will transfer the carbon dioxide (CO_2) from the OPP by pipeline for permanent storage under the southern North Sea. The OPP captures around 90% of the CO_2 emissions and has the option to co-fire biomass.

Delivery of the project is through Capture Power Limited (CPL), an industrial consortium formed by General Electric (GE), BOC and Drax, and National Grid Carbon Limited (NGCL), a wholly owned subsidiary of National Grid.

This report provides a description of the development of the project with respect to health and safety and provides insights to what has already been learnt in undertaking the FEED as well as laying out how the project expects to manage health and safety issues during execution and operation. Health and Safety is a key concern for any project and business operation but, when establishing a new industry such as is being currently done with CCS, this is particularly important as the approaches taken to manage any new risks on the first projects are likely to set the foundations for how the industry develops in the future.

After the introductory sections that deal with health and safety issues across the Full Chain, this report is divided into sections dealing with the OPP and T&S separately as the legislative regimes and hazards are largely different (although the hazards of CO_2 are, of course, common to both) and as separate companies will be responsible for the building and operation of the assets. It should be noted that it is a requirement of good engineering practice as well as certain elements of the legislation (e.g. the domino principle within the Control Of Major Accident Hazards Regulations 2015) to consider hazards that transcend boundaries of individual projects and installations. This cross-chain interaction has been a feature of the design work in FEED and will continue to be a key concern in implementation and operation.

As noted above, the project has been undertaking a FEED in preparation for Final Investment Decisions by DECC and other investors. The extent of the work undertaken within FEED has been governed by the need to reduce risk and uncertainty to a level at

which those investment decisions can be taken. Naturally the amount of work and level of detail of that work has varied in different sections of the Full Chain dependent on the analysed level of risk and uncertainty. This has resulted in the quantity and extent of Health and Safety related investigation varying in different elements of the Full Chain; for instance in some elements it has been only necessary to undertake Hazard Identification (HAZID) and in others preliminary Hazard and Operability (HAZOP) studies have been undertaken. This report reflects the work that has been undertaken to date and, irrespective of the quantity and level of detail of safety in design and construction work that will be undertaken at the time of project execution.

Her Majesty's Government (HMG) Spending Review was set out on 25 November 2015 outlining its capital budget and priorities. A market announcement on the same day indicated that the £1 billion ring-fenced capital budget for the Carbon Capture and Storage Competition was no longer available, the Spending Review accordingly did not include such budget. This meant that the Competition could not proceed as originally envisaged. Following this decision, a notice of termination was issued on 23 December 2015 under the White Rose FEED Contract, which terminated accordingly on 25 January 2016, prior to the expected completion date of FEED. The Government and CPL are committed to sharing the knowledge from UK CCS projects, and this Key Knowledge Deliverable represents the learning achieved up to the cancellation of the CCS Competition and termination of the FEED Contract and therefore does not necessarily represent the final and completed constructible project.

1 Introduction

1.1 Background

The White Rose Carbon Capture and Storage (CCS) Project (White Rose) is an integrated Full Chain CCS project comprising a new coal-fired Oxy Power Plant (OPP) and a Transport and Storage (T&S) network that will take the carbon dioxide (CO_2) from the OPP and transport it by pipeline for permanent storage under the southern North Sea.

The OPP is a new ultra-supercritical power plant with oxyfuel technology of up to 448 MWe gross output that will capture around 90% of CO_2 emissions and also have the option to co-fire biomass.

One of the first large scale demonstration plants of its type in the world, White Rose aims to prove CCS technology at commercial scale as a competitive form of low-carbon power generation and as an important technology in tackling climate change. The OPP will generate enough low carbon electricity to supply the equivalent needs of over 630,000 homes.

White Rose is being developed by Capture Power Ltd (CPL), a consortium of General Electric (GE), BOC and Drax. The project will also establish a CO_2 T&S network in the region through the Yorkshire and Humber CCS pipeline being developed by National Grid Carbon Ltd (NGCL).

1.2 Oxy Power Plant

CPL will provide the OPP element of the project. The OPP includes all elements on a conventional coal fired power station plus additional elements necessary to achieve CCS.

The conventional power plant includes the boiler, turbine hall, power generation and transformers and Air Quality and Control Systems (AQCS). The CCS elements include an Air Separation Unit (ASU) and a Gas Processing Unit (GPU) for purification and compression of CO_2. In addition to these elements, the OPP includes a cooling water facility and interconnections with the existing Drax site.

In effect, the OPP is formed by taking a conventional coal fired power plant and adding a chemical plant to either end (ASU at the front end and GPU at the back). From a health and safety aspect this bringing together of industries introduces a number of challenges. For instance, within the OPP there are gaseous hazards relating to oxygen enrichment, oxygen depletion and CO_2 which need to be minimised and managed.

As well as being subject to the Construction (Design and Management) Regulations 2015 (CDM), as are all construction projects, the plant will be subject to the Control of Major Accident Hazards Regulations 2015 (COMAH). These are the two principle health and safety regimes that will govern project delivery but are themselves underpinned by the general requirements of the Health and Safety at Work Act 1974 (HASAWA) and many other items of legislation, regulation and Health & Safety Executive (HSE) guidance on specific topics.

1.3 Transport and Storage

NGCL will provide the transportation and storage element of the project. This includes the transportation pipeline and pressure boosting facilities; offshore CO_2 reception and processing facilities, and injection wells into an offshore storage reservoir.

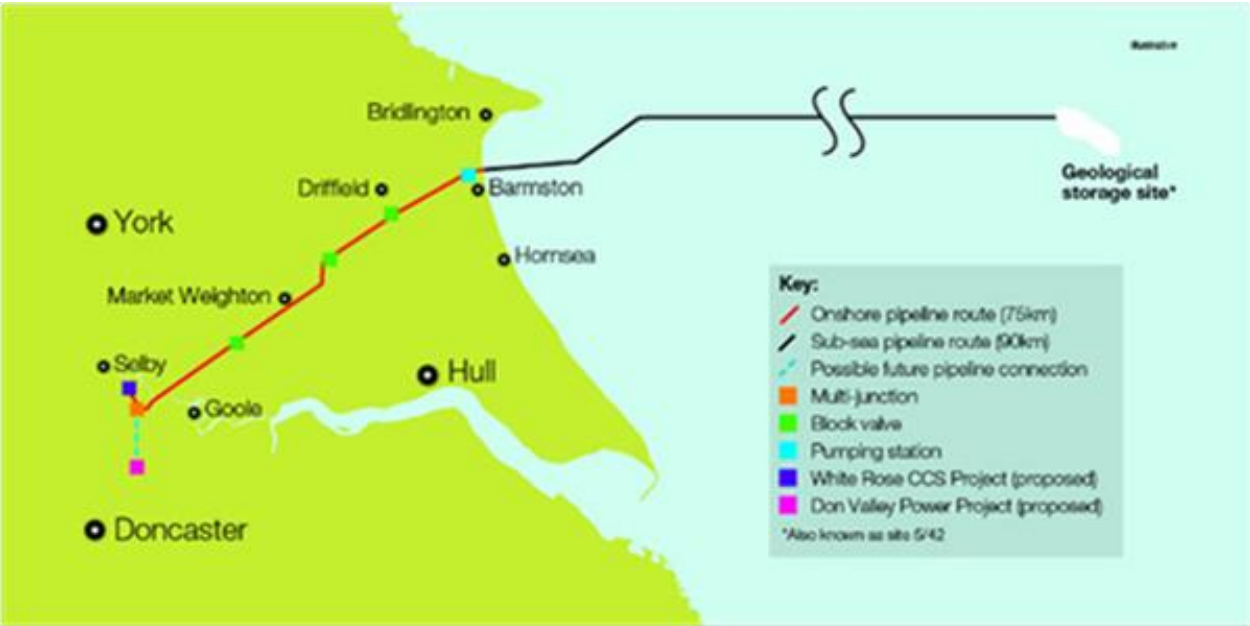
The T&S for the White Rose CCS Project comprise two elements: the "Onshore Scheme", which includes the construction of a Cross Country Pipeline, including the Above Ground Installations (AGI) such as Pipeline Internal Gauge Traps, a multi-junction, it's block valve sites and an onshore pumping station, to transport CO_2 in dense phase from electricity generation and industrial capture plants in the region, and the "Offshore Scheme" which includes an offshore pipeline to transport the CO_2 to a permanent storage site beneath the North Sea. The Onshore and Offshore Schemes are located, sized and designed to accommodate CO_2 emissions captured from multiple sources; although an initial, direct connection which the White Rose CCS Project power station itself forms the primary focus of the FEED Contract.

The Onshore Scheme requires a new buried high pressure cross country pipeline of approximately 67km in length with an external diameter of 610mm for the transportation of the dense phase CO_2 to a location on the Holderness coast. The Offshore Scheme requires a new high pressure 90km sub-sea pipeline to a geological storage site. The storage site presently proposed is a saline aquifer located approximately 1000m below the seabed. The Onshore and Offshore Schemes would be joined at the Mean Low Water Mark using appropriate landfall techniques.

The T&S system shares some common legislative requirements with the OPP as described above (e.g. HASAWA and CDM) but has other industry specific regimes such as the Pipeline Safety Regulations 1996 and Energy Act 2008.

Figure 1.1 below gives a geographical overview of the proposed CO_2 transportation system.

Figure 1.1: Geographical Overview of the Transportation Facility



The overall integrated control of the end-to-end CCS chain would have similarities to that of the National Grid natural gas pipeline network. Operation of the T&S system would be undertaken by NGCL. However, transportation of CO_2 presents differing concerns to those of natural gas; suitable specific operating procedures would be developed to cover all operational aspects including start-up, normal and abnormal operation, controlled and emergency shutdowns. These procedures would include a hierarchy of operation, responsibility, communication procedures and protocols.

1.4 This Report

This report is designed to give an overview of the health and safety matters that have to be managed in the deployment of this CCS project including the safety in design processes that have already been undertaken in executing the FEED work as well as those that will be required in project execution and operations. The report explains the work that has been done to date to mitigate health and safety risks, including how the principle of As Low As Reasonably Practical (ALARP) has been applied to that risk reduction. It also gives details of the diverse legislative framework within which the project does and will continue to need to operate.

1.5 CO_2 as a Hazardous Substance

One specific issue that needs to be highlighted in this introduction relates to the nature of CO_2 itself. By its very nature, the hazards associated with CO_2 form one of the important elements of process and plant design for the project particularly as the project proposes to transport CO_2 in dense phase at relatively high pressure. As a gas, CO_2 is both an asphyxiant and toxic. In addition, a release to atmosphere when in dense phase and at pressure will cause potentially difficult to manage phase change effects. However, within the legislative and regulatory framework, CO_2 is not specifically identified as a hazardous substance and, therefore for instance, does not contribute to the designation of COMAH tier status or entail that the CO_2 pipeline is designated a Major Accident Hazard pipeline.

Notwithstanding this apparently anomalous designation, operators of equipment that contain CO_2 in quantities have the underlying obligations derived from the HASAWA 1974 to undertake their operations whilst minimising the risk to their employees and the general public. As a result, both CPL for the OPP and NGCL for the T&S have considered and will continue to consider CO_2 to be a hazardous fluid and will design their systems accordingly.

2 Full Chain

2.1 Introduction

As well as being commercially viable, the White Rose project will be designed, built and operated to standards and procedures that ensure health and safety risks are designed out where possible and reduced to As Low As Reasonably Practicable (ALARP) where they cannot be completely designed out.

As part of the project development, the ongoing design has been studied from an early stage and health and safety issues have been identified for the main elements of the project. This work has been applied to the White Rose project as a whole; i.e. fuel supplies and services, combustion, power generation, CO_2 removal and compression, transmission and injection into geological off-shore storage. This is referred to as the Full Chain.

Throughout the design and operation of the Full Chain the overall delivery of safety is achieved through layering a variety of safety elements to ensure that the residual risk of the system to its operators and the general public is ALARP.

These layers include:
- Intrinsic safety in the design of the equipment;
- Programmable control systems;
- Hard wire automatic and manually operated shut down systems based on instrumentation which achieve required safety integrity levels;
- Operating procedures designed to ensure the proper monitoring and operation of the systems;
- Competent operators; and
- Audit.

2.1.1 Project Overview

The White Rose Full Chain is subdivided into individual chain elements, operators and owners as follows:
- Drax services and interconnections – Drax;
- OPP – CPL (design and installation by GE and BOC for the ASU);
- CO_2 Onshore and Offshore Pipeline including the Pumping Station – NGCL; and
- CO_2 Injection and Geological Offshore Storage – NGCL.

In this K12 Safety Report, the last two elements are combined by the term T&S.

The interfaces between elements are most important, notably:
- The OPP interface with the Drax interconnections; and
- The OPP interface with the T&S system.

2.1.2 Full Chain Scope

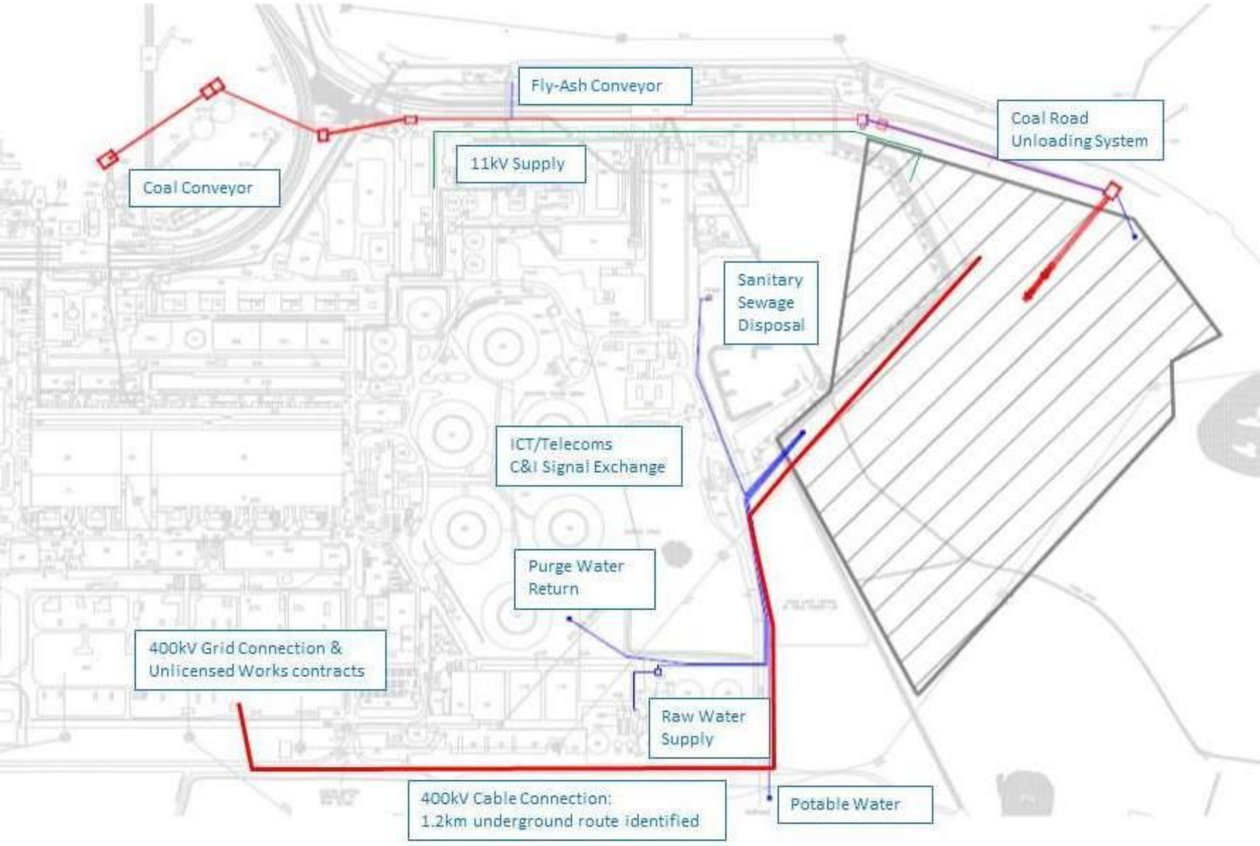
The White Rose Full Chain aims to ensure alignment of the Full Chain elements' individual health and safety mitigation and planning. Health and safety reports from each of the main elements and interfaces of the Full Chain have been included in this K12 Health & Safety Report. The Full Chain overview seeks to demonstrate that the individual health and safety risk assessments and management activities form a coherent management system and plan for the Full Chain.

2.1.2.1 *Drax Interconnections*

The following services are made available to the OPP from the Drax Site and are presented in Figure 2.1

- Coal feed (with biomass co-firing as an option);
- HV and MV power interconnections;
- Raw water supply;
- Purge water / Waste water disposal;
- Potable water supply;
- Sewage system;
- Ash removal; and
- Interfaces with Drax telecom, control and alarm systems.

Figure 2.1: Drax Interconnections Showing the Relative Location of the OPP Site



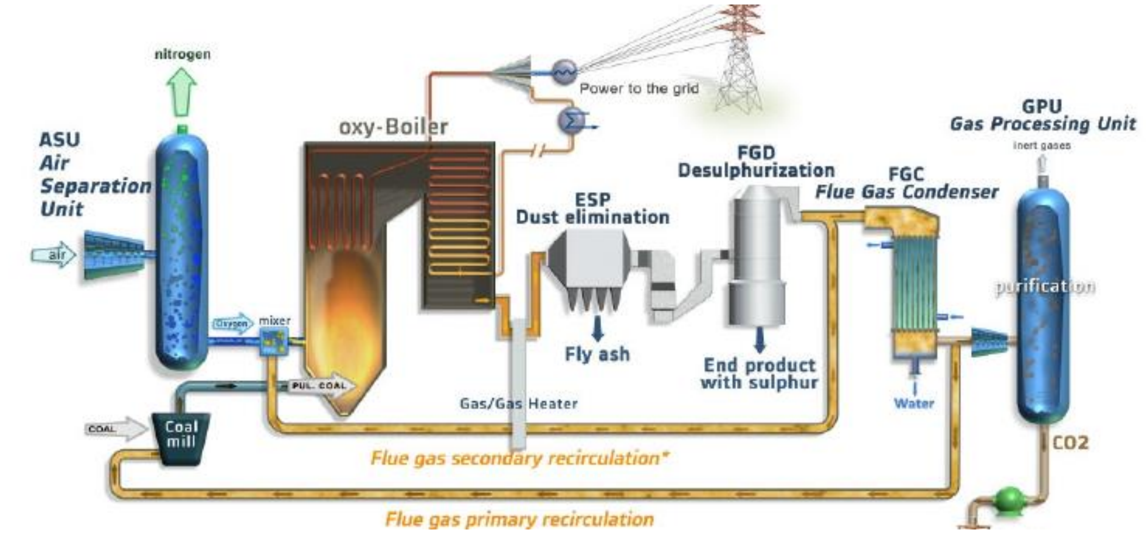
2.1.2.2 *Oxy Power Plant*

The key elements of the Power Plant are as follows and presented in Figure 2.2:

- Fuel handling;
- ASU;
- Oxy-fired boiler;
- Power generation from the steam produced in the oxy-boiler and associated condensers;
- Selective Catalytic Reduction (SCR) for oxides of nitrogen (NOx) removal;

- Recirculated gas heater;
- Electrostatic Precipitator (ESP) for dust (fly ash) removal;
- Wet Flue Gas Desulphurisation (FGD); and
- GPU.

Figure 2.2: Schematic of the OPP



2.1.2.3 T&S

The onshore dense phase transport system consists of the following:

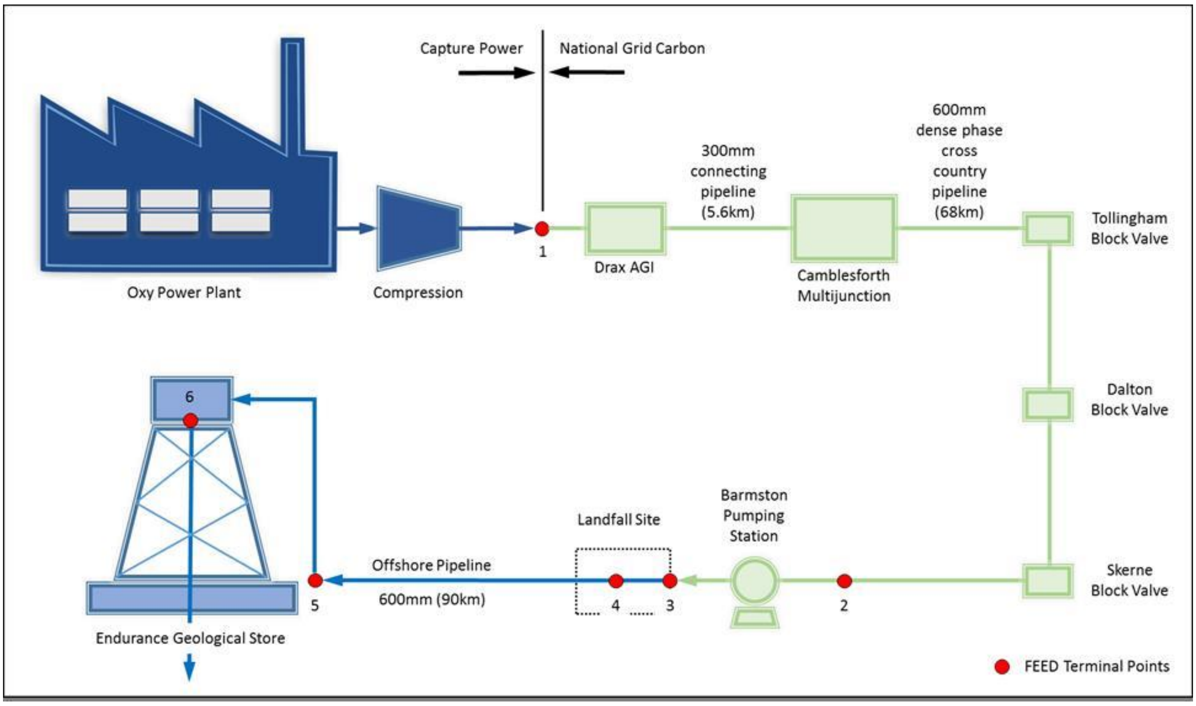
- 300mm diameter pipeline from OPP to Drax AGI Pig trap;
- 5.6km long 300mm diameter pipeline from the site to Camblesforth Multi-junction. [Note: future provision for other carbon capture projects to join the transport pipeline at this point];
- 600 mm cross country pipeline (68km) to Barmston Pumping Station; and
- Landfall pipeline 600mm (0.5km) to landfall site.

The offshore T&S system consists of the following:

- Offshore pipeline 600mm (90km) from landfall site to offshore platform;
- Offshore platform; and
- Multiple injection wells into geological storage.

Figure 2.3 depicts the onshore and offshore T&S system.

Figure 2.3: Schematic of the T&S System Showing the Interface to the OPP



2.1.3 Future Inclusions

After the completion of the White Rose project Implementation Phase, further sources of CO_2 could be added to the T&S network. The increased CO_2 flow rates would be expected to impact on the equipment and associated maintenance requirements of the T&S network in the areas of pumping and injection activities. However, this document does not address the potential introduction of future sources of CO_2.

2.2 Full Chain Hazard Identification Studies

A number of Hazard identification (HAZID) studies have been conducted throughout the FEED phase of the project. These were:

- A HAZID concentrating on the hazards due to the CO_2 interface between the OPP and the T&S system (see T&S section);
- The studies for hazards caused by the plant itself and the interfaces with Drax (see OPP section); and
- The studies for hazards from the T&S system (see T&S section).

2.3 Full Chain CO_2 Venting Philosophy

The detailed requirements and principles of the health & safety approach for venting of CO_2 within each element of the White Rose project are presented in the elements' own sections of this report.

The requirements and key principles applied to the Full Chain are summarised below.

- Provide overpressure/thermal relief Provide a means for controlled system depressurisation; and
- Support the isolation of high pressure systems (e.g. using double block and bleed arrangements).

Particular objectives relating to health & safety are:

- To minimise the quantity of CO_2 released into the atmosphere (venting large volumes of high concentration, high pressure CO_2 into the atmosphere may have health, safety, environmental and engineering implications); and
- The venting system must achieve a high standard of health, safety, environmental and engineering performance while complying with UK regulations and legislation and with operating organisations' policies and procedures.

Each element of the Full Chain will manage its own venting system design and implementation, subject to the following two requirements:

- Impacts of potential cumulative releases are taken into account; and
- Venting systems (and the underlying processes) are designed to ensure that there are no venting event "knock on" effects across element boundaries.

The features and constraints incorporated into the design that will help to implement these health & safety requirements include:

- Venting systems will be designed to combine vented streams, where practical, to reduce the number of CO_2 release points. Where this is not practical, e.g. for minor vents etc., then venting will be carried out in well ventilated areas;
- The venting systems will also be designed to minimise the likelihood that personnel will come into contact with released CO_2 as this could result in cold burns;
- The noise generated at the vent tip as a result of CO_2 venting operations will require consideration with reference to limits agreed with the Local Planning Authority (LPA) and occupational health limits. Noise will be considered during the implementation phase; and
- The installation CO_2 detection systems are primarily designed to identify local releases from the system. They will remain in service during venting operations. Temporary CO_2 detection can be utilised to support temporary venting operations.

2.4 Control Philosophy

Each of the Full Chain elements will be equipped with an individual control system. These will include the Drax Power Plant (DPP) material handling systems, the GE OPP Distributed Control System (DCS), the BOC ASU control system, and the NGCL control systems. The individual control systems for the elements of the Full Chain will be designed to communicate and interface with the adjacent systems to facilitate safe and secure control of the entire system and to provide monitoring and management information to the control centres.

In order to provide a set of individual control systems that will interact to provide an overall control approach ensuring safe, stable, reliable and consistent Full Chain operation, the adjoining control systems will be connected through hard wired and serial link interfaces to achieve a coordinated control scheme. This covers control aspects of the Full Chain from the materials handling systems in the existing DPP through the OPP, including the ASU and GPU, through the T&S system.

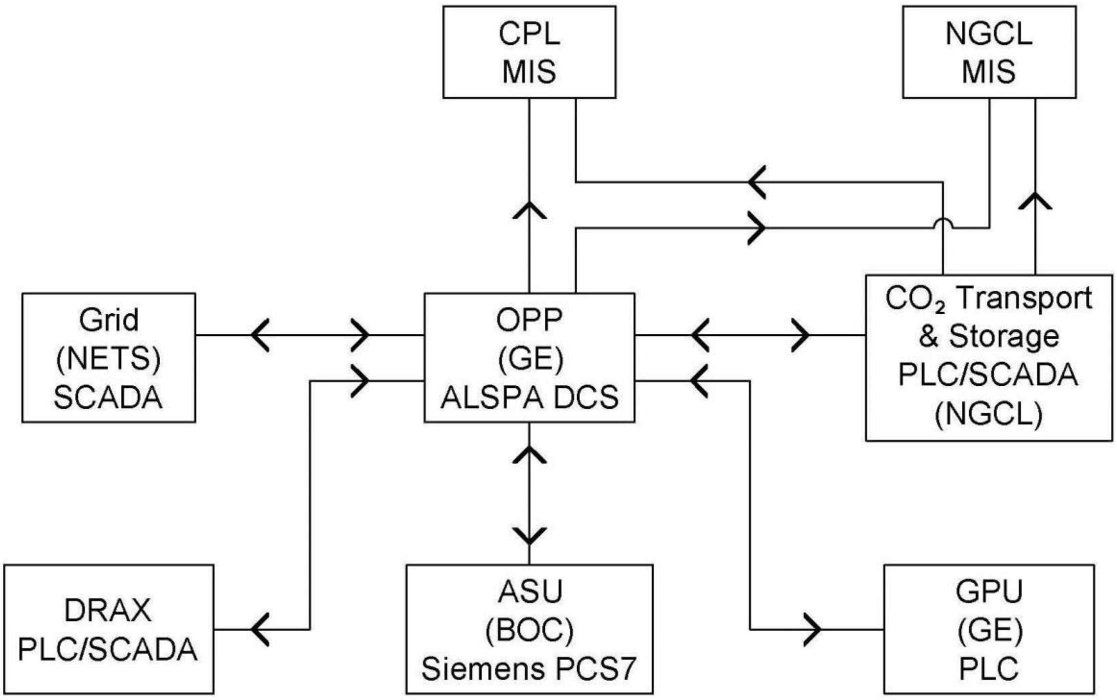
The principal functions relating to health & safety are designed to:

- Ensure automatic, safe, secure and efficient operation of each Full Chain element under all conditions;
- Raise and manage alarms if the process or equipment moves out of normal limits;
- Achieve a sufficient level of automation reducing dependence on operators activities;

- Allow remote control of the equipment (via a remote Human Machine Interface (HMI)); and
- Enable a safe emergency shutdown if required.

The control systems to be used in the project are presented schematically in Figure 2.4 below.

Figure 2.4: Overview Diagram of the Full Chain Control Scheme



The Full Chain control systems will be interfaced rather than integrated. This means that they will be entirely independent of each other but will include the signal exchange required to provide reliable coordination of the overall process and appropriate responses to emergency or out of limits measurements, as well as routine process variations. The signals and data exchanged between control systems will not execute directly control actions on the receiving party's system. The individual element control system and the operators in charge will respond to signal inputs from other elements according to the requirements of the process. This is important because the control requirements of each element are implemented in a manner that is appropriate to the subsystem's special operational requirements.

Drax site interconnections will supply services/materials to the OPP. Permissive signals will be exchanged between the two plants to stop the systems in the case of plant failures or safety issues.

The details of the Full Chain coordination will be developed during the implementation design phase for both process and safety reasons.

The CCS chain elements are interconnected such that a start, controlled stop or trip of any component within the chain can provide information and alarms to both the upstream and downstream process systems. Interfacing signals between the chain elements are therefore required to ensure the process is managed safely and efficiently.

Signal interfacing between the systems will be implemented by a combination of hard wired and serial communications links. Hard wired connections are used for safety functions, such as Emergency Shut Down (ESD) and permissive interlocks, and also for command signals such as start and stop. Serial links may be used for control or safety related functions provided the link and associated equipment can be demonstrated to provide sufficient security for the function. This can be achieved by subjecting the design to rigorous analysis using procedures set out in standards such as IEC 61508 and 61511 for the design of safety instrumented functions.

Each installation in the Full Chain will have a number of industrial safety systems installed that are designed to protect the personnel, the environment, and plant (equipment and structures) from potential process hazards. Safety control systems will be independent from their respective process control systems and may be certified by a relevant third party organisation.

The key safety systems for the project are:

- ESD systems;
- CO_2 composition analysis;
- Fire and Gas (F&G) detection system;
- CO_2 detection; and
- High Integrity Pressure Protection System (HIPPS).

2.4.1 ESD Systems

Stand-alone ESD systems will be provided for each of the main plant control systems including the OPP and GPU, ASU, materials handling systems, and T&S system.

The Full Chain elements are interconnected such that a start, controlled stop or trip of any component within the chain can provide information and alarms to both the upstream and downstream process systems. Interfacing signals between the chain elements are therefore required to ensure the process is managed safely and efficiently.

Signal exchange will be established between the chain systems such that key operating parameters, permissive signals and trips are immediately communicated and displayed on HMI in the various control centres. Executive action will, however, only be taken from the control room responsible for each element of the Full Chain, (i.e. no cross boundary executive actions).

The ESD systems ensure that the Full Chain elements remain in a safe state and are based on fail safe technology. The systems are responsible for tripping the associated plant and equipment in the event of dangerous conditions occurring or if the critical process variables are outside their normal safe operating range.

The ESD systems will be designed in accordance with standards IEC 61508 and IEC 61511 which set out the generic approach for safety strategies to be followed for the process industry sector. The safety strategy requires that a hazard and risk assessment will be carried out for each of the Full Chain elements to enable the Safety Integrity Level (SIL) for each safety function to be derived.

Safety systems will include all of the components necessary to carry out the safety function.

2.4.2 CO_2 Composition Analysis

For safe operations, the CO_2 composition will be analysed at the transfer point between the OPP and T&S system. The CO_2 entering the transportation system at the OPP AGI will be required to comply with the CO_2 composition specification.

Should the produced CO_2 approach any of the specification limits an alarm will be raised. Should the CO_2 composition breach any of the process limits the OPP will stop supplying CO_2 to the T&S system and lock-in the CO_2 inventory, in order to ensure as little off-specification CO_2 enters the T&S system as possible.

2.4.3 Fire and Gas Detection System

Dedicated F&G detection systems will be provided for the OPP (and its associated systems i.e. ASU and GPU) and for the T&S systems. Drax has F&G systems in operation for the existing plant which will encompass the new materials handling systems as well as the existing cooling water and other services.

The systems at each site will be independent systems that will reliably detect, alarm and if necessary initiate an orderly system control or shutdown in the event of emergencies (via the ESD systems). Generally, the system will comprise of F&G detectors, workstations, F&G alarm panels, audible and visual alarms and all necessary cabling. Principal alarm and monitoring signals will be transmitted from the F&G panels to the integrated control systems (OPP DCS and NGCL control system) for alarm and recording purposes.

The system design and installation will comply with relevant international standards.

2.4.4 CO_2 Detection Systems

Dedicated CO_2 detection and monitoring schemes will be implemented where appropriate on each chain section for the safety of the personnel (including the local populace) from the risks of CO_2 exposure. CO_2 levels at the ASU inlet will be monitored by OPP. Increased levels of CO_2 at the ASU compressor inlet would dramatically affect the ASU processing and could lead to ASU shutdown.

2.4.5 High Integrity Pressure Protection System

HIPPS may be required to protect downstream systems from potential overpressures from compressors. If required, the OPP and the Barmston Pumping Station may be equipped with HIPPS.

HIPPS will isolate the pipeline rapidly before an unacceptable pressure level occurs and will be designed to comply with the requirements of IEC 61508.

2.5 Operation & Maintenance Philosophy

The principal operational and maintenance objectives of the project include ensuring a high standard of environmental, health and safety performance. This includes the management of risks to be ALARP.

The elements of the Full Chain will be controlled separately by CPL and NGCL. NGCL will coordinate the preparation of the emergency arrangements for the T&S system while CPL will coordinate all activities for the OPP, interfaces with Drax services and interfaces with NGCL. These protocols will establish the actions necessary to restore the system or the affected part of the system to a safe condition.

Once agreed, the actions will be communicated for approval/acceptance – to neighbouring facilities, regulatory bodies, emergency services and local communities. The emergency arrangements will be tested regularly. Control centre contingency and disaster recovery arrangements will also be developed in consultation with the appropriate parties.

The chain element operators will develop a common policy for planning and implementing both routine and non-routine operations, such as breaking containment, to ensure that all operational, safety and environmental aspects are given appropriate consideration and that all hazards are effectively controlled. To ensure a high level of safety and reliability in operation, a system of inspection and maintenance will be established for assets associated with the transportation of CO_2.

In addition, a common approach will be adopted, allowing efficient and cost effective maintenance and ensuring compliance with statutory legislation and policy.

Occasionally, it may be necessary to carry out operations involving hazardous plant, processes and substances that have not been conducted before or are not covered by existing site procedure. They will be subject of a detailed safe system of work.

In accordance with the HSE's Guidance Note HSE-HSG274 (Legionnaires' disease), if a system can be shown to be free from fouling, i.e. the deposition of particulate material and debris, there is no need for it to be cleaned at a set time interval, rather the system should be cleaned whenever it is known or suspected to have become fouled. However, as cleaning operations are disruptive, it is common to adopt a precautionary approach, with cleaning operations being scheduled to coincide with planned shutdowns or at a predetermined interval.

Statutory requirements defining required inspections will be scheduled to coincide with planned shutdowns, as will any insurance related inspection shutdowns.

The maintenance strategy will align with the requirements associated with a COMAH site in terms of the following:

- The operators and maintenance staff will all be fully trained and assessed as competent in respective disciplines prior to working on site with particular emphasis on specific safety related systems which will be identified through the relevant process safety assessments such as Layers of Protection Analysis (LOPA) and other techniques; and
- All safety related systems will be clearly identified and highlighted separately in the respective maintenance planning systems with specific tasks allocated.

2.6 Implementation Phase

During the Implementation Phase the Full Chain considerations with respect to health and safety in design and construction will be taken forward in a similar manner. Detailed design work and construction co-ordination within each element of the Full Chain will be taken forward by the individual parties responsible for these but CPL will remain responsible for ensuring the design and, in due course, operation of the interfaces between those elements is managed so as to minimise health and safety risks. This will involve the next level of work around interface HAZID, Hazard and Operability (HAZOP) and CO_2 venting is undertaken on the interfaces and ensuring a co-ordinated approach to regulatory compliance with respect to both CDM Regulations 2015 and COMAH Regulations 2015.

All equipment, systems and overall facilities have been designed and built to meet statutory and owners/NGCL Health and safety standards.

During the FEED the management of health and safety has been a key consideration within the design. The overall health and safety approach has considered key legislation and best practice and are described in the relevant sections within this KKD. During the Implementation Phase the overall approach assumes CPL will establish, implement, maintain and continually improve the Health and Safety Management System (HSMS) throughout the Construction and Operation Phase of the Project.

Topics covered by the HSMS are outlined below:

- **Process safety leadership -** define and communicate the level of health and safety performance expected from the project and the necessary resources to be put in place to achieve the required level of performance;
- **Risk identification & assessment** - Methods to be put in place to identify and assess the risks that the project needs to manage in order to assure the integrity of their operations, how the necessary control measures are identified and how the process safety knowledge from risk identification and assessment should be recorded;
- **Risk management -** How the project should implement and manage the different categories of control measures that have been identified during the risk assessment activities; and
- **Review & improvement -** How the project should measure and review compliance with the HSMS how the project should ensure that lessons learned from these measurements and reviews are feed-back into the HSMS.

CPL will establish documented procedures to monitor and measure the progress of the Project in relation to the objectives and targets outlined within the HSMS. This will make particular reference to compliance with applicable legislation. An audit programme and procedure will be established and undertaken during the Construction and Operation Phase to determine whether the project is being implemented in line with the HSMS.

3 Oxy Power Plant

3.1 Introduction

During the execution of the OPP FEED a number of Environmental, Health and Safety (EHS) related studies have been undertaken commensurate with the stage of design work represented by FEED.

This FEED work followed initial work undertaken Pre-FEED. In particular:

- A HAZID workshop was undertaken on 29 March 2012 to identify the key hazards likely to be encountered during construction and operation. This workshop was chaired by an independent safety expert; and
- A meeting was held with the HSE and Environment Agency (EA) on 12 July 2013 to explore issue relating to the COMAH designation of the site.

The technical FEED work on the OPP identified that it would be appropriate to undertake additional HAZOP work specifically on the oxygen related systems of the boiler and power island. As this would be an extension of GE's FEED scope it was agreed between GE and CPL that this should be managed as a Change request under their FEED Sub-Contract or, if that is not possible, as an early activity during Project Implementation Phase. All such FEED Change requests are subject to approval by DECC prior to them being instigated and thus this work will be undertaken if and when DECC have provided their agreement to the Change.

The COMAH Tier Assessment was undertaken in accordance with the 2015 version of the regulations that derive from the European Seveso 3 Directive and provided to DECC. This concluded that that the site will be lower tier.

Following completion of the technical FEED work on the project and in the light of 2015 revisions of both the CDM and COMAH Regulations, further meetings were held with the HSE's Construction Division and the Hazardous Installation Directorate to provide general updates on project progress and to have specific discussions on the applications of the Regulations to the project.

3.2 Purpose

This section covers the OPP and includes an overall narrative of the approach to health and safety and is retrospective (looking back at the work undertaken in this area during FEED) and prospective (laying out the approach to health and safety management that will be followed during the implementation phase).

The section includes:

- A summary of HAZID undertaken and a summary of key actions;
- A summary of HAZOP undertaken and a summary of key actions specific to the application of CCS
- COMAH status assessment;
- Project health and safety plan for the Implementation Phase;
- A summary of the CO_2 vent dispersion modelling; and
- A summary of the Project's response to ALARP.

The key outcomes of the studies are outlined in the following sections.

3.3 HAZID

This section is a summary of key actions.

A HAZID review was carried out for the OPP and Drax interfaces. The HAZID meeting took place on 15 May 2014 at the offices of CPL in London.

The objective of the HAZID review was to:
- Identify possible hazards and threats in an early stage of the design development;
- Assess the control measures available and indicate where additional controls are required;
- Formulate the recommendations to control possible hazards and threats; and
- Provide input for the various safety related philosophy documents and studies (such as HAZOP, Safety Instrumented System (SIS)), firefighting and Atex/ zone classification.

The HAZID review focused on two separate elements:
- External hazards which are natural and environmental hazards and external third party hazards; and
- Facility internal hazards which are process hazards due to separate units or functional blocks of the process and non-process hazards due to accommodation, site internal transportation or third party site intervention.

3.3.1 Summary of Key Outputs

The key issues identified through the HAZID study were:
- Internal and external security threats shall be further analysed by owner (CPL discuss with Drax security);
- Domino effect with ammonia or O_2 storage shall be further analysed by CPL & Drax, Drax to provide safety report of Lytag plant;
- HAZOP study shall be conducted during project execution to ensure that the design is correctly done;
- Frost protection concept to be prepared during project execution;
- Fire hazards and firefighting shall be further studied during project execution;
- Explosion hazards & detection/protection and hazardous area classification (Atex/DSEAR) shall be studied during project execution, taking into account the high risk of oxygen enriched atmosphere (due to high oxygen quantity on site);
- CO_2 hazards & detection/protection and critical area identification shall be studied during project execution;
- Heating, Ventilation and Air Conditioning (HVAC) concept shall be defined during project execution, taking into account the high risk of oxygen-enriched atmosphere; and
- SIS for functional safety to be further analysed during project execution.

Table 3.1: Summary of Key HAZID Actions for OPP Plant and Drax Interface

No	Potential hazard & effect	Actions
1	Insufficient manufacturing of the pipes (faulty welding, grease, protective coating and oil on surfaces that will be in contact with pure oxygen or oxygen enriched gases)	Instructions to be developed during execution phase
2	Operator errors leading to hazardous conditions	Protection philosophy – Alarm management – O&M manual – Training sessions – Emphasis will be placed on potential hazards found in oxygen enriched

		atmospheres (O_2 detectors may be needed)
3	Not having a proper maintenance philosophy can cause severe problems by the maintenance of the plant, loss of operation (longer maintenance periods)	Plant general maintenance program and procedure to be developed. Emphasis will be placed on potential hazards found in oxygen-enriched atmospheres. (O_2 detectors + CO_2 detectors may be needed)
4	Insufficient maintenance of oxygen pipes/equipment can lead to fire hazard	Safety manual to be developed during execution phase
5	Release of hazardous inventory due to structure failure of storage	Spillage risk for ASU and Drax interconnection scope will be studied separately by BOC and Drax
6	O_2 release to atmosphere in case of mechanical leakage or rupture of gas duct or furnace	Install oxygen detectors in critical areas -BOC will provide expertise during the review of the design
7	CO_2 release to atmosphere in case of mechanical leakage or rupture of flue gas duct Gas may accumulate in hazardous amounts in low lying areas especially inside confined spaces, resulting in a health hazard.	CO_2 detectors in critical areas (These could be used to detect both low and high levels of CO_2)
8	Ammonia release to atmosphere in case of mechanical leakage	Indoor and outdoor detection with alarm -personnel protection provided on site -Safety eye wash station and shower will be provided in the ammonia storage area, and eye wash station provided in the boiler area -safety procedure according to regulation to be submitted
9	Release of liquid oxygen. Damage to surrounding equipment. Severe burns to personnel	BOC will provide expertise during the review of the design
10	Overfill of chemical storage tanks	Spillage risk for ASU and Drax interconnection scope will be studied separately by BOC and Drax
11	Overfill of liquid oxygen storage vessels. Risk of spillage and release of low temperature fluid.	BOC will provide expertise during the review of the design
12	Internal fire due to mill system increased O_2 content, or non-uniform gas distribution and O_2 stratification	Boiler supplier to describe how O_2 content is controlled and protected from internal fire during project execution -boiler supplier to check if CO monitoring is necessary?
13	Fire & explosion caused by equipment or system malfunction in oxygen enriched atmosphere.	The operational and design risks which occur from the utilization of oxygen will be identified. Industry accepted methods (use of the correct electrical enclosures, proper fire protection systems and most of all, ample ventilation capability in the tripper enclosure and the boiler enclosure) will be implemented to mitigate or eliminate those risks
14	Discharge of CO_2 from stack in the event of trip in Oxy Mode requiring sudden opening of stack damper	Review whether dispersion of discharged CO_2 from stack could form dangerous concentrations at ground level (by CPL)

3.4 HAZOP

For most sections of the plant the FEED work has not included HAZOP studies as the level of detail of the system designs completed in FEED does not allow such studies to be completed and the assessment of risk was such that it was not necessary to develop the design to the point at which HAZOPs could be completed. They will be undertaken in the Implementation Phase. The one significant system for which a HAZOP was identified as necessary in the original FEED scope was the GPU and this HAZOP was undertaken. During FEED it was identified that an additional HAZOP relating the oxygen systems within the boiler should be undertaken. These have not yet been undertaken.

3.4.1 GPU HAZOP

3.4.1.1 GPU HAZOP – Study Work

The overall objectives of this HAZOP study on the GPU for White Rose CCS Project are:

- To check the current design for possible deficiencies which could lead to hazards or operability problems;
- To identify possible hazards or operability problems which need to be addressed in more detail; and
- To make recommendations for specific design aspects or safety measures which should be considered or installed.

The HAZOP meetings for the GPU were carried out between 21st July .2014 to 13th August 2014. The HAZOP methodology was based on the international standard: IEC 61882, first edition, 2001-05.

The HAZOP assessment covered the following elements of the process:

- Flue gas condensation;
- Flue gas compression;
- Drying and regeneration;
- Flue gas chilling and separation;
- CO_2 compression; and
- Chemicals.

The scope of assessment included the internal GPU unit and the following operation modes:

  - Normal;
  - Start up;
  - Shut down; and
  - Emergency shut down.

The scope of the assessment did not include:

- GPU interface HAZOP (planned to become an extra HAZOP session later);
- Relief system design, including FA-0501;
- Regeneration system, including EA-0206 and EA-0208;
- Utility systems;
- GB-0201 wash water system;
- N_2 supply system;
- Depressurization and isolation concept;
- Draining concept;
- Commissioning;
- Maintenance; and
- All changes and design modifications documented in the Piping and Instrumentation Diagrams/Drawings (P&ID) after the documented HAZOP P&ID version are to be subject for an additional HAZOP session.

The HAZOP assessment identified in excess of 100 recommendations across for the OPP GPU. The recommendations covered a full range of areas while the following section summarises the key areas which were identified specifically for CCS.

3.4.1.2 *Summary of Key Outputs Related to CCS*

The GPU HIPPS needs to protect the T&S pipework from over pressure and potential fracture. A surge analysis was recommended to cover both upstream and downstream effects of HIPPS operation.

The CO_2 delivery temperature from the OPP GPU needs to be limited to avoid exceeding the design temperature (25 ^{o} C) of the T&S pipeline. Exceeding the temperature could lead to pipeline fracture. Therefore a temperature alarm and trip function for the GPU was recommended.

It was also recommended that the OPP GPU CO_2 product analyser should be connected to the protection system to trip CO_2 export if the product is out of limits for the T&S system.

3.4.2 Boiler HAZOP

As noted in 3.1 above the Technical FEED work on the OPP identified that it would be appropriate to undertake additional HAZOP work specifically on the oxygen related systems of the boiler and power island. This will be undertaken either later in FEED or as an early activity in project implementation.

3.5 COMAH Review

3.5.1 COMAH Regulations Compliance

Whilst the COMAH Regulations provide general principles that are applicable to all installations that contain hazardous substances, they lay out particular requirements on installations depending on the quantity of those substances. In particular they designate sites as either “upper tier” or “lower tier” with that designation being dependent on the level of hazard calculated on a weighted aggregate basis across all the hazardous substances on the site. For each hazardous substance the Regulations lay down threshold quantities which would, on the basis of that substance alone, place a site into either the lower or upper tiers. It is these thresholds that are used in the aggregate calculation.

As laid out in this report the prescribed calculations for the OPP, based on the currently assumed quantities of each hazardous substance, shows the installation to be lower tier. This is principally driven by the quantities of two substances; anhydrous ammonia, used in the SCR process that removes NOx from the boiler flue gas, and the Liquid Oxygen (LOX) that is held within the Air Separation Plant, both within the plant itself and within the back-up storage system.

The general requirements for safety in design and operation and the approach to management of major accident hazards by CPL are not affected by the COMAH tier status as it is a key aspect of the company’s corporate responsibility.

3.5.2 Hazardous Substances

The OPP will store and use ‘Hazardous Substances’ (as defined in the CLP Regulations - Regulation (EC) No. 1272/2008) and thus comes under the EU Seveso III directive (2012/18/EU), which has been incorporated into UK law as:

- The COMAH Regulations 2015; and

- The Planning (Hazardous Substances) Act 1990 and The Planning (Hazardous Substances) Regulations 1992.

An assessment has been carried out on the potential status of the facility. It was concluded that under the COMAH Regulations the site will be lower tier.

Although categorised as lower tier, as part of FEED work, two studies have been undertaken as part of this process of design with respect to the hazardous substances; a layout risk assessment and an Occupied Building Risk Assessment (OBRA).

3.5.2.1 *Layout Risk Assessment*

Building on the work done Pre-FEED (see 3.1 above), the design team undertook an initial FEED Layout Risk Assessment on 24 February 2014. This review created a number of actions that were subsequently closed out as part of FEED design. A further layout review was undertaken at the close of OPP technical FEED to ensure that none of the small changes that had occurred in FEED since the initial review resulted in any issues that need to be addressed.

3.5.2.2 *Occupied Building Risk Assessment*

The project team has proceeded with an OBRA study undertaken by CPL's Technical Adviser Mott MacDonald. This review showed there were no matters of significant concern although final consideration on the positioning of the anhydrous ammonia storage should be undertaken to ensure the risk is ALARP. This has been completed in FEED.

3.5.2.3 *Requirements for all COMAH Sites*

For all COMAH sites the requirements on the operator are:

- To notify the relevant authorities (HSE and EA);
- Be able to demonstrate that: it has taken 'all measures necessary' to prevent major accidents and limit their consequences to persons and the environment (this implies that the operator has identified the Major Accident Hazards);
- To produce and implement a Major Accident Prevention Policy (MAPP) prior to commencement of operation. The purpose of the MAPP is to provide a statement of the senior management's commitment to achieving high standards of major hazard control. A MAPP must –
  a. be designed to ensure a high level of protection of human health and the environment;
  b. be proportionate to the major accident hazards (i.e. the greater the hazards the more information that is required);
  c. set out the operator's overall aims and principles of action;
  d. set out the role and responsibility of management, and its commitment towards continuously improving the control of major accident hazards;
- Provide information to the public. Information must be available to anyone in an area likely to be affected by a major accident. This area is known as the Public Information Zone (PIZ). The Competent Authority (CA) is responsible for providing this information including
  a. the name of the operator and the address of the establishment;
  b. confirmation that the COMAH Regulations apply to the establishment and that the notification has been sent to the competent authority;

c. an explanation in simple terms of the activity or activities undertaken at the establishment;
d. the hazard classification of the relevant dangerous substances involved at the establishment which could give rise to a major accident, with an indication of their principal dangerous characteristics in simple terms;
e. general information about how the public will be warned, if necessary, and adequate information about the appropriate behaviour in the event of a major accident or an indication of where that information can be accessed electronically;
f. the date of the last site visit carried out further to a programme for routine inspections, and where more detailed information about the inspection and the related inspection plan can be obtained upon request; and
g. details of where further relevant information can be obtained.

Safety Report

Production of a Safety Report prior to construction (Pre-Construction Safety Report) and a revised version prior to the introduction of hazardous substances (Pre-Operational Safety Report). The purpose of the Safety Reports is to:

- demonstrate that a MAPP and a safety management system for implementing it have been put into effect;
- demonstrating that the major accident hazards and possible major accident scenarios in relation to the establishment have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences for human health and the environment;
- demonstrating that adequate safety and reliability have been taken into account in the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected with the establishment's operation which are linked to major accident hazards inside the establishment;
- demonstrating that an internal emergency plan has been prepared, which includes sufficient information to enable an external emergency plan to be prepared; and
- providing sufficient information to the CA to enable decisions to be made regarding the siting of new activities or developments around establishments.

These safety reports are submitted to the CA, which is the HSE and EA for comment. A prohibition is in place on the operation of the facility until the CA is satisfied with the Pre-Operational Safety Report.

COMAH Safety Reports should be reviewed and revised at least every 5 years or if there is a major change to the facility or its operations.

On Site Emergency Plan

A COMAH emergency plan must have the following objectives:

- containing and controlling incidents so as to minimise the consequences, and to limit damage to human health, the environment and property;
- implementing the necessary measures to protect human health and the environment from the consequences of major accidents;
- communicating the necessary information to the public and to the services or authorities concerned in the area; and
- providing for the restoration and clean-up of the environment following a major accident.

The On-site emergency plan is prepared by the facility operator.

Off-site Emergency Plan

The external emergency plan details the roles to be carried out by emergency services, local authorities and other external organisations in the event of a major accident. This includes the arrangements established to help with the emergency response on site. The degree of planning should be proportionate to the probability of a major accident and consequences of the accident occurring. The responsibility for the Off-site emergency lies with the Local Authority. However the facility operator has to liaise with the local authority and provide information to support the off-site emergency plan.

Regular testing of Emergency Plans

The testing of the Emergency Plans (on-site and off-site) should be carried out at least once every three years.

Provision of Information to the Public at Upper Tier Sites

Everyone within the PIZ of an upper tier site will be sent, without having to request it, clear and intelligible information on safety measures and requisite behaviour in the event of a major accident at the establishment. When preparing the PIZ information the operator must consult the local authority on safety measures and behaviour required in the event of a major accident.

The operator must review and, where necessary revise, the information sent to the public at intervals not exceeding 3 years or in the event of a major change.

3.6 Project Health and Safety Plan (Implementation Phase)

3.6.1 Overview

In line with CPL's Environment, Health, Safety and Quality policy, presented in Appendix C "The safety and health of our colleagues, customers, business partners and communities in which we do business are paramount and are at the forefront of our business objectives." health and safety is a key performance indicator and critical success factor for the Implementation Phase. CPL's vision is for zero incidents and safe, secure and healthy working conditions for all who work with and for us. CPL's contracting of the project execution will be undertaken in accordance with these principles.

Given that implementation includes engineering design, construction and commissioning the Implementation Phase Health and Safety Plan has to cover three distinct areas:
- Safety in design (Both process safety and design for construction safety);
- Safety in construction; and
- Safety in commissioning operations.

CPL will ensure all aspects are undertaken in accordance with Good Industry Practice (GIP) within the framework provided by the relevant regulations. Whilst all implementation activities are governed by the duties created by the HASAWA (1974) with the many Regulations that have been established flowing from it, the two primary Regulations applicable to this phase of the work on the OPP are the CDM Regulations, which govern the design for construction safety and safety in construction, and the COMAH Regulations which govern process safety design and commissioning operations.

Overall responsibility for health and safety during implementation lies with CPL but it will be managed on its behalf by the Project Management Contractor (PMC) it will employ to manage project execution. CPL will be employing a main Engineering Procurement and Construction (EPC) contractor to deliver the OPP work and separate EPC contractors to deliver the Interconnections and Enabling Works. Each element of the works will be executed in accordance with the health and safety procedures of the relevant EPC contractor with the PMC confirming that these are no less stringent than CPL's own requirements. With respect to operations it is CPL's current intention to employ an Operation and Maintenance (O&M) contractor with responsibility for the operation and ongoing maintenance of the OPP whilst the Interconnections will be operated by DPL as part of the operation of the existing power station.

This report focusses on how CDM and COMAH responsibilities in relation to the OPP are envisaged to be assigned to the various supply chain parties undertaking the work given the nature of the contractual arrangements and the physical and design interfaces between the elements of the project.

3.6.2 CDM

Discussions have taken place between the project and the regional Construction Division of the HSE who will be responsible for the OPP construction at Drax. These have led to an agreed understanding of how the project will be managed, under CDM which in turn, has allowed the project to assign specific division of responsibilities to the supply chain over and above the general obligations under CDM relating to both the design process and construction organisation. These latter, generic processes are not addressed in this report.

3.6.2.1 CDM Project Structure

Given that the scopes of work are mutually exclusive with only limited physical interfaces, it is agreed that at the OPP site we shall identify three separate, mutually exclusive but interfacing projects for the purposes of CDM, each with their own F10 notification to the HSE:

- The main OPP site within the permanent fence line of the OPP site and the temporary laydown areas that are allocated to the EPC contractor;
- The Interconnections connecting the OPP site to the existing Drax infrastructure; and
- The Onshore Pipeline, including Drax AGI Pig trap, being constructed by NGCL as part of the T&S infrastructure.

(Note: Whether the small Enabling Works contract will form a fourth project or will be regarded as part of one or more of the above will depend on eventual timing of the works – whether they are to be undertaken alongside work in the OPP and Interconnections contracts or wholly independently of them. Once that timing is known decisions relating to the management of CDM with respect to the Enabling Works will be undertaken. This element of the work is not discussed further in this report.)

Each of the above projects will have an identified Principal Contractor (PC). It is essential that the demarcation between the sites is maintained when tie-in work is being undertaken – i.e. that each physical tie-in clearly lies in one site under the management co-ordination of a single PC with the PC of the adjoining site becoming a Contractor within the CDM designation of the site in which the work is being performed. This may require site boundary fences to be temporarily moved to ensure the clarity of demarcation.

CPL will have a single Principal Designer (PD) covering both the OPP and Interconnection projects. NGCL will have a PD who will probably be different from the CPL PD with the two PDs co-operating over design issues at the interface between the projects. To ensure there is no diminution of the engineering responsibilities within the EPC contracts for the OPP and the Interconnections the designers working for those contractors will be responsible for undertaking the design risk management required under CDM, the identification of residual construction risk and the passing of Pre-Construction Information (PCI) to the construction teams within the contractor's organisation. This PCI shall be copied to the CPL PD so that the PD can be assured that the PCI is being appropriately provided. The EPC contractors will be responsible for compiling the Health and Safety File for their scope of work.

CPL's PD will be responsible for:

- Overseeing design health and safety issues at the interfaces;
- Ensuring that the EPC designers are providing full and appropriate PCI to their construction teams
- Providing PCI originating from outside the EPC contractor to the EPC contractors' designers;
- Ensuring the Health and Safety Files compiled by the EPC contractors are acceptable; and
- Compiling the overall Health and Safety File from the elements provided by the EPC contractors.

3.6.2.2 *CDM – Supply Chain Responsibilities*

Based on the above agreed implementation of CDM within the OPP element of the project the following key responsibilities will be assigned to the supply chain counterparties.

CPL

- To act as Client for the OPP and Interconnections projects;
- To appoint a PD for the OPP and Interconnections projects;
- To appoint the OPP and Interconnections EPC contractors as PCs for their respective scopes of work;
- To appoint a PMC with a health and safety advisory function capable of monitoring on its behalf and assuring the competency of the EPC contractors' health and safety management processes.

NGCL Transport and Storage Service Agreement (TSSA)

- To act as Client for the T&S infrastructure work undertaken at the OPP site (and beyond);
- To appoint a PD and a PC for their work;
- Their PD to collaborate with CPL's PD;
- When working on the OPP site their work shall be fully segregated from the work of the OPP EPC contractor. Where this is not possible (e.g. site access and formation of the Terminal Point (TP)13 tie-in) then there shall be absolute clarity under which Principal Contractor the work falls; and
- To be responsible for their own PCI and Health and Safety File.

OPP EPC Contractor

- To be PC for all work on OPP site (once they arrive) except for that ring-fenced to NGCL;
- To work under Interconnections EPC contractor as PC for work they undertake on the Drax operational site (400kV cable laying, ash conveyor installation and the last leg of the coal conveyor);

- Their designers to be responsible for undertaking the design risk management required under CDM, the identification of residual construction risk and for passing PCI to their EPC construction team. This should be copied to the CPL PD so that the PD can be assured that the PCI is being provided;
- To be responsible for compiling the Health and Safety File for their scope; and
- Their designers to collaborate with CPL's PD who will be assuring CPL of EPC's CDM compliance and co-ordinating safety in design issues at the tie-in points.

Interconnections EPC Contractor

- To be PC for all interconnection work on the Drax operational site including that done by the OPP EPC contractor;
- Their designers to be responsible for undertaking the design risk management required under CDM, the identification of residual construction risk and for passing PCI to their EPC construction team. This should be copied to the CPL PD so that the PD can be assured that the PCI is being provided.
- To be responsible for compiling the Health and Safety File for their scope; and
- Their designers to collaborate with CPL's PD who will be assuring CPL of EPC's CDM compliance and co-ordinating safety in design issues at the tie-in points.

3.6.3 COMAH

Discussions have taken place between the project and the regional Hazardous Installation Directorate of the HSE who will be responsible for the OPP. These have led to an agreed understanding of how the project will be managed under COMAH. This, in turn, has allowed the project to assign specific division of responsibilities to the supply chain over and above the general obligations for process safety design. These latter, generic processes are not addressed in this report.

3.6.3.1 COMAH Overall Responsibilities

- The role of "operator" is key to the assignment of responsibilities under COMAH. For this project there will be different operators at different phases of the project:
  - CPL is regarded as the Operator under COMAH until the long term O&M contractor is formally appointed;
  - The EPC contractor will be the Operator for commissioning, i.e. from the time the hazardous substances are introduced to the site until the formal hand-over of the plant to CPL and its O&M contractor;
  - For long term operations the O&M contractor will be Operator as they will be a single legal entity with "operational autonomy". The concept of operational autonomy is a key test. Whilst they will be provided with a required operating plan from the energy traders and will work to performance targets agreed with CPL, they will have the ability to decide whether the plant or any part of the plant is safe to operate. They will work to their own procedures with the staff of their choosing; and
- CPL will be responsible for the management of change as the Operator changes from EPC contractor to O&M contractor at take-over of the plant.

3.6.3.2 COMAH Administrative Matters

- It is agreed that site raising is not "construction" for COMAH purposes. The start of "construction" is marked by start of foundation installation; and
- As the site is designated lower tier, then the HSE will come to review what the project has put in place as a MAPP once we are operational (probably during commissioning).

3.6.3.3 COMAH Supply Chain Responsibilities

Based on the above agreed overall responsibilities for a lower tier COMAH site the following key responsibilities will be assigned to the supply chain counterparties.

CPL

- Is regarded as the Operator under COMAH until the long term O&M contractor is formally appointed;
- Develop a high level MAPP which will link to the MAPPs developed by the EPC and O&M contractors; and
- Will be responsible for the management of change as the Operator changes from EPC contractor to O&M contractor at take-over of the plant.

OPP EPC Contractor

- Will be COMAH "operator" for the commissioning period through to plant hand-over.
- Will ensure that the design associated with COMAH hazardous substances meets GIP and achieves appropriate SILs and must collaborate with CPL and the O&M Contractor to ensure the delivery of the agreed SIL through design and operational protocols;
- Will ensure remainder of design meets GIP;
- Will issue the Pre-Commissioning Operations Notification to the HSE;
- Will develop a MAPP appropriate for the commissioning period;
- Will involve CPL and the O&M contractor in appropriate design processes (HAZOPs etc.);
- Will develop operating procedures for the commissioning period and discuss/review these with the O&M contractor; and
- Will collaborate with CPL and the O&M contractor in hand-over of operations to the O&M contractor.

Interconnections EPC Contractor

- As there are no specific COMAH hazardous substances involved in the Interconnections there are no COMAH specific responsibilities.

NGCL TSSA

- Collaborate with the operator of the OPP (this will only be the OPP O&M contractor during the OPP operational phase as no T&S operations are anticipated whilst the OPP is in commissioning) in commissioning) in preparing the MAPP.

OPP O&M Contractor

- Will be the COMAH "operator" for the operations period;
- Will be involved in the EPC contractor's appropriate design processes (HAZOPS etc.);
- Will collaborate with CPL and the EPC Contractor to ensure the delivery of the agreed SIL through design and operational protocols;
- Will develop operating procedures and discuss/review these with the EPC contractor;
- Will collaborate with CPL and the EPC contractor in the hand-over of operations to the O&M contractor; and
- Will prepare adequate MAPP for operations and achieve "no objection" from the HSE.

Interconnections Operator

- Will collaborate with the operator of the OPP (the EPC contractor in commissioning and the O&M contractor in operations) in preparing the MAPP.

3.7 CO_2 Vent Dispersion Modelling

3.7.1 Leakage of CO_2

The potential CO_2 leakage locations are from the:

- Boiler flue gas system under positive pressure;
- Secondary oxidant system under positive pressure ;
- Gas to Gas Heater secondary seal & rotor purge system under positive pressure;
- Primary oxidant system under positive pressure;
- Boiler Seal Gas System under positive pressure;
- ESP;
- FGD; and
- GPU.

3.7.2 Venting Scenarios

The following venting scenarios of the OPP have been defined.

- **Normal Operation** – Oxy Mode The oxy mode operation involves far less venting and emissions than the air mode operation as 90% of the CO_2 is captured. Emissions of oxides of sulphur (SO_x), NO_x and CO_2 are also reduced. As the flow of flue gas is significantly lower in oxy mode than in air mode, a dedicated flue is used for oxy mode;
- **Start-up** - As the plant is started in air mode, the flue gas is sent to the air mode stack. The transition from air mode to oxy mode is conducted once the plant has been stabilized at a load of at least 40% Boiler Maximum Continuous Rating (BMCR). During this transition, the primary and secondary flue gas recycles are started and oxygen is injected in the recycles to replace the oxygen from the air as air inlet dampers are progressively closed. As the nitrogen content of the flue gas decreases, the total flue gas flow also decreases. When the GPU flue gas compressor is started, the CO_2 rich flue gas can be sent to the oxy mode stack and the damper to the air mode stack is progressively closed. The flue gas is sent to the GPU process system where it is circulated and expanded then sent to the stack. The expansion of the flue gas allows the progressive cooling of the cryogenic system and the separation of the CO_2 which is vented in the oxy mode flue as long as it is not at the required specification; and
- **Major Intermittent Venting Scenarios** - Besides venting in normal operation and start-up, intermittent venting of CO_2-rich gas can happen on operation incidents (e.g. compressor trip, GPU shutdown). The plant will be able to operate without the CO_2 compression and separation system in operation. Facilities for safe venting of CO_2 to atmosphere under these circumstances have therefore been provided.

3.7.3 Modelling Approach

3.7.3.1 Venting Scenarios Modelled

Two scenarios were modelled as shown in Table 3.2.

- Case 3.1 – Start-up in oxy-mode; and
- Case 4.2 – CO_2 vent where the T&S is temporarily unavailable.

Table 3.2: Cases Modelled

Parameter	Case 3.1	Case 4.2
Phase	Vapour	Vapour
Total Flow kg/hr	351,838	258,485
Temperature C	31.0	10
Pressure Bar	1.013	1.013
Density kg/cum	1.647	1.907
Average MW	40.90	44.01
Mole Fraction		
CO_2	0.764077	0.999690
O_2	0.057309	0.000010
Ar	0.036430	0.000162
N_2	0.141671	0.000001
NO	0.000006	0.000000
NO_2	0.000110	0.000137
HNO_3	0.000000	0.000000
SO_2	0.000000	0.000000
H_2SO_4	0.000000	0.000000
H_2O	0.000000	0.000000
CO	0.000396	0.000000
NH_3	0.000000	0.000000
HCL	0.000000	0.000000
Stack Diameter (mm)	1,100	600

Case 3.1 could continue for a considerable length of time (modelled as 1hr) whereas Case 4.2 would be for a shorter duration (modelled as 10 minutes). An end point of 50ppm was modelled for both cases as a concentration that would have negligible effect on both persons and the ASU. Note: this is a 50ppm increase on normal atmospheric CO_2 concentration.

The models were for releases from the stack height (120m above ground level).

3.7.3.2 *Modelling Software*

CO_2 dispersion during start-up venting has been modelled using the GL-DNV (Det Norsk Veritas) Phast modelling software version 7.1. This is a well-recognised accident consequence software package and is widely used by Government safety agencies worldwide.

3.7.3.3 *Atmospheric Conditions*

The amount of turbulence in the ambient air has a major effect upon the rise and dispersion of gas plumes. The amount of turbulence can be categorised into defined increments or "stability classes". The most commonly used categories are the Pasquill stability classes A, B, C, D, E, and F (sometimes class G is also used). Class A denotes the most unstable or most turbulent conditions and Class F denotes the most stable or least turbulent conditions.

The Pasquill stability classes are presented in Table 3.3 as they are defined by the prevailing meteorological conditions of:

- surface wind speed measured at 10 metres above ground level; and
- day-time incoming solar radiation or the night-time percentage of cloud cover.

Table 3.3: Pasquil Stability Conditions, Wind Speed and Solar Radiation

Surface Wind speed		Daytime Incoming Solar Radiation			Night-time Cloud Cover	
m/s	miles/hr.	Strong	m/s	miles/hr.	Strong	m/s
<2	<5	A	<2	<5	A	<2
2-3	5-7	A-B	2-3	5-7	A-B	2-3
3-	7-11	B	3-	7-11	B	3-
5-6	11-13	C	5-6	11-13	C	5-6
>6	>13	C	>6	>13	C	>6
Note: Class D applies to heavily overcast skies, at any wind speed day or night.						

The stability conditions that are most relevant to UK conditions are:

- D – Cloudy and breezy; and
- F – Calm night time.

The default modelling conditions for Phast program are shown in Table 3.4.

Table 3.4: Standard weather conditions for Phast Modelling

Wind Speed	Pasquill (Atmospheric) Stability Category	Definition
5 m/s	D	Neutral
1.5 m/s	D	Neutral
1.5 m/s	F	Stable

These conditions are available for all models while Phast has the option for user defined weather conditions as well.

It should be noted that the 1.5F (1.5m/s wind speed with F atmospheric stability) conditions are those used by US regulatory authorities to model dense plume dispersion and are typically the conditions that give furthest spread of gas plumes. The 3 default conditions used by Phast are those most commonly used in the consequence modelling to support COMAH safety reports.

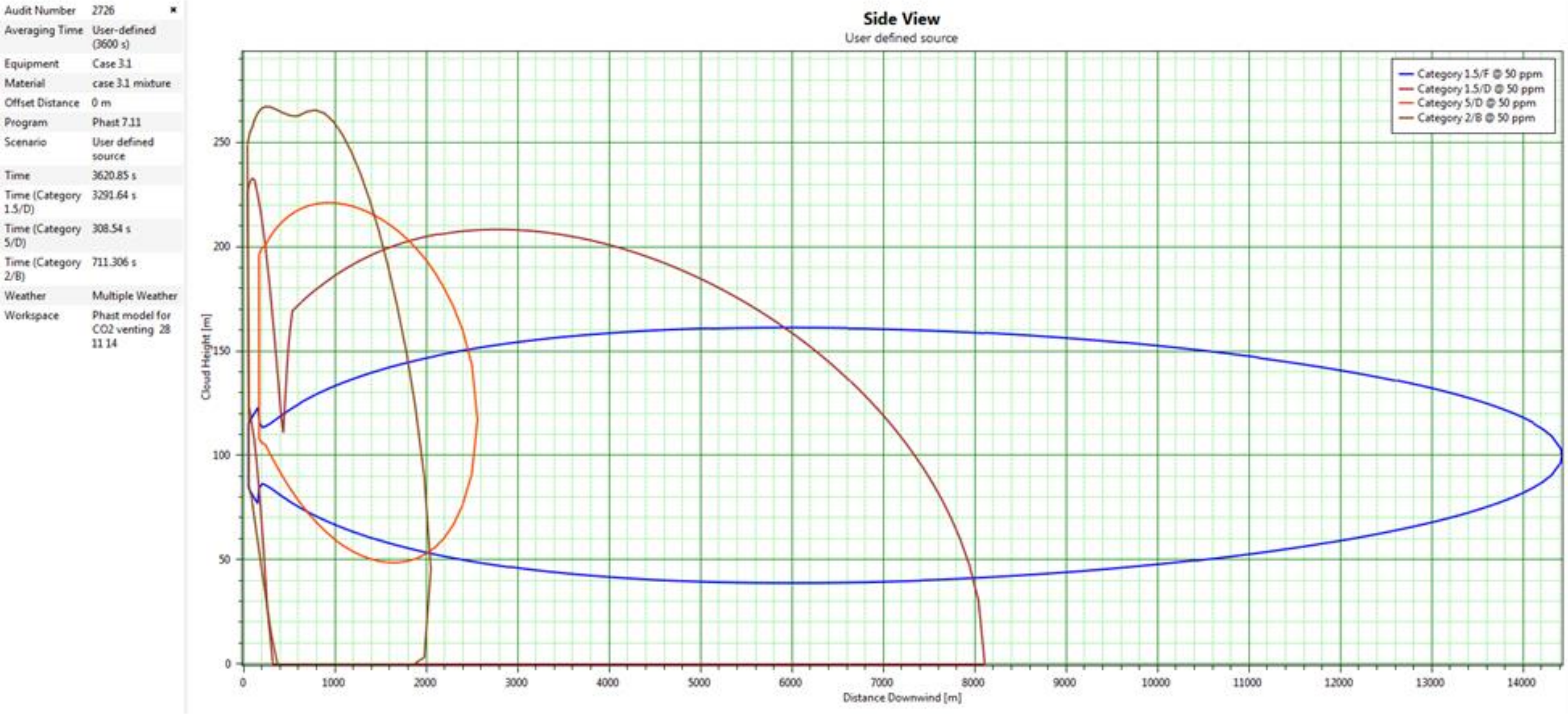
Normally, when modelling gas releases the situation most of concern is the when the gas does not disperse and follows the ground contours. In those circumstances 1.5F conditions often give the worst realistic results. In this case, CO_2 the release is at 120m and the ASU air intakes are at low level about 160m away, more turbulent conditions may give greater dispersion of CO_2 to the ASU air intakes and to personnel at ground level. The most turbulent conditions (Pasquill Stability Condition A) are rare in the UK (~0.5%). Pasquill Stability Condition B is more common (~5% occurrence). We have modelled 2B (2m per second at category B stability) conditions, as representative of typical unstable atmospheric conditions, as well as the 3 standard conditions.

3.7.4 Modelling Results

3.7.4.1 Case 3.1

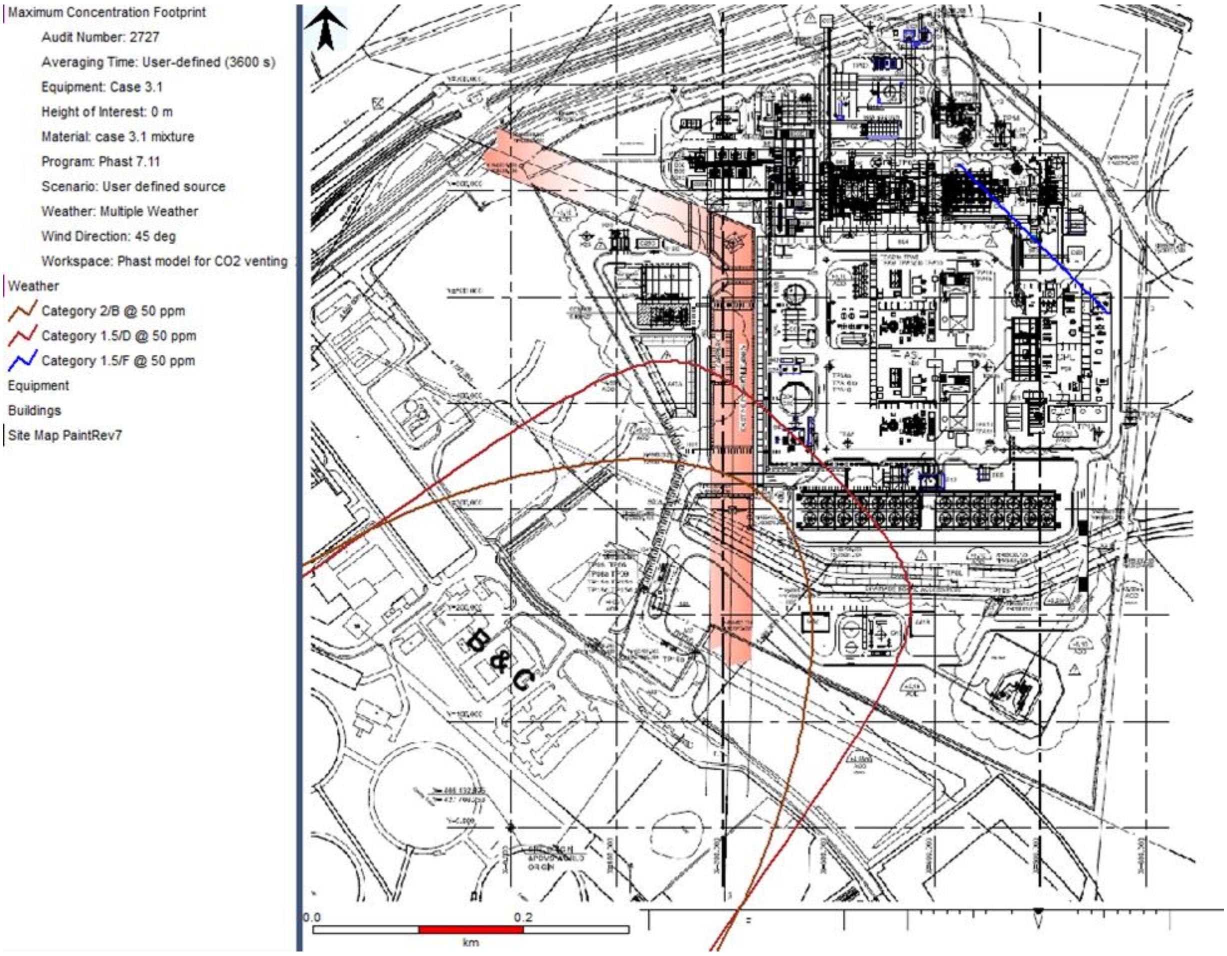
This release was modelled as a gas mixture rather than pure CO_2.

Figure 3.1: Side View of Case 3.1 Release



The following figure shows the maximum concentration footprints for those weather conditions where the plume reached down to ground level (the concentration does not reach 50ppm at ground level for 5D conditions).

Figure 3.2: Maximum Concentrations Footprint – Case 3.1

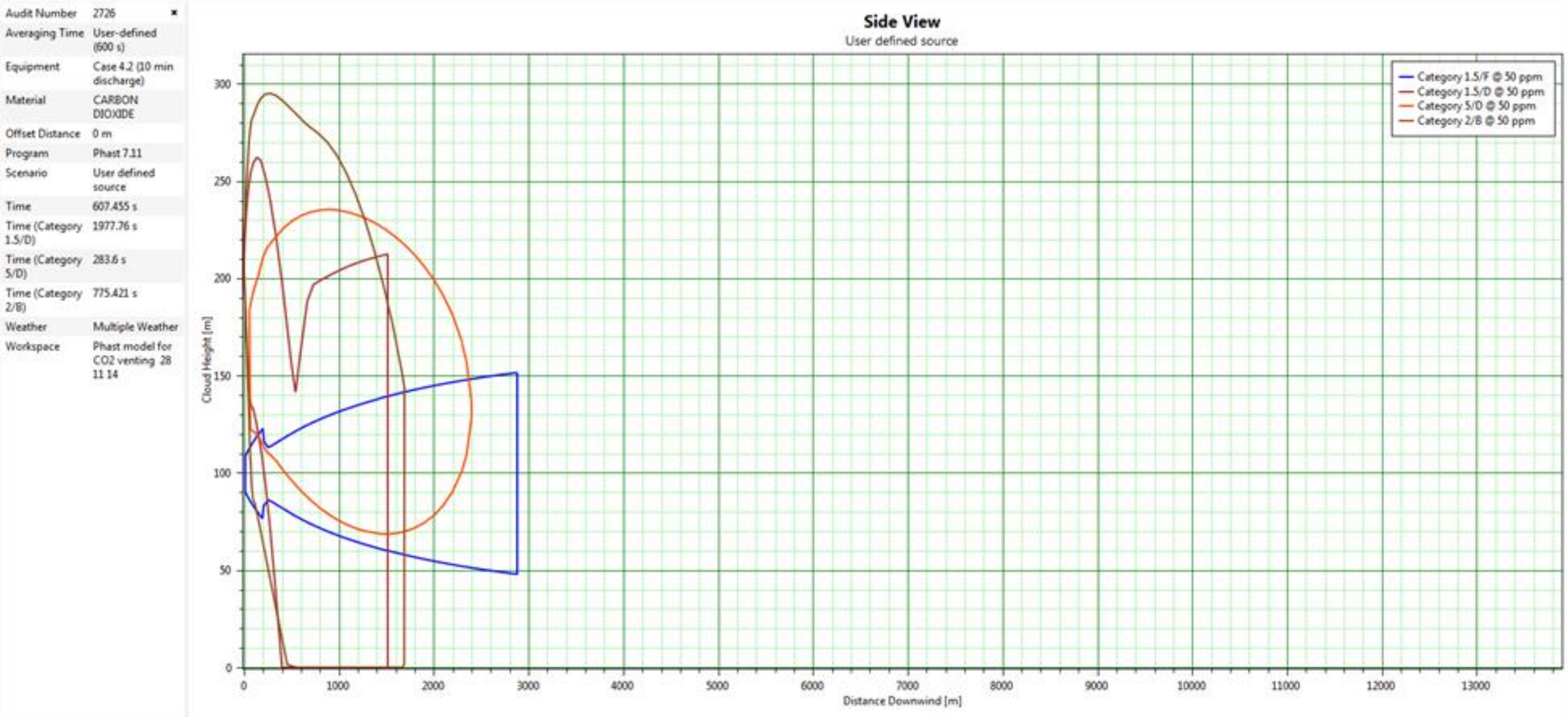


These figures show that there will be a low concentration of at ground level and that venting CO_2 through the stack (Case 3.1) will not lead to significant ingress of CO_2 into the ASUs and will not be a risk to personnel.

3.7.4.2 Case 4.2

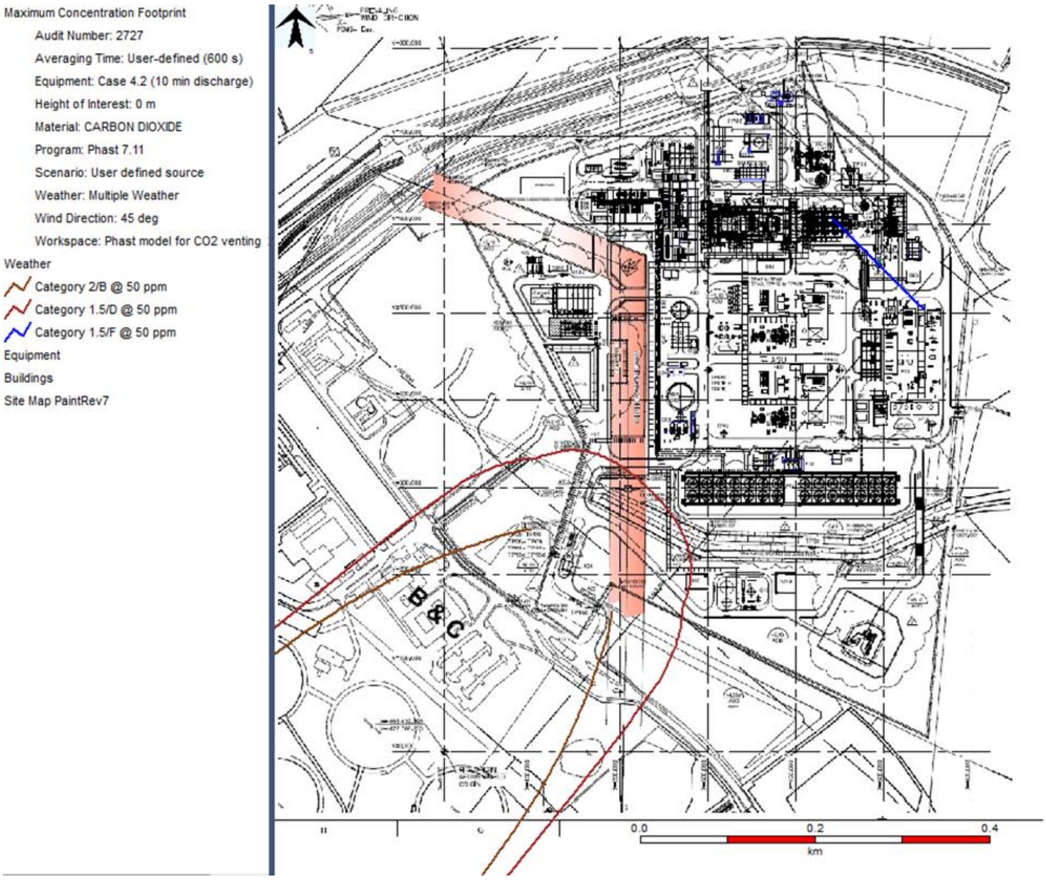
This case was modelled as pure CO_2.

Figure 3.3: Side View of Case 4.2 Release



The following figure shows the maximum concentration footprints for those weather conditions where the plume reached down to ground level.

Figure 3.4: Maximum Concentration Foot print – Case 4.2



These figures show that there will be a low concentration of at ground level and that venting CO_2 through the stack (Case 4.2) will not lead to significant ingress of CO_2 into the ASUs.

3.7.5 Conclusions of Venting Study

The modelling has shown that in both cases the CO_2 will disperse and that the concentration of CO_2 at ground level due to the venting will be low. This low concentration of CO_2 will not be a risk to personnel on site nor adversely affect the operation of the ASUs.

3.8 ALARP Requirements

3.8.1 The 'ALARP' Principle

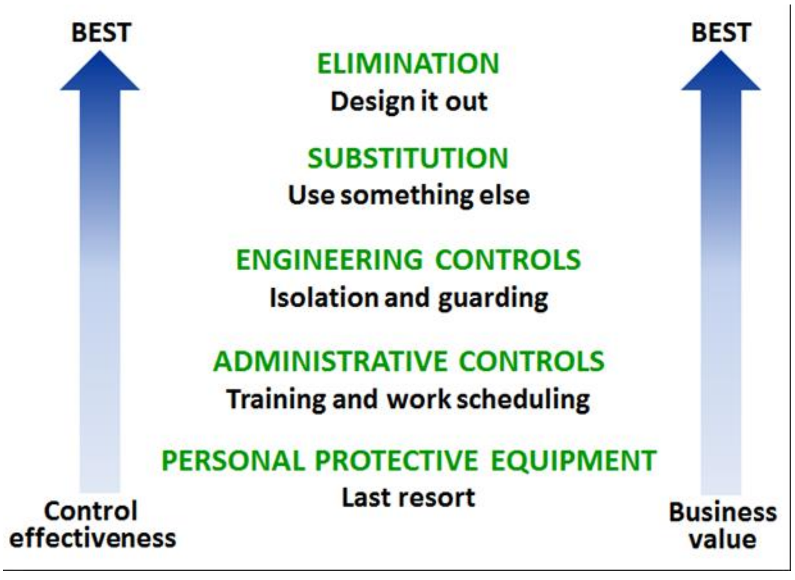
The HASAWA (1974) puts a duty on the employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees, including the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health. The process of discharging this duty requires that risks are reduced to be ALARP.

The COMAH Regulations, which are regulations under the Health and Safety at Work Act, also require that 'all measures necessary' be taken to reduce the risk from hazardous substances, which is an equivalent requirement.

The duties under this legislation require that the facility designers, constructors and operators assess the level of risk and where risk levels are significant, consider measures to reduce the risk. The guidance on the tolerability of risk is provided in the HSE document 'Reducing Risk Protecting People' (R2P2).

There is a generally accepted hierarchy of risk reduction measures based on their perceived effectiveness. This is illustrated in the figure below.

Figure 3.5: Hierarchy of Controls



3.8.2 Compliance with Standards

Risks from potential hazards can be reduced by identifying the appropriate UK and international standards and codes of practice that should apply to the plant and equipment and ensuring that the design specifies that the plant and equipment meet these standards. As part of the FEED design appropriate standards and codes of practice have been identified.

3.8.3 Reduction of the Hazardous Chemical Inventory

3.8.3.1 Oxygen Storage

Towards the end of FEED reviews of the commercial impact of the use of vaporised liquid oxygen as back-up to a short outage of an ASU has resulted in further work being undertaken to ascertain whether this approach makes commercial sense. If it is concluded that it does not then the amount of liquid oxygen stored on the site will be reduced greatly and it may result in the OPP being designated as lower tier COMAH site.

3.8.3.2 Use of Hydrazine

The original intention was to use Hydrazine solution as an oxygen scavenger in the boiler feed water system (to reduce corrosion). Hydrazine is a hazardous substance under the COMAH regulations due to its carcinogenic properties and the amount required would have been above the upper tier COMAH limit. During the FEED proceed it was agreed that a less hazardous alternative, Carbohydrazide, which is not a hazardous substance under the COMAH regulations, would be used.

3.8.3.3 HAZID, HAZOP and Layout Assessments

The HAZID, HAZOP and Layout Assessment studies identified potential hazards and safeguards and mitigation already in the design that would reduce the risk from the hazards where:

- Safeguards are the design features that will prevent the hazard occurring; and
- Mitigation is the design features and other measures that will reduce the consequences of the hazard.

The HAZID, HAZOP and Layout Assessment meetings review these safeguards and mitigations and raise actions to consider specific additional measures. The process of raising actions and where appropriate, including additional measures in the facility design, helps towards reducing the risks so that they are ALARP.

Decisions particularly pertinent to the CCS related aspects of the design that came out of these included:

- The placement of the ASU in such a position in relation to prevailing wind conditions to ensure that the air intake has as clean air as possible; and
- The decision to have no basements, cable trenches or other below-ground voids (unless absolutely unavoidable) to eliminate places where CO_2 or cold oxygen/nitrogen could accumulate.

3.8.3.4 Quantified Risk Assessment

Quantified Risk Assessments (QRAs) attempt to measure the risk from hazards and compare them against the criterion developed by the HSE for tolerability of risk.

The OBRA included QRA of the risks to staff in the occupied buildings on site from releases of hazardous materials. A result of the OBRA was that the risks to staff in the Control Block were not sufficiently low that they could be considered ‘Broadly Acceptable’ due to the proximity to Anhydrous Ammonia storage facilities and therefore further measures to reduce the risk should be considered in accordance with the ALARP principle. As a result of the OBRA QRA the site of the Anhydrous Ammonia storage facilities has been revised to locate them further away from the Control Block.

The OBRA also suggested measures for the reducing risk to the operators from the anhydrous ammonia unloading facilities to be implemented in project execution and operation.

3.8.3.5 *Future Work*

Throughout the life of the project: through detailed design, procurement, construction, commissioning and operation, measures to reduce the risk should be kept in consideration. Final demonstration that the risks are ALARP can only be provided when the facility is constructed and commissioned.

4 Transport and Storage

4.1 Introduction

NGCL is a wholly owned subsidiary of the National Grid group of companies. CPL and NGCL have entered into a key subcontract agreement pursuant to which NGCL will perform a project called the White Rose T&S FEED Project which will meet that part of CPL's obligations under the FEED Contract which are associated with the T&S assets. The T&S assets include, broadly: the transportation pipeline and pressure boosting facilities; offshore CO_2 reception and processing facilities and injection wells into an offshore storage reservoir.

4.2 Purpose

This section covers the T&S assets and includes an overall narrative of the approach to health and safety and is retrospective (looking back at the work undertaken in this area during FEED) and prospective (laying out the approach to health and safety management that will be followed during the implementation phase).

The section includes summaries on:

- (HAZID study, including Hazard Analysis (HAZAN) where undertaken, being a summary of key actions specific to the application of CCS;
- A summary Hazardous and Operations Study (HAZOP) close-out report being a narrative summary of the HAZOPs undertaken;
- COMAH Regulations review;
- Project health and safety plan for the implementation phase;
- The CO_2 vent dispersion modelling; and
- Implementation ALARP requirements.

4.3 HAZID

This section is a summary of key actions specific to the application of CCS.

Five individual HAZID studies were undertaken which looked at the FEED scope of design from the interface between the OPP (terminal 1, Figure 2.3 through the onshore pipeline system to the offshore T&S system (terminal 6) including:

- Interface between OPP and the CO_2 T&S system;
- *onshore pipeline;
- Drax Pipeline Inspection Gauge (PIG) trap AGI;
- Camblesforth Multi-junction;
- *Tollingham, Dalton and Skerne Block Valve Stations;
- Barmston Pumping Station; and
- Offshore T&S.

*Note that both these parts of the scope of design were assessed in one single HAZID.

The HAZID study is a systematic assessment to identify hazards and problem areas associated with plant, system, operation, design and maintenance.

Workshops were undertaken to identify all credible hazards along with all potential initiators of the hazards and consequences of the hazards. Existing safeguards and their mitigating effects were identified and listed.

Additional safeguards and risk reduction measures were identified and listed when required. Safeguards were considered on a preferential basis using the following hierarchy:

- Prevention (elimination) of hazard through:
  - Equipment design;
  - Operational procedures and philosophy;
- Control or mitigation of effects of hazard, through:
  - Isolation;
  - Pressure relief;
  - Venting; and
  - Emergency response.

A recommendation was only made for action if the risk reduction measure or safeguard could and should be implemented with consideration of factors such as practicality. Potential cost alone was not used as a basis for dismissing a risk reduction measure.

When a risk reduction measure or safeguard was to be implemented, an actionee (person undertaking the action) was assigned.

All actions were transferred to the Safety Action Management System (SAMS) register. The SAMS register is an action tracking system which enables controlled and auditable close-out of actions arising during the project. The SAMS register also acts as an interface to the CDM register.

4.3.1 Summaries of HAZID Actions

4.3.1.1 Interface between the OPP and the CO_2 Transport and Storage System

Table 4.1: Interface between the OPP and the CO_2 T&S System

Ref	Action	Actionee
1	NGCL to consider the design of the cathodic protection and the earthing of the pipeline in the light of the proximity of the power plant and its earthing and lightning protection system	NGCL
2	GE to consider the design of the cathodic protection and the earthing of the pipeline in the light of the proximity of AGI and its earthing and lightning protection system	GE
3	Confirm whether dense phase CO_2 is an electrical insulator or conductor	NGCL
4	CPL to consider the need to include the AGI (PIG launcher) area within the overall site security fence	CPL
5	Ensure emergency egress design for OPP and NGCL is aligned	
6	Co-ordinate design to ensure alignment of AGI and OPP access requirements	
7	Ensure road drainage within AGI connects to OPP road drainage system	
8	Review the need for redundant instruments to allow online maintenance	GE
9	Add the potential need for a Simultaneous Operations (SIMOP) review to CDM risk register	CPL
10	Ensure the redundancy requirements for CO_2 monitoring is be considered as part of the control strategy	
11	Determine whether pipeline can be over pressured and provide adequate overpressure protection as required	GE

Ref	Action	Actionee
12	Determine whether pipeline maximum design temperature can be exceeded and provide adequate protection as required	
13	Ensure dispersion calculations are carried out to identify the extent of occupational hazards of ammonia leakage	CPL
14	Review the need for export filters upstream of the AGI to meet NGCL specification for particulates in the Basis of Design (BoD)	GE
15	Ensure the installation plan for the pipeline includes suitable protection against mechanical damage and adequate route marking	NGCL
16	Clarity on response required from CPL and NGCL to incident at PIG trap (The AGI enclosure is normally unmanned, but will be manned during PIG operations)	CPL
17	Ensure that site alarms are audible and visible within AGI site	GE
18	Ensure that overpressure from other CCS lines is included in the NGCL HAZID/HAZOP	NGCL
19	Add the need to evaluate the requirement for a dedicated gas release alarms to the CPL HAZOP	CPL

4.3.1.2 *Pipeline and Tollingham, Dalton and Skerne Block Valve Stations*

Table 4.2: Pipeline and Tollingham, Dalton and Skerne Block Valve Stations

Ref	Action	Actionee
21	Consider provision of CCTV not only to detect intruders but also to detect visible leaks	NGCL
22	Ensure that the emergency response plan includes other stakeholders and emergency services and includes local residents	
23	Consider the need for the detection of CO_2 external to buildings	
24	Ensure that the dispersion modelling from flange leaks or vents addresses the possibility of dense clouds of CO_2 flowing off site for example down any slope (and the actions to be taken should this occur and the effect on third parties)	
25	Define the philosophy for evacuation of the block valve sites in the event of a major CO_2 release and identify the optimum position for escape routes	NGCL/Genesis Safety
26	Confirm that the dispersion of the CO_2 from the vent during depressurisation of the upstream or downstream pipeline does not adversely affect personnel or local residents	Genesis/ NGCL
18	Review the pipeline design once the seismic activity has been defined	Genesis Pipelines
19	Normal operating procedures must highlight the importance of maintaining pipeline pressure at the high point	Genesis Process
20	Depressurising calculations need to ensure that minimum temperature limits are not transgressed at the high points of the pipeline	

4.3.1.3 *Drax PIG Trap AGI*

Table 4.3: Drax PIG Trap AGI

Ref	Action	Actionee
27	Consider provision of CCTV not only to detect intruders but also to detect visible leaks	NGCL
28	Ensure that the local PIG launcher site Emergency Response Plan (ERP) is dove tailed with the Drax site ERP	
29	Review impact of OPP venting with CPL to ensure no adverse effects at the PIG launcher	
30	Confirm that Drax have procedures in place to prevent interference with the pipeline and that the pipeline is adequately marked	
31	The need for the external detection of CO_2 to be considered and whether this should link into the Drax	

Ref	Action	Actionee
	system	
32	Ensure that the dispersion modelling addresses the possibility of dense clouds of CO_2 flowing off site for example down any slope (and the actions to be taken should this occur)	
33	Define the philosophy for evacuation of the PIG launcher site in the event of a major CO_2 release or a Drax emergency. This should also identify the escape routes for each emergency	NGCL/Genesis Safety
34	Confirm that the dispersion of the CO_2 from the vent during depressurisation of the PIG launcher does not adversely affect personnel (including Drax site)	Genesis/ NGCL
35	Confirm that Drax have adequate facilities in place to detect presence of water or other contaminants and isolate the export system before off-specification gas enters the NGCL pipeline	NGCL
36	Determine the actions to be taken if off-specification CO_2 enters the NGCL pipeline, which has no allowance for corrosion	

4.3.1.4 *Camblesforth Junction*

Table 4.4: Camblesforth Multi-junction

Ref	Action	Actionee
37	Consider provision of CCTV not only to detect intruders but also to detect visible leaks	NGCL
38	Ensure that the emergency response plan includes other stakeholders and emergency services and includes local residents	
39	Consider the need for the detection of CO_2 external to buildings	
40	Ensure that the dispersion modelling addresses the possibility of dense clouds of CO_2 flowing off site for example down any slope (and the actions to be taken should this occur and the effect on third parties)	
41	Define the philosophy for evacuation of the Camblesforth site in the event of a major CO_2 release	NGCL/ Genesis Safety
42	Confirm that the dispersion of the CO_2 from the vent during depressurisation of the PIG launcher/receiver does not adversely affect personnel or local residents	Genesis/NGCL

4.3.1.5 *Barmston Pumping Station*

Table 4.5: Barmston Pumping Station

Ref	Action	Actionee
5	Confirm that the building design is in accordance with appropriate codes and standards	Genesis Civils
6	Consider whether suitable road clearing and gritting facilities should be made available	NGCL Operations
7	Complete Barmston Pumping Station site drainage study	Genesis Civils
8	Consider provision of CCTV not only to detect intruders but also to detect visible leaks	NGCL
9	Consider the need for the detection of CO_2 external to buildings	
10	Consider whether facilities are required to direct operators to emergency exits from buildings if visibility is reduced by CO_2	
11	Define the philosophy for controlled access to buildings containing CO_2 equipment	
12	Consider the need for additional crossing points over the ditch to improve evacuation routes	Genesis Layout
13	Define the philosophy for evacuation of the site in the event of a major CO_2 release	Genesis Safety
14	Consider the need for an emergency escape gate at the entrance (if the main gate is to be locked when personnel are on site)	
15	Ensure there is a procedure for testing low points where dense CO_2 vapour may accumulate	NGCL

Ref	Action	Actionee
	before entry is allowed	
16	Ensure that the dispersion modelling addresses the possibility of dense clouds of CO_2 flowing off site for example down the ditch (and the actions to be taken should this occur)	
17	Consider the possibility of incorporating one or more low points with CO_2 detection specifically located to trap CO_2 in the event of a release.	

4.3.1.6 *Offshore Transport and Storage*

Table 4.6: Offshore T&S

Ref	Action	Actionee
1	Confirm that there are no mining activities in the area that would affect the design or routing of the offshore pipeline	Genesis Projects
2	Resolve whether additional facilities need to be incorporated into the current design for the future accommodation and transportation of construction workers to the platform	NGCL
3	Provide back-up information on current best practice for access to normally unmanned installations	Genesis Projects
4	Review the requirement for thermal screening to reduce the demand rate on thermal relief valves	
5	Ensure a detailed geo-technical survey is completed before detailed design	NGCL
6	Review the capacity of the Totally Enclosed Motor Propelled Survival Craft (TEMPSC) (currently based on POB of 10 plus two helicopter crew)	
7	Consider the need to pre-invest (for example provide additional space) for unplanned future developments	
8	Mechanical handling study to include requirements for any future pre-investment of equipment	Genesis Mechanical
9	Consider whether the crane is required to cover the helideck	NGCL
10	Review the requirement to access infrequently operated isolation valves and equipment to determine whether permanent access is required, or whether temporary access will be acceptable	Genesis Projects
11	Consider the need to initiate a platform shut down after a time delay following loss of communications	NGCL
12	Review how long wells can continue to operate without corrosion inhibitor injection	Genesis Process
13	Develop the ESD philosophy for the both the manned and unmanned situations	NGCL
14	Ensure that an emergency air supply is available within TEMPSC since launching the TEMPSC may drop into a cloud of CO_2 at the sea surface	Genesis Safety
15	Ensure that the dropped objects study includes the impact of dropped and swinging objects on the platform topsides	
16	Review the consequences of leaks to determine areas where liquid CO_2 might impact structural steel and determine what additional safeguards might be required to prevent brittle fracture	NGCL Safety/Genesis Safety
17	Define the philosophy for protection of personnel and provision of escape sets, personal CO_2 monitors and so on	Genesis Safety
18	Define the noise philosophy and the occupational exposure limits for internal and external equipment	NGCL

4.4 HAZOP

This section is a narrative summary of the HAZOP studies undertaken.

Two onshore HAZOP studies were undertaken at a nodal level which looked at the scope of design from the interface between the OPP (terminal 1, Figure 2.3), through the onshore pipeline system to the connection into the offshore pipeline (terminal 7) including:

- Onshore transport (pipeline), covering the pipeline system between the OPP boundary and the inlet to Barmston Pumping Station, comprising:
  - The 12in pipeline from the OPP to the Drax PIG Launcher AGI;
  - The 12in pipeline from the Drax PIG Launcher AGI to the Camblesforth Multi-junction AGI;
  - The 24in pipeline from the Camblesforth Multi-junction AGI to Barmston Pumping Station inlet;
  - Tollingham, Dalton and Skerne Block Valve Stations;
- Onshore transport, covering Barmston Pumping Station and the connection into the offshore pipeline, comprising:
  - The incoming 24in pipeline;
  - The fine filters;
  - The booster pumps;
  - The metering skid; and
  - The export pipeline up to the landfall section before the start of the offshore pipeline.

One offshore HAZOP study was undertaken at a nodal level which looked at the scope of design from the interface between the onshore and landfall pipeline (terminal 3) and the injection wellheads (terminal 6), including:

- Offshore T&S, comprising:
  - The landfall pipeline;
  - The 24in offshore (subsea) pipeline;
  - Pipeline riser (from subsea pipeline to topsides);
- Platform topsides systems, including:
  - CO_2 metering and PIG receiver;
  - CO_2 fine filters;
  - CO_2 injection manifold and wellhead;
  - Seawater system;
  - Temporary water wash skid;
  - Power generation system;
  - Mono Ethylene Glycol (MEG) storage and injection system; and
  - Diesel system.

The HAZOP studies were undertaken to:

- Assess the hazard potentials of each system/subsystem and identify any issues which affect the safety of the facilities;
- Assess the operability of each system/subsystem and identify any issues which affect the availability and maintainability of the facilities;
- Identify existing safeguards and review against the impact of a credible deviation; and
- Identify requirement for amendment or additional mitigation.

The HAZOP procedure was as follows:

- Define the design intent;
- Confirm operating conditions;
- Confirm mode of operation;
- Identify credible deviations;

- Consider the existing safeguards against the impact of a credible deviation and whether the existing safeguards are adequate;
- Propose actions (recommendations) as appropriate;
- Determine if any additional safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of the project FEED.

A recommendation was only made for action if the risk reduction measure or safeguard could and should be implemented with consideration of factors such as practicality. Potential cost alone was not used as a basis for dismissing a risk reduction measure.

When a risk reduction measure or safeguard was to be implemented, an actionee was assigned.

All actions were transferred to the SAMS register. The SAMS register is an action tracking system which enables controlled and auditable close-out of actions arising during the project. The SAMS register also act as an interface to the CDM register.

4.4.1 Summaries of HAZOP Actions

4.4.1.1 Onshore Transport (Barmston Pumping Station)

The HAZOPs reviewed the hazard potentials and generated 49 actions that are summarised below:

Table 4.7: Onshore Transport (Barmston Pumping Station)

Ref	Action	Actionee
1	Consider a soft interlock to ensure that a stand-by filter inlet valve is opened before the duty filter inlet valve is closed	Genesis Instruments
2	Consider opening the free-flow bypass 33-HV-001 if the pressure differential is low enough (? <5bar) to allow this (differential between 33-PI-018 and 33-PI-048)	Genesis Process
3	Ensure that the pump logic will prevent the booster pump from starting, or trip it if it is running, if the suction Emergency Shutdown Valve (ESDV) is not shown to be fully open by the position switch	
4	Confirm there is sufficient margin between the dead head pressure of the pump at maximum suction pressure, maximum density, maximum speed and the setting of the thermal relief valve on discharge to prevent the pressure relief valve from lifting	Genesis Process/Mechanical
5	Ensure that the pump logic will trip the pump if it is in normal operation and the discharge ESDV is not shown to be fully open by the position switch	Genesis Process
6	Confirm that 33-PI-048HH will operate before the HIPPS valves in order to minimise the demand rate on the HIPPS	
7	Define the details of the pump restart process, in particular whether the recycle could or should be used to maintain the operation of one pump ready for immediate restart	
8	Relocate 33-PT-003/6/9 downstream of the pump inlet strainers	
9	Show 33-PI-018 as 33-PIC-018	
10	Define how the set pressure of 33-PIC-018 should vary with flow	
11	Define alarm set points of 33-PIC-018 high and low for each set point on 33-PIC-018	
12	Consider the need for high and low pressure alarms on 33-PIC-018 in free flow condition, when it has no control function	

Ref	Action	Actionee
13	Define the overall system control philosophy which should specify how control parameters should be adjusted in anticipation of changes in flow rate through the system	
14	Develop a restart procedure which defines how the duty pump should be made ready for introduction of flow and how the pump station inlet valves should be opened in a controlled fashion to allow the pump control system to take control (the shutdown procedure should allow an orderly shutdown which leaves the pumps in the best position to restart)	
15	The Control Philosophy requires that control function and ESD function are separate and independent. For the specific case of the booster pumps, the manual isolation valves downstream of 33-ESDV-003/6/9 and 33-ESDV-002/5/8 should be modified to Shutdown Valves (SDVs) which are controlled by the pump proving control system. 33-ESDV-003/6/9 and 33-ESDV-002/5/8 should only be closed by the ESD system	
16	Ensure the SDVs have position indicators and the pump proving control logic will raise a discrepancy alarm if any valve is in the incorrect position	
17	Define the philosophy for controlled access to buildings containing CO_2 equipment.	NGCL
18	Consider whether facilities are required to direct operators to emergency exits from buildings if visibility is reduced by CO_2	
19	Consider installing CO_2 detection on building HVAC air intakes	
20	Consider installing a CO_2 detection system for external areas of Barmston pump Station	NGCL
21	Ensure that the findings of the Computational Fluid Dynamics (CFD) modelling of flange releases and the low temperatures that are generated, are taken into account in material selection	Genesis Projects
22	Consider acoustic leak detection	Genesis Safety
23	Consider a soft interlock, or an operating mode selection switch, to prevent 33-HV-001 from opening when any pump is in feed forward mode	Genesis Process
24	Operating procedures to provide a detailed method for changing from free-flow mode to pump operation and vice-versa	
25	Confirm there are no trapped inventories that cannot be monitored or depressurised during extended shutdown	
26	Revise the Cause and Effect matrix to show that only the recycle pump is tripped on high temperature at the recycle cooler exit, not all pumps as currently shown	Genesis Process/Instruments
27	Consider whether there is a credible fire scenario in the pump houses. If so 33-PRV-005/8/11 and 33-PRV-002/15/16 should be sized for fire scenario	Genesis Process / Safety
28	Review the pump design to ensure it can operate with the maximum density CO_2 that can be produced	Genesis Mechanical
29	Clarify limitations on venting, which are currently under review/discussion	NGCL
30	Prepare the black-out plan for pump station	NGCL
31	Ensure that the design of the pump control system takes account of failure of local communication within Barmston Pumping Station	Genesis Instruments
32	Consider the need to provide a bypass around the recycle cooler to allow pumps to be restarted during unplanned maintenance of the cooler	Genesis Process
33	Consider putting a locked open isolation valve upstream and downstream of thermal relief valves where necessary to allow the pressure relief valve to be tested and maintained whilst the isolatable section is not isolated	
34	Confirm that instrument specification covers galvanic action between stainless steel and carbon steel components	Genesis Instruments
35	Ensure that CPL provides continuous feed to NGCL of the product analyser and the upstream water analyser output. If off-specification material is detected by the Barmston analysers at the metering skid the onshore pipeline will already contain a significant inventory of off-specification material	NGCL

Ref	Action	Actionee
36	Confirm that there are no compatibility issues between seal oil and the CO_2	Genesis Mechanical
37	Ensure that the pump specification requires that low level in the seal oil will trip the pump	
38	Ensure that electrical surge arresters are in place where necessary	Genesis Instruments
39	Complete the flow assurance transient study	Genesis Flow Assurance
40	Ensure that the hazardous area classification takes into account any flammable gas in the analyser house	Genesis Safety
41	Consider the need for vibration monitoring on the recycle cooler fans	Genesis Mechanical
42	Develop human factors integration plan	NGCL
43	Ensure that training programme takes account of the unusual hazards relating to the handling of CO_2	
44	Develop specifications requiring rigorous attention to suitability for CO_2 duty	Genesis Projects
45	Design grey and black water disposal system	Genesis Environmental
46	Prepare waste management plan	
47	Complete noise study and subsequent mapping which takes into account operating equipment and venting and demonstrate compliance with the Development Consent Order (DCO)	
48	Confirm the peak loading for recycle coolers and pump restart	NGCL
49	Design conditions for PD 8010 on outlet of pumping station to be revised to -46 to 50°C and a design pressure of 281.5barg	Genesis Process / Pipelines

4.4.1.2 *Onshore Transport (Pipeline)*

The HAZOPs reviewed the hazard potentials and generated 27 actions that are summarised below:

Table 4.8: Onshore Transport (Pipeline)

Ref	Action	Actionee
1	Ensure that the integrity of the booster pump control system is reviewed in the Safety Integrity Level (SIL) assessment	Genesis Safety
2	Consider whether the ESDV 34-ESDV-001 should be fail-last to improve system availability	Genesis Process
3	Consider whether ESDV 34-ESDV-002 should be fail-last to improve system availability	
4	Consider remote actuation of 34-HV-001 so that it could be used as a sectioning valve if required	NGCL Projects
5	Ensure operating procedures require the NGCL control room operator to inform the CPL control room if the pipeline is shut-in, either accidentally or deliberately	NGCL Projects
6	Detail design of CO_2 fine filters should consider potential surges in flow during start-up or restart and the differential pressure across the elements that these might generate	NGCL
7	Consider provision of a CO_2 detection system at all AGIs	
8	Ensure that the findings of the CFD modelling of flange releases and the low temperatures that are generated, are taken into account in material selection	Genesis Projects
9	Review the configuration of double block and bleed (DBB) isolations where there is only a single isolation valve on the vent against an operating pressure of 135barg	Genesis Process
10	Add a thermal relief valve for the section of pipeline between TP13 and the downstream isolation valve and update the Piping and Instrumentation Diagram (P&ID) to show that this section of	NGCL/Genesis Process

Ref	Action	Actionee
	pipeline is above ground	
11	Review the consequences of exceeding the current design temperature of the pipeline (25°C). If necessary, consider adding safeguards at CPL to protect the pipeline against excessive temperature	NGCL
12	Complete the venting depressurisation calculations to ensure that the minimum design temperature is not transgressed during venting	Genesis Process
13	Ensure that the valve specifications take account of low temperatures generated by valve stem leakage	Genesis Piping and Pipelines
14	Develop the operating procedures to ensure there is timely communication between the CPL and NGCL control centres to ensure smooth operation	NGCL
15	Consider changing the motor operated sectioning valves to electro-hydraulic to improve availability	Genesis Instruments
16	Prepare the black-out plan for the onshore pipeline system	NGCL
17	Consider whether there should be an interchange of information and/or executive action between the CPL and NGCL control and safety systems, particularly to safeguard against fast acting transients	NGCL & CPL
18	Review the philosophy for check valves and if not beneficial remove them	NGCL
19	Ensure that the maintenance procedures specify the venting arrangements to allow the safe discharge of the large inventory of CO_2	NGCL
20	Confirm that the instrument specification addresses galvanic action between stainless steel and carbon steel components	Genesis Instruments
21	Ensure CPL provides continuous feed to NGCL of the product analyser output and the upstream water analyser output	NGCL
22	Ensure that electrical surge arresters are in place where necessary	Genesis Instruments
23	Complete flow assurance transient study	Genesis Flow Assurance
24	Develop specifications requiring rigorous attention to suitability for CO_2 duty	Genesis Projects
25	Confirm that the CPL supply pump is tripped at a discharge pressure of 135barg and that the full flow PSVs on the pump discharge are set at 148.5barg	Capture Power
26	Resolve the nomenclature for valves, particularly whether valves are ESDV or not	Genesis Process
27	Since third party emitters are not considered in this HAZOP then ensure that the potential overpressure from other CCS lines must be reviewed in a future HAZOP	NGCL

4.4.1.3 *Offshore Transport and Storage*

The HAZOPs reviewed the hazard potentials and generated 63 actions that are summarised below:

Table 4.9: Offshore T&S

Ref	Action	Actionee
1	Show a direct input from 15-PIC-001 to the choke valve and change 10-FIC-100 to 10-FI-100	Genesis Process
2	Update Control and Electrical (C&E) diagram to remove the subsurface valve (currently shown as subsea) and remove the wash water valve from closing on low-low pressure at 15-PT-002	Genesis Instruments
3	Clarify the requirement for a filter bypass, as required in the Basis of Design (BoD) and if not necessary remove it	NGCL
4	Confirm that the Car Sealed Closed (CSC) arrangement provided on vent valves is required (it is	

Ref	Action	Actionee
	currently provided for commercial verification)	
5	Review the venting of each item of equipment or section of piping and ensure that the worst case scenarios are identified and that adequate safeguards are provided to ensure that minimum design temperature limits are not transgressed	Genesis Process
6	Consider whether the vent line from the Pressure Relief Valve (PRV) on each fine filter should be removed to ensure that venting is from low points	
7	If NGCL transfers the offshore facility to a third party then the operation of the integrated system needs to be reflected in the overall system control philosophy and inter party communications	NGCL
8	Update the C&E matrix to show that a level 2 shutdown is initiated on loss of power, with a time delay of one minute (configurable)	Genesis Instruments
9	Update C&E matrix to show that sub surface valves are only closed for level 1 shutdown and not for level 2 or level 3	
10	Update the C&E matrix to show that a level 2 shutdown is initiated on loss of LP hydraulic supply	
11	Confirm the maximum acceptable period for operating the platform blind, since there are no immediate safety issues if communications are lost	NGCL
12	Review the quantity of Nitrogen required to establish a pressure of 40barg in a filter after maintenance and consider providing a small bore pressuring bypass line around the outlet isolation valve if Nitrogen demand is excessive	Genesis Process
13	Confirm that the instrument specifications cover galvanic action between stainless steel and carbon steel components	Genesis Instruments
14	Ensure that CPL provides a continuous feed to NGCL of the output from the CO_2 product analyser and the upstream water analyser	NGCL
15	Ensure that surge arresters are in place where necessary for lightning protection	Genesis Instruments
16	Complete Flow Assurance Transient study	Genesis Flow Assurance
17	Consider the need for a subsea isolation valve in the pipeline to minimise the release of CO_2 in the event of riser failure	Genesis Safety
18	Develop technical specifications that require rigorous attention to demonstrating the suitability of components for CO_2 duty	Genesis Projects
19	Ensure that the operating procedure produced by the EPC contractor specifies that the choke valve must be closed before restarting the well	NGCL
20	Ensure that the effect of phase separation in the well string is investigated during well FEED and that safeguards such as bull heading with Nitrogen are identified	
21	Ensure that the well FEED reviews the benefits of the subsea safety valve	
22	Ensure that well FEED reviews the simultaneous opening of all choke valves	
23	Ensure that the well FEED reviews the requirement for limiting the maximum flow into any given well if necessary (for example soft stop on maximum choke valve opening)	NGCL
24	Review the requirement for a check valve in each well flow line since no reverse flow scenarios have been identified	Genesis Process
25	Provide a soft interlock to prevent 10-ESDV-100 from opening unless 10-ESDV-101 is confirmed to be closed	Genesis Instruments
26	Ensure that the chemical injection supply pressure does not exceed 200barg	Genesis Process
27	Ensure that the well FEED considers the effects of the reservoir fluid entering the well string during an extended shutdown	NGCL
28	Ensure that the feedback from the well FEED is included in the well shutdown and start-up procedures (for example injecting MEG into the well string before restart)	
29	Ensure that the well FEED addresses the issue of water washing and the consequences of inadequate water wash time	

Ref	Action	Actionee
30	Ensure the well FEED takes account of the minimum temperature downstream of the choke valve during start-up	
31	Ensure that the EPC contractor specifies the correct sequence for opening and closing tree valves in start-up and shutdown to prevent mechanical damage to valve seats	
32	Ensure that the vendor package HAZOP identifies an appropriate means of warning the operator that injection of corrosion inhibitor has stopped	
33	Either ensure that the diesel storage tank in the wash water skid provides sufficient capacity to maintain operations between operator visits, or provide a mechanism to allow safe top up of the water wash diesel day tank from the main diesel storage tank	Genesis Process
34	Ensure that the Reliability, Availability and Maintainability (RAM) study takes into account the availability of the diesel supply system	Genesis RAM
35	Ensure that the setting of the low level alarm on the gap control 51-LIC-002 provides sufficient storage capacity to allow intervention	Genesis Process
36	Ensure that the diesel transfer pump control logic prevents the pump from starting if 51-ESDV-006 is closed, or trips the pump if 51-ESDV-006 closes during normal operation	
37	Provide a high pressure trip on the discharge of each diesel transfer pump to trip the pump and minimise the demand rate on the associated PRV	
38	Review the need for 51-ESDV-001	
39	Provide a manual valve upstream of 51-ESDV-001	
40	Review how much of the crane supply is hard piped and how much is flexible hose (and whether the same hose can be used to refuel both the crane and the TEMPSC)	Genesis Layouts
41	Consider the need for a drains connection to allow the strainer in the diesel bunkering line to be drained before maintenance	Genesis Process
42	Provide a check valve in 50-FD-51-217-1A1-N-D200 downstream of the take-off to 51-PCV-005	
43	Ensure that the sample point on the diesel storage tank is below the pump suction line since water is likely to be the primary contaminant	
44	Review the size of the vent on the service tank and confirm that it has sufficient capacity to provide fire relief	
45	Ensure that the MEG injection pump control logic prevents the pump from starting if 64-ESDV-002 is closed, or trips the pump if 64-ESDV-002 closes during normal operation	
46	Provide a mode selection switch to change from MEG injection to water wash and vice versa	
47	Define the logic for controlling the two modes of operation and ensuring that water cannot be injected without MEG during the MEG injection phase	
48	Consider isolating the flow into the well if MEG flow is lost during MEG injection	
49	Consider adding closure of 64-ESDV-001 when the MEG injection pumps are tripped to minimise the risk of pressure leaking back through the injection pumps and also relocating the 1A1/15A1 spec break upstream of 64-ESDV-002	Genesis Process
50	Ensure that operating procedures require the operator to shut down the MEG injection should the water flow be lost and not restarted until the water supply problem has been resolved	NGCL
51	Ensure that the consequences of the blocked outlet of the water injection pump are addressed in the water package vendor HAZOP	NGCL
52	Review the sizing of 45-FV-001 and the range of 45-FT-001, which will be required to measure and control a flow rate of 41.7 m^3/hr during water wash and 2.6 m^3/hr during MEG injection	Genesis Instruments
53	Provide two levels of high and low flow alarm on 45-FIC-001 for water wash and MEG injection respectively	
54	Raise a technical query to propose that the design of the MEG injection system is changed to allow injection of pre-diluted MEG into the well rather than combining the two flows as at present in order to avoid the risk of injecting excessively diluted MEG by mistake	Genesis Process
55	Confirm that the vent sizing on 03-TA-64001-D200 takes account of reverse flow, fire, out breathing during bunkering and other relieving cases	

Ref	Action	Actionee
56	Ensure that the Vendor package HAZOP takes into account the potential for reverse flow causing high pressure within the temporary wash water package.	NGCL
57	Ensure that the Vendor package HAZOP takes account of the potential for MEG to migrate backwards through the recycle valve 45-PV-007 into the wash water service tank	
58	Provide an indication of MEG tank level at the loading area together with an audible alarm on high level in the MEG storage tank (as for the diesel system)	Genesis Process
59	Ensure that the operating procedures specify the total volume of MEG required for each MEG injection operation as measured by 64-FQI-001 (this will vary between wells)	NGCL
60	Add a note to the P&ID to state the requirement for insulating flanges between carbon steel piping and the MEG stainless steel tank	Genesis Process
61	Ensure that the vendor HAZOP of the temporary wash water package considers the requirements for chemical dosing into the seawater	NGCL
62	Ensure that the stand-by seawater lift pump will start automatically if the duty pump shuts down	Genesis Process
63	Consider the need for a high pressure alarm on 45-PI-002/5	

4.5 Safety Review

4.5.1 Overview

The COMAH Regulations 2015 are not applicable to the T&S section of the CCS scheme. However a number of safety reports in line with Regulation 8 of these regulations have been undertaken for the following elements:

- The onshore pipeline;
- The Barmston pumping facility; and
- The offshore pipeline.

The safety reports include:

- A list of all formal process safety assessment activities undertaken through the FEED study;
- A summary of key themes and significant risk identifies through the formal process safety assessment; and
- A discussion around these key items which remain a significant risk.

These are summarised briefly below, and have been presented in full for completeness in Appendix A.

4.5.2 Summary of the Onshore Pipeline Process Safety Report

The contents of the Onshore Pipeline Process Safety report are summarised in this Section.

A description of the pipeline and AGI's is given including the project design philosophies and specifications, the process description and conditions, feed gas composition, the engineering design, and the pipeline route including identification of population centres along the route.

Formal safety assessments have been completed including HAZID workshops, HAZOP workshops, technical reviews such as SIL assessment, Environmental Aspects and Impact Identification (ENVID) and review of the three dimensional model of the onshore transport system. A preliminary escape time assessment has been carried out for escape from potentially manned areas at the AGI's to the muster area or the escape gates. Other relevant assessments carried out during FEED include an Interface HAZID, QRA, Layout Assessments, and a Vent Dispersion Analysis.

The arrangements for safe operation which would prevent accidents or limit their consequences are described including the shutdown system, isolation and sectionalisation, pressure protection, venting, and fire protection. Emergency response provisions are also included, and design compliance with Emergency Regulations during Construction is covered.

As far as reasonably practicable, the results of formal safety assessments (in particular the qualitative formal workshops) have been adapted into the FEED design.

4.5.3 Summary of Barmston Pumping Station Process Safety Report

The contents of the Barmston Pumping Station Process Safety report are summarised in this Section.

The report objectives are to demonstrate:

- the project's commitment to full compliance with UK legislative requirements for safety in design, NGCL specifications, project philosophies and normative and informative codes and standards;
- that as far as reasonably practicable, measures have been implemented in Barmston Pumping Station FEED to prevent, detect and alarm and control and mitigate the risk of and from, process loss of containment; and
- that escape and muster facilities have been implemented in design to ensure personnel safety during emergencies.

The COMAH Regulations 1999 (and new COMAH 2015) are not applicable to Barmston Pumping Station site; however the COMAH framework has been referenced in the application of a structured hierarchy in development of preventive, control and mitigation measures in the design.

The report includes a description of the pumping station including the project design philosophies and specifications, the process and utility description, process conditions and feed gas composition. The engineering design, and site layout is also described.

Formal safety assessments have been completed HAZID workshops, HAZOP workshops, technical reviews such as SIL assessment, ENVID and review of the three dimensional model of the pumping station layout. Other safety assessments completed include a Fire Hazard Assessment, ventilation and dispersion analyses, and preliminary escape time assessment has been carried out for escape from potentially manned areas.

The arrangements for safe operation which would prevent accidents or limit their consequences are described including the detection and alarm system, the integrated control and safety system which includes the emergency shutdown system, pressure protection, venting, and fire protection systems. Emergency response provisions are also detailed, and emergency, Escape, Evacuation and Rescue (EER) design compliance is described.

4.5.4 Summary of the Offshore Pipeline Process Safety Report

The contents of the Offshore Pipeline Process Safety report are summarised in this section.

The offshore pipeline is not classed as a Major Accident Hazard Pipeline under the Pipelines Safety Regulations (PSR) 1996. However, the safety design principles of Part II of PSR (safe design and operation) are applicable.

A description of the pipeline is given including the process design parameters, gas composition and design flowrates.

As far as reasonably practicable, risk management in the offshore FEED was implemented through a risk based design approach, which typically involved the following:

- Identification of hazards and potential effects via formal workshops or via desktop studies;
- Quantified assessment of hazards;
- Determination of residual risk to personnel and third parties and to the asset;
- Determination of risk reduction measures where required – for example reinforcement or additional protection; and
- Re-evaluation of risks via quantified assessments (including cost benefit analysis if appropriate), following the iterative process outlined above.

The technical studies that supported this process include an offshore HAZID workshop, offshore HAZOP workshops, offshore SIL workshop, and offshore ENVID workshop. Other relevant assessments carried out during FEED include a dropped objects assessment, trawl gear interaction analysis, QRA, Layout Assessments, and Dispersion Analyses.

The risk based design approach was applied alongside the risk management framework set by the NGCL specifications and good engineering design practice and provided a basis for demonstration that residual risks associated with the FEED design are ALARP.

A description of the risk management measures implemented during the offshore pipeline FEED design are detailed. Risk management measures were implemented in the following hierarchy:

- Legislation, codes and standards;
- Prevention;
- Control and mitigation; and
- Emergency response.

The arrangements for safe operation which would prevent accidents or limit their consequences are described including the shutdown system, over-pressure protection, and pipeline depressurisation. Safety critical elements are identified along with their performance standards, and emergency response provisions are also described. An emergency systems survivability assessment has also been completed.

4.6 Project Health and Safety Plan (Implementation Plan)

A detailed project health and safety implementations plan has been undertaken and is provided in Appendix B and covers all elements of the implementation phase.

The sets out what NGCL would include, in its contracts for the construction work:

- Project health and safety requirements for detailed design and construction documents, which would need HS&E management and planning during the implementation phase of the project.

For the onshore work, the document would refer to the HS&E requirements associated with project HS&E planning and the requirements to comply with the CDM Regulations 2015.

For the offshore work, the document project HSE planning and is aligned to the principles associated with the Offshore Installations (Safety Case) Regulations 2005.

This plan sets out the specific health and safety requirements of the employer for the planning and designing the National Grid Carbon transportation system; and the designer is expected to comply with such requirements in full during the course of their design and/or survey works. Queries, clarifications, deviations and/or relaxation of a requirement can only be granted by the employer and shall be sought through the project manager.

The health and safety requirements set out on Appendix B set out the minimum requirements to:

- Mitigate health and safety hazards and risks by the planning and design process;
- Avoid, or if not practicable, reduce and control, health and safety hazards and risks;
- Identify significant hazards and risks;
- Identify and record key design issues;
- Communicate hazards, risks and controls;
- Comply with all relevant legal, regulatory and employer requirements; and
- Continually monitor and improve the health and safety performance.

4.6.1 Key CCS Health and Safety Requirement

The Health and Safety Implementation Plan has stated that where CCS interface hazards and risks that are of significance, and/or where risk mitigation must be aligned and coordinated across the project as a whole, shall be recorded on the CDM risk register. These entries shall be clearly denoted as a CCS chain interface issues.

The health and safety report has identified the following CCS Chain Interface Risks;

- The different sections of the CCS chain will have different hazards and risks that are to be identified, mitigated and/or controlled through the design, commissioning and construction works;
- Design solutions developed in isolation by the CDM Designer may not be the optimum, nor the engineering, process or operationally preferred solution for the CCS chain as a whole;
- The CDM Designer shall attend and proactively partake in all CCS chain interface meetings, Formal Process Safety Assessments (FPSA)s and reviews when requested; providing the relevant competent resource to ensure hazards and risks, including engineering, process, commissioning and operational issues, are identified that may impact and/or alter the developing design solution;
- The CDM Designer shall prepare and maintain relevant technical interface documents. The CDM PD shall review and comment on technical interface documents prepared by others within the CCS chain, to identify and determine design conflicts and to ensure alignment of the works;
- The CDM PD shall review and comment on safety management systems prepared by others within the CCS chain, to identify and determine conflicts and where there is misalignment; and
- It is a key requirement of the employer, that the CDM PD and CDM Designer be proactive in identifying key interface alignment issues and proposing alignment options and solutions.

The employer has carried out an extensive Research and Development (R&D) programme with regard to the physical and chemical performance and impacts associated to the transportation of CO_2 in its different states. The interpretation and analysis of the data and findings will be an on-going process.

Suppliers of prefabricated arrangements and fittings of the permanent works that are supplied on the basis of a functional specification; and where the Supplier subsequently completes the detail design to ensure performance compliance with the functional specification; shall be regarded as CDM Designers in accordance with the CDM Regulations. Design cooperation, co-ordination and risk mitigation with such Suppliers shall be an inherent aspect of the design process; and as part of the design review by the CDM PD shall be demonstrable.

Suppliers of packaged systems such as; meter/filter skids, valve control arrangements, instrument buildings; operational buildings; CO_2 composition analysis and cooling systems shall ensure that health and safety be considered in performance, installation, operation, maintenance and removal; and shall communicate such issues to the CDM Designer and other CDM Designers.

CO_2 has the potential to damage elastomers (materials that have the ability to stretch easily and return to their original shape when stress is removed) through a process known as rapid gas decompression. Rapid gas decompression occurs when CO_2 is absorbed into the elastomer material at high pressure and rapidly expands when the seal is returned to atmospheric pressure. The causes of rapid gas decompression are complex and are dependent upon a range of factors such as the type of elastomer material, hardness, system pressure, temperature and seal design.

The HSE Research Report No 485: Elastomeric Seals for Rapid Gas Decompression Applications in High - Pressure Service provides further details. Elastomers can also suffer from a range of other failure mechanisms, such a low temperature embrittlement, extrusion, and chemical attack, for example hydrogen sulphide.

In addition CO_2 can act as a solvent for lubricants and greases.

To ensure the integrity of the design the CDM Designer shall identify any elastomer material or other materials and substances that in isolation, or in combination, could be in contact or exposed to CO_2 and shall fully assess and certify as fit for purpose.

The CDM Designer shall record on a seals register all elastomers, or other materials that could suffer degradation when exposed to CO_2. The register shall list the location, nature of exposure, exposure pressures, physical details and properties, failure consequences and secondary impacts associated with the ‘seal’ or material. For each of the identified seals or materials the CDM Designer shall fully assess and certify as fit for purpose and provide evidence of certification where available.

The CDM Designer shall identify where an arrangement of seals and the like which cannot meet the integrity performance criteria. The CDM Designer shall adopt an iterative approach to identify and assess the ‘at-risk’ barriers.

4.7 CO_2 Vent Dispersion Modelling

Detailed ventilation and gas dispersion modelling, using Computational Fluid Dynamics (CFD), were carried out for:

- Onshore transport (Barmston Pumping Station); and
- Offshore T&S.

4.7.1 Onshore Transport (Block Valves and Barmston Pumping Station)

4.7.1.1 Purpose

The purpose of this section is to present the study basis and the main results of the detailed CFD venting dispersion analysis for Barmston Pumping Station.

Due to the local topography surrounding Barmston Pumping Station, specifically the 5m high retention walls, detailed CFD ventilation and dispersion analyses were undertaken to understand the interaction of the airflow with the local natural landscape and built features to evaluate its impact on the dispersion behaviour on vented CO_2.

The main stages of the analysis of the CFD model for the proposed Barmston Pumping Station site were, as follows:

- Construct a detailed three dimensional CFD model of Barmston Pumping Station for ventilation and plume dispersion modelling;
- Carry out steady state airflow simulations to determine local ventilation rates and to identify stagnant regions;
- Carry out transient plume dispersion simulations for a range of anticipated controlled venting scenarios to determine maximum extents of the resulting CO_2 gas clouds as well as maximum concentrations and dosages; and
- Demonstrate that the vent system design will ensure safe disposal of inventory with minimal potential for personnel exposure.

4.7.1.2 Description

The venting dispersion analysis includes vent contour information resulting from the vent study analysis and utilising the mathematical dispersion model and will account for a range of factors including:

- The exit velocity from the vent stack;
- Pressure, temperature, density and flow of the CO_2;
- Height and diameter of the vent stack;
- Atmospheric conditions;
- Wind direction; and
- Local topography.

4.7.1.3 *Modelling Approach*

CFD Software Package

The detailed ventilation and dispersion analysis was carried out using a commercial CFD software package.

The governing equations of fluid flow and gas dynamics were solved by means of a finite-volume method. The CFD modelling solves the fluid flow problem, taking into account the different phenomena that affect the dispersion of the gas cloud (for example turbulent and diffusive mixing, buoyancy forces and so on).

4.7.1.4 *Release Flow Rate Calculations*

Leakage flow rate calculations were performed using a process dynamic simulation software package, supplemented with the commercial risk assessment software package to help determine equivalent source parameters.

4.7.1.5 *CFD Atmospheric Dispersion Model Validation*

The main purpose of the CFD atmospheric dispersion model described in this technical note is to evaluate the consequences of dense phase CO_2 releases in the mid- to far-field regions, with a level of accuracy suitable in the context of hazard analysis.

Integral or Gaussian modelling cannot capture the effects of terrain and obstacles on atmospheric dispersion (i.e. “flat earth” assumption). By simplifying and focusing the dispersion model on the mid- to far-field regions, CFD can provide further insights on the plume behaviour within reasonable computational timescales and thus allowing more scenarios to be investigated. Some of the benefits of the CFD atmospheric dispersion model are the accurate representation of the effects of the 3D surroundings and the inclusion of the full transient release flow rate profiles, which can also be critical in the correct understanding of the consequences from some CO_2 releases.

For this reason, a practical modelling approach using an “equivalent vapour source” some distance downstream of the actual release location is suggested. The CFD model is therefore not intended to solve the complex multiphase physical phenomena associated with dense CO_2 releases in the near-field region (though feasible as a separate study if required).

This validation work is to ensure that the practical CFD modelling approach suggested (i.e. “equivalent vapour source”) is fit-for-purpose and can reasonably predict the behaviour for idealised “flat earth” cases (against NGCL’s experimental programme COOLTRANS and the integral tools developed by a third party as part of the COOLTRANS programme). By achieving this, the atmospheric dispersion model can then be applied with confidence to more complex scenarios, for which CFD presents numerous benefits as already highlighted previously.

Based on these observations, it was concluded that the level of accuracy of the suggested CFD atmospheric dispersion model is suitable in the context of HAZAN for unconfined horizontal jet releases

4.7.1.6 *Study Basis*

This subsection summarises the engineering data provided and any key assumptions/simplifications, which were used in the venting dispersion CFD study.

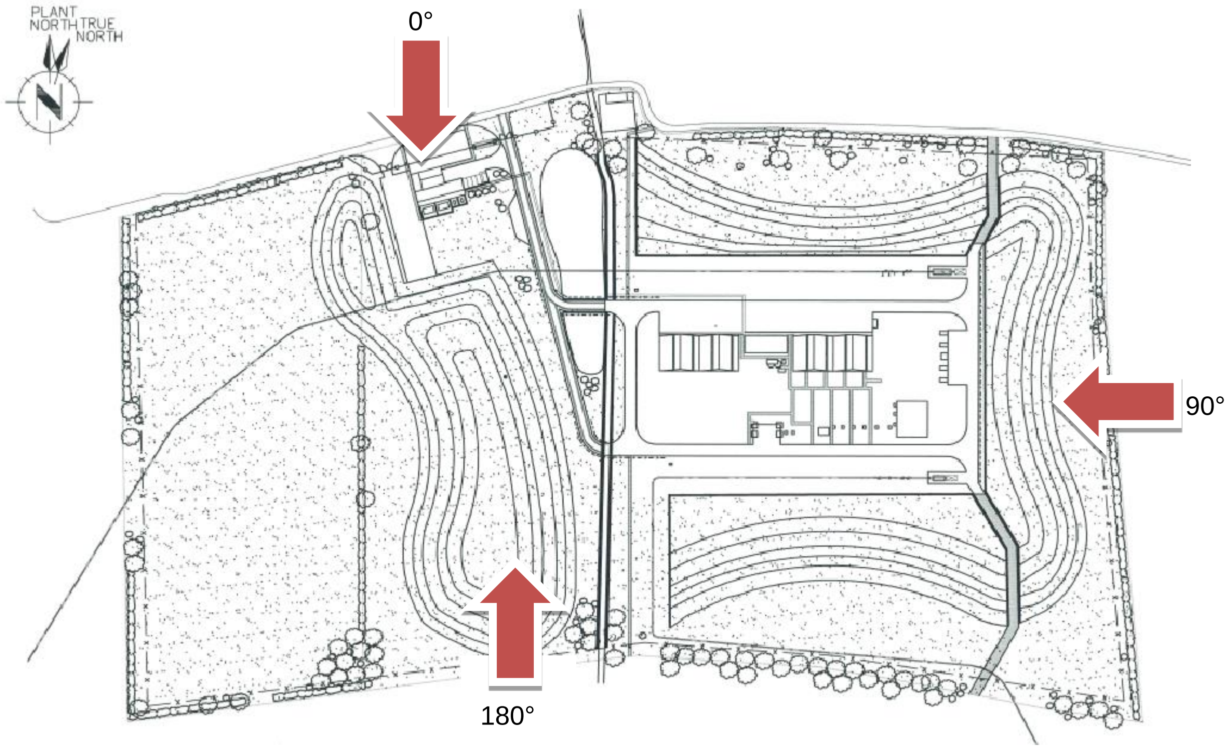
Meteorology Data Overall

Wind Convention

The convention is to specify an approaching wind, where the wind angle increases from the plant north side (0°) in a positive clockwise direction, as presented in Figure 4.1.

For example, wind directions of 90° and 180° imply winds approaching from the plant east and the plant south sides respectively. Undisturbed wind speeds were at 10 m above the ground level unless noted otherwise. Plant north is 18° west of true north.

Figure 4.1: Onshore Wind Convention



Atmospheric Wind Statistics

Wind statistics for the South Yorkshire area (Leconfield Station, November 2009 to October 2014) from the Met Office were provided for twelve wind direction sectors and seven wind speed ranges.

The predominant wind directions are from the plant west southwest sectors (approximately 55% of the time). The remaining wind directions show more or less the same frequencies of occurrence.

The wind speed probability distribution was derived from these values and is shown in Figure 4.3, giving an average of:

- 90% annual exceedance wind speed of 2.7mph (P90, characteristic low wind speed);
- 50% annual exceedance wind speed of 8.7mph (P50, characteristic average wind speed);
- 10% annual exceedance wind speed of 17.7mph (P10, characteristic high wind speed); and
- The probability of wind speeds exceeding 25mph is very low (approximately 1% of the time).

Table 4.10 details the 90%, 50% and 10% exceedance wind speeds specific for each direction.

Atmospheric Temperature Statistics

The following air temperature data was used for Barmston Pumping Station:

- Design maximum of 28°C; and
- Design minimum of -7°C.

A constant ambient temperature equal to the average day time recorded for the field (15º C) was assumed in the dispersion analysis.

Figure 4.2: Annual Wind Rose for the South Yorkshire Area (true coordinates)

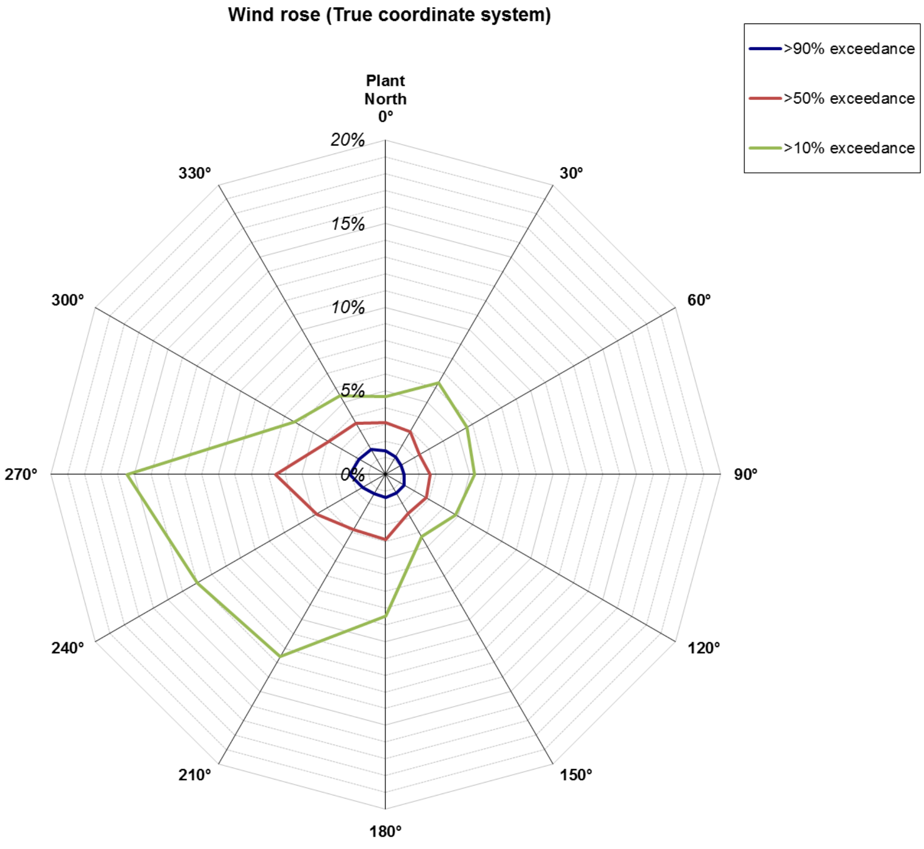


Figure 4.3: Annual Average Wind Speed Probability Distribution for South Yorkshire

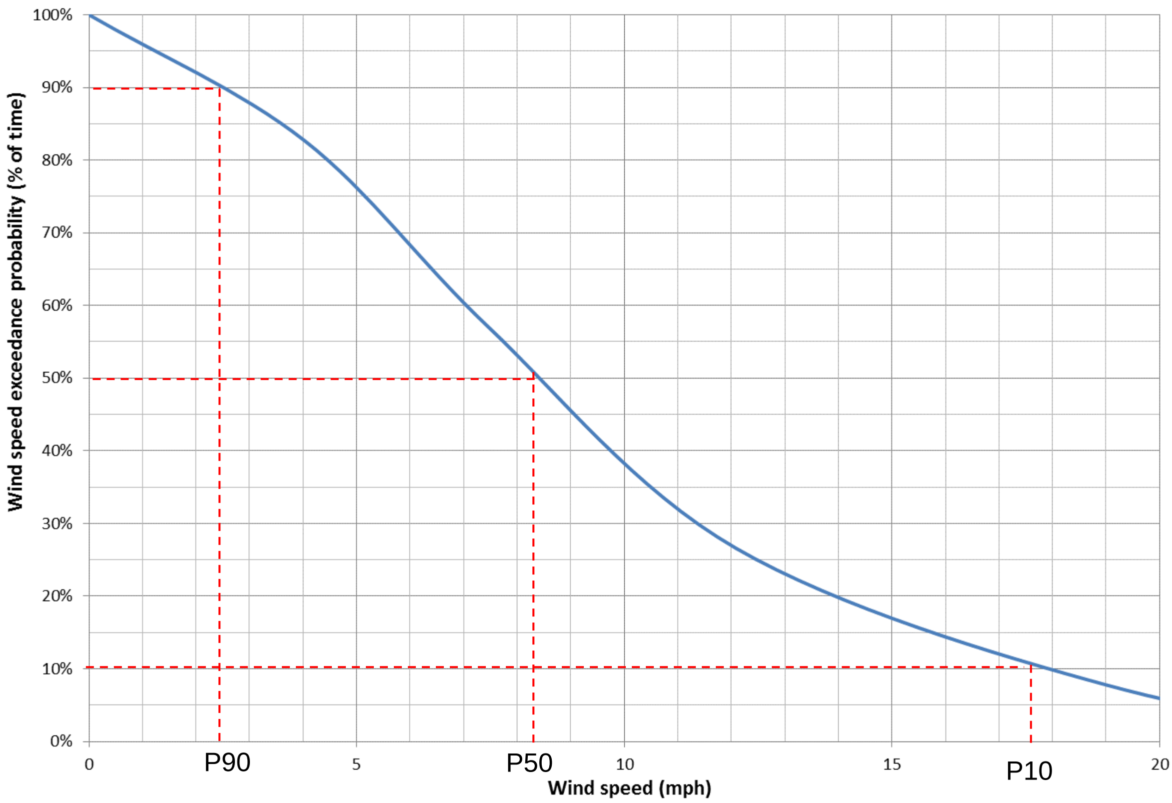


Table 4.10: Characteristic Wind Speeds for each Wind Direction

Wind direction (degrees)	N 0	30	60	E 90	120	150	S 180	210	240	W 270	300	330
Annual 10% exceedance wind speed (mph)	12.6	16.9	18.3	16.9	14.6	13.6	17.2	21.7	20.4	18.4	12.6	14.2
Annual 50% exceedance wind speed (mph)	5.9	8.2	9.1	7.8	6.7	6.3	8.3	11.3	10.2	9.0	6.2	6.1
Annual 90% exceedance wind speed (mph)	1.3	2.3	2.3	2.1	1.6	1.4	2.6	4.3	3.8	3.2	1.4	1.3

4.7.1.7 Assessment Criteria

Workplace Exposure Limits

Workplace Exposure Limits (WELs) are concentrations of hazardous substances in the air averaged over a specified period of time, referred to as Time Weighted Averages (TWA). Two time periods are used:

- Long Term Exposure Limit (LTEL) (8 hours); and
- Short Term Exposure Limit (STEL) (15 minutes).

The effects of exposure to substances hazardous to health vary considerably depending on the nature of the substance and the pattern of exposure.

Some effects require prolonged or accumulated exposure. The LTEL (8 hour TWA) is intended to control such effects by restricting the total intake by inhalation over one or more work shifts, depending on the length of the shift.

Other effects may be seen after brief exposures. STEL (usually 15 minutes) may be applied to control these effects. Short term exposure limits are set to help prevent effects such as eye irritation, which may occur following exposure for a few minutes.

Table 4.11: Workplace Exposure Limits for CO_2

LTEL (8-hour TWA)	STEL (15-minute TWA)
5,000ppm	15,000ppm

Note that the table gives the UK HSE WEL toxic impairment limits for CO_2.

Toxic Loads

The toxicological hazard is determined by UK HSE based on the duration of exposure as specified according to the toxic load. Risk estimates are based on the likelihood of a hypothetical individual receiving an exposure equal to or greater than a threshold level of toxic load known as the Specified Level of Toxicity (SLOT), corresponding to a 1% to 5% mortality. The toxic load relating to the mortality of 50% of an exposed population is also specified by a threshold level known as the Significant Likelihood of Death (SLOD).

To calculate the toxic load, the following formula is used:

$$TL = \int_0^T c^n dt$$

where

- c is the instantaneous gas concentration at a point in space; and
- t is the duration of exposure and n is the toxic load exponent.

Table 4.12: Toxic Load Parameters for CO_2

Toxic Load Exponent, n	Specified Level of Toxicity (1-5% fatality)	Significant Likelihood of Death (50% fatality)
8	1.5 x 1,040ppm 8.min	1.5 x 1,041ppm 8.min

Table 4.12 presents the UK HSE recommended toxic load limits for CO_2.

For carbon dioxide, the exponent n is eight reflecting the highly nonlinear response to exposure. A factor of two increase in CO_2 concentration produces a factor of 256 increase in the toxic load.

For this reason, any fluctuations in concentration (for example due to turbulence or time-varying wind conditions) will very quickly tend to increase the toxic load. As the CFD model approach used would not reproduce all turbulent mixing scales and the sideways meandering and intermittency of the plumes, an additional factor of 50 was conservatively added to all dosage calculations. This is roughly assuming a sinusoidal variation of the concentration fluctuations, in which the peak is twice the mean and the substance is always present.

4.7.1.8 *Venting Scenarios*

Manual Controlled Venting Scenarios

Controlled Venting Release Sources

Barmston Pumping Station has the following release sources from manual controlled venting:

- Eight year 1-5 booster pump vents with a permanent stack height of 8m;
- One recycle cooler vent with a permanent stack height of 8m;
- One metering vent with a permanent stack height of 8m;
- Eight year 5-10 booster pump vents with a permanent stack height of 8m;
- Four filter vents with a permanent stack height of 8m;
- One PIG receiver vent with a local temporary stack height of 7m;
- One PIG launcher vent with a local temporary stack height of 3m; and
- One year 1-5 pipeline vent with a permanent stack height of 8m.

All vents are orientated vertically upwards. It should be noted that the PIG launcher vent is a local vent with the tip at a height of only 3m and that the vent stack from the CO_2 export to offshore pipeline is located at the collective year 1 to 5 stack area with the vent discharges from the pumps/recycle cooler/metering package.

Additionally, given the operational resources required for co-current maintenance activities, it is not expected more than two major equipment items will be vented at any time.

Various venting scenarios (controlled manual) were considered in the CFD analysis. All vent locations were considered but particular focus was made on the PIG launcher vent due to its lower stack height of 3m and therefore the potential for higher gas accumulation at ground level.

Controlled Venting Release Rates and Compositions

The transient profiles of the overall venting mass flow rate, together with the fluid temperature and pressure at the stack exit, were extracted for each item of equipment from the existing HYSYS dynamics blow down model. The sizes of the orifices located at the top of the stacks that will limit the flow in the vent lines were also determined.

Only the Heat and Material Balances (HMB) cases giving the maximum depressurising flow rates for each venting scenario were considered in the CFD analysis; they are believed to be the worst case scenarios in terms of potential toxic gas impairment at ground level.

They were subsequently used in the detailed CFD venting dispersion modelling.

All venting outflow profiles present the same pattern:

- An initial peak release rate decaying rapidly associated with dense phase CO_2 in the vent system;
- A longer period with almost constant release rate (plateau period) during which saturated liquid is entering the vent system; and
- A final period with the release rate decaying exponentially, typical of depressurising of gas phase.

Except for the pipeline venting, all outflow profiles reach the plateau conditions within 10s to 20s, meaning that the initial peak release rates (maximum peak rate of approximately 130,000kg/hr for each booster pump) are of very short durations. The durations of the plateau periods (maximum plateau rate of approximately 60,000kg/hr for each of the booster pumps) are between 250s and 350s (approximately 4 to 6 minutes). The overall durations of the venting scenarios are all less than 10 minutes.

For the pipeline venting, the durations are much longer: it takes approximately four hours to reach the plateau conditions (200,000kg/hr) from the initial peak release rate of 500,000kg/hr. The depressurising of the pipeline is then expected to last overall for more than 14 days. For this reason, the pipeline venting scenarios were modelled using a steady state approach in the detailed CFD analysis considering the constant plateau flow rate.

Initial CFD Ventilation Analysis

Barmston Pumping Station is sheltered by landscape mounds (5m high retention walls on the north, east and south sides). Additionally, the pump buildings represent significant blockages to the incoming air flow. For this reason, a detailed CFD ventilation analysis was carried out.

As a minimum, the worst case wind direction in terms of local ventilation rate (determined from the detailed CFD ventilation analysis) combined with the low 90% exceedance wind speed was simulated for each venting scenario. Additional sensitivities on wind speeds and directions were conducted for some selected scenarios.

4.7.1.9 *Relief Valve Venting*

Relief Valve Release Sources

The following release sources from relief valve venting are present at Barmston Pumping Station:

- Four year 1 to5 building relief valves;
- Four year 5 to10 building relief valves;
- One PIG receiver relief valve;
- One PIG launcher relief valve;
- Two HIPPS relief valves;
- Four CO_2 filters relief valves; and
- One recycle cooler relief valve.

All relief valves were considered to have a 3m high vent stack and to release vertically upwards.

Realistic worst case scenarios, such as releases from multiple relief valves simultaneously lifting from different pieces of equipment at peak release rate were considered in the analysis.

Relief Valve Release Rates and Compositions

The expected peak release rates per relief valve were estimated from HYSYS process dynamic simulations. The majority of the relief cases are for thermal (solar) radiation. The required orifice areas are small and a standard relief valve orifice of an ASME 5 Crosby valve (with an area of 54.2mm²) was selected for all the thermal reliefs.

The peak release rates for the relief valve are much smaller than the release flow rates observed for the manual controlled venting scenarios. The maximum peak rate of approximately 5,000kg/hr was observed for the year 1 to5 building relief valves (to compare with the plateau rate of approximately 60,000kg/hr for the booster pumps).

Dynamically, actual relief valves will show a complex lift/drop behaviour over a certain period of time. They would be expected to initially discharge at peak flow rates and then quickly drop to a lower plateau flow rate before they reseal. At this stage of the design, the transient profiles of the overall venting mass flow rate are not known. For this reason, it was conservatively assumed in the CFD analysis that all relief valves would lift for a period of three minutes at peak flow rate.

Initial CFD Ventilation Analysis

Barmston Pumping Station is sheltered by landscape mounds (5m high retention walls on the north, east and south sides). Additionally, the pump buildings represent significant blockages to the incoming air flow. For this reason, a detailed CFD ventilation analysis was carried out.

As a minimum, the worst case wind direction in terms of local ventilation rate (determined from the detailed CFD ventilation analysis) combined with the low 90% exceedance wind speed was simulated for each venting scenario. Additional sensitivities on wind speeds and directions were conducted for some selected scenarios.

4.7.1.10 CFD Venting Dispersion Analysis

General

This section presents the main dispersion results from the detailed venting CFD analysis.

Unsteady Reynolds Averaged Navier Stokes (URANS) gas dispersion simulations were carried out for a range of venting scenarios to determine the maximum extent of the resulting CO_2 gas clouds as well as maximum concentrations and dosages.

Steady state ventilation simulations were carried out prior to the start of the transient release simulations to establish the air flow characteristics (velocity and turbulence quantity distributions) around Barmston Pumping Station.

Manual Controlled Venting

Workplace Exposure Limits and Concentration Levels

Models for each manual controlled venting case simulated the isosurfaces of CO_2 concentration at STEL (15,000ppm in red) and LTEL (5,000ppm in blue) and the CO_2 concentration contours on a horizontal plane 1.5m above the ground at different times during the venting event. Full animations of the STEL and LTEL gas clouds were also provided to NGCL.

Except for the steady state pipeline cases V4.1 and V4.2, the 8 hour LTEL is not relevant as the gas clouds will be fully dispersed well within this time period due to the relatively short duration of the releases (maximum of approximately 10 minutes).

Steady gas cloud sizes were quickly achieved once the plateau periods are reached. The initial peak rates did not last long enough (less than 10s) to sustain larger gas clouds. The gas cloud sizes drop very rapidly after the plateau periods.

For all release scenarios considered, the vented flow was observed to return to the ground immediately around the source (blanket behaviour) with the low 90% exceedance wind speeds (between 1.3mph and 3.2mph). At the medium 50% exceedance and high 10% exceedance wind speeds, the venting releases always form free plumes (non-blanketing) and therefore there was no STEL concentration at ground level.

4.7.1.11 *Recommendations*

The following is recommended:

- When conducting equipment manual venting operations, it is recommended that personnel entry into the process plant area is restricted; if personnel are required to enter the process plant area as part of the venting operations then personnel must be equipped with a full self-contained breathing apparatus set;
- When conducting equipment manual venting operations, it is recommended that the HVAC system dampers at the administration building are closed;
- Given the required duration of a pipeline venting operation and the potential for the plume to breach the security fence at concentrations up to the LTEL, it is recommended that offshore pipeline venting operations are not conducted onshore;
- As far as practicable, manual venting operations in low wind speed conditions should be avoided; and
- Any personnel entering the process plant area carry a CO_2 monitor with them.

4.7.2 Offshore Transport and Storage

4.7.2.1 *Purpose*

Detailed gas dispersion modelling, has been performed using CFD for the offshore topsides facilities.

Due to the relatively high local congestion on all platform decks, detailed CFD analysis has been undertaken to understand the interaction of the airflow with the local three-dimensional geometry (which is not captured by flat earth models) and to evaluate its impact on dispersion behaviour.

It should be noted that there are no other facilities for manual or relief venting along the offshore pipeline, between Barmston Pumping Station and the offshore topsides facilities.

The main objectives of the CFD venting dispersion analysis for the offshore topsides facilities are as follows:

- Construct a detailed three dimensional CFD model of the offshore topsides facilities suitable for ventilation and plume dispersion modelling;
- Carry out steady state airflow simulations;
- Carry out transient plume dispersion simulations for a range of anticipated controlled venting scenarios to determine maximum extents of the resulting CO_2 gas clouds as well as maximum concentrations and dosages; and
- Demonstrate that the current vent system design will ensure safe disposal of inventory with minimal potential for personnel exposure.

The purpose of this technical report is to present the study basis and the main results of the detailed CFD venting dispersion analysis for the offshore topsides facilities

4.7.2.2 Description

This report shall include vent contour information resulting from the vent study analysis. The report will account for a range of factors including:

- The exit velocity from the vent stack;
- Pressure, temperature, density and flow of the CO_2;
- Height and diameter of the vent stack;
- Atmospheric conditions;
- Wind direction; and
- Local topography.

4.7.2.3 Modelling Approach

CFD Software Package

The detailed ventilation and dispersion analysis was carried out using the general-purpose commercial CFD software package.

The governing equations of fluid flow and gas dynamics are solved by means of a finite volume method. The CFD modelling solves the fluid flow problem, taking into account the different phenomena that affect the dispersion of the gas cloud (for example turbulent and diffusive mixing, buoyancy forces).

Release Flow Rate Calculations

The leakage flow rate calculations were performed using the process dynamic simulation software package, supplemented with a commercial risk assessment software package.

CFD Atmospheric Dispersion Model Validation

The main features of the CFD atmospheric dispersion model applied and the validation works carried out to confirm the applicability of the CFD model for consequence modelling assessment.

4.7.2.4 *Study Basis*

General

This section summarises the engineering data provided and any key assumptions/simplifications, which were used in the venting dispersion CFD study.

Overall Geometry Description

The geometry used in the CFD analysis was based on the three dimensional Plant Design Management System (PDMS) software model and additional engineering drawings.

Meteorology Data Overall

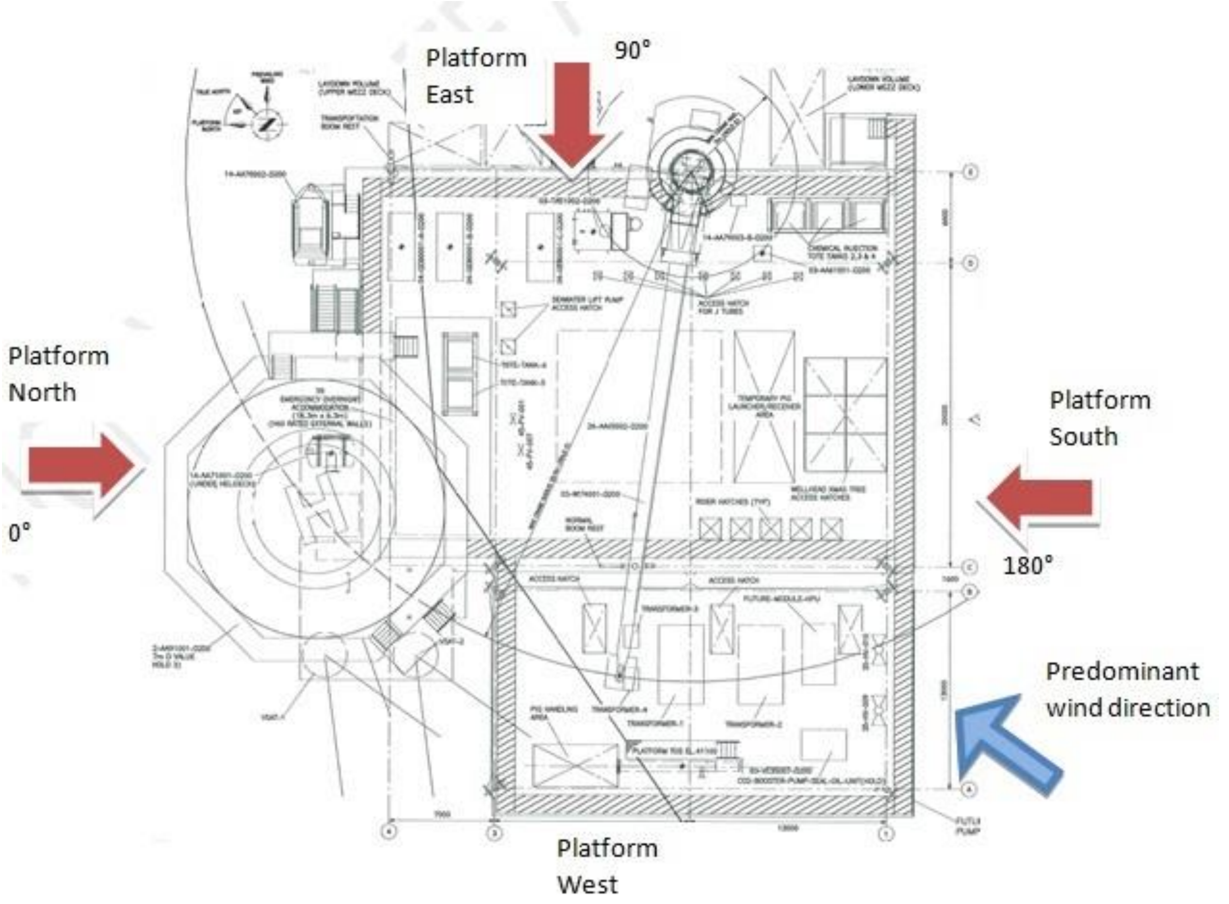
Wind Convention

The convention is to specify an approaching wind, where the wind angle increases from the platform North side (0°) in a positive clockwise direction, as presented in Figure 4.4 below.

For example, wind directions of 90° and 180° imply winds approaching from the platform East and the platform South sides respectively. Undisturbed wind speeds were at 10 m above the sea level unless noted otherwise.

Platform north is 45° to the west of true north.

Figure 4.4: Offshore Topsides Wind Convention



Atmospheric Wind Statistics

Wind statistics for the field were provided in the Metocean Report for eight wind direction sectors and nineteen wind speed ranges. They are presented in Table 4.13.

The wind rose is presented in Figure 4.5. The predominant wind directions are from the platform west southwest sectors (approximately 40% of the time). The remaining wind directions show more or less the same frequencies of occurrence.

The wind speed probability distribution was derived from these values, giving an average of:

- 90% Annual exceedance wind speed of 7.5 mph (P90, characteristic low wind speed);
- 50% Annual exceedance wind speed of 17.5 mph (P50, characteristic average wind speed); and
- 10% Annual exceedance wind speed of 30.3 mph (P10, characteristic high wind speed).

Figure 4.5 details the 90%, 50% and 10% exceedance wind speeds specific for each direction.

Atmospheric Temperature Statistics

The following air temperature data for the field were provided in the Metocean Report:

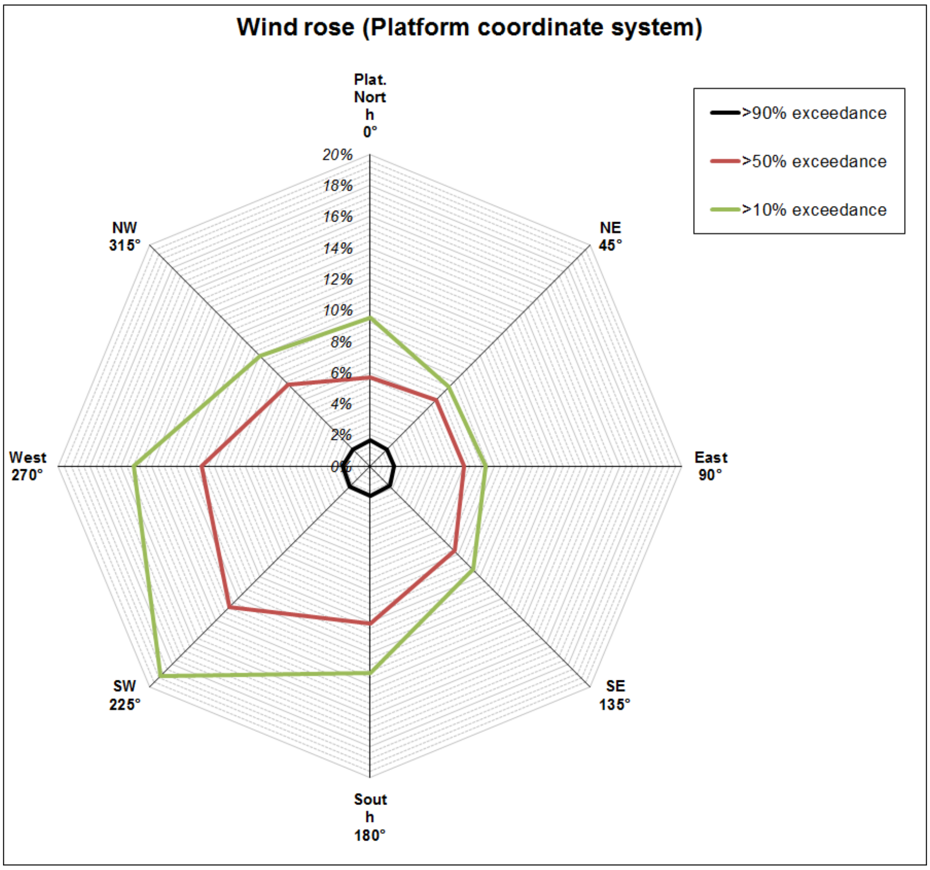
- Design maximum of 28°C; and
- Design minimum of -7°C .

A constant ambient temperature equal to the mean for the field (10°C) was assumed in the dispersion analysis.

Table 4.13: Annual Wind Statistics for the Offshore Location (Platform Co-ordinates)

Wind Velocity (mph)		Wind Speed Probability [%]								
Higher or equal to	Lower than	N	NE	E	SE	S	SW	W	NW	Total
54	58	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02
49	54	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.04	0.01	0.09
45	49	0.02	<0.01	<0.01	<0.01	0.06	0.09	0.11	0.05	0.33
40	45	0.08	0.05	0.03	0.04	0.18	0.24	0.28	0.16	1.06
36	40	0.25	0.09	0.14	0.1	0.41	0.68	0.58	0.32	2.57
31	36	0.45	0.19	0.27	0.25	0.72	1.47	1.07	0.56	4.98
27	31	0.73	0.38	0.52	0.59	1.2	2.62	1.76	1	8.81
22	27	1.23	0.76	0.85	1.09	1.94	3.6	2.62	1.57	13.67
18	22	1.89	1.27	1.21	1.73	2.56	4.28	3.44	1.91	18.30
13	18	2.16	1.6	1.7	2.09	3.05	3.96	3.27	2.13	19.97
9	13	1.88	1.61	1.61	2.08	2.55	2.72	2.33	1.84	16.63
4	9	1.21	1.11	1.09	1.32	1.49	1.41	1.35	1.14	10.13
0	4	0.42	0.43	0.42	0.44	0.45	0.44	0.43	0.4	3.43
	Total	10.33	7.50	7.85	9.74	14.64	21.55	17.31	11.10	100

Figure 4.5: Annual Wind Rose for the Offshore Location (Platform Coordinates)



4.7.2.5 *Venting Scenarios*

Manual Controlled Venting - Controlled Venting Release Sources

The following release sources from manual controlled venting are present at the offshore facilities:

- One PIG receiver vent;
- Four filter vents;
- Six booster pump vents;
- One PIG launcher vent;
- One future export pipeline vent;
- One injection manifold vent;
- Six injection well vents; and
- One recycle cooler vent.

All above stacks are grouped at the vent boom, located at the northeast corner of the platform at cellar deck level. All vent tips are pointing outboard, towards platform east and are directed 45° downwards. The vent boom extends approximately 6 m from the edge of the platform, along the cellar deck laydown area.

The different venting scenarios (controlled manual) were considered in the CFD analysis. Releases from the filters, the booster pumps and the pipeline were selected as they cover the range of venting scenarios present at the offshore facilities and therefore deemed sufficient to conclude on the potential hazard associated with controlled venting (see below for further details).

Manual Controlled Venting - Controlled Venting Release Rates and Compositions

The transient profiles of the overall venting mass flow rate, together with the fluid temperature and pressure at the stack exit, were extracted for each equipment from the existing blow down model. The sizes of the orifices located at the tip of the stacks that will limit the flow in the vent lines were also determined.

Only the HMB cases giving the maximum depressurising flow rates for each venting scenario were considered in the CFD analysis. It is believed to be the worst case scenarios in terms of potential toxic gas impairment within the platform.

The transient mass flow rate profiles were subsequently used in the detailed CFD venting dispersion modelling. The profiles for the PIG receiver, the filter, the PIG launcher and the injection well were quite similar and the same was observed for the booster pump and injection manifold profiles. For this reason, releases from the filters, the booster pumps and the pipeline were selected as they cover the range of venting scenarios present at the offshore facilities and therefore deemed sufficient to conclude on the potential hazard associated with controlled venting.

All venting outflow profiles present the same pattern:

- An initial peak release rate decaying rapidly associated with dense phase CO_2 in the vent system;
- A longer period with almost constant release rate (plateau period) during which saturated liquid is entering the vent system; and
- A final period with the release rate decaying exponentially, typical of depressurising of gas phase.

Except for the pipeline venting, all outflow profiles reach the plateau conditions within 10s to 20s, meaning that the initial peak release rates (maximum peak rate of approximately 230,000kg/hr for each booster pump) are of very short durations. The durations of the plateau periods (maximum plateau rate of approximately 96,000kg/hr for each of the booster pumps) are between 100s and 450s (approximately two to seven minutes). The overall durations of the venting scenarios are all less than ten minutes.

For the pipeline venting, the durations are much longer: it takes approximately four hours to reach the plateau conditions (200,000kg/hr) from the initial peak release rate of 500,000kg/hr. The depressurising of the pipeline is then expected to last overall for more than 14 days. For this reason, the pipeline venting scenarios were modelled using a steady state approach in the detailed CFD analysis considering the constant plateau flow rate.

Initial CFD Ventilation Analysis

The two worst case wind directions (which are from platform east and north), having the potential to push back the toxic gas clouds towards the facilities, combined with the three characteristic wind speeds (10%, 50% and 90% exceedance wind speeds), were simulated for each selected venting scenario.

4.7.2.6 Relief Valve Venting

Relief Valve Release Sources

The following release sources from manual controlled venting are present at the offshore facilities:

- Six injection well relief valves;
- Four filter relief valves;
- One PIG receiver relief valve;
- One PIG launcher relief valve;
- One HIPPS relief valve;
- One injection manifold relief valve;
- One import manifold relief valve; and
- Sixteen booster pump relief valves.

All relief valves are connected to vent stacks with tips approximately 1m below the cellar deck primary steel and pointing downwards.

As worst but realistic scenarios, releases from multiple relief valves simultaneously lifting from different pieces of equipment at peak release rates were considered in the analysis.

Relief Valve Release Rates and Compositions

The expected peak release rates per relief valve were estimated from HYSYS process dynamic simulations. The majority of the relief cases are for thermal (solar) radiation. The required orifice areas are small and a standard relief valve orifice of an ASME 5 Crosby valve (with an area of $54.2mm^2$) was selected for all the thermal reliefs.

The peak release rates for the relief valve selected are much smaller than the release flow rates observed for the manual controlled venting scenarios. The maximum peak rate of approximately 10,000kg/hr was observed for the CO_2. Injection manifold relief valve (to compare with the plateau rate of approximately 96,000kg/hr for the booster pumps).

Dynamically, actual relief valves will show a complex lift/drop behaviour over a certain period of time. They would be expected to initially discharge at peak flow rates and then quickly drop to a lower plateau flow rates before they reseal. At this stage of the design, the transient profiles of the overall venting mass flow rate are not known. For this reason, it was conservatively assumed in the CFD analysis that all relief valves would lift for a period of three minutes at peak flow rate.

Initial CFD Ventilation Analysis

The worst case wind direction (from platform west, towards supply boat), having the potential to push back the toxic gas clouds towards the supply boat, combined with the two characteristic wind speeds (10% and 90% exceedance wind speeds), were simulated for each selected venting scenario.

4.7.2.7 CFD Venting Dispersion Analysis

General

This section presents the main dispersion results from the detailed venting CFD analysis.

URANS gas dispersion simulations were carried out for a range of venting scenarios to determine maximum extents of the resulting CO_2 gas clouds as well as maximum concentrations and dosages.

Steady state ventilation simulations were carried out prior to the start of the transient release simulations to establish the air flow characteristics (velocity and turbulence quantity distributions) around and within the platform.

Manual Controlled Venting

Workplace Exposure Limits and Concentration Levels

Except for the steady state pipeline cases (V3.x), the 8 hour LTEL is not relevant as the gas clouds will be fully dispersed well within this time period due to the relatively short duration of the releases (maximum of approximately 10 minutes).

Steady gas cloud sizes were quickly achieved once the plateau periods are reached. The initial peak rates do not last long enough (less than 10s) to sustain larger gas clouds. The gas cloud sizes will drop very rapidly after the plateau periods.

For all release scenarios considered, the vented flow was never observed to return to the topsides facilities. Due to the orientation of the vent tips (outboard, 6 m away from the edge of the platform, pointing 45 degrees downwards), the plume is seen to disperse underneath the platform for any wind conditions simulated.

Except for the steady state pipeline cases (V3.x), the STEL clouds for the low wind speed condition very briefly drop to the sea before stabilising to steady sizes between the sea level and the cellar deck. For the higher wind speed conditions, no STEL concentration level was recorded at the sea surface at any time. Additionally, all STEL clouds are fully dispersed within 15 minutes, again due to the relatively short duration of the releases.

Therefore, those venting scenarios would also not affect any activities at the sea surface (supply vessels located in the vicinity of the platform).

Toxic Loads

Due to the relatively short duration of the venting, the SLOD and SLOT envelopes remain small and restricted to the area close to the vent stack exit and never reach the facilities or the sea surface.

4.7.2.8 Conclusions

The following main conclusions were drawn:

- For all release scenarios (manual controlled and relief valves), the vented flow is never observed to impair the topsides facilities due to the orientation and location of the vent tips. The plumes are seen to disperse underneath the platform; and
- The long duration pipeline depressurising scenarios (up to 14 days) give rise to large STEL clouds accumulating on the sea surface and therefore significant dosage values. This would impact any activities at the sea surface, such as supply vessels located in the vicinity of the platform or standby vessel located within the 500m zone of the platform.

4.7.2.9 Recommendations

The following is recommended:

- Manual venting procedures should be produced using the results contained within this study to ensure helicopter and supply vessel operations are not impacted/impaired.

4.8 ALARP Requirements

This section provides a review of the project's requirement for the residual risks in the FEED design to be ALARP.

Design Integrity and Risk Overview Reports were written to provide:

- A summary of the design principles applied;
- An evaluation of the design integrity; and
- Presentation of the residual risk associated with the design.

4.8.1 Onshore Transport System (Onshore Pipeline and Barmston Pumping Station)

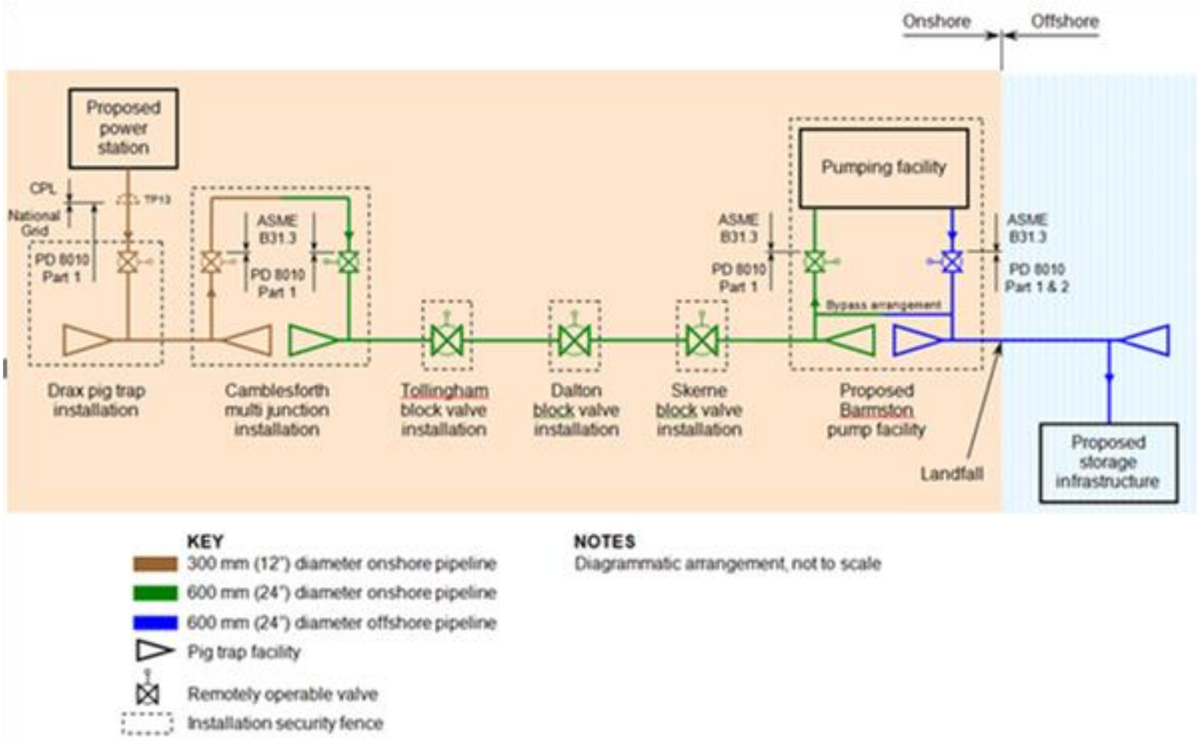
4.8.1.1 Description

The onshore transport system comprises:

- Pipeline and AGIs, including:
  - A section of 300 mm (12in), below ground piping, from the OPP interface point (TP13) to a PIG trap facility located on Drax PIG launcher AGI;
  - A 5.7km 300mm (12in) below ground pipeline from the Drax PIG Launcher to a PIG receiver located on the Camblesforth Multi-junction AGI, which is designed as a manifold station to enable tie-in of future emitters. A cross connection to a 600 mm (24in) pipeline is provided at the Camblesforth Multi-junction AGI;
  - A 19.8km 600 mm (24in) below ground pipeline from the PIG Launcher at Camblesforth Multi-junction AGI to the Tollingham Block Valve Station. The block valve stations enable sectionalisation and manual depressurisation of the pipeline in the event of an emergency;
  - A 19.6km 600mm (24in) below ground pipeline from the Tollingham Block Valve Station to the Dalton Block Valve Station;
  - A 14.4km 600mm (24in) below ground pipeline from the Dalton Block Valve Station to the Skerne Block Valve Station;
  - A 13.7km 600mm (24in) below ground pipeline from the Skerne Block Valve Station to the PIG receiver at Barmston Pumping Station; and
- Barmston Pumping Station.

Barmston Pumping Station will boost the pressure of the CO_2 to ensure delivery into the reservoir. The requirement to boost the pressure will come when the offshore storage aquifer pressure increases due to continual injection, hence additional head will be needed from the Barmston pumps over that provided by the OPP. Barmston Pumping Station will also provide filtration and metering facilities and will be capable of metering full load requirements over a range of process conditions. Additionally, connections for additional pumping capability shall be provided to accommodate the future expansion of the CO_2 transportation network. It will be possible to bypass the pump packages in the event of the pump packages not being required. This bypass flow will be filtered and metered.

Figure 4.6: Onshore Transport System Schematic



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4.8.1.2 *Safety Design Principles*

Introduction

The FEED design intent was that the project would comply with the highest legislative, company, project and industry standards for design safety. A design safety philosophy was developed to ensure implementation of safety principles across the FEED project design. As a minimum, the philosophy defined:

- The applicable safety legislation;
- The project hazard and risk management philosophy;
- Onshore pipeline and AGI design safety requirements;
- Barmston Pumping Station design safety requirements; and
- Emergency response requirements.

Hazard and Risk Management Objectives

The onshore transport system hazard and risk management objectives ensured:
- Full compliance with UK regulatory requirements, company specifications, CCS industry guidelines and international codes and standards;
- The output from formal safety assessments is applied alongside engineering judgement and applicable codes and standards, to achieve the highest practicable levels of safety; and
- That key design decisions affecting safety design are transparent and their justification is recorded.

Hazard and Effects Management Process

Opportunities for risk reduction were identified and implemented in the following hierarchy:
- Elimination;
- Prevention;
- Detection; and
- Control and mitigation.

4.8.1.3 *Evaluation of FEED Design Integrity*

Overview

Evaluation of design integrity is achieved through application of a Hazard and Effects Management Process (HEMP). The HEMP typically involves the following steps:
1. Identification of hazards and potential effects;
2. Quantified assessment of hazards including determination of residual risks to personnel (and third parties) through assessment, escape and muster impairment assessments;
3. Assessment of residual risks against UK HSE risk tolerability criteria;
4. Determination of risk reduction measures where required – for example design modification/ optimisation or development of operational/procedural mitigation; and
5. Re-evaluation of risks through quantified assessments (including cost benefit analysis), following the iterative process outlined above.

The process outlined above also forms the basis for demonstration that residual risks associated with the design are ALARP.

4.8.1.4 *Summary of Residual Risk*

Overview

As far as reasonably practicable, measures have been implemented during FEED to prevent, detect and control and mitigate the risk of process loss of containment.

Outstanding Safety Design Actions Areas – Onshore Pipeline

The significant risk areas were identified during the FEED project and a number of safety design areas were identified as requiring more detailed review and technical safety assessment to aid design optimisation during detailed design. The identification of these safety design optimisation areas is based on:

- Review of outstanding actions which could not be closed out during FEED:
  - Areas requiring technical safety assessments where those assessments were outside of the FEED scope of work; and
  - The safety design areas requiring further assessment are discussed in the sections that follow.

Layer of Protection Analysis

The SIL determination workshop covering the onshore transport system was based on the risk graph approach.

One of the failure causes identified as having potential to lead to loss of containment on the onshore pipeline is a loss of control on the CPL after cooler or a failure of the CPL chilled water system for an extended period of time leading to exceedance of the pipeline design temperature. There is a requirement to conduct a LOPA as this will allow for better representation of the mitigating factors that would prevent this sequence of events. The LOPA should be conducted during detailed design once NGCL have set a TMEL.

Detector Layout Design Optimisation

As far as reasonably practicable, the layout design of the detectors at the AGIs followed the requirements of the gas leak detection and control philosophy.

However, as dispersion modelling data was unavailable at the time of development of the detector layout drawings, there remains a requirement to assess and optimise the layout design. This assessment at detailed design should include:

- Development of the major accident dispersion scope for AGIs;
- Assessment of the detector layout design to ensure the proposed design provides adequate coverage at the specified set-points; and
- Adapt assessment results into the layout design.

Escape and Muster Assessment

As far as reasonably practicable, the design of the escape and muster facilities at the AGIs followed the requirements of the design safety philosophy.

However, a quantified assessment at detailed design is recommended as follows once the major accident dispersion data for each AGI has been developed:

- Assess the escape route and muster facilities design (against impairment tolerability criteria);
- Determine whether diverse and adequate escape routes are in place to enable personnel to reach the designated muster area and whether the muster area location is acceptable; and
- Determine the required capacity and type of escape set provisions.

Determination of Residual Risk and Demonstration of ALARP

As far as reasonably practicable, the results of formal safety assessments (in particular the *qualitative* formal workshops) have been adapted into the FEED design.

It would be recommended that identification of design optimisation opportunities and quantified assessment of the design variations (through risk assessment and cost benefit analysis) be undertaken at detailed design and reviewed at subsequent project stages.

Outstanding Safety Design Actions Areas – Barmston Pumping Station

These assessments will provide input into demonstration that the residual risks associated with the detailed design are ALARP.

The significant risk areas identified during the FEED project are as outlined in section B.2.17.

There are areas of safety design that have been identified as requiring more detailed technical safety assessments as part of detailed design. The identification of these areas is based on:

- Outstanding actions which could not be closed out during FEED; and
- Recommendations from the studies conducted during the FEED scope of work.

The safety design areas requiring further assessment are discussed in the sections that follow.

Detector Layout Design Optimisation

As far as reasonably practicable, the layout design of the CO_2 detectors followed the requirements of the gas leak detection and control philosophy.

However, as dispersion modelling data was unavailable at the time of development of the detector layout drawings, there remains a requirement to optimise the layout design.

The layout optimisation process should be as follows:

- Develop the full major accident dispersion scope for Barmston Pumping Station;
- Determine if the proposed layout design provides adequate coverage at the specified set-points (in particular for the smallest leaks);
- Identify potential low points on site; and
- Adapt assessment recommendations into the layout design.

Escape and Muster Assessment

As far as reasonably practicable, the design of the escape and muster facilities followed the requirements of the design safety philosophy.

A general compliance assessment was conducted. A limited major accident dispersion modelling scope of work was also conducted and recommendations from these assessments are outlined below:

- It is recommended that a quantified technical assessment is conducted at detailed design. The assessment should include CFD dispersion modelling of all isolatable sections, leak sizes and wind conditions to allow a probabilistic analysis to be completed. The assessment should include:
  - Assessment of the escape route and muster layout design against impairment tolerability criteria;
  - Review of whether diverse and adequate escape routes are in place to enable personnel to reach the designated safe areas;
  - Determination of the required capacity, type and locations of escape set equipment (including confirmation of requirement to carry an escape set vs provision at fixed locations (in cabinets) across the process area;
  - Confirmation of requirement for personnel entering the pump buildings to wear a breathing apparatus set;
  - Review of administration building HVAC philosophy when gas is detected in the process plant;
  - It is recommended that personnel are always equipped with personal CO_2 monitors; and
  - It is recommended that NGCL develop local authority notification and third party emergency response procedures to be initiated in the event of major accident leak or rupture event.

Pump Building HVAC Design Optimisation

The following is recommended based on the results of CFD dispersion modelling simulations of CO_2 major accident leaks inside the pump rooms:

- It is recommended that further CFD analysis is conducted during detailed design (to include the full scope of major accident cases) to facilitate optimisation of the HVAC design, including air intake and exhaust duct locations; and
- It is recommended that an HVAC philosophy is developed to include philosophy on detection of internal CO_2 leaks inside the pump rooms or external leaks in the process area.

Venting Philosophy

A venting dispersion analysis for Barmston Pumping Station was conducted and the procedural recommendations from the analysis were as follows:

- When conducting equipment manual venting operations, it is recommended that personnel entry into the process plant area is restricted. If personnel are required to enter the process plant area as part of the venting operations, then personnel must be equipped with a full self-contained breathing apparatus set;
- When conducting equipment manual venting operations, it is recommended that the HVAC system dampers at the administration building are closed;
- Given the required duration of a pipeline venting operation and the potential for the plume to breach the security fence at concentrations up to the LTEL, it is recommended that offshore pipeline venting operations are not conducted onshore; and
- Where practicable, it is recommended that manual venting operations in low wind speed conditions are avoided to mitigate the risk of the plume slumping to ground level.

Determination of Residual Risk and Demonstration of ALARP

As far as reasonably practicable, the results of formal safety assessments such as the formal workshops have been adapted into FEED. An assessment was carried out of risk including determination of residual risk to personnel and third parties and demonstration that the residual risk.

The following assessments which are required to be conducted at each project stage (concept, FEED and detailed design) are recommended to be conducted at detailed design:

- Identification of design optimisation opportunities and quantified assessment of the design variations (through risk assessment and cost benefit analysis).

These assessments will provide input into demonstration that the residual risks associated with the detailed design are ALARP.

Layer of Protection Analysis

The SIL determination workshop covering the onshore transport system (including Barmston Pumping Station) was based on the risk graph approach.

One of the failure causes identified as having potential to lead to phase separation in the onshore pipeline is a prolonged failure of the pump control system at Barmston Pumping Station. There is a requirement to conduct a LOPA as this will allow for better representation of the mitigating factors that would prevent this sequence of events. The LOPA should be conducted during detailed design once NGCL have set a TMEL.

4.8.2 Offshore Transport and Storage System

4.8.2.1 Description

The offshore T&S system comprises the following:

- 88.3km 600mm (24in) pipeline supplying CO_2 from onshore. The pipeline includes a 1.3km onshore/landfall pipeline section from Barmston Pumping Station;
- A normally unmanned wellhead injection platform with:
  - Filtration facilities;
  - Metering facilities (on individual injection well lines);
  - Injection manifold;
  - Three wells and allocation for three future wells;
  - Utility systems – MEG, water wash and general utilities;
  - Support systems – emergency overnight accommodation, power generation, battery room, crane, helideck, marine navigation aids, telecoms;
  - Safety systems – fire and CO_2 detection systems, public address/general alarm system, Deck Integrated Fire Fighting System (DIFFS), TEMPSC and life rafts;
  - Water disposal caisson to allow disposal of produced water from injection aquifer (future requirement) and seawater cooling return line;
  - One future CO_2 export pipeline riser;
  - Two future CO_2 injection well risers; and
  - Endurance Storage site.

4.8.2.2 Safety Design Principles

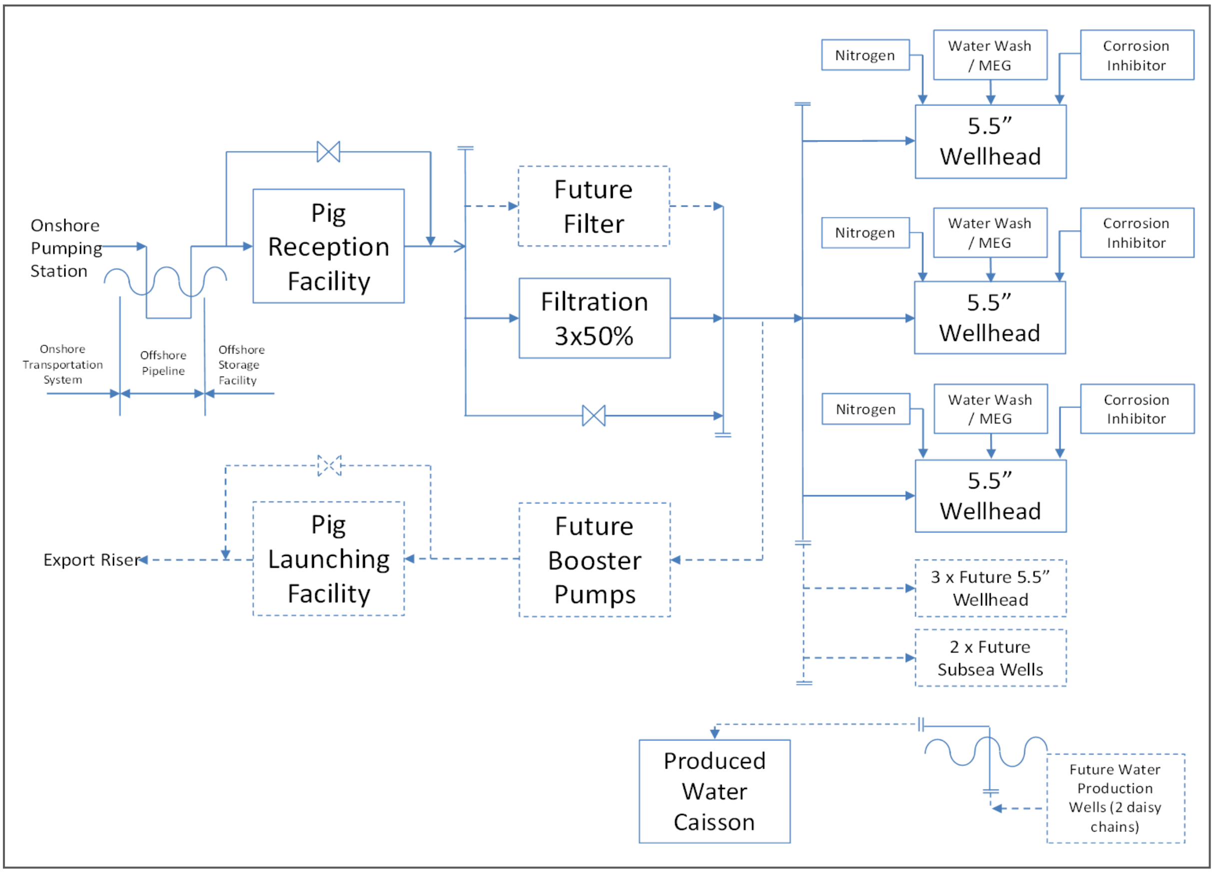
Overview of Safety Design Principles

The FEED intent was that the design will comply with the highest regulatory, NGCL and industry standards for design safety. A risk based design approach was implemented in the offshore FEED.

Key safety design principles were implemented in the hierarchy outlined below:

- Inherent safe design – implement inherent safe design in accordance with all applicable legislative requirements, NGCL specifications, FEED project documents and normative and informative industry codes and standards;
- Prevention and elimination – identify opportunities for elimination of hazards at the design stage;
- Detection and alarm – provide means of early incident detection and notification to personnel on the platform and to operators at the remote NGCL control centre;
- Control and mitigation – provide means of control and mitigation of the effects of major accident events such that incident escalation is prevented or delayed until personnel can reach a place of safety;
- Emergency response – provide means of personnel protection, escape, muster and evacuation from the platform; and
- Detailed descriptions of key preventive, detection and control and mitigation measures implemented in FEED are provided in the safety reports referenced.

Figure 4.7: Offshore T&S System Schematic



4.8.2.3 *Evaluation of FEED Design Integrity*

Overview

As far as reasonably practicable, a risk based design approach was implemented with the output from formal safety assessments being applied alongside engineering judgement and applicable specifications, codes and standards, to achieve the highest practicable levels of safety.

The risk based design approach involved the following:
- Identification of hazards and potential effects by formal workshops and desktop studies;
- Quantified assessment of hazards;
- Determination of residual risk to personnel at the platform and to third parties along the pipeline route;
- Assessment of residual risks against UK HSE risk tolerability criteria;
- Determination of risk reduction measures where required – for example additional protection or procedural mitigation; and
- Re-evaluation of risks using quantified assessments (including cost benefit analysis if appropriate), following the iterative process outlined above.

This process formed the basis for demonstration that residual risks associated with the design are ALARP.

As far as possible, technical studies were scheduled such that their findings and recommendations could be incorporated into the design within the FEED project timescales. Where incorporation into FEED design was impractical or outside scope, the outstanding design issues will be transferred to detailed design. The transfer process is being managed through SAMS.

Assessment of FEED Design

The offshore FEED has been subject to technical review during the formal safety workshops and the design has also been assessed using the following primary technical safety assessments:
- EER Assessment – which assessed the layout design of EER facilities and design integrity of the Emergency Overnight Accommodation (EOA), including assessment of residual impairment frequency against risk tolerability criteria;
- Platform and offshore pipeline assessment – which incorporated the findings from the EERA, calculated the residual risks to personnel and third parties and assessed the residual risk against UK HSE individual risk tolerability criteria. The assessment was based on the year 10 configuration (including future facilities) and also included the wellheads and Christmas trees so that the total risk associated with future operation would not be underestimated;
- Emergency systems survivability assessment – which assessed the ability of emergency systems to survive and control a major accident events or facilitate emergency response actions;
- Dropped objects assessment – which assessed the potential for dropped and swinging load impacts onto the topsides and dropped object impact onto subsea infrastructure; and
- Offshore topsides CFD venting dispersion analysis – which assessed the vent system design to ensure safe disposal of inventory with minimal potential for personnel exposure.

In all the technical assessments, the primary objective was to determine if there was a requirement for design modification or provision of additional risk reduction measures such that the residual risk could be reduced to ALARP.

4.8.2.4 Summary of Residual Risk

Introduction

As far as reasonably practicable, measures have been implemented during FEED to prevent, detect and alarm and control and mitigate the risk of process loss of containment such that the residual risks at the end of FEED are ALARP. These measures are detailed in the reports and design documentation produced during FEED including philosophies, basis of design documents, specifications, offshore infrastructure design rationale documents and technical reports.

Residual Risks

Barmston Personnel – Onshore/Landfall Pipeline

The offshore pipeline is partially routed through Barmston Pumping Station from plant southeast to southwest. The results show that if there is a pipeline loss of containment, SLOD or SLOT exceedance at the nearby process area from small or medium (10mm or 20mm) leaks is unlikely. The process area is taken to be a nominal point near the recycle cooler. However, there is potential for exceedance of the dose criteria at the process area from full bore releases. In developing the risk transect no credit was taken for wind directionality. The distance to the process area is approximately 22m (exceedance frequency 2E-04 per year).

Third Party – Onshore/Landfall Pipeline

As for Barmston Pumping Station pipeline section, exceedance of SLOD and SLOT criteria from onshore/landfall pipeline releases will only occur within close proximity of the release. No credit is taken for wind directionality.

Based on a nominal rupture location upstream of the cliffs the results show that there should be no exceedance of concentrations above the LTEL at the nearest population centres.

Third Party – Offshore Pipeline

Risks from a leak or rupture on the subsea section of the pipeline have been considered within the context of potential impacts on personnel on an attendant vessel (for example standby vessel), with potential impacts on third party vessels (for example fishing trawler) assumed to be similar. The nominal impact height is assumed to be approximately 6m above the sea surface, with the standby vessel height taken as 5m above sea surface (based on Genesis' experience on projects) and the average height of a person in a range of postures assumed to 1m.

Table 4.14 shows the results of the analysis, with impacts based on the LTEL. The results show that there is potential for the plume elevation from full bore releases to extend to the assumed deck elevation of a standby vessel. The total frequency (over the full pipeline length) with which the full bore release event may occur is 4.5E-04 per year. However, the personnel or third party exposure probability (and therefore associated risk) is likely to be orders of magnitude lower because the presence of a vessel and proximity to the pipeline will be transient. This is particularly true of third party vessels. An attendant vessel such as a standby vessel will be aware of the pipeline location.

Table 4.14: Impacts from Subsea Releases

Hole Size (mm)	LTEL Contour Elevation (Low Wind Speed 90% Exceedance)	Total Event Frequency/Year	Potential for Impact on Person at Vessel Deck Level
10	4.2m	–	No
20	5.2m	–	No
FB	12m	4.5E-04	Yes

Platform Personnel – Offshore Pipeline and Platform

The residual risks to personnel on the platform have been assessed as part of the platform and offshore pipeline assessment. Note that the FEED assessment takes no credit for the use of escape sets.

Figure B.5 (Individual Risk per Annum (IRPA) by Worker Group) provides a summary of the residual risks to personnel by worker group. The most exposed worker group are the technicians, with a total (process and non-process) Individual Risk Per Annum (IRPA) of 7.9E0-4 per year.

Escalation risk forms a significant contribution to the individual process risk (estimated 80%) due to the small platform footprint and the assumption of rapid failure of any adjacent piping/inventories in the near field of a CO_2 release from cryogenic embrittlement. This means there is significant potential for personnel to be caught in secondary events before they are able to reach the EOA. The individual risks for all worker groups are below the UK HSE risk tolerability criterion of 1E-03 per year. For all worker groups, the risk levels lie within the tolerable region of the ALARP triangle, depicted in Figure B.6 with demonstration of ALARP required. The ALARP summary is provided in Table 4.17.

The total potential loss of life is of the order 6.1E-03 per year. There are no UK HSE risk tolerability criteria relating to potential loss of life, however, this risk measure provides a basis for NGCL to compare the White Rose platform group risk against other normally unmanned installations.

ALARP Summary

Provision of Subsea Isolation Valve on the Pipeline

A sensitivity study was conducted as part of the platform and offshore pipeline assessment to determine the potential risk benefit of provision of a subsea isolation valve on the pipeline. For the purposes of the analysis, it was assumed that the subsea isolation valve would be located at the bottom of the riser thus limiting the inventory available for release as that between the subsea isolation valve and 34-ESDV-005 (which isolates the pipeline from the topsides).

Since there is no escalation reduction benefit in providing a subsea isolation valve (a smaller inventory does not limit potential for cryogenic embrittlement), the variation in modelling between the base case assessment model and the sensitivity study lies in a variation in evacuation philosophy as summarised in Table 4.15. The assessment results show that the potential risk reduction gained from installation of a subsea isolation valve on the pipeline would be negligible; the reduction in evacuation fatality risk is of the order 0.002%. On this basis, this option is ruled out.

Table 4.15: Subsea Isolation Valve Sensitivity – Evacuation Rule Set

Scenario	Evacuation Philosophy	Evacuate?	
		Base	Subsea Isolation Valve
Isolated process release – topsides small to medium leaks	Escape to muster/EOA, no immediate evacuation required	✗	✗
Isolated process release – topsides large leak or full bore		✓	✓
Unisolated process release		✓	✓
Riser release – topsides (upstream 34-ESDV-005)		✓	✗
Riser or pipeline release – subsea		✓	✓
Well incident		✓	✓
Utility fire incident		✗	✗

Provision of Thermal Protection on Injection Manifold

A sensitivity study was conducted as part of the platform and offshore pipeline assessment to determine the potential risk benefit of provision of thermal protection on the injection manifold and on other large piping systems. The sensitivity study was considered because provision of thermal protection could mitigate potential for inventory to inventory escalation (where secondary loss of containment events are caused by near-field system exposure to cold CO_2). In the sensitivity study, it was assumed that inventories that have thermal protection do not contribute to escalation risk. The sensitivity study results in Table 4.16 show that there is a notable reduction in escalation risk and in the process individual risk for each worker group.

Table 4.16: Cold Splash Protection Sensitivity – Risk Reduction

Worker Group	Escalation Fatality Risk (/Year)			Total Process IR (/Year)		
	Base Case	Cold Splash Protection	% Reduction	Base Case	Cold Splash Protection	% Reduction
OIM	5.80E-05	1.65E-04	37%	3.24E-04	2.27E-04	30%
Technicians	1.28E-04	3.82E-04	36%	7.28E-04	5.13E-04	30%
Crane Driver	2.04E-05	1.23E-05	33%	4.27E-05	3.66E-05	14%
Maintenance	1.16E-04	3.30E-04	37%	6.43E-04	4.50E-04	30%
Helicopter Crew	5.06E-06	3.05E-06	33%	1.09E-05	9.38E-06	14%

This risk reduction option was assessed further using cost benefit analysis.

Provision of Mattressing on the Spool Piece

The dropped objects assessment shows that, based on the scope of lifts assumed, the total residual risk of impact on the pipeline is low (2.5E-07 per year) because the pipeline is largely protected by routing/location. The assessment also shows that the frequency with which impacts exceeding 168 kJ may occur is <1E-09 per year – that is impacts which may cause >20% dent depth and could result in loss of containment. The frequency with which impacts between 20-109kJ may occur is of the order of 6E-08 per year – that is impacts which may cause between 5% and15% dent depth, with no loss of containment but with potential impact on PIG operations.

The residual risk to the pipeline will remain low provided that the risk is managed through operational controls including the following:

- No lifting operations should be conducted at platform west;
- Restrictions should be placed on lifting operations using the jack-up crane over the west of the platform above the subsea pipeline. All jack-up lifts should be subject to individual risk assessment; and
- All heavy or unusual lifts should be subject to risk assessment.

However, at this stage of the project, there is some uncertainty on the scope of lifts which may be required to be conducted using the jack-up. As such, concrete mattressing is specified to protect the spool piece. The specification details are provided on the platform approach drawing. It is recommended that the dropped objects protection requirements are reviewed during detailed design once the scope of lifts is better defined.

ALARP Summary

Table 4.17 shows the risk reduction options and status summary.

Table 4.17: ALARP Summary

Risk Reduction Measure	Implemented in FEED (Y/N)	Comments
Provision of subsea isolation valve	N	The assessment results show that the risk benefit (reduction) of this option is minimal (<<1% reduction in evacuation risks). On this basis, this option is not considered further
Provision of Thermal Protection on injection manifold	N (Consider further during detailed design)	The assessment results show that there is a notable risk benefit to provision of this risk reduction measure (~30% reduction in process risk for the most exposed worker group). This risk reduction measure was not implemented in FEED but is recommended for further review during detailed design
Provision of mattressing on pipeline spool piece	Y (Review during detailed design)	Based on the configuration of the platform and the assumed operational lift data, the Dropped Objects Assessment has concluded that the residual risk of pipeline impact is low (order of 2.5E-07 per year). However, due to uncertainly on the scope of lifts which may need to be carried out from the jack-up, concrete mattressing is specified for the spool piece

5 Glossary

Abbreviations	Meaning or Explanation
ACH	Air changes per hour
AGI	Above Ground Installation
ALARP	As Low As Reasonably Practicable
AQCS	Air Quality Control System
Ar	Argon
ASU	Air Separation Unit
ATEX	The Explosive Atmospheres Directive 99/92/EC
BIM	Building Information Modelling
BMCR	Boiler Maximum Continuous Rating
BoD	Basis of Design
BOSIET	Basic Offshore Safety Induction and Emergency Training
CA	Competent Authority
CCS	Carbon Capture and Storage
CCTV	Closed Circuit Television
CDM	Construction (Design and Management) Regulations
C&E	Control and Electrical
CFD	Computational Fluid Dynamics
CLP	European Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Equivalent Carbon Dioxide is the concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas
COMAH	Control Of Major Accident Hazards
CPL	Capture Power Limited
CSC	Car Sealed Closed
DBB	Double Block and Bleed
DCO	Development Consent Order
DCS	Distributed Control System
DECC	UK Government's Department of Energy and Climate Change
DIFFS	Deck Integrated Fire Fighting System
DPP	Drax Power Plant
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations 2002
EA	Environment Agency
EER	Escape, Evacuation and Rescue
EERA	Escape, Evacuation and Rescue Assessment
EHS	Environment Health and Safety
EMC	Electromagnetic Compatibility
ENVID	Environmental Aspects and Impact Identification
EOA	Emergency Overnight Accommodation
EPC	Engineering Procurement and Construction
EPS	Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations

Abbreviations	Meaning or Explanation
ERP	Emergency Response Plan
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Vallve
ESP	Electrostatic Precipitator
ESSA	Emergency Systems Survivability Analysis
EU	European Union
FAR	Fatal Accident Rate
FEED	Front End Engineering Design
F&G	Fire and Gas
FGD	Flue Gas Desulphurisation
FPSA	Formal Process Safety Assessments
GE	General Electric
GIP	Good Industry Practice
GL-DNV	Ground Level – Det Nork Veritas (Phast modelling Software)
GPU	Gas Processing Unit
GWP	Global Warming Potential
H_2	Hydrogen
H_2O	Water
H_2SO_4	Sulphuric Acid
HASAWA	Health and Safety at Work Act
HAZAN	Hazard analysis
HAZID	HAZard Identification
HAZOP	HAZard and Operability
HCL	Hydrochloric Acid
HDD	Horizontal Directional Drilling
HEMP	Hazard and Effects Management Process
HFIP	Human Factors Integration Plan
HHH	Hand injury prevention", "safe working at Height" and "Housekeeping"
HIPPS	High Integrity Pressure Protection System
HMB	Heat and Material Balances
HMI	Human Machine Interface
HNO_3	Nitric Acid
HSC	Hazardous Substances Consent
HSE	Health and Safety Executive
HS&E	Health, Safety and Environment
HSMS	Health and Safety Management System
HVAC	Heating Venting and Air Conditioning
ICSS	Integrated Control and Safety System
IID	Intelligent Inspection Devices
IAOGP	International Association of Oil and Gas Producers
IPCC	Intergovernmental Panel on Climate Change
IRPA	Individual Risk Per Annum

Abbreviations	Meaning or Explanation
JIP	Joint Industry Project
KKD	Key Knowledge Deliverable
LDA	Local Detection and Alarm
LED	Light Emitting Diode
Leq	Sound pressure level in dB, equivalent to the total sound energy over a given period of time
LOPA	Layer Of Protection Analysis
LOX	Liquid Oxygen
LP	Low Pressure
LPA	Local Planning Authority
LTCS	Low Temperature Carbon Steel
LTEL	Long Term Exposure Limit
MAC	Manual Alarm Callpoint
MAOP	Maximum Allowable Operating Pressure
MAPP	Major Accident Prevention Policy
MEG	Monoethyleneglycol
MIP	Maximum Incidental Pressure
MIS	Management Information System
MIST	Minimum Industry Safety Training
MJS	Maximum Justifiable Spend
MODUs	Mobile Offshore Drilling Units
MWe	Megawatt electrical
N_2	Nitrogen
NETS	National Electricity Transmission System
NGCL	National Grid Carbon Limited
NH_3	Ammonia
NO	Nitic Oxide
NO_x	Generic term for the mono-nitrogen oxides and nitric oxide (NO) and nitrogen dioxide (NO_2)
NO_2	
OBRA	Occupied Buildings Risk Assessment
O&M	Operation and Maintenance
O_2	Oxygen
OPEP	Oil Pollution Emergency Plan
OPP	Oxy-Power Plant
PAGA	Personnel Announcement and General Alarm
PC	Principal Contractor
PCI	Pre-Construction Information
PCS	Process Control System
PD	Principal Designer
PDMS (software)	Plant Design Management System
PDT	Project Delivery Team
P&ID	Piping and Instrumentation Diagram

Abbreviations	Meaning or Explanation
PIG	Pipeline Inspection Gauge
PIZ	Public Information Zone
PLC	Programmable Logic Control
PPM	Parts per Million
PRV	Pressure Relief Valve
PSR	Pipeline Safety Regulations
PSV	Pressure Safety Valve
QRA	Quantitative Risk Assessment
RAM	Reliability, Availability and Maintainability
R&D	Research and Development
ROW	Right of Way
RTU	Remote Telemetry Unit
R2P2	Reducing Risk Protecting People
SAMS	Safety Action Management System
SCADA	Supervisory Control And Data Acquisition
SCEIRA	Safety Critical Element Impairment Risk Assessment
SCR	Selective Catalytic Reduction
SDV	Shutdown Valve
SIL	Safety Integrity Level
SIMOP	Simultaneous Operations Review
SIS	Safety Instrumented System
SLOD	Significant Likelihood Of Death
SLOT	Specified Level Of Toxicity
SO_x	Oxides of Sulphur
SO_2	Sulphur Dioxide
SSSV	Subsea Safety Valve
STEL	Short Term Exposure Limit
SWDS	Safe Working Design Studies
TEMPSC	Totally Enclosed Motor Propelled Survival Craft
TMEL	Target Mitigated Event Likelihood
TMP	Traffic Management Plan
T&S	Transport and Storage
TWA	Time Weighted Averages
UPS	Uninterruptable Power Supply
URANS	Unsteady Reynolds Average Navier Stokes gas dispersion simulations
VSD	Variable Speed Drive
WEL	Workplace Exposure Limit

Appendices

Appendix A CPL's Environmental, Health, Safety and Quality General Statement of Policy

Environment, Health, Safety and Quality

General Statement of Policy

The Board of Capture Power Ltd requires that all its business is undertaken with the highest regard to matters of Environment, Health, Safety and Quality (EHSQ). This Policy lays out the Principles, Vision and Commitment of the Board to EHSQ.

Our Principles:

- Safety, health, quality and care for the environment are foundational principles of our business.
- The safety and health of our colleagues, customers, business partners and communities in which we do business are paramount and are at the forefront of our business objectives.
- Visible leadership and personal accountability for EHSQ, at all levels.

Our Vision:

- Zero incidents.
- Safe, secure and healthy working conditions for all who work with and for us.
- High quality, safe and environmentally responsible operations that meet or exceed our stakeholder expectations.
- Responsible use of natural resources.
- Economic and environmental sustainability in everything we do.

Our Commitment:

- Comply with applicable legal, regulatory and industry requirements.
- Design and, in due course, construct, operate and decommission our facilities in a safe, secure, efficient and environmentally responsible way.
- Contract only with those who share fully the Principles, Vision and Commitment of this EHSQ policy.
- Promote open communication with all stakeholders and sharing of EHSQ knowledge.
- Continuously improve our performance and actively manage risk in our business.

The policy is integral to Capture Power Ltd's strategy and is reviewed annually by the Board. A specific review will be undertaken prior to the White Rose Project entering the Implementation Phase. The Board is committed to the implementation of this EHSQ policy through its General Manager supported by the Management Team.

Stephen Burgin **Peter Emery** **Leigh Hackett** **Mike Huggon**

Andrew Koss **Andreas Opfermann** **Sébastien Rouge**

16 January 2014

Appendix B T&S Safety Review

B.1 Overview

Although this regulation is not applicable to the T&S section of the CCS scheme, this Appendix provides a review of the safety reports in line with Regulation 8 of the COMAH Regulations 2015.

Regulation 8 Purposes of Safety Reports

1. Every operator of an upper tier establishment must prepare a safety report for the purposes of:
   a. demonstrating that a MAPP and a safety management system for implementing it have been put into effect in accordance with the information set out in Schedule 3;
   b. demonstrating that the major accident hazards and possible major accident scenarios in relation to the establishment have been identified and that the necessary measures have been taken to prevent such accidents and to limit their consequences for human health and the environment;
   c. demonstrating that adequate safety and reliability have been taken into account in the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected with the establishment's operation which are linked to major accident hazards inside the establishment;
   d. demonstrating that an internal emergency plan has been prepared in accordance with regulation 12, which includes sufficient information to enable an external emergency plan to be prepared; and
   e. providing sufficient information to the CA to enable decisions to be made regarding the location of new activities or developments around establishments.

The review of the safety reports are divided into the following sections:

- B.2 Summary of the onshore pipeline process safety report close out report;
- B.3 Summary of the Barmston Pumping facility (station) process safety report close out report; and
- B.4 Summary of the offshore pipeline process safety report close out report.

B.2 Summary of the Onshore Pipeline Process Safety Report

B.2.1 Scope

The scope of design is from the first high integrity isolation valve upstream of TP13 up to emergency shutdown valve 34-ESDV-003 at Barmston Pumping Station inlet receiver.

The report included:

- A list of all formal process safety assessment activities undertaken through the FEED study;
- A summary of key themes and significant risks identified through the formal process safety assessment process in FEED, drawing on the HAZID and HAZOP chairperson reports; and
- A discussion around those key themes which remain a significant risk.

B.2.2 Project Design Philosophies and Specifications

A number of project design philosophies, design basis documents and reports were developed to facilitate the onshore pipeline and AGI FEED and provide input into the safety design.

International codes, standards and industry guidance documents were referenced as appropriate. A summary list of key documentation is presented in Table B.1.

Table B.1: International Codes, Standards and Guidelines

Reference	Title/Description
PD 8010-1	British Standard Code of Practice for Pipelines – Steel Pipelines on Land
PD 8010-2	British Standard Code of Practice for Pipelines – Subsea Pipelines
DNV-RP-J202	Design and Operation of CO_2 Pipelines
CO2RISKMAN (JIP)	Guidance on CCS CO_2 Safety and Environment Major Accident Hazard Risk Management (Level 1 to 4)
EI 15	Area Classification Code for Installations Handling Flammable Fluids
API RP 521	Guide for Pressure-Relieving and Depressurising Systems
DNV TN B 306	Relief, Depressurising, Flare and Cold Vent Systems
HSE RR973	Review of Alarm Setting for Toxic Gas and Oxygen Detectors
EEMUA 191	Alarm Systems - A Guide to Design, Management and Procurement
BS EN 60079-29-3	Guidance on Functional Safety of Fixed Gas Detection Systems
ASME B31.3	Process Piping Design
EN 54/11	Fire Detection and Fire Alarm Systems Part 11: Manual Call Points
EN54/23	Fire Detection and Fire Alarm Systems Part 23: Fire Alarm Devices - Visual Alarm Devices
IEC 60331	Tests for Electric Cables Under Fire Conditions (Fire Resistant)
IEC 60332	Tests on Electric and Optical Fibre Cable Under Fire Conditions (Flame Retardant)
IEC 61508	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
IEC 61000	Electromagnetic Compatibility (EMC)

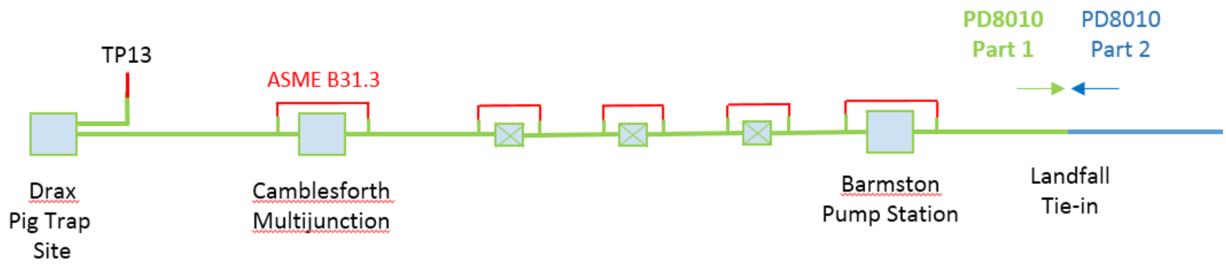
The pipeline design was in accordance with the requirements of the primary design code:

- PD 8010-1 (Code of Practice for Pipelines – Steel Pipelines on Land); and
- Supplementary NGCL requirements.

Within the requirements of PD 8010-1, dense phase CO_2 was classed as substance type E, defined as Flammable and/or toxic fluids that are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases and/or liquids.

The battery limits of PD 8010-1 are as shown in Figure B.1. ASME B31.3 design requirements are applicable to piping at the AGIs.

Figure B.1: PD 8010-1 Battery Limits



B.2.3 Pipeline Route

The routing of the onshore pipeline corridor is set by the parameters defined in the Development Consent Order. The onshore pipeline system and its associated AGIs are outlined in Table B.2 and illustrated in Figure B.2. The AGIs are designed for unmanned operation.

Figure B.2: Onshore Transport System

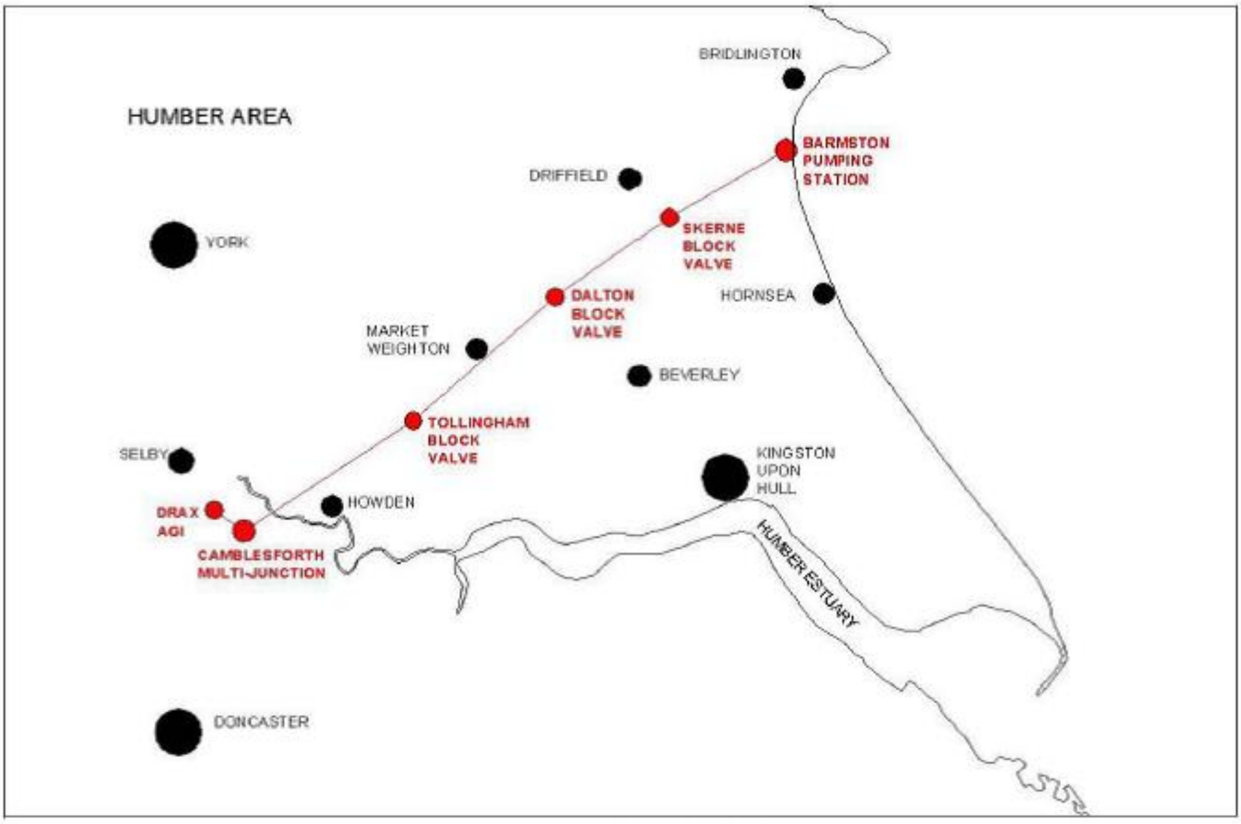


Table B.2: Pipeline Route

From	To	km	AGI Location
TP13	KP0 (Drax AGI)	0.267	Drax – 466726.01E, 428111.22N
KP0	KP5.681 (Camblesforth Inlet)	5.68	Camblesforth inlet tie in – 466972.22E, 425460.59N Camblesforth outlet tie in – 466968.64E, 425445.95N
KP5.696 (Camblesforth outlet)	KP25.506 (Tollingham Block Valve)	19.81	Tollingham – 482157E, 435623N
KP25.506	KP45.052 (Dalton Block Valve)	19.55	Dalton – 495144E, 447191N
KP45.052	KP59.457 (Skerne Block Valve)	14.41	Skerne – 505661E, 454650N
KP59.457	KP73.122 (Barmston inlet)	13.67	Barmston inlet – 516096.76E, 461061.14N

B.2.4 Third Party Population Centres along Route

Notable population centres and individual residences in relatively close proximity to the AGIs include the following:

- Drax AGI – The OPP is located south of the Drax AGI (Drax AGI is located inside the OPP security fence), Drax Abbey Farm lies 270 m north east, Foreman's Cottage lies 280m north;
- Camblesforth Multi-junction – Drax Village lies 775m north, Wade House Lane lies 17 m north west), residential property at Brock Holes (600m east);
- Tollingham Block Valve Station – Skiff Lane lies 520m north east, Skiff Farm lies 650m north, Holme Industrial Estate lies 60m east, residential property at Throlam (500m south);
- Dalton Block Valve Station – nearest house is 435m south, House Farm (890m north), Vicarage Farm (1km north east), Lund Wold Road (north), Holme Wold Road (south); and
- End of onshore Pipeline at Barmston inlet – Barmston Village (1.3km south), Fraisthorpe (750m north), Rose Cottage (625m).

The nearest pipeline approach to a relatively large residential population centre is at Market Weighton. However, the pipeline is also routed close to other sensitive locations including Read School near Drax Village, which has boarding facilities.

B.2.5 Process Description

Camblesforth Multi-junction is designed as a manifold station to allow tie-in of other emitters into the T&S system in the future. The FEED basis for development is as outlined in Table B.3.

Table B.3: Development of Transport System

	Year 1 (First Load)	Year 5	Year 10
Flow Case	Million Tonnes per Hour		
Design	2.68	10.0	17.0
Normal	2.31	10.0	17.0
Minimum	0.58	0.58	0.90

B.2.6 Process Conditions

Process conditions on the pipeline and associated AGIs are summarised in Table B.4.

Table B.4: Process Conditions

Parameter	Units	Max	Min	Normal
Pipeline				
Maximum Incidental Pressure (MIP)	barg	148.5	-	-
Design Pressure/Maximum Allowable Operating Pressure (MAOP)		135	-	-
Normal Operating Pressure			90	-
Design Temperature	C	25	0	-
Normal Operating Temperature		20	5	≤20
Buried Pipeline Temperature		15	4	-

Parameter	Units	Max	Min	Normal
AGIs				
AGI Design Pressure	barg	148.5	-	-
AGI Design Temperature	C	50	-46	-

B.2.7 Feed Gas Composition

NGCL's specification sets out the maximum allowable impurity levels including water, nitrogen, argon, oxygen and methane, the exceedance, of which adversely affects the phase boundary.

The anticipated first load (year 1) composition contains 99.7 vol% CO_2 and up to 10ppmv of oxygen and 50ppmv of water. The balance of the fluid composition comprises nitrogen and argon. Year 5 and 10 compositions may additionally contain trace amounts of hydrogen, carbon monoxide, NO_x, SO_x, H_2S and methane. The composition of the feed gas will be assured by the upstream OPP (and future emitters).

B.2.8 Pipeline

B.2.8.1 Selection of Materials

Selection of materials for use in the onshore transport system was based on the requirement to mitigate risk of material degradation and failure by ensuring that:

- They are fit for service for the design life (40 years) based on corrosion assessments for both the internal and external environments;
- They are fit for service at maximum and minimum design temperatures;
- The options minimise the requirements for inspection and maintenance as far as practicable; and
- The options maximise equipment availability, reliability and safety.

A material selection study was conducted, with the following results:

- Carbon steel grade L450/X65 is selected for the pipeline as there will be no free water in the system. Control of water content and impurities will be assured by the upstream OPP (and future emitters). The OPP production system includes a cold box which would freeze out any water and also provides product analysis to ensure the feed gas specification requirements are met thus mitigating the risk of contaminants adversely affecting the phase boundary;
- Monolithic isolation joints shall comprise Low Temperature Carbon Steel (LTCS) and HNBR 4007/glass reinforced epoxy tested under simulated operating conditions;
- LTCS with no corrosion allowance is specified for ground pipework, valves and PIG traps at the AGIs;
- Relief valves at the AGI PIG traps and associated vent piping shall be UNS S31600/S31603;
- Instrumentation and tubing shall be UNS S31603 austenitic stainless steel; and
- Selection of non-metallic soft seals shall be based on historical data and satisfactory performance testing under the exact composition range, impurities and operating conditions of dense phase CO_2 transported.

B.2.8.2 Corrosion Protection

The potential for internal corrosion caused by the presence of free water is mitigated using the measures described in the section above.

External corrosion protection on the pipeline is specified as follows:

- The pipeline will be coated with fusion bonded epoxy with an average thickness of 800µm; buried components on the pipeline will be coated with a modified high build epoxy coating containing glass fibre; and
- Cathodic protection will provide a secondary layer of protection. A permanent Impressed Current Cathodic Protection (ICCP) system is proposed due to anticipated seasonal variations in soil resistivity. A temporary sacrificial anode protection system will be used prior to installation and commissioning of the permanent ICCP system. The design life for the temporary sacrificial anode protection system will be three years.

B.2.8.3 Pipe Wall Thickness

The specification of pipeline wall thickness, shown in Table B.5 followed NGCL requirements. NGCL's development of the pipeline wall thickness specification was facilitated by QRA studies, the details of which are held by NGCL.

Since the wall thicknesses were pre-specified by NGCL, a population density based assessment to determine the wall thickness and design factor parameters was not conducted. The design factors shown Table B.5 are based on a back calculation from the specified wall thickness.

Table B.5: Wall Thickness and Design Factor

From	To	Diameter ("/mm)	Wall Thickness (mm)	Design Factor
TP13	KP0.267 (Drax AGI tie-in)	12in/323.9mm	17.05mm	0.3
KP0 (Drax AGI outlet)	KP0.380			
KP0.380	KP5.681 (Camblesforth Inlet)		11.9mm (normal routing)	0.43
KP0.134	KP0.182		17.05mm (crossing)	0.3
KP0.558	KP0.596			
KP0.945	KP0.985			
KP1.333	KP1.386			
KP1.609	KP1.739			
KP2.312	KP2.411			
KP2.520	KP2.544			
KP2.984	KP3.759		17.05mm (sensitive location proximity) Note 1	
KP3.935	KP3.963		17.05mm (crossing)	
KP4.378	KP4.396			
KP4.667	KP4.682			
KP5.282	KP5.463		17.05mm (sensitive location proximity) Note 2	
KP5.716 (Camblesforth outlet)	KP73.122 (Barmston inlet)	24in/610mm	19.1mm (normal routing and crossings)	0.504

Notes:
1) Includes the section of pipeline routed past Read School.

2) Includes the section of pipeline routed past Wade House Lane.

B.2.8.4 *Pipeline Crossing Techniques*

The selected pipeline crossing techniques are as follows:

- Horizontal Directional Drilling (HDD) – crossing at River Ouse and River Foulness;
- Micro tunnel – crossing at Driffield to Hutton Cranswick Railway, Howden to Wressle Railway, River Hull, Wansford;
- Long auger bore – crossing at Drax Services, Carr Lane, A645 (x2), A614 Holme Road, Disused Market Weighton Canal, A1079 Arras Hill (Market Weighton), Nafferton Highland Stream; and
- Auger bore and open cut – crossing at all remaining roads, ditches and service crossings.

An assessment of the crossing techniques has been made and the specified crossings detailed.

B.2.8.5 *Depth of Cover*

The full length of the pipeline will be buried to mitigate the risk of third party interference and to mitigate the potential for temperature variations (solar gain and chill). The exception to this will be the raised valve stems at the AGIs and at Barmston Pumping Station inlet.

The pipeline is buried with a minimum depth of cover of 1.2m. Some crossings types will have a greater depth of cover as specified in Table B.6. In addition, open cut crossings will be provided with concrete slab protection.

A detailed depiction of the depth of cover along the full onshore pipeline route is provided on the pipeline alignment sheets.

Table B.6: Depth of Cover at Crossings

Crossing Type	Minimum Cover (m)
Agricultural or Horticultural Activity Note 1	1.2
Ditch, Stream Note 2	1.7
Railways Note 3	3.0
Roads Note 4	2.15
Tracks	2.0
Major River Note 2	2.0
Residential, Industrial and Commercial Areas	1.2
Rocky Ground	1.2

Notes:
1) Cover shall not be less than the depth of normal cultivation.
2) To be measured from true clean bottom.
3) To be measured from the bottom of the rail and determined in conjunction with the rail authority.
4) To be measured from the road surface to the product pipe. (2.0m to the sleeve where used).

B.2.8.6 *Pipeline Markers*

Marker posts will be provided along the pipeline route to indicate the pipeline location and mitigate the risk of third party inadvertent interaction/impact. The marker post facilities are as follows:

- Aerial marker posts will be provided along the full pipeline route. The installation of aerial markers shall be such that they are visible from the air or ground; and
- Boundary marker posts will be provided to indicate crossings.

The locations of both aerial and boundary markers are detailed on the pipeline alignment sheets.

B.2.8.7 *Design and Operating Conditions*

PD 8010-1 specifies that the MAOP of the pipeline should not exceed the design pressure and that the MIP should not exceed the design pressure by more than 10%.

The operating margins on the pipeline are compliant with the PD 8010-1 requirements. The onshore pipeline design pressure (135barg) is equal to the MAOP and the MIP (148.5barg) does not exceed the design pressure by more than 10%.

B.2.8.8 *Pipeline PIG Operations*

Both the 12 inch pipeline between Drax and Camblesforth AGI inlet and the 24 inch pipeline between Camblesforth outlet and Barmston inlet will be provided with PIG launcher and receiver facilities to allow initial cleaning PIGs and subsequent intelligent PIGs to be run through the pipeline for inspection and monitoring.

The specified minimum bend radius is 3 times the Diameter (3D) to allow for PIG operations. Selected PIGs shall be suitable to run through spools and bends and past barred tees.

B.2.8.9 *Upstream Over Pressure Protection*

Overpressure protection and non-exceedance of pipeline MIP will be assured by CPL and future emitters.

B.2.9 Above Ground Installations (AGIs)

B.2.9.1 *Site Layout*

The AGI site plans for FEED were based on the requirements of the DCO which stipulates the maximum envelope within which the infrastructure could be designed.

The layout design within the parameter plan for each AGI was driven by:

- The preliminary layout from the DCO; and
- NGCL Specification for site location and layout for minimum separation distance between process handling areas and the site boundary to mitigate risk of third party exposure.

Each AGI is designed such that piping is predominantly buried, with only valve stems raised above ground.

At the Drax and Camblesforth Multi-junction AGIs, the launchers and receivers are oriented so that the trap doors open away from the local site infrastructure and piping. The Drax and Camblesforth AGI sites are also provided with internal site access roads which are routed up to the rear of the PIG launcher and receiver facilities thus allowing the loader vehicles ready access for PIG delivery and retrieval.

Each AGI site layout development was subject to formal review. An assessment of block valve site layout compliance against NGCL requirements was also conducted by NGCL's third party supplier.

B.2.9.2 Hazardous Area Classification

A hazardous area classification review was conducted for each AGI site. Hazardous areas are defined by the Model Code of Practice Part 15: Area Classification Code for Installations Handling Flammable Fluids (EI15).

All AGI sites are classed as non-hazardous.

B.2.9.3 AGI Site Detection and Alarm Systems

The AGI sites will be provided with fixed detection systems. A gas leak detection and control philosophy was developed to guide the fixed F&G detection system design during FEED. The scope of the philosophy included a description of the design approach, system interfaces and minimum functional requirements.

B.2.9.4 Detector Layout Design

The layout design of the detection systems was informed by a scenario based identification of potential hazards. The layout design process included:

- Review of CO_2 hazard characteristics; and
- Determination of required detector type, principle of operation and location.

As the AGIs are open layout minimum infrastructure sites, infra-red open path CO_2 detection was specified to facilitate detection of CO_2 gas migration. The open path detection is supplemented with acoustic leak detection. A smoke detector is provided in the instrument building at each site. Manual Alarm Callpoints (MACs) are also provided to supplement the fixed detection systems.

The layout design of the detection field devices and MACs is detailed on the CO_2 and fire detector layout drawings.

The minimum functional requirements of the detectors, including set points and requirements for calibration, are detailed in the gas leak detection and control philosophy and on the onshore F&G data sheets.

B.2.9.5 System Interfaces

Each AGI will be provided with a Local Detection and Alarm (LDA) panel located in the instrument building. The F&G system at each AGI will be part of the LDA panel and the general alarm system at each AGI will be initiated directly by the LDA panel.

Each AGI facility will be provided with a Remote Telemetry Unit (SSSV) located in the instrument building. The F&G and alarm status for each facility will be communicated to the NGCL control centre Supervisory Control and Data Acquisition (SCADA) by the Remote Telemetry Unit (RTU).

B.2.9.6 Alarm System

Each AGI site will have a general alarm system which will be initiated using the LDA panel interface with the F&G system.

Specified alarm system field devices include both sounders and beacons. Multiple sounders will be provided at each AGI site so that alarms are audible across the site. The minimum output of sounders will be 65dB(A), or at least 5dB(A) above the operating background noise level at each area. At process piping and equipment areas, the sounders are supplemented with visual beacons.

Once initiated, the alarms will not auto stop and reset. The alarms can only be stopped by manual intervention at the LDA panel or at the NGCL control centre.

The layout design of the alarm field devices is detailed on the CO_2 and fire detector layout drawings.

B.2.10 Control and Mitigation

B.2.10.1 AGI Facility Control

The AGIs will be normally unmanned and will operate using the RTUs. System status information from the RTU will be transmitted to the SCADA in the NGCL control centre on a polling basis. The RTU programme will be supported in FLASH memory with battery back-up, which will maintain system integrity in the event of power failure.

The RTUs will be capable of operating independently of the SCADA and in the event of a SCADA server failure the facilities will continue to operate normally.

The RTU at each AGI site will interface with the LDA panel at each site allowing communication with field devices such as detectors and alarms.

When manned, it will be possible to operate the AGI facilities locally.

B.2.10.2 Pipeline Shutdown System

The project shutdown level hierarchy is defined below:

- ESD Level 1: Total shutdown of the end to end CCS Chain (inclusive of the onshore transportation AGIs and offshore storage facility);
- ESD Level 2: Entire process shutdown of each individual installation (onshore transportation AGIs and offshore storage facility) and partial utility shutdown at the facility; and
- ESD Level 3: Process system shutdown within an installation (onshore transportation AGIs and offshore storage facility).

B.2.10.3 *Isolation and Sectionalisation of Pipeline*

The function of Tollingham, Dalton and Skerne Block Valve Stations is to enable high integrity isolation of the pipeline into discrete sections to allow manual depressurisation. The isolation valves will be 600mm (24in) type 2 power actuated (electro/hydraulic) valves (class 900#), initiated using the NGCL control centre SCADA. There will be a pressurisation bypass across each valve with pressure and temperature monitoring to permit safe restart. The valves are designed to fail in their last position. Sectionalisation of the pipeline upstream of Tollingham Block Valve Station (between Drax and Camblesforth) will also be possible using type 2 power actuated (electro/hydraulic) valves (class 900#) provided upstream of the Drax AGI and at Camblesforth Multi-junction.

It will be possible to initiate ESD level 1 (shutdown of full CCS chain including pipeline) using the remote shutdown facility in the NGCL control centre.

On confirmed gas detection, activation of ESD level 2 (shutdown of AGIs) will be possible using physical pushbuttons in the instrument buildings at Drax and Camblesforth AGIs.

When operating in unmanned mode, if there is a loss of communication between the NGCL control centre and the Drax or Camblesforth AGIs, a production shutdown will be initiated (after a period of 48 hours, configurable). Once shut down, a manual reset of the system will be required.

B.2.10.4 *Pressure Protection*

Thermal relief is required to provide mitigation against the overpressure conditions which may arise if thermal expansion from solar gain occurs during a blocked in scenario, for example shut down for maintenance.

The pipeline is buried and is therefore largely protected against atmospheric temperature variations. However, equipment above ground at the AGIs is provided with thermal relief valves. This includes the pipeline section upstream of the Drax AGI, the PIG launcher at Drax AGI and the PIG receiver and launcher at the Camblesforth AGI.

Discharge lines from the relief valves are routed vertically to atmosphere with the tip at 3m above ground level. The discharge lines are sized in order to maintain a high velocity to aid dispersion but within sonic velocity limits, so that the flow is not choked.

B.2.10.5 *Temporary Vent System*

Manual venting at the AGIs will be by temporary vent stacks. Temporary vent stacks are required for:
- PIG launcher/receiver maintenance depressurisation; and
- Pipeline depressurisation.

The specified pipeline depressurisation location requirements are as outlined in Table B.7.

Table B.7: Pipeline Depressurisation

Pipeline Section	Location of Temporary Stack Connection
Drax–Camblesforth	Drax Launcher/Camblesforth Receiver

Pipeline Section	Location of Temporary Stack Connection
Camblesforth–Tollingham	Tollingham (Camblesforth side)
Tollingham–Dalton	Tollingham (Dalton side)
Tollingham–Dalton	Dalton (Tollingham side)
Dalton–Skerne	Dalton (Skerne side)
Dalton–Skerne	Skerne (Dalton side)
Skerne–Barmston	Skerne (Barmston side)

A vent dispersion analysis was conducted by NGCL’s third party supplier using the Tollingham Block Valve Station temporary vent as representative.

B.2.10.6 *Fire Protection Requirements*

The AGI facilities will be unmanned. Ancillary equipment in the instrument building at each AGI will include:

- RTU;
- Switchgear and the Uninterruptible Power Supply (UPS) system; and
- Telecommunications systems.

Manual fire-fighting facilities in the form of fire extinguishers will be provided in each instrument building to allow personnel to extinguish small local fires whilst at their incipient stage.

B.2.11 AGI Emergency Response

B.2.11.1 *Escape Routes*

Each AGI site is provided with diverse designated escape routes at the above ground equipment areas. Escape routes are designed with a minimum clear width of 1000mm. Each AGI is also provided with a minimum of three diverse personnel escape gates leading offsite.

The arrangement of the escape route design is detailed on the escape routes and safety equipment layout drawings.

B.2.11.2 *Muster Area*

The muster point at each AGI site is located adjacent to the main gate exit to facilitate personnel (vehicle) evacuation from site, should this be required.

B.2.11.3 *Emergency Lighting*

External areas at each AGI site will be provided with pole mounted (2.3m) Light Emitting Diode (LED) luminaires which are battery backed for 90 minutes for emergency lighting use. Battery backed LED luminaires are also mounted above each personnel escape gate. The instrument building and the approach to the building at each site will be provided with 90 minute battery backed LED luminaires.

The battery backed luminaires will be wired with an inhibit contact to prevent discharge of batteries if power is lost when the facility is unmanned.

The emergency lighting arrangements are detailed on the lighting and small power layout drawings.

B.2.11.4 *Emergency Power*

Emergency lighting luminaires will be battery backed as described in the section above.

If there is a loss of main power, other critical systems including local detection and alarm and telecommunications will be supplied from single non-redundant AC UPS systems.

B.2.11.5 *Alarm Tones*

Separate alarm tones for fire (smoke) detection, CO_2 detection and evacuate facility will be provided through the general alarm system at each site.

B.2.11.6 *Emergency Communications*

The general alarm system will be the primary means of emergency communications to personnel. The locations of fixed field devices at each AGI (including sounders and beacons) will cover all working areas as detailed on the CO_2 and fire detector layout drawings.

Each AGI will also have an analogue telephone located in the instrument building.

B.2.11.7 *Safety Equipment*

Safety equipment will be provided in the instrument building at each AGI. Safety equipment will include spare escape sets, a stretcher, first aid kit and manual fire-fighting equipment.

B.2.12 Formal Safety Assessments

B.2.12.1 *Introduction*

This section describes only the safety assessments conducted during the FEED design.

B.2.12.2 *Pipeline HAZID Workshop*

A HAZID study workshop for the onshore transport system was conducted 15 October 2014. The workshop covered the full onshore transport system FEED scope including the pipeline and AGIs.

The workshop was conducted on a system/subsystem basis to ensure that all the hazards were adequately identified. The workshop procedure was aligned with the requirements of the NGCL HAZID specification, as follows:

- Identify hazards – guideword prompt;
- Identify failure mode/cause;
- Identify direct/indirect consequences;
- Identify safeguards in place;
- Assess mitigating effect of safeguards;
- If required, recommend additional safeguards/risk reduction measures;

- Where a requirement for additional safeguards is identified, determine if safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of FEED.

B.2.12.3 *Pipeline HAZOP Workshop*

A HAZOP workshop for the onshore transport system was conducted between 20-23 October 2014. The HAZOP workshop covered the full onshore transport system scope of design including the pipeline and AGIs.

The HAZOP study was initially performed on the basis that the transport system was in full operation, with input only from CPL and no input from future third parties.

The HAZOP workshop was conducted on a nodal level, with the pipeline and AGIs forming a single node. The HAZOP procedure was as follows:

- Define the design intent;
- Confirm operating conditions for example pressure, temperature;
- Confirm mode of operation for example normal, start-up;
- Identify credible deviations (using guideword prompts);
- Consider the existing safeguards against the impact of a credible deviation and whether the existing safeguards are adequate;
- Propose actions (recommendations) as appropriate;
- Determine if any additional safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of FEED.

B.2.12.4 *SIL Workshop*

A SIL workshop for the onshore transport system was conducted 24 October 2014. The scope of the SIL assessment included all instrumented control loops identified as having a potential protective function (Safety Instrumented Functions, SIFS). The SIFs requiring assessment were identified prior to the SIL workshop, based on a review of P&IDs, with confirmation during the pipeline HAZOP workshop.

The primary objective of the SIL workshop was SIL determination. Determination of a SIL provides a statistical representation of the required availability of the SIF to act on demand in order to achieve functional safety. This therefore enforces a requirement for implementation of a programme of routine maintenance and testing as required to maintain the SIL rating.

The basic approach was as follows:

- Identify SIF control loops within the project scope and record the tag and P&ID numbers – identified during the pipeline HAZOP;
- Determine the functionality of the loop and the potential safety hazards against which the loop is protecting;
- Identify possible causes for demand on the loop being evaluated;
- Evaluate the consequences if the loop fails on demand; at this point no credit shall be taken for other relevant independent risk reduction measures for example mechanical protective systems;

- Determine the SIL target for each function;
- Agree the environmental loss parameter (E) and use the environmental risk graph to determine the environmental integrity level required on environmental risk considerations;
- Agree the financial loss parameter (F) and use the asset risk graph to determine the Asset Integrity level required on financial loss risk considerations;
- Determine the overall SIL requirement (that is, the greater of the three SIL numbers from safety, environmental and financial impact is taken);
- Where independent risk reduction measures existed, for example PSVs, credit was taken for those measures and a reduction in the integrity level was applied; and
- Record the results and any associated assumptions or actions.

B.2.12.5 Onshore ENVID Workshop

An ENVID workshop for the onshore transport system was conducted on the 4th November 2014. The scope included the pipeline, with potential environmental impacts identified as being most likely to occur during construction and civil engineering works.

The workshop procedure was as follows:

- Pre-populate the assessment worksheets with available information on the activity, its aspect and associated environmental impacts related to the activity;
- During the workshop, complete the worksheets including information on all environmental aspects and impacts;
- Risk rank impacts (using a likelihood x severity score) into low, medium and high significance/risk score;
- Identify controls and actions; and
- Risk rank impacts with consideration of controls and mitigation.

B.2.12.6 Three Dimensional Model Review

A formal review of the onshore transport system three dimensional PDMS models was conducted 5 November 2014. The review included assessment of the AGI layout, maintenance and operability and venting requirements.

Additional HAZOP Workshop (Onshore Transport)

A second HAZOP workshop for the onshore transport system was conducted 27 January 2015. The objective was to review operation of the system in year ten, with import of CO_2 from other, as yet unspecified, emitters in addition to CPL and operation at the design capacity of the system.

It was agreed that the original worksheets could be used as a basis for the additional HAZOP review and that the worksheets could be revised and updated as necessary to take account of additional equipment and to reflect the increased throughput.

B.2.13 Venting Case Definition

B.2.13.1 Introduction

Local venting at the AGIs may be required during maintenance activities, for thermal relief, or as part of pipeline emergency depressurisation operations. One of the key design requirements for the local venting systems is that the discharge locations, heights and velocities allow adequate dilution of vent gases thus mitigating the residual risk of exposure to personnel and third parties.

B.2.13.2 Venting Cases and Modelling Input Data

Potential venting cases for the AGIs were identified and a dispersion modelling input data package was developed. The purpose of the modelling input data package was to facilitate venting dispersion studies which were to be conducted by NGCL/NGCL third party supplier.

The modelling input data package included:

- Four relief valves – at Drax PIG launcher, Camblesforth PIG receiver, Camblesforth PIG launcher and on the short above ground pipeline section upstream of the Drax AGI; and
- Nine temporary manual venting connections – with facilities provided at the Camblesforth PIG launcher (equipment blowdown) and at the locations listed in Table B.8.

The modelling input data associated with the relief valves was developed using the AspenTech HYSYS Dynamics Package, with fluid properties governed by GERG 2008 equation of state. A peak relief rate was developed for each relief valve. The valves are required primarily to provide relief against thermal expansion overpressure due to solar gain so the required orifice area is small. A standard relief valve orifice of an ASME 5 Crosby valve (with an area of 54.2mm²) was selected for all the thermal reliefs.

The modelling input data associated with pipeline depressurisation was developed as part of the flow assurance transient report using OLGA v7.3, with fluid properties governed by Multiflash 4.1 with GERG 2008 equation of state. The calculated data for the block valve station temporary venting systems included peak rates and orifice size at the vent stack tip as shown in Table B.8.

Table B.8: Pipeline Depressurisation at Block Valve Stations

Temporary Vent Location	Vent Tip Orifice Size (mm)	Peak Rate (kg/h)
Tollingham	25.4	226,000
Dalton	25.4	224,000
Skerne	25.4	219,000

B.2.14 Design Compliance with Emergency Regulations during Onshore Construction

B.2.14.1 Introduction

The subsections that follow describe the design compliance assessment of the emergency response facilities. General compliance requirements are drawn from the CDM Regulations 2015.

B.2.14.2 Detection and Alarm

Requirement – Detection and Alarm [CDM 2015 Regulation 32(1)] provide that here necessary in the interests of the health or safety of a person on a construction site, suitable and sufficient fire-fighting equipment and fire detection and alarm systems must be provided and located in suitable places.

Each AGI site is provided with a fixed local detection system and an alarm system.

Diverse detector types will be provided including for detection of gas leak, gas migration and smoke (instrument building). Primary emergency communication to personnel will be through the local alarm system. Audible alarms will be provided including separate alarm tones for fire (smoke) detection, CO_2 detection and evacuate facility. Audible alarms are supplemented by visual alarms at process piping areas. Personnel will have UHF hand portable radios. Communications with third parties will be facilitated by the analogue telephone located in each instrument building.

Each AGI is provided with a LDA panel. The F&G system at each AGI will be part of a LDA panel and the local alarm system will be initiated directly by the facility LDA panel.

No requirement for additional fixed systems is identified. However, it is recommended that personnel are equipped with personal CO_2 monitors.

B.2.14.3 Escape and Muster

Requirement – Escape and Muster [CDM 2015 Regulation 31(1, 3, 4 & 5)]

Each AGI site is provided with access roads, including for vehicular access into each site. Each AGI has diverse local primary escape routes leading from the process piping areas to the personnel escape gates and the muster area. Escape routes are designed with a minimum clear width of 1000mm.

The muster point is located adjacent to the main gate exit to facilitate emergency evacuation by vehicle. Each AGI site is also provided with three diverse personnel escape gates provided.

As far as reasonably practicable, each AGI is provided with diverse escape routes leading to the personnel escape gates or the muster area. It is recommended that an assessment of escape route and muster impairment risk tolerability is conducted during detailed design to facilitate escape and muster layout optimisation and escape set requirements.

B.2.14.4 Emergency Lighting

Requirement – Emergency Lighting [CDM 1015 Regulation 35(3) and 31(4)]

External areas including escape routes, approach to the instrument building and the personnel escape gates will be provided with pole mounted LED luminaires (2.3m). The luminaires are battery backed for 90 minutes. The instrument building is also provided with a 90 minute battery backed luminaire. The battery backed luminaires will be wired with an inhibit contact to prevent discharge of batteries if power is lost when the facility is unmanned.

No requirement for additional mitigation is identified.

B.2.14.5 *Personal Protective Equipment*

Requirement – Escape and Muster [CDM 2015 Regulation 30(2) d&e]

Safety equipment stored in the instrument building will include spare escape sets, a stretcher, a first aid kid and a fire extinguisher.

It is assumed in the first instance that personnel will carry an escape set on their person. Escape set requirements (including type, location and requirement for personnel to carry an escape set) must be determined at detailed design based on the results of escape and muster risk tolerability assessments and detailed escape time assessments.

B.2.15 Preliminary Escape Time Assessment

B.2.15.1 *Introduction*

The scope of the preliminary escape time assessment described below was based on escape from potentially manned areas to the muster area or the escape gates. This high level escape time assessment does not include for:

- The time to CO_2 gas detection/alarm;
- Time to stop, react and secure work area; and
- Time to don an escape set.

B.2.15.2 *Results*

Drax AGI

The estimated escape times associated with the Drax AGI are summarised in Table B.9 with a base case horizontal surface transit speed of 1m/s applied. The muster and escape gate locations are detailed on the escape route and safety equipment layout drawing. A transit speed of 1m/s may be considered to be conservative starting point as this order of transit speed typically represents vulnerable populations such as the very young or the elderly.

Table B.9 also shows the comparative escape times based on a reduced transit speed (40% reduction), to represent hindered movement due to injury or visual obscuration. This order of reduction in transit speed is typically applied when representing evacuation from smoke filled buildings and may be conservative for the external transit scenarios under consideration here.

In all cases, personnel are able to reach a safe area in less than 10 minutes.

Table B.9: Escape Time Drax AGI

	Escape Times – Transit speed 1m/s			
Start Location	**Muster Area**	**Emergency Exit 1**	**Emergency Exit 2**	**Emergency Exit 3**
Instrument Building	13	9	30	34
PIG Handling Area	34	34	11	42

Start Location	Escape Times – Transit speed 1m/s			
Start Location	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3
Cathodic Protection Kiosk	50	50	46	28
Start Location	Hindered Escape Time – Transit speed 0.6m/s			
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3
Instrument Building	22	15	50	57
PIG Handling Area	57	57	18	70
Cathodic Protection Kiosk	83	83	77	47

Camblesforth Multi-junction AGI

The estimated escape times associated with the Camblesforth Multi-junction AGI are summarised in Table B.10 The muster and escape gate locations are detailed on the escape route and safety equipment layout drawing. Both the base case escape time (transit speed 1m/s) and comparative hindered escape time (hindered transit 0.6m/s) are presented. In all cases, personnel are able to reach a safe area in under ten minutes.

Table B.10: Escape Time Camblesforth AGI

	Escape Times – Transit speed 1m/s			
Start Location	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3
Instrument Building	25	25	75	68
PIG Handling Area	61	61	47	64
Cathodic Protection Kiosk	76	76	83	8
Start Location	Hindered Escape Times – Transit speed 0.6m/s			
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3
Instrument Building	42	42	125	113
PIG Handling Area	102	102	78	107
Cathodic Protection Kiosk	127	127	138	13

Tollingham Block Valve Station

The estimated escape times associated with the Tollingham Block Valve Station are summarised in Table B.11. The muster and escape gate locations are detailed on the escape route and safety equipment layout drawing. Both the base case escape time (transit speed 1m/s) and comparative hindered escape time (hindered transit 0.6m/s) are presented. In all cases, personnel are able to reach a safe area in under ten minutes.

Table B.11: Escape Time Tollingham Block Valve Station

	Escape Times – Transit speed 1m/s				
Start Location	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3	Emergency Exit 4
Instrument Building	8	5	29	23	35
PIG Handling Area	40	38	20	23	9
Cathodic Protection Kiosk	46	44	8	37	28

Start Location	Escape Times – Transit speed 1m/s				
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3	Emergency Exit 4
Start Location	Hindered Escape Times – Transit speed 0.6m/s				
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3	Emergency Exit 4
Instrument Building	13	8	48	38	58
PIG Handling Area	67	63	33	38	15
Cathodic Protection Kiosk	77	73	13	62	47

Dalton Block Valve Station

The estimated escape times associated with the Dalton Block Valve Station are summarised in Table B.12. The muster and escape gate locations are detailed on the escape route and safety equipment layout drawing. Both the base case escape time (transit speed 1m/s) and comparative hindered escape time (hindered transit 0.6m/s) are presented. In all cases, personnel are able to reach a safe area in less than ten minutes.

Table B.12: Escape Time Dalton Block Valve Station

Start Location	Escape Times – Transit speed 1m/s				
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3	Emergency Exit 4
Instrument Building	9	7	37	19	27
PIG Handling Area	32	30	16	22	13
Cathodic Protection Kiosk	48	46	4	38	22
Start Location	Hindered Escape Times – Transit speed 0.6m/s				
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3	Emergency Exit 4
Instrument Building	15	12	62	32	45
PIG Handling Area	53	50	27	37	22
Cathodic Protection Kiosk	80	77	7	63	37

Skerne Block Valve Station

The estimated escape times associated with the Skerne Block Valve Station are summarised in Table B.13. The muster and escape gate locations are detailed on the escape route and safety equipment layout drawing. Both the base case escape time (transit speed 1m/s) and comparative hindered escape time (hindered transit 0.6m/s) are presented. In all cases, personnel are able to reach a safe area in less than 10 minutes.

Table B.13: Escape Time Skerne Block Valve Station

Start Location	Escape Times – Transit speed 1m/s				
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3	Emergency Exit 4
Instrument Building	14	12	34	25	21
PIG Handling Area	32	30	18	14	20
Cathodic Protection Kiosk	47	45	6	35	30
Start Location	**Hindered Escape Times – Transit speed 0.6m/s**				
	Muster Area	**Emergency Exit 1**	**Emergency Exit 2**	**Emergency Exit 3**	**Emergency Exit 4**
Instrument Building	23	20	57	42	35
PIG Handling Area	53	50	30	23	33
Cathodic Protection Kiosk	78	75	10	58	50

B.2.16 Supplementary Feed Assessments

B.2.16.1 Interface HAZID

A HAZID study covering the interface between the upstream OPP and NGCL Onshore Transport system was conducted by CPL and attended by representatives from NGCL.

B.2.16.2 Quantified Risk Assessments

NGCL requested a third party supplier to conduct an assessment for:

- Drax AGI and Camblesforth Multi-junction AGI;
- Tollingham, Dalton and Skerne Block Valve Stations; and
- onshore pipeline.

B.2.16.3 Barmston Pumping Station and Skerne Block Valve Station Layout Assessments

NGCL requested a third party supplier to review the FEED layout of the block valve stations and the pumping station.

B.2.16.4 Tollingham Block Valve Station Vent Dispersion Analysis

A vent dispersion analysis was conducted by NGCL's third party supplier using the Tollingham Block Valve Station temporary vent as a basis.

B.2.17 Summary of Significant Risks

B.2.17.1 Overview

This section provides a summary of the primary risks identified during the FEED project, for which further consideration during detailed design is required. Identification of risk was based on a structured formal workshop approach which included HAZID workshops, HAZOP workshops and technical reviews.

B.2.17.2 *Feed Gas Composition from CPL (and Future Emitters)*

The composition of feed gas into the Onshore Transport system will be assured by CPL and future emitters. The required feed gas specification is described in section B.2.7.

Analysis and metering facilities will be provided at the downstream Barmston Pumping Station; however, detection of off-specification gas at Barmston would mean that the onshore pipeline would already contain the off-specification gas.

Exceedance of the feed gas impurity thresholds may result in:

- Corrosion, if free water (>50ppmv) is allowed into the system; and
- Adverse impact on the phase boundary if trace levels of N_2, O_2 and H_2 are exceeded.

The OPP carbon capture production system includes a cold box which would freeze out any water and also provides product analysis to ensure the feed gas specification requirements. It is recommended that CPL (and future emitters) should be required to provide a continuous feed to NGCL of the product analyser and the upstream water analyser output.

B.2.17.3 *Overpressure Protection from Future Emitters*

The export rate into the onshore pipeline system will be assured by CPL and future emitters. Control of the export rate from future emitters will be critical in ensuring that the design pressure of the pipeline is not transgressed.

The pipeline basis of design given to all future emitters must require that suitable overpressure protection for the pipeline is provided.

B.2.17.4 *Temperature Control from CPL (and Future Emitters)*

The pipeline design temperature (25°C) is selected based on fracture toughness requirements. The operating temperature of the feed gas into the pipeline will be assured by CPL and future emitters.

Exceedance of the design temperature (for example due to failure of the after-cooler in the CPL export system) may require specification of thicker walled pipeline or higher toughness in order to arrest a propagating crack. Higher temperatures may also have an impact on crop yield, microbial activity and soil water content, which in turn may lead to increased cost due to compensation payments to land owners.

The pipeline basis of design given to CPL and future emitters must require provision of suitable temperature trips on their export systems.

B.2.17.5 *Phase Separation at High Point*

The high point on the pipeline route lies between Tollingham and Dalton Block Valve Stations (approximately 130m above Barmston Pumping Station elevation). Loss of pressure at the high point may result in phase separation and low temperatures which in turn may lead to brittle fracture and loss of containment.

A low pressure trip has been included on the common suction manifold to protect against phase separation in the pipeline. It will be configured to close Barmston Pumping Station boundary emergency shutdown valves 34-ESDV-003/4 on low pressure, with low-low suction pressure alarm set points as follows: 98barg year 1-5; 93barg year 5-10; 90barg year 10.

The flow assurance transient report has confirmed that the pipeline can be operated in the dense phase if the pressure is maintained above 90barg. However, under conditions of extended cool down to winter ambient temperature combined with a composition containing trace impurities, there is still potential for gas break out at the high point. The risk can be mitigated by maintaining sufficient CO_2 flow into the pipeline and packing the system such that the pressure at the high point remains above ~70barg (outside the phase envelope).

Further development of normal operating procedures is required during the project execution phase and the operating procedures must highlight the importance of maintaining pipeline pressure at the high point.

B.2.17.6 Selection of Polymeric Materials

The process of material selection during FEED is detailed in section B.2.8.1.

In addition, there is a requirement to ensure that suitable non-metallic polymeric material seals are used for all equipment components used in CO_2 service. Due to the solvent properties of CO_2 when in supercritical phase, commonly used polymers may absorb the CO_2 leading to swelling and changes in their physical properties.

Polymeric materials proposed for use in valves, flanges and isolation joint sealing should therefore be demonstrated (through testing) to be suitable for use in CO_2 service.

B.2.17.7 Minimum Temperatures on Depressurisation

The pipeline minimum design temperature is 0°C; however, colder temperatures are likely to occur during pipeline depressurisation. Additional Charpy testing is required to ensure the pipeline can maintain integrity at lower temperatures down to -20°C.

The AGIs are designed with a minimum design temperature of -46°C. However, flanges which are specified ≤6in with a 900# rating, or ≤4in with a 1500# will need to be impact tested to -55° C for suitability. Bolts will need to be impact tested to the lowest temperature for the material selected (-80° C).

B.2.17.8 Uncontrolled Venting

The manual venting rate will need to be carefully controlled to mitigate the risk of depressurisation cooling effects transgressing the minimum design temperature of the equipment and pipeline.

Operational procedures for the manual venting process are required to be developed. Development of physical limiters in the system should be considered during detailed design in preference to reliance on operator decision.

B.2.17.9 *Maintenance of Check Valves*

There are two check valves in the pipeline system, the first just downstream of TP13 and the second just downstream of the PIG receiver at Camblesforth.

The pipeline will not be able to receive CO_2 from CPL if maintenance of the first check valve is required, or from any future producers is maintenance of the second check valve is required. The use of ring type joint flanges means that the flanges cannot be sprung sufficiently to allow removal of the check valves. A large quantity of CO_2 will need to be vented.

The requirement for the check valves should be reviewed during detailed design. If the check valves are to remain in the system, then maintenance and venting procedures should be developed to ensure safe venting of the CO_2 inventory.

B.2.17.10 *Re-opening of Pipeline Sectioning Valves*

During a pipeline system restart, if the sectioning valve is opened before the bypass, there may be surge of flow which could result in mechanical damage to the valve or to equipment downstream such as the Barmston CO_2 fine filters if sectioning valve 34-HV-004 at Skerne is opened before the bypass.

Development of operating procedures during the execution phase of the project should ensure that the bypass is always opened before the sectioning valve.

B.2.17.11 *Communications Failure/Inability to Close Sectioning Valves*

A communications failure may result in loss of ability to monitor and control operational parameters and could also lead to inability to remotely close the pipeline sectioning valves.

A black-out plan is required to be developed during detailed design to specify what actions should be taken on loss of communications.

B.2.17.12 *Communication between CPL and NGCL Control*

Communications during Process Emergencies

There is a requirement for timely notification to CPL (and future emitters) if the onshore pipeline system is shut-in.

Development of communications procedures during the execution phase of the project should consider whether there should be interchange of information and/or executive action between CPL (and future emitters) and NGCL control and safety systems, particularly to safeguard against fast acting transients.

During system restart, there is a requirement to ensure that equipment and systems in the NGCL onshore transport system are ready to receive feed gas from CPL (and future emitters).

Development of operating procedures during the execution phase of the project should ensure that communications systems and data exchange between the NGCL control centre and CPL (and future emitters) are implemented.

B.2.17.13 Pipeline Loss of Containment

The pipeline is buried, with specified wall thickness as given in Table B.5 which provides mitigation against loss of containment due to third party external interference and impact. The pipeline also handles a dry fluid which mitigates the risk from internal corrosion.

A pre-FEED assessment of the pipeline risk is provided in the DCO and further risk assessments were conducted.

B.2.18 Actions List Status

All actions, including those required to mitigate the risks were transferred to the SAMS register.

The SAMS register provides a record of all actions logged from formal workshops, audits and reviews and includes background notes and references from the source documentation.

Use of the SAMS register ensured that:
- All design safety actions were recorded and notified to lead discipline engineers;
- All actions could be tracked;
- The method of resolving actions was recorded so that there was a clear and auditable trail;
- All action responses could be reviewed and reference documentation checked, before formal sign off by the engineering manager as part of the acceptance and closure procedure; and
- Any actions not closed at the end of FEED could be taken forward to detailed design.

B.2.19 Action List Status

The onshore pipeline and AGI action list status at the time of issue of this report is as follows:

- total raised (Genesis and NGCL) 74;
- total closed 18;
- total open with response under consideration 29;
- total open and ready for NGCL sign-off 0;
- total open with no response 20 (NGCL); and
- total open – transfer to EPC 7.

All open actions would be taken forward to detailed design to be managed to closeout.

B.2.20 Outstanding Safety Design Actions Areas

The significant risk areas identified during the FEED project are as outlined in section B.2.17.

A number of safety design areas have been identified as requiring more detailed review and technical safety assessment to aid design optimisation during detailed design. The identification of these safety design optimisation areas is based on:
- Review of outstanding actions which could not be closed out during FEED (section B.2.18); and
- Areas requiring technical safety assessments where those assessments were outside of the Genesis FEED scope of work.

The safety design areas requiring further assessment are discussed in the sections that follow.

B.2.20.1 *Layer of Protection Analysis*

The SIL determination workshop covering the onshore transport system was based on the risk graph approach (see section B.2.12.4).

One of the failure causes identified as having potential to lead to loss of containment on the onshore pipeline is a loss of control of the OPP carbon capture after-cooler or a failure of its chilled water system for an extended period of time leading to exceedance of the pipeline design temperature. There is a requirement to conduct a LOPA as this will allow for better representation of the mitigating factors that would prevent this sequence of events. The LOPA should be conducted during detailed design once NGCL have set a TMEL.

B.2.20.2 *Detector Layout Design Optimisation*

As far as reasonably practicable, the layout design of the detectors at the AGIs followed the requirements of the gas leak detection and control philosophy.

However, as dispersion modelling data was unavailable at the time of development of the detector layout drawings, there remains a requirement to assess and optimise the layout design. This assessment at detailed design should include:

- Development of the major accident dispersion scope for AGIs;
- Assessment of the detector layout design to ensure the proposed design provides adequate coverage at the specified set-points; and
- Adapt assessment results into the layout design.

B.2.20.3 *Escape and Muster Assessment*

As far as reasonably practicable, the design of the escape and muster facilities at the AGIs followed the requirements of theCDM Regulations 2015 and the design safety philosophy. A general compliance assessment was conducted and is outlined in section B.2.14.

B.2.20.4 *Determination of Residual Risk and Demonstration of ALARP*

As far as reasonably practicable, the results of formal safety assessments (in particular the qualitative formal workshops) have been adapted into the FEED design.

An assessment of risk including determination of residual risk to personnel at the AGIs and third parties along the pipeline route and demonstration that the residual risk is ALARP was undertaken.

B.3 Summary of Barmston Pumping Station Process Safety Report

B.3.1 Scope

The scope of design is from emergency shutdown valve 34-ESDV-003 at the Barmston PIG receiver up to emergency shutdown valve 34-ESDV-004 at the Barmston PIG launcher.

The report included:

- A list of all formal process safety assessment activities undertaken through the FEED study;
- A summary of key themes and significant risks identified through the formal process safety assessment process in FEED, drawing on the HAZID and HAZOP chairperson reports; and
- A discussion around those key themes which remain a significant risk.

B.3.1.1 Overview

The primary objectives of the report were to:

- Demonstrate the project's commitment to full compliance with UK legislative requirements for safety in design, NGCL specifications, project philosophies and normative and informative codes and standards;
- Demonstrate that as far as reasonably practicable, measures have been implemented in Barmston Pumping Station FEED to prevent, detect and alarm and control and mitigate the risk of and from, process loss of containment; and
- Demonstrate that escape and muster facilities have been implemented in design to ensure personnel safety during emergencies.

B.3.1.2 Exclusions

Risk management during the Genesis FEED was implemented primarily through:

- The framework set by the NGCL specifications;
- Implementation of good engineering design practice; and
- A partial HEMP implemented through formal workshops (such as the HAZOP, HAZID, SIL) and the SAMS register.

B.3.2 Project Design Philosophies and Specifications

The project FEED intent was that the design will comply with the highest UK regulatory, NGCL and industry standards for design safety. Safety design requirements were applied in the following hierarchy:

- UK legal requirements (laws, edicts, regional or local regulations, etc.);
- Company specifications;
- Data sheets/drawings (where applied);
- Project design philosophies;
- Primary project specifications;
- Contractor specifications and standards approved by the company; and
- International codes and standards.

A summary of the key legislation, philosophies and specifications and normative and informative codes and standards utilised during FEED is outlined below. These and other, documents are referenced where appropriate in subsequent sections of this report.

B.3.2.1 UK Legal Requirements

The governing safety legislation in the development and implementation of safety principles in Barmston Pumping Station FEED is the HASAWA 1974.

The project is also notifiable under the CDM Regulations 2015.

The COMAH Regulations 1999 (and new COMAH 2015) are not applicable to Barmston Pumping Station site; however the COMAH framework has been referenced in the application of a structured hierarchy in development of preventive, control and mitigation measures in the design.

A number of project design philosophies, design basis documents and reports were developed to facilitate Barmston Pumping Station FEED and input into the safety design.

International codes, standards and industry guidance documents were referenced as appropriate. A summary list of key safety documentation is presented in Table B.14.

Table B.14: International Codes, Standards and Guidelines

Reference	Title/ Description
EI 15	Model code of safe practice Part 15: Area Classification Code for Installations Handling Flammable Fluids
API RP 521	Guide for Pressure-Relieving and Depressurising Systems
DNV TN B 306	Relief, Depressurising, Flare and Cold Vent Systems
HSE RR973	Review of Alarm Setting for Toxic Gas and Oxygen Detectors
EEMUA 191	Alarm Systems - A Guide to Design, Management and Procurement
BS EN 60079-29-3	Guidance on Functional Safety of Fixed Gas Detection Systems
EN 54/11	Fire Detection and Fire Alarm Systems Part 11: Manual Call Points
EN54/23	Fire Detection and Fire Alarm Systems Part 23: Fire Alarm Devices - Visual Alarm Devices
IEC 60331	Tests for Electric Cables Under Fire Conditions (Fire Resistant)
IEC 60332	Tests on Electric and Optical Fibre Cable Under Fire Conditions (Flame Retardant)
IEC 61508	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
IEC 61511	Safety Instrumented Systems for the Process Sector
IEC 61000	Electromagnetic Compatibility (EMC)
CO2RISKMAN (JIP)	Guidance on CCS CO_2 Safety and Environment Major Accident Hazard Risk Management (Level 1 to 4)

B.3.3 Description of Site and Operations

B.3.3.1 Location

Barmston Pumping Station will be located approximately at 515905E, 460941N. The location is set by the parameters defined in the DCO.

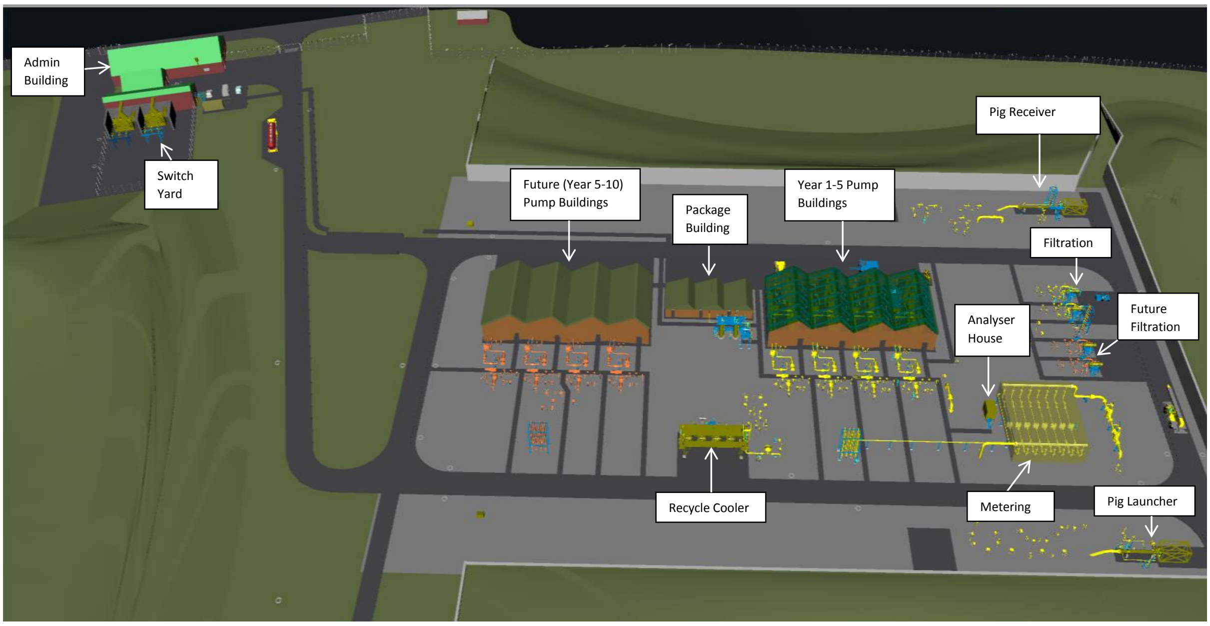
It will be approximately 500 m landward of the landfall location. Notable residential population centres near the site include Barmston Village (approximately 1.3km south) and Fraisthorpe Village (approximately 750m north). The nearest identified residential location is Rose Cottage which is located approximately

625 m from the site. There are also public footpaths which run parallel to the facility at a distance of less than 625m.

B.3.3.2 Site Layout and Topography

The area that surrounds Barmston Pumping Station comprises relatively flat agricultural land. The Barmston Pumping Station itself will be bordered on all sides by landscape mounds (5m height), as part of the DCO requirement to minimise visual impact of process equipment and above ground piping.

Figure B.3: Overview of the Site Layout



B.3.3.3 Meteorological Conditions

The key meteorological conditions at the site are as follows:

- Wind conditions – prevailing wind direction is from plant west-southwest (based on wind data taken from Leconfield Station 2009-2014);
- Humidity – average annual humidity is approximately 81%;
- Ambient temperature – design maximum 28°C, design minimum -7ºC; and
- Seismicity – low seismic activity.

B.3.4 Process and Utility Description

The Barmston Pumping Station, which normally will operate as an unmanned facility, will boost the pressure of the CO_2 to ensure deliverability into the reservoir. The requirement to boost the pressure will come when the aquifer pressure increases due to continual injection, hence additional head will be needed from the Barmston pumps over that provided by the GPU pump at the OPP.

CO_2 from the OPP arrives through the 24in pipeline. Emergency shutdown valve 34-ESDV-003 is provided at the inlet facilities to allow isolation of the facility from the pipeline in the event of an emergency. The reception facilities include a 24in PIG receiver to allow use of pipeline Intelligent Inspection Devices (IID) for monitoring and inspection of the onshore pipeline.

CO_2 is routed from the inlet facilities to the fine filters to remove particles in the CO_2, thus protecting the downstream pumps and reservoir. The filters are configured with adequate provision for future tie-in to accommodate full design flow of 17 million tonnes per hour. The configuration ensures at least one filter is always available as a spare. Each filter has adequate isolation and manual venting provision for maintenance and the isolation valves are configured to permit remote switching of the filters.

The filtered CO_2 is routed to the pump suction manifold. Electric motor driven, variable speed, centrifugal pumps have been selected in a suitable configuration to accommodate first load, including expected minimum flow, with the provision to tie-in future pumps to accommodate full design flow. The pumps have a variable speed drive to allow for turndown during the various operating scenarios during the life of the transportation network. ESDVs are provided at pump suction and discharge to allow isolation of each pump in the event of an emergency. The pumps are tested/proved in full recycle. A recycle cooler will ensure acceptable temperatures during full recycle. Pump proving and testing is only expected at the first start (i.e. during commissioning) and post maintenance work on the pump. The recycle line is not required for normal pump starting/stopping. The cooler is an air cooler sized for full flow from one pump only (as it is envisaged that only one pump is tested/proved at a time).

It will be possible to 'free flow' the CO_2 from the OPP to the normally unmanned offshore platform during the early years of operation when the pressure in the reservoir is sufficiently low. This will be achieved via a bypass around the pumps. The bypass will also allow continued transportation to the offshore platform in the event of a shutdown or failure of Barmston Pumping Station. When the bypass is in operation, the CO_2 will still need to be filtered and metered to meet the requirements of the offshore facilities and the flow rate will need to be measured for monitoring purposes. The bypass will be provided with a non-return valve to prevent recirculation of the CO_2 stream when the CO_2 booster pumps are operating.

The discharge CO_2 from the pumps and the bypass (when in use) is fiscally metered through a number of meter runs prior to export offshore. The number of meter runs has been selected to accommodate the range of flow rates expected over the design life, the turndown requirements and availability requirements. The meters are orifice type. The metering package will include appropriate instrumentation for compositional analysis of the exported fluids.

The export facilities include a 24in PIG launcher to allow intelligent PIG operations of the offshore pipeline.

B.3.5 Process Conditions

Process conditions at Barmston Pumping Station are detailed in the onshore transport design basis and summarised in Table B.15.

Table B.15: Barmston Pumping Station Inlet and Outlet Conditions

Parameter	Units	Max	Min	Normal
Inlet Conditions				

Parameter	Units	Max	Min	Normal
Design Pressure	barg	148.5	-	-
Normal Operating Pressure	barg	135	90	-
Design Temperatures	°C	50	-46	-
Normal Operating Temperatures	°C	18	4.5	15
Outlet Conditions				
Design Pressure	barg	281.5	-	-
Normal Operating Pressure	barg	182	159	-
Design Temperatures	°C	50	-46	
Normal Operating Temperatures	°C	45	4.5	30

B.3.6 Feed Gas Composition

Refer to section B.2.7.

B.3.7 Utility Summary

Utility systems at Barmston Pumping Station will include:

- Vent systems with permanent vent stacks;
- Air compressor and dryer package supplying air at a dew point of -40º C for all pneumatic valve actuation (control valves, ESDVs); the package will also supply the plant air system;
- Water system – potable usage; and
- Single circuit 66kV power, which is connected by underground cable, to be provided by Northern Powergrid. Essential power will be provided by the UPS systems for critical instrument and telecommunications loads.

B.3.7.1 Equipment, Piping and Component Design

The FEED process design intent was that all equipment, piping and components should be suitable for service with appropriate design margins on capacity, temperature and pressure included to ensure safe operation. Design and operating conditions are as described in the onshore transport process description and summarised in Table B.16.

Table B.16: Equipment Design and Operating Conditions

Equipment Item	Design Conditions: Pressure (barg)	Design Conditions: Temperature Min/ Max (°C)	Operating Conditions: Pressure (barg)	Operating Conditions: Temperature (°C)
PIG Receiver	148.5	-46/50	90 – 135 Note 2	4.5 – 15
Inlet Filters	148.5	-46/50	90 – 135 Note 2	4.5 – 15
CO_2 Booster Pumps	281.5	-46/50	90.1 (suction) / 178.2 (discharge)	4.5 – 15
CO_2 Booster Pumps Recycle Cooler	281.5	-46/50	Up to 178.2	4.5 – 45 Note 3
PIG Launcher	281.5 Note 1	-46/50	Up to 182	4.5 – 45 Note 3

Notes:

1 PIG Launcher is rated to 2500#. A HIPPS system, located downstream of the pumps, is employed to protect the offshore pipeline from overpressure in the event of a blocked discharge.

2 Operating pressure is the normal export pressure of the upstream OPP less pipeline losses and is dependent upon CO_2 flowrate within the transport system. Minimum operating pressure is set throughout the transportation system to ensure a margin above the critical point so that the CO_2 remains in the dense phase.

3 Pump maximum operating temperature during proving/testing operation when pump is operating in recycle.

A number of specifications were developed detailing the minimum requirements for equipment, piping and components in CO_2 service.

B.3.7.2 Protection of Process and Utility Systems

Process and utility systems are provided with two levels of instrumented protection:

- The first level comprises process control loops, comprising control transmitters connected to a Process Control System (PCS) which act on an end element (for example a control valve) to ensure system process parameters are maintained within normal and hence safe, operating ranges; and
- The second level is a separate safety system with transmitters connected to an ESD System (see section B.3.13.3)

B.3.8 Prevention

B.3.8.1 Site Layout

The site parameter plan for FEED was determined by the requirements of the DCO, which stipulated the maximum envelope within which the buildings and infrastructure could be designed.

The layout design within the parameter plan was driven by:

- The preliminary layout from the DCO; and
- The requirements of the NGCL specification.

The specification defines the requirements for:

- Separation distances between process handling equipment/areas – to mitigate escalation risk;
- Separation distances between process handling areas and occupied buildings – to mitigate risk of process hazards at non-hazardous areas; and

- Separation distances between process handling areas and the site boundary – to mitigate risk to third parties.

Note: The NGCL specification defines occupied buildings as, "Buildings that do not contain hazardous process equipment and are occupied for a significant period of time, for example office. This is defined as a person being present for at least 2 hours in a 24 hour period each day of the working week".

The site layout development was subject to formal review. An assessment of the site layout compliance against the requirements of NGCL was conducted by NGCL's third party supplier.

B.3.8.2 Hazardous Area Classification

Hazardous area classification was developed for Barmston Pumping Station. Hazardous areas are defined by the Model Code of Practice Part 15: Area Classification Code for Installations Handling Flammable Fluids (EI15) as:

"*three dimensional spaces in which a flammable atmosphere may be expected to be present at such frequencies as to require special precautions for the design and construction of equipment and control of other potential ignition sources*"

Identification of hazardous area zone classifications at Barmston Pumping Station followed the definitions in standard EI15 as follows:

- Zone 0 – that part of a hazardous area in which flammable atmosphere is continuously present or present for long periods;
- Zone 1 – that part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation;
- Zone 2 – that part of a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short period; and
- Non-hazardous Area – areas that do not fall into any of the above.

Barmston Pumping Station will not routinely handle or store flammable process fluids. The Zone 0 and Zone 1 classifications are therefore not applicable. Most areas onsite are non-hazardous. The exceptions to this are the pump buildings and the package building which are designated Zone 2.

B.3.8.3 Ignition Prevention

Electrical equipment in Zone 2 hazardous areas shall be selected in accordance with IEC 60079 Electrical Apparatus for Explosive Gas Atmospheres and, unless specified otherwise, shall be suitable for use in gas group IIB with a temperature class of T3.

Motors installed in the Zone 2 hazardous areas shall be:

- LV Motors: Ex de/Ex nA; and
- MV Motors: Ex de.

In addition, all inherently non-sparking equipment such as junction boxes, terminal boxes and other electrical and instrument equipment shall be Ex e (as a minimum). However, all inherently sparking equipment shall be Ex d or Ex de (as required for Zone 1 areas).

Electrical apparatus for use in Zone 2 hazardous areas shall be compliant with the requirements of the ATEX Directive.

Non-classified (standard) items of electrical equipment (switchgear, distribution boards, AC UPS and DC systems, motor starters, voltage regulation, power factor correction and batteries) and VSDs will be located within non-hazardous areas.

The compliance requirements are detailed fully in the onshore electrical design specification.

B.3.8.4 Safety Integrity Levels

A formal SIL workshop was conducted to determine the required SIL of SIFs in the onshore transport system including Barmston Pumping Station.

Determination of a SIL provides a statistical representation of the required availability of the SIF to act on demand in order to achieve functional safety. This therefore enforces a requirement for implementation of a programme of routine maintenance and testing as required to maintain the SIL rating.

The most stringent SIL rating (SIL 3) relates to the HIPPS package which is located at Barmston Pumping Station but is provided to protect the offshore pipeline from the booster pumps pressure. Instrumented functions in the booster pump control system have a SIL 2 rating. The SIL assessment results are detailed in the onshore SIL workshop report.

B.3.9 Material Selection

Selection of materials for use in process and utility systems was based on the requirement to mitigate risk of material degradation and failure by ensuring that:

- Selected materials are fit for service for the design life (40 years) based on corrosion assessments for both the internal and external environments;
- Selected materials are fit for service at maximum and minimum design temperatures;
- Selected materials minimise the requirements for inspection and maintenance as far as practicable; and
- Selected materials maximise equipment availability, reliability and safety.

A material selection study was conducted, with materials selected as follows:

- Low Temperature Carbon Steel (LTCS) with no corrosion allowance has been specified for ground pipework, valves, PIG traps, filters and metering equipment. This is on the basis that maintenance venting will be controlled to limit the minimum temperature to -46°C;
- Flanges will be LTCS. Flanges which are specified ≤6in with a 900# rating, or ≤4in with a 1500# will need to be impact tested to -55°C for suitability. All bolts will need to be impact tested to the lowest temperature for the material selected (-80º C). The flange material selection was facilitated by CFD analysis;
- Relief valves, thermal stand-off pipes and vent piping shall be UNS S31600/S31603;
- Instrumentation and tubing shall be UNS S31603 austenitic stainless steel; and

- Selection of non-metallic soft seals shall be based on historical data and satisfactory performance testing under the exact composition range, impurities and operating conditions of dense phase CO_2 transported.

B.3.10 Corrosion Protection

The likelihood of internal corrosion caused by the presence of free water is minimal. Internal corrosion allowance for systems in CO_2 service is not specified.

External corrosion protection on equipment and piping in CO_2 service will be as follows:
- Equipment and piping above ground will be painted or coated in accordance with NGCL specification; and
- Equipment components and piping below ground will be painted or coated and will have Impressed Current Cathodic Protection (ICCP) as a secondary system of protection.

B.3.11 Detection and Alarm System

B.3.11.1 Development of Detection Philosophy

A gas leak detection and control philosophy document was developed to guide the F&G detection system design. The scope of the philosophy included a description of the CO_2 detection system design approach, system interfaces and minimum functional requirements.

The CO_2 detection system design requirements from the gas leak detection and control philosophy were supplemented by those from the design safety philosophy which covered requirements for fire detection.

B.3.11.2 Detector Layout Design

The layout design of the detection systems was informed by a scenario based identification of potential hazards. The layout design process included:
- Identification of CO_2 process hazard areas (internal and external) and non-process fire and utility hazard areas;
- Determination of the hazard characteristics; and
- Determination of required detector type, principle of operation and location.

The final detection design was as follows:
- Infrared open path CO_2 gas detection in external areas where there is potential for gas migration;
- Infra-red point CO_2 detectors in areas where is potential for gas accumulation such as the pump buildings and at HVAC inlets of potential welfare buildings including the administration building;
- Acoustic leak detection to supplement CO_2 infrared point and open path detection;
- Oil mist detectors in the pump buildings;
- Hydrogen detector in the battery rooms (administration building and electrical switch room);
- Smoke detectors inside buildings; and
- MACs to supplement the fixed detection systems.

The layout design of the detection system field devices and MACs is detailed on the CO_2 and fire detector layout drawings.

The minimum functional requirements of the detectors, including set points and requirements for calibration, are detailed in the gas leak detection and control philosophy and on the onshore F&G data sheet.

B.3.11.3 System Control and Interfaces

The F&G detection system at the Barmston Pumping Station forms a part of the facility Integrated Control and Safety System (ICSS).

The F&G detection system will interface with the Public Address and General Alarm (PAGA) system for automatic initiation of site alarms. No other automatic executive actions on confirmed fire or gas detection are specified.

B.3.12 PAGA System

The Barmston Pumping Station will have a dedicated PAGA system. Site alarms will be automatically initiated via the PAGA system interface with the F&G detection system.

Sounders will be provided and sited such that they are audible across all areas of the facility including all buildings. The minimum output of sounders will be 65dB(A), or at least 5dB(A) above the operating background noise level at each area. Sounders will be supplemented with visual beacons in areas of high noise (such as the pump buildings). Once initiated, the alarms will not auto stop and reset. The alarms will only be stopped by manual intervention at the local HMI or at the NGCL control centre.

The layout design of the alarm field devices is shown on the CO_2 and fire detector layout drawings.

B.3.13 Control and Mitigation

B.3.13.1 Integrated Control and Safety System (ICSS)

The Barmston Pumping Station will be provided with a local ICSS for monitoring and control of the facility. The ICSS will interface with the SCADA system at NGCL control centre. The ICSS will comprise the Process Control System (PCS) the ESD system and the F&G system.

The ICSS will be configured to operate in manned or unmanned mode. When in unmanned mode, the facility will be remotely operated and controlled, with executive actions initiated by the operator in the NGCL control centre. When manned, it shall be possible to manage the facility locally.

B.3.13.2 Process Control System

The PCS will be accessible through the HMIs in the local control room and at the NGCL control centre. The PCS facility will include the ability to:

- Adjust controller set points and to set in manual or auto control;
- Monitor and control utilities;
- Monitor and control the status of all sequence and shutdown valves;
- Start/stop and sequence electrical drives and perform duty/standby changeover;
- Monitor the power distribution system, UPS and storage batteries;

- Accept and reset (process system) alarms;
- Monitor the status of the ESD system and effect manual shutdown;
- Monitor the status of the F&G sensors;
- Monitor and control the HVAC system;
- Display diagnostic functions from field devices;
- Interface with third party controllers to provide a common operator interface; and
- Switch control between remote NGCL control centre and local control at the facility and provide data hand off of information related to the facilities.

B.3.13.3 Emergency Shutdown System

The project emergency shutdown hierarchy is defined below:

- ESD Level 1: Total shutdown of the end to end CCS chain (inclusive of the onshore transportation AGIs and offshore storage facility);
- ESD Level 2: Entire process shutdown of each individual installation (onshore transportation AGIs and offshore storage facility) and partial utility shutdown at the facility; and
- ESD Level 3: Process system shutdown within an installation (onshore transportation AGIs and offshore storage facility).

B.3.13.4 Barmston ESD System

The Barmston Pumping Station is provided with a stand-alone ESD system.

ESD Level 1 will be initiated under the following conditions:

- Manually via a physical pushbutton in the Barmston Pumping Station local control room on confirmed fire detection; and
- From the NGCL control centre is there is a loss of communication with the onshore transport system (6 hour configurable time delay).

Initiation of ESD Level 1 will result in:

- Closure of the Barmston Pumping Station system battery limit emergency shutdown valves 34-ESDV-003/4;
- Closure of pump suction, discharge and recycle emergency shutdown valves and stopping of pumps;
- Shutdown of utilities. UPS shall remain available to power the control and safety systems; and
- Notification to the OPP (and future emitters).

On ESD Level 1, the CO_2 inventory will remain within the isolated sections. The set point of the booster pumps suction pressure controller will be set to ensure CO_2 remains in the dense phase or liquid only region of its phase envelope under shutdown conditions.

ESD Level 2 will be initiated manually via pushbutton in the Barmston Pumping Station local control room, or from the NGCL control centre on confirmed gas detection. ESD Level 2 will also be initiated automatically if there is an upset in critical utility systems such as instrument air. ESD Level 2 will result in process and partial utility shutdown.

ESD Level 3 will be initiated automatically if there is a process system upset (system trip). It will also be possible to manually initiate ESD Level 3 by local pushbutton, for example at the pump buildings. Initiation of ESD Level 3 will:

- Isolate the inlet and outlet streams to a unit;
- Stop any heat input; and
- Stop all related electrical and rotating process equipment.

B.3.13.5 *Remote Shutdown Facility*

A separate remote shutdown for the Barmston Pumping Station will be provided at the NGCL Control centre. Remote shutdown will be via a manually activated push button. The remote shutdown will not be part of the local ESD system at Barmston but is instead provided as a single shutdown initiator to safely and rapidly shutdown equipment and isolation valves in the correct sequence during an emergency event.

B.3.13.6 *Functionality of ESD Valves*

ESDVs shall be used for inventory isolation only. ESDVs will not be used as control valves.

ESDVs in CO_2 service shall be metal seated with maximum acceptable leakage rates to be confirmed during detailed design. All other ESDVs shall be tight shut-off.

Pneumatic actuators are specified. Actuation will be possible at the maximum pressure drop across the valve.

All ESDVs will ‘fail closed’ in the event of a fault, loss of instrument air or loss of control signal.

B.3.13.7 *Pressure Protection*

Thermal relief is required to provide mitigation against the overpressure conditions which may arise if thermal expansion from solar gain occurs during a blocked in scenario, for example shut down for maintenance.

All major equipment items are provided with relief valves including the PIG receiver, PIG launcher, filters, pumps and the HIPPS packages.

Discharge lines from relief valves are routed vertically to atmosphere, with the tip at 3m above ground level. The discharge lines are sized in order to maintain a high velocity to aid dispersion but within sonic velocity limits so that the flow is not choked.

B.3.13.8 *Manual Vent System*

The Barmston Pumping Station is provided with vent systems to allow manual depressurisation of equipment.

Permanent vent stacks are provided in five site areas. The five areas and equipment routed to each are as follows:

- PIG Receiver (plant north-east);

- CO_2 fine filters and future CO_2 fine filters (plant east);
- CO_2 booster pumps, recycle cooler and CO_2 metering and analysis package, pipeline depressurising line (year 1-5 vent stack);
- Future CO_2 booster pumps (year 5-10 vent stack); and
- Barmston PIG launcher (plant south-east).

The pipeline depressurising line is sized to depressurise the offshore pipeline section from the CO_2 booster pump discharge ESDVs up to 34-ESDV-005 (riser ESDV offshore), though the line may also be used to depressurise the onshore pipeline section from the Skerne Block Valve Station up to emergency shutdown valve 34-ESDV-004 (the onshore/offshore isolation ESDV).

B.3.14 Fire Protection Systems

B.3.14.1 Active Fire Protection Systems

Barmston Pumping Station will be provided with manual fire-fighting systems in the form of fire extinguishers to enable personnel to extinguish small local fires whilst at their incipient stage. The specified fire-fighting facilities are detailed on the escape routes and safety equipment layout drawings.

The fire hazard assessment identified no credible major accident process fire incidents and thus no requirement for a water-based centralised active fire protection system is foreseen.

B.3.14.2 Passive Fire Protection Systems

The internal partitions between the pump buildings have a specified A60 rating to achieve 60 minute protection against cellulosic fire types.

Internal fire protection requirements for the administration Building, including temperature regulation and maintenance of a smoke barrier, will need to be developed as part of the Building Regulations application during detailed design.

B.3.15 Emergency Response

B.3.15.1 Escape Routes

The Barmston Pumping Station is provided with access roads which run along the perimeter of the process area allowing ready escape from all main plant areas and vehicular access for third party emergency crews.

Diverse local primary escape routes are also provided at plant south of the pump houses and at the cooler area, leading onto the access roads. Local primary escape routes are designed with a minimum clear width of 1000mm, whilst secondary escape routes have a minimum clear width of 800mm. Escape routes inside buildings are provided with a minimum clear height of 2100mm.

A wind sock is provided and located at plant north-east. Installation of the wind sock should be at an elevation which ensures that the wind sock is visible to personnel from all escape routes within the plant.

Enclosed areas and buildings which may be manned during maintenance visits are provided with two diverse exits. This includes the pump rooms and VSD rooms, switch house, workshop, local electrical room and local control room and welfare areas.

The arrangement of the escape route design is detailed on the escape routes and safety equipment layout drawings and on the building fire plans.

B.3.15.2 Muster Area

The muster point is located adjacent to the main gate exit to facilitate personnel evacuation from site, should this be required. Three diverse emergency escape gates are also provided.

The location of the muster area and the escape gates is detailed on the escape routes and safety equipment layout drawings.

B.3.15.3 Emergency Lighting

External areas, including access roads, escape routes, approach to buildings and escape gates will be provided with pole mounted LED luminaires (2.3m), which are battery backed for 90 minutes.

Buildings, including the pump buildings, package building and switch room, will be provided with fluorescent luminaires mounted at 2.7m and exit signs, all of which will be battery backed (90 minutes).

The battery backed luminaires will be wired with an inhibit contact to prevent discharge of batteries if power is lost when the facility is unmanned.

B.3.15.4 Emergency Power

Emergency lighting luminaires will be battery backed.

UPS will be provided to ensure power to safety critical systems is not disrupted if there is a loss of main power. UPS systems will include:
- Single non-redundant AC UPS systems with a minimum eight hour supply for safety critical systems including the F&G system, telecommunications system and ICSS; and
- Dual redundant DC UPS systems with a minimum eight hour supply for switchgear tripping and electrical protection equipment in the substation.

B.3.15.5 Alarm Tones

Separate alarm tones for fire detection, CO_2 detection and evacuate facility will be provided via the PAGA system.

B.3.15.6 Emergency Communications

The PAGA system will be the primary means of emergency communications to personnel, including alarm tones and voice over communications if required. Initiation of the PAGA system will be automatic through interface with the F&G system.

The locations of field devices (including sounders and beacons) will cover all working areas as shown on the CO_2 and fire detector layout drawings.

Personnel in the plant will also be able to communicate with each other via UHF hand-held portable radios. Communications with third parties will be facilitated by analogue landline and VOIP telephones.

B.3.15.7 *Safety Equipment*

Safety equipment will be provided in the administration Building as this is expected to be the coordination centre during emergencies. Safety equipment will include a stretcher, first aid kit, electrical safety kit, spare escape sets and manual fire-fighting equipment.

Personnel attending the process areas for routine maintenance may be required to carry escape sets on their person. Development of the detailed requirements for escape sets including type, confirmation of capacity and requirement to carry are outside the FEED scope of design. These requirements will need to be confirmed during detailed design.

B.3.16 Formal Safety Assessments

B.3.16.1 *Introduction*

This section describes only the safety assessments conducted by Genesis during FEED.

Supplementary safety assessments were conducted by NGCL/NGCL's third party supplier during FEED.

B.3.16.2 *Formal Pumping Station HAZID Workshop*

A HAZID workshop for the Onshore Transport system was conducted on the 15th October 2014. The HAZID workshop covered the full Onshore Transport system scope of design, including the Barmston Pumping Station. A terms of reference document was developed and issued before commencement of the workshop to ensure all participants had a common understanding of the workshop format, methodology and means of reporting.

The workshop was facilitated by an independent chairperson and was attended by engineers from both NGCL and Genesis. The workshop was conducted on a system/subsystem basis to ensure that all the hazards were adequately identified. The workshop procedure was aligned with the requirements of the NGCL Specification and was as follows:

- Identify hazards – guideword prompt;
- Identify failure mode/cause;
- Identify direct/indirect consequences;
- Identify safeguards in place;
- Assess mitigating effect of safeguards;
- If required, recommend additional safeguards/risk reduction measures;
- Where a requirement for additional safeguards is identified, determine if safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of FEED.

The workshop proceedings were recorded on HAZID worksheets, which were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the Barmston Pumping Station HAZID Report.

B.3.16.3 *Formal Pumping Station HAZOP Workshop*

A HAZOP workshop for the onshore transport system was conducted between 20-23 October 2014. The HAZOP workshop covered the full Onshore Transport system scope of design, including the Barmston Pumping Station. A terms of reference document was developed and issued before commencement of the workshop.

To ensure continuity in understanding of the system, the HAZOP workshop was facilitated by the same independent chairperson who facilitated the HAZID study. The HAZOP workshop was attended by engineers from both NGCL and Genesis. The workshop procedure was aligned with the requirements of the NGCL Specification.

The HAZOP study was initially performed on the basis that the transport system was in full operation, with input only from CPL and no input from future third parties. Although the transport system is designed to free-flow initially, when the reservoir pressure is sufficiently low to allow this, it was assumed that the first phase booster pumps would be in operation. Free-flow operation and later operation with additional pumps and fine filters in operation were then reviewed after the base case review.

The HAZOP workshop was conducted on a nodal level, with the Barmston Pumping Station assessed as a single node. The HAZOP procedure was as follows:

- Define the design intent;
- Confirm operating conditions for example pressure, temperature;
- Confirm mode of operation for example normal, start-up;
- Identify credible deviations (using guideword prompts);
- Consider the existing safeguards against the impact of a credible deviation and whether the existing safeguards are adequate;
- Propose actions (recommendations) as appropriate;
- Determine if any additional safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of FEED.

The workshop proceedings were recorded on HAZOP worksheets. The worksheets were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the Barmston Pumping Station HAZOP Report.

B.3.16.4 *SIL Workshop*

A SIL workshop for the Barmston Pumping Station was conducted on the 24th October 2014. The scope of the SIL assessment included all instrumented control loops identified as having a potential protective function (Safety Instrumented Functions, SIFS). The SIFs requiring assessment were identified prior to the SIL workshop, based on a review of P&IDs, with confirmation during the Barmston Pumping Station HAZOP workshop. The objective of the SIL workshop was SIL target determination. A terms of reference document was developed and issued before commencement of the workshop.

To ensure continuity in understanding of the system, the SIL workshop was facilitated by the same independent chairperson who facilitated the HAZOP study and the HAZID study. The SIL workshop was attended by engineers from both NGCL and Genesis.

The SIL workshop procedure was based on a semi-quantified Risk Graph approach, which follows the standard IEC 61511. The Risk Graph approach uses a number of parameters, which together describe the nature of the hazardous situation which could arise when SIFs fail or are not available. These parameters allow a graded assessment of the risks to be made and represent key risk assessment factors.

The basic approach was as follows:

- Identify SIF control loops within the project scope and record the tag and P&ID numbers – identified during HAZOP;
- Determine the functionality of the loop and the potential safety hazards against which the loop is protecting;
- Identify possible causes for demand on the loop being evaluated;
- Evaluate the consequences if the loop fails on demand. At this point no credit was taken for other relevant independent risk reduction measures for example mechanical protective systems
- Determine the SIL target for each function;
- Agree the environmental loss parameter (E) and use the environmental risk graph to determine the Environmental Integrity Level required on environmental risk considerations;
- Agree the financial loss parameter (F) and use the asset risk graph to determine the Asset Integrity level required on financial loss risk considerations;
- Determine the overall SIL requirement (i.e. the greater of the three integrity level numbers from Safety, Environmental and Financial Impact is taken);
- Where independent risk reduction measures existed, for example PSVs, credit was then taken for those measures and a reduction in the integrity level was applied; and
- Record the results and any associated assumptions or actions.

The SIL workshop proceedings were recorded on SIL worksheets. The worksheets were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the SIL workshop report.

B.3.16.5 ENVID Workshop

An ENVID workshop for the onshore transport system was conducted on the 4th November 2014. The scope of the ENVID workshop included the Barmston Pumping Station. The assessment of Barmston Pumping Station included process design, civils design, pumps and associated equipment.

The ENVID workshop was facilitated by an independent chairperson and was attended by engineers from both NGCL and Genesis. A terms of reference document was developed and issued before commencement of the workshop.

The workshop procedure was as follows:

- Pre-populate the assessment worksheets with available information on the activity, its aspect and associated environmental impacts related to the activity;
- During the workshop, complete the worksheets including information on all environmental impacts;

- Risk rank impacts (using a likelihood x severity score) into low, medium and high significance/risk score;
- Identify controls and actions; and
- Risk rank impacts with consideration of controls and mitigation.

The workshop proceedings were recorded on ENVID worksheets, which were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the onshore ENVID Report.

B.3.16.6 *Three Dimensional Model Review*

A formal review of the Barmston Pumping Station layout was conducted on 5th November 2014. The review of Barmston Pumping Station layout included assessment of access and escape; maintenance and operability; foundations; utilities; mechanical handling, review against P&IDs and venting.

The layout review meeting was attended by representatives from both Genesis and NGCL. A terms of reference document was developed and issued prior to commencement of the meeting.

The following safety actions relating to the Barmston Pumping Station were minute:

- Access platforms (where required) should incorporate fixed stairs rather than ladders;
- A wind sock should be provided;
- Review building safety in relation to fire risk due to building materials and equipment within the pump buildings;
- Review arrangement of bunds and requirement for ventilation analysis; and
- The FEED layout design is now frozen.

Escape route layouts drawings were developed, including internal and external escape route diagrams.

A ventilation analysis of Barmston Pumping Station has been conducted.

B.3.16.7 *Additional HAZOP Workshop (Onshore Transport)*

A second HAZOP workshop for the onshore transport system was conducted 27 January 2015 (additional HAZOP workshop). The objective of the second HAZOP workshop was to review operation of the system in year 10, with import of $CO_2$from other, as yet unspecified, emitters in addition to CPL and operation at the design capacity of the system. The scope of the additional HAZOP workshop included the additional fine filters and booster pumps at the Barmston Pumping Station.

To ensure continuity in the formal safety assessment workshops, the additional HAZOP workshop was facilitated by the same independent chairperson as the original HAZOP workshop, the HAZID workshop and the SIL workshop. The additional HAZOP workshop was attended by engineers from both NGCL and Genesis. The assessment methodology was consistent with that described in section 4.4. A terms of reference document was developed and issued prior to commencement of the meeting.

It was agreed that the original worksheets could be used as a basis for the additional HAZOP review and that the worksheets could be revised and updated as necessary to take account of additional equipment and to reflect the increased throughput.

The workshop proceedings were recorded on HAZOP worksheets. The worksheets were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the additional HAZOP workshop report.

Three new actions relating to the Barmston Pumping Station were raised and transferred to the SAMS register.

B.3.17 Fire Hazard Assessment

B.3.17.1 Introduction

A fire hazard assessment was conducted to identify credible fire scenarios at Barmston Pumping Station. The primary process comprises non-flammable fluid and no large inventories of flammable materials are intended to be stored onsite. The focus of the fire hazard assessment was therefore on smaller non-process fires which may occur in enclosed areas. Such fire events would not typically be classed as major accident events, however the fire hazard assessment was required to inform decision making on fire-fighting requirements.

B.3.17.2 Pump Buildings

Each pump building will have separately compartmentalised pump rooms, with each pump room also containing a VSD room. The mechanical seals on the pumps will each have a high pressure mineral oil accumulator. There will be two centralised top up systems inside the package building (one future), with high pressure mineral oil lines (~180barg) running between the centralised top up skid and each of the pumps. Each pump will also have a lube oil system built into the pump skids (approximately 5barg system pressure).

Mineral oil is a high flash point fluid (typically ~150°C) which, in liquid form (and without considerable heating), does not constitute a credible fire hazard. However, a pinhole leak in a high pressure line may form a fine spray/mist which, if ignited, may constitute a local flash fire hazard.

An assessment of the potential for mist formation was conducted, based on the fluid characterisation and algorithms proposed by Bowen and Shirvill (1994). The droplet atomisation assessment shows that there is credible potential for formation of a flammable mist, based on the discharge conditions considered.

To mitigate risk of ignition, each pump room has been classed as a Zone 2 hazardous area. The pump room enclosure, equipment and instrumentation shall be required to meet the requirements of the Zone 2 classification. The pump room is provided with an HVAC system. Specification of the forced ventilation system ensures that if a flammable mist does develop, there is minimal potential for the mist to ‘persist’. The operational rate of the HVAC system will be required to meet the requirements of the Zone 2 classification (uniform exchange rate of 12ach) or the requirement for heat dissipation, depending on which is the more onerous.

Each pump room is provided with two diverse exits to mitigate the risk of personnel becoming trapped in the unlikely event of a fire incident.

The VSD rooms are designated non-hazardous but are provided with mechanical ventilation which provides room pressurisation relative to the pump room. The HVAC system is described in the Barmston HVAC system specification. There may be potential for small fires to occur inside the VSD rooms, however each VSD room is provided with two diverse exits to mitigate the risk of personnel becoming trapped.

B.3.17.3 Package Building

The package building will comprise three separate rooms containing the air supply system, the mineral oil top-up skid and the future mineral oil top-up skid. The rooms housing the mineral oil top-up skids will be designated Zone 2 hazardous areas on a similar basis to the pump houses. The package building HVAC system shall meet the requirements of the Zone 2 classification or the requirement for heat dissipation, depending on which is the more onerous.

Each room in the package building is provided with two diverse exits to mitigate the risk of personnel becoming trapped in the unlikely event of a fire incident.

B.3.17.4 Analyser House

There may be potential for small electrical fires to occur in the analyser house. However, when personnel are on site, local fires should be readily extinguished whilst at their incipient stage. The future (year 10) composition may contain trace amounts of hydrogen which may necessitate use of hydrogen in the future carrier gas. However, the anticipated composition is only ~2% by volume of hydrogen and as such the future carrier gas will also only contain a trace amount of hydrogen.

B.3.17.5 Switch Room

The switch room will house electrical equipment including 6.6kV and 0.42kV switchboards, LV 6.6/0.42 kV transformers, UPS and battery banks in an adjoining room.

The LV 6.6/0.42kV transformer will use a fire safe cast resin insulation medium. There may be potential for small electrical fires to occur. However, whilst the site is manned, these local fires should be readily extinguished whilst at their incipient stage. The Switch House will have two diverse exits (plant north and west) to mitigate potential for personnel to become trapped.

B.3.17.6 Switch Yard

The switch yard will house the HV 66/6.6kV transformer and 66kV disconnector units.

The HV 66/6.6kV will use a synthetic ester MIDEL 7131 as the insulating medium. In the unlikely event of a major fault inside the transformer, there may be vaporisation of the insulating medium. A spring loaded pressure relief device with a vent pipe fitted on the outlet will deflect any gas and liquid to ground level and this will be contained in the stone fill of the transformer bund. An electrical arcing fault inside of the transformer tank will be quenched by the remaining insulating medium. Potential for flames to be ejected via the pressure relief device is minimal.

B.3.17.7 Temporary Generator

A temporary mobile generator may be required in the event of sustained grid shutdown or on loss of the HV 66/6.6kV transformer. Diesel will not be bunkered onsite. Instead, the generator will come with a diesel bowser.

Diesel is a high flash point fluid (~100°C) so in the event of a local spill, ignition is unlikely. The location of the temporary diesel generator will be external thus, in the unlikely event of a fire, personnel should be able to readily escape the area.

B.3.17.8 Workshop

The workshop may be used to store small quantities of hazardous substances such as paint. At this stage of the project, details of storage requirements are unavailable, however the development of storage requirements during detailed design should include classification of all chemical inventories to be stored (regardless of quantity) and provision of a COSHH cabinet in accordance with The Control of Substances Hazardous to Health Regulations 2002.

Potential for fires will remain low provided that good housekeeping procedures are enforced to ensure that the inventory of combustible materials is kept to a reasonable minimum. Depending on materials stored, small fires may produce irritant gases. The workshop is provided with two diverse escape exits (at plant north leading into the main administration Building and at plant east leading outside), thus minimising potential for personnel to become trapped and suffer long term exposure.

There may also be potential for small electrical fires in the electrical and instruments workshop and the HVAC room which adjoin the workshop. The exits from these rooms lead into the workshop.

B.3.17.9 Local Electrical Room and Local Control Room

There may be potential for small electrical fires in the local electrical room or the local control room. However, whilst the site is manned, these local fires should be readily extinguished whilst at their incipient stage. Both the local electrical room and the local control room are provided with two diverse exits, minimising potential for personnel to become trapped.

B.3.17.10 Battery Room and UPS Room

There may be potential for small electrical fires to occur in the battery room or the adjoining UPS room. However, whilst the site is manned, local fires should be readily extinguished whilst at their incipient stage. The battery room is provided with two exits, whilst the UPS room is provided with one.

The battery room is provided with hydrogen detection. The detector set points will be such that there is an alarm and stop charge sequence at a level that is well below the lower flammable limit of hydrogen.

B.3.17.11 Admin Building – Welfare Area

The administration building is provided with welfare rooms including office, meeting room, library and kitchen/mess areas.

Small local fires in this area are most likely to occur when the area is manned and such fires should be readily extinguished whilst at their incipient stage. Exits from all welfare rooms lead onto a central corridor which has building exits at plant west and east.

B.3.17.12 Active Fire Protection Requirements

No requirement for a water-based centralised active fire protection system is identified as there are no credible major accident process fire events. Since the Barmston Pumping Station is an industrial site, it is expected that the Operator will have in place suitable emergency response arrangements which enable the local fire-fighting authority to attend the site in the event of a fire incident. Access roads which run along the perimeter of the plant area will ensure that fire engines and fire tenders have access to all site areas. Attendance of local fire-fighting authorities to an industrial facility would typically involve multiple fire tenders so water from the pond is unlikely to be required.

Potential for local fires has been identified in some enclosed areas. Manual fire-fighting facilities in the form of portable or wheeled fire extinguishers are provided in these areas (as specified on the escape route and safety equipment layout drawings. These manual fire-fighting facilities are intended for use in fighting small local fires only.

B.3.17.13 Passive Fire Protection Requirements

The internal partitions between the pump buildings have a specified A60 rating to achieve 60 minutes protection against cellulosic fire types.

Internal fire protection requirements for the administration Building, including temperature regulation and maintenance of a smoke barrier, should be developed as part of the Building Regulations application during detailed design. As a minimum, it is recommended that internal fire doors should have a 30 minute fire rating with smoke seals and consideration should be given to specification of A60 rated partitions to protect the welfare areas from cellulosic fire types.

B.3.18 CFD Ventilation Analyses

B.3.18.1 Introduction

Due to the complex local topography of the Barmston Pumping Station; and in particular the arrangement of the landscape mounds, a three dimensional Computational Fluid Dynamics (CFD) model of the site was developed. Integral or Gaussian models cannot capture the effects of complex terrain and obstacles on local air flow patterns and so development of the CFD model was necessary. The general purpose software ANSYS CFX (version 15) was used for the analysis.

The primary objectives of the ventilation analysis were to:

- Assess the effects of the site topography on local airflow patterns inside the landscape mounds; and
- Identify stagnant areas and the conditions under which they develop, as these areas may in turn adversely affect local dispersion behaviour during venting operations or under major accident event conditions.

B.3.18.2 Methodology

The CFD model was based on the three dimensional PDMS model dated 15/01/2015, engineering drawings. One subsequent update to the initial CFD model was made to reflect design changes to the following vent stack arrangements:

- Venting of Barmston PIG launcher – changed to a local vent with tip height 3m; and
- Venting of offshore pipeline – permanent stack added at year 1 to 5 array.

The final CFD model explicitly represented all large geometrical details that have the potential to affect local airflow patterns and therefore dispersion behaviour. This included all buildings/shelters, equipment items, above ground large bore piping, primary structural supports, security fence, retaining wall and local topography. Smaller items (such as small bore pipework, stairs, ladders), were judged not to significantly influence local airflow and were therefore not included.

B.3.18.3 Wind Data

An analysis of wind rose data from the Leconfield Station (November 2009 to October 2014, was conducted. A wind speed probability distribution was derived, with average omni-directional values as follows:

- 90% annual exceedance wind speed – 1.2m/s;
- 50% annual exceedance wind speed – 3.9m/s; and
- 10% annual exceedance wind speed – 7.9m/s.

The probability of wind speeds exceeding 10m/s was found to be very low (occurring approximately 1% of the time). The predominant wind directions is from plant west-southwest (occurring approximately 55% of the time).

A total of 12 wind directions were simulated in the ventilation analysis (0 to 330°). 10%, 50% and 90% exceedance wind speeds were simulated in each of the 12 wind directions.

B.3.18.4 Assessment Criteria

The assessment of ventilation adequacy within the site was based primarily on the Model Code of Practice Part 15: Area Classification Code for Installations Handling Flammable Fluids which defines ventilation as being adequate if a uniform rate of 12 air changes per hour (ach) is achieved with no stagnant areas.

Stagnant areas were defined as areas with flow velocities lower than 0.5m/s.

B.3.18.5 Results

In general, large low-velocity recirculation zones were observed in the wakes of large structures such as the landscape mounds and the pump buildings. The extent of the stagnant zones was particularly significant when the wind direction was from plant north or south and less so when the wind direction was from plant west. When the wind direction is from plant north, the vertical extent of the recirculation zone in the wake of the pump buildings may extend up to approximately 7-9m. Above this recirculation zone elevation, the wind flow will be relatively undisturbed.

The conclusions of the Ventilation Analysis were as follows:

- The local geometry of the Barmston Pumping Station (buildings and retaining walls) induces large stagnant areas with recirculation of air for all wind directions that could lead to larger gas accumulations under those ambient conditions;
- This effect could be more pronounced for smaller (or buried) releases which have a lower initial jet momentum;
- The worst case scenarios in terms of volume of stagnant regions were observed for winds coming from the plant north, east and south;
- Winds coming from the plant west were found to give slightly better natural ventilation; and
- The stagnant regions can vertically extend to an elevation of up to around 7m to 9m, which is similar to the elevation of the vent stack tips. This could hamper gas dispersion from controlled venting, especially for winds coming from the platform north.

The potential effects of stagnant areas on local dispersion were studied as part of the dispersion analysis.

B.3.19 CFD Dispersion Analyses

B.3.19.1 Introduction

The CFD model and ventilation analysis provided the basis for dispersion modelling studies including:

- Major accident dispersion modelling; and
- Venting dispersion modelling.

The dispersion assessments are described in the sections that follow.

B.3.19.2 Validation of CFD Dispersion Model - Major Accident Leak Model Validation

The CO2PIPETRANS Joint Industry Project (JIP) has made available datasets from field scale CO_2 release and dispersion experiments conducted at the Spadeadam Test Site. The datasets are freely available for public download the intention being that modellers can benchmark their dense phase CO_2 predictions against the experimental data.

A CFD dispersion model validation study was conducted, using two test cases from the CO2PIPETRANS JIP field scale experiments (Test 11 and Test 3). Both tests consisted of steady-state horizontal discharges onto an open test pad with a well-defined mass flow rate of liquid CO_2.

CFD simulations were conducted using similar initial discharge and ambient conditions as for the test cases. For the purposes of the CFD modelling, with the primary interest being in mid to far field dispersion, the initial discharge conditions from the test cases were recalculated into an equivalent vapour source located a short distance downstream of the discharge location. Calculation of an equivalent vapour source allowed a reduction in computational time because phase changes and behaviours in the near field including high-speed compressibility effects, expansion and liquid flashing, solid particle formation and sublimation are not modelled.

The equivalent vapour source was modelled as a cylindrical momentum source with known exit velocity, vapour mass flow rate, initial air entrainment, mixture temperature and initial turbulence parameters.

The conclusions of the CFD dispersion model validation study were as follows:
- There is reasonable alignment between the CFD dispersion model predictions and the CO2PIPETRANS JIP test cases including the downwind concentration profiles and plume widths over the dispersion range of interest; and
- The level of accuracy of the CFD dispersion model is reasonable when modelling unconfined horizontal jet releases of dense phase CO_2.

The CFD accidental leak dispersion model was therefore suitable for use in the major accident dispersion study.

B.3.19.3 Manual Venting Model Validation

Field scale experiments for vertical vent releases and horizontal releases from shock tube of dense phase CO_2 were commissioned by National Grid as part of the COOLTRANS research program. The COOLTRANS tests were conducted at the Spadeadam Test Site.

A CFD dispersion model validation study was conducted, using test case data from two of the COOLTRANS field scale experiments (Test 7 and Test 11). Both COOLTRANS test cases involved vertical vents.

The CFD simulations used similar initial discharge and ambient conditions as the test cases, with application of an equivalent vapour source.

The conclusions of the CFD dispersion model validation study were as follows:
- There is reasonable alignment between the CFD dispersion model predictions and the COOLTRANS test cases in terms of both vertical penetration of the plume and ground level concentrations; and
- The level of accuracy of the CFD dispersion model is reasonable when modelling vertical vent releases.

The CFD venting dispersion model was therefore suitable for use in the venting dispersion study. Note: An independent analysis of the Genesis CFD venting dispersion model was conducted by NGCL's third party supplier (section B.2.13.2).

B.3.20 Major Accident Dispersion Analysis

B.3.20.1 Failure Case Definition

There was a requirement to develop discharge data for use in the major accident dispersion modelling study.

A desktop study was conducted to identify the major accident hazards/accident events that require *quantified* assessment, including both process and non-process hazards. The desktop study included a data review of the following:
- Barmston Pumping Station HAZID and HAZOP reports;
- Process flow diagram;
- P&IDs;
- Onshore transport process description and utility summary; and

- Heat and material balance.

The results of the desktop study are presented in Table B.17.

Table B.17: Desktop Review

Hazard	Potential Causes	Potential Consequences	Requires Quantified Assessment?
Barmston Process and Utility Hazards			
Process releases – external above ground	Large piping or equipment failure, Valve, flange and small bore piping connection failure, Material/fabrication defect, External Impact, Exposure/brittle fracture (for example release at adjacent inventory)	Near field cryogenic/abrasive jet Equipment damage (brittle fracture)/escalation Toxic/asphyxiating gas Personnel injury/fatality Third party injury/fatality	Yes
Process releases – inside pump buildings	Large piping or equipment failure, Valve, flange and small bore piping connection failure, Material/fabrication defect	Cryogenic/abrasive jet Toxic/asphyxiating gas accumulation Personnel injury/fatality	Yes
Process releases – buried piping	Material/fabrication defect, Ground movement	Near field impinged jet Toxic/asphyxiating gas Personnel injury/fatality	Yes
Utility hazards	Valves, flanges and piping connection failure, Material/fabrication defect, Impact	Personnel injury/impact (for example compressed air) Electrocution	No – Potential for injury/fatality should be accounted for via occupational risk Fatal Accident Rate (FAR).
Impact from Upstream and Downstream Pipeline			
Process releases – buried pipeline (within site)	Material/fabrication defect Ground movement	Near field impinged jet Toxic/asphyxiating gas Personnel injury/fatality Third party injury/fatality	Yes – pipeline sections immediately upstream and downstream of the Barmston process are routed partially within site. Releases from these sections may be a significant contributor to Barmston personnel risk.
Process releases – buried pipeline (offsite)	Material/fabrication defect Ground movement Third party excavation/interference	Near field impinged jet Toxic/asphyxiating gas Personnel injury/fatality	Yes – releases from pipeline sections upstream or downstream of the Barmston process may be a contributor to Barmston personnel risk.

Hazard	Potential Causes	Potential Consequences	Requires Quantified Assessment?
Non-Process Hazards			
Occupational	Cryogenic burns Slips, falls and trips Sharp objects Electrocution Utility high pressure release – impact	Personnel injury/fatality	Yes
Road Transportation – road accident risk from a daily or rotation-based commute to the facility	Human error Mechanical defect Collision	Personnel injury/fatality	Yes
Vehicle Incidents onsite –mobile vehicles including trucks	Human error Mechanical defect Collision	Personnel injury/fatality	Yes – should be assessed as part of occupational FAR.
Structural Failure	Material/construction defect Extreme weather Earthquake	Movement or progressive structural collapse Process release (toxic/asphyxiating gas) Personnel injury/fatality	No – equipment and structures to meet design load requirements. Low seismicity area.
Dropped/swinging loads	Equipment failure, cable, slings, guide wires Human error Adverse weather conditions	Process release (toxic/asphyxiating gas) Personnel injury/fatality	No – The site arrangement ensures that heavy lifts (associated with installation of future equipment) will not occur over live equipment. There is no credible potential for a maintenance drop to result in process loss of containment – i.e. pump rooms (and VSD rooms) are separately compartmentalised and there are no stacked equipment trains. There should therefore be no requirement for mobile lifting equipment to traverse over live equipment.

From Table B.18 failure cases associated with process release events were defined. This involved determination of discrete sections, defined by points of positive isolation, thus defining the maximum releasable volume of inventory from each section on successful operation of the ESD system. The identified sections are presented in Table B.18.

Major accident leak sizes were selected to ensure consistency with NGCL's existing assessment studies, with the basis as follows:

- 5mm (very small) – represents small component leaks;
- 10mm (small) – represents small component leaks;

- 20mm (medium) – represents small bore connection leaks;
- 50mm (large) – represents small rupture scenarios; and
- 100mm (full bore) – represents rupture of large piping.

Major accident discharge conditions were developed using AspenTech HYSYS dynamics package, with fluid properties governed by GERG 2008 equation of state. Major accident leak and rupture events were modelled as transient from the point of isolation. All discharges followed a similar trend:

- Initial peak release rate decaying rapidly, associated with dense phase CO_2 in the system;
- A longer period with an almost constant release rate ('plateau' period) during which saturated liquid is leaked; and
- A final period with the release rate decaying 'exponentially', typical of gas phase depressurisation.

A discharge data package was developed for all potential leak sizes of interest, including development of flow rate, pressure and temperature profiles. The failure case data provided a basis for the major accident dispersion modelling.

Table B.18: Barmston Process Failure Cases

Section	Description	From	To	Volume (m^3)
8	Barmston PIG receiver	DBB	15-VE35004-D150	3.79
9	Barmston filtration (including recycle coolers)	34-ESDV-003	33-ESDV-001/003/004/006 / 007/009/010/012/013/015 / 016/018/019/021/022	156.99
10(A)	Barmston pump A	33-ESDV-001	33-ESDV-002/003/DBB	5.2
10(B)	Barmston pump B	33-ESDV-004	33-ESDV-005/006/DBB	5.2
10(C)	Future Barmston pump C	33-ESDV-007	33-ESDV-008/009/DBB	5.2
10(D)	Future Barmston pump D	33-ESDV-010	33-ESDV-011/012/DBB	5.2
10(E)	Future Barmston pump E	33-ESDV-013	33-ESDV-014/015/DBB	5.2
10(F)	Future Barmston pump F	33-ESDV-016	33-ESDV-017/018/DBB	5.2
10(G)	Future Barmston pump G	33-ESDV-019	33-ESDV-020/021/DBB	5.2
11	Barmston metering	33-ESDV-002/005 / 008/011/014/017 / 020	Barmston ESDV 002	47.52
12	Barmston PIG Launcher	DBB	15-VE35005-D150	2.43

B.3.20.2 *Summary of Major Accident Dispersion Simulations*

A comprehensive range of release types were modelled in the CFD analysis including external releases above and below ground and releases inside the pump buildings with variation in leak size and wind conditions.

One additional scenario was developed as follows:

- Buried pipeline downstream of the Barmston Pumping Station (offshore isolatable Section 15). This section falls within the offshore scope of work, however, part of the pipeline is routed within the Barmston site from plant south east (Barmston PIG Launcher area) to west.

It was assumed that all releases from buried piping/pipeline (including the smallest leak sizes) have potential to cause displacement of soil resulting in formation of a crater. Predictive models for crater size modelling were based on those developed for the COOLTRANS research programme. The soil composition was assumed to be sandy, which results in larger and deeper crater prediction when compared with the clay soil algorithms.

The HVAC system was assumed to be operational with a uniform minimum air change rate of 12ach. The air supply duct to each pump room is located at plant south of the building, with the air supply duct to the Variable Speed Drive (VSD) room also located at plant south of the building (adjacent to the pump room air supply). The extract duct for the pump rooms is also located at plant south, whilst the extract duct for the VSD rooms is located at plant north of each building.

In most cases, the variation in leak direction vs wind direction was set such that the leak was oriented towards poorly ventilated areas.

Table B.19: CFD Major Accident Dispersion Simulations

Section	Description	Release Location	Hole Size Basis	Wind Direction	Wind Speed
8	PIG Receiver	Plant north east	5mm	From plant north	Low (90% exceedance)
			5mm	From plant north	High (10% exceedance)
			20mm	From plant north	Low (90% exceedance)
			20mm	From plant north	High (10% exceedance)
			100mm	From plant north	Low (90% exceedance)
			100mm	From plant north	High (10% exceedance)
9	Filtration	Plant east	5mm, 20mm, 100mm	From plant east	High (10% exceedance)
9	Filtration	Recycle cooler area	5mm, 20mm, 100mm	From plant south	High (10% exceedance)
10	Pumps A-G	Inside pump building	5mm	From plant north	Low (90% exceedance)
			5mm	From plant east	Medium (50% exceedance)
			20mm	From plant north	Low (90% exceedance)
			20mm	From plant south	Low (90% exceedance
			20mm	From plant south	Medium (50% exceedance)
			20mm	From plant east	Medium (50% exceedance)
10	Pumps (A-D) Buried Piping	Crater – wake of year 1-5 pump buildings	5mm, 20mm	From plant north	Low (90% exceedance)
11	Metering	Plant south east	5mm, 20mm, 100mm	From plant south	High (10% exceedance)
12	PIG Launcher	Plant south east	5mm, 20mm	From plant south	High (10% exceedance)
15	Buried Pipeline	Crater – plant south east	10mm, 20mm, Full bore	From plant south	Low (90% exceedance)

B.3.20.3 Assessment Criteria

The criteria of interest in the major accident dispersion analyses were as follows:

- Alarm set points – 0.5% high alarm (Alert) and 1.5% high-high alarm (action);
- SLOT DTL – 1.5 x 10^{40}ppm^8.min; and
- SLOD DTL –1.5 x 10^{41}ppm^8.min.

Note: For CO_2, the component 'n' in the DTL relationship is 8, which reflects the highly nonlinear response to exposure. Fluctuations in concentration due to turbulence or time-varying wind conditions will tend to increase the toxic load. The CFD modelling approach does not reproduce the large scale meandering and plume intermittency which may occur in the mid to far field and as such an additional factor of 50 was conservatively added to the dose calculations. The application of this factor roughly assumes a sinusoidal variation of the concentration fluctuations in which the peak is twice the mean.

B.3.20.4 Results

Above Ground External Releases

The dispersion modelling shows that once fully developed, the plume from small (5mm representative) leaks has potential to extend beyond the local area of release and, under stable low wind speed conditions, could extend downwind to other parts of the process area. Higher wind speed conditions will aid dilution, resulting in lower concentrations in the process area. The results also show that the retaining walls provide a 'bounding effect' to the plume spread from small leaks.

The results show that if a large leak or rupture event occurs (100mm representative), the fully developed plume will affect large parts of the process area. The plume is also likely to extend to the administration Building area and to breach the site boundary. Higher wind speeds will partially mitigate the plume size; however there will still be potential for impact at the administration Building area and offsite.

Releases from Buried Piping and Onsite Pipeline

Leak and rupture events from all buried piping/onsite pipeline sections are assumed to have potential to cause ground displacement with crater formation. The results show that the release from the crater source has significant momentum and forms a vertical jet. However, in low wind speed conditions the plume will slump to ground locally and affect large parts of the process area. The results show that the impact from a full bore rupture of the onsite buried pipeline sections would be widespread with impacts extending offsite. However, large leak and rupture events also have lower occurrence frequencies.

Releases Inside the Pump Rooms

The basis for the in-building dispersion modelling was that the HVAC system is operational with a minimum air change rate of 12ach. Note: The HVAC design basis is a requirement to meet Hazardous Area Zone 2 classification and dissipation of heat not dilution of internal CO_2 leaks.

The dispersion modelling shows that the CO_2 inventory from small to medium leaks (5mm and 20mm representative) expands rapidly to fill the pump room. Since the HVAC system is operational, the HVAC system will facilitate gas plume movement into the wake of the pump buildings via the pump room extract at plant south of the building. Since the VSD room air supply is also located at plant south of the building, if the HVAC system remains operational, the CO_2 plume may also be drawn back into the VSD room. The effects of large and full bore releases inside the pump room are likely to follow a similar pattern but with more rapid expansion and external impacts into the process area south of the pump buildings.

B.3.20.5 *Recommendations*

Recommendations arising from the major accident dispersion modelling study are included in section B.3.32.

B.3.21 Venting Dispersion Analysis

B.3.21.1 *Introduction*

Venting will be required during commissioning and start-up, for disposal of off-specification CO_2, for thermal relief and during maintenance activities.

The design of the venting system at Barmston was assessed to ensure that the discharge locations, heights and velocities allow adequate dilution of vent gases thus mitigating the residual risk of exposure to personnel and third parties.

B.3.21.2 *Development of Dispersion Modelling Input Data*

The specific venting requirements for the process system at the Barmston Pumping Station include:
- 17 equipment relief valve lines;
- 33 equipment manual venting lines; and
- 1 manual venting line which enables venting of the offshore pipeline through Barmston.

A vent system data package was developed to facilitate the vent dispersion analyses. The dispersion modelling input data was developed using the AspenTech HYSYS dynamics package, with fluid properties governed by GERG 2008 equation of state.

Manual equipment vent releases were modelled as transient with the following data calculated for each line:
- Inside diameter of pipe;
- Height of vent stack tip;
- Line length from vent valve to stack tip;
- Pressure profile;
- Flow rate profile;
- Temperature profile; and
- Inventory volume.

Due to large inventory size, the pipeline vent line was modelled as a constant release.

A peak relief rate was developed for each relief valve. The valves are required primarily to provide relief against thermal expansion overpressure due to solar gain so the required orifice area is small. A standard relief valve orifice of an ASME 5 Crosby valve (with an area of $54.2 mm^2$) was selected for all the thermal reliefs.

B.3.21.3 *Summary of Venting Dispersion Simulations*

Table B.20 provides a summary of the manual venting dispersion cases modelled in the CFD analyses.

Table B.20: Manual Venting Dispersion Modelling Cases

Case	Description	Location	Vent Tip Elevation	Wind Direction	Wind Speed
V1.1	Simultaneous venting of 1x pump and recycle cooler	Year 1-5 Stack Array	8 m	From plant north	Low (90% exceedance)
V1.2					High (10% exceedance)
V2.1	PIG receiver	Local stack at plant north east	7 m	From plant north	Low (90% exceedance)
V2.2					High (10% exceedance)
V3.1	PIG launcher	Local stack at plant south east	3 m	From plant south	Low (90% exceedance)
V3.2					Medium (50% exceedance)
V3.3					High (10% exceedance)
V3.4				From plant north	Low (90% exceedance)
V3.5					High (10% exceedance)
V4.1	Pipeline	Year 1-5 Stack Array	8 m	From plant south	Low (90% exceedance)
V4.2					Medium (50% exceedance)
V5.1	Simultaneous venting of 1x pump and filter	Simultaneous Year 1-5 Stack Array and Filter Stack	8 m	From plant north east	Low (90% exceedance)
V5.2					High (10% exceedance)
V6.1	1x future pump	Year 5-10 Stack Array	8 m	From plant west	Low (90% exceedance)

Table B.21 provides a summary of the relief valve venting dispersion cases modelled. As for the major accident dispersion modelling, selection of wind direction was informed by the results of the ventilation analysis.

Dynamic simulation of a representative relief valve showed complex lift/rest cyclic behaviour over the course of an hour, with the lifts lasting approximately three minutes and the rest periods lasting 4 to5 minutes. It is noted that the observed lift/rest behaviour is applicable to the representative relief valve type considered and may not be applicable to a different valve specification. However, for the purposes of the dispersion analysis, a release duration of three minutes at the peak rate was modelled. This provided a suitably conservative basis for assessment since in practice the discharge rate will decrease towards the end of the lift period.

Table B.21: Relief Valve Venting Dispersion Modelling Cases

Case	Description	Tip Height	Wind Direction	Wind Speed	Release Duration
RV1.1	Simultaneous vent of 4 x year 1-5 booster pump relief valves	3 m	From north	Low (90% exceedance))	3 minutes
RV2.1	PIG receiver relief valve		From north		
RV3.1	PIG launcher relief valve		From south		
RV4.1	Simultaneous vent of 2 x HIPPS relief valves		From north		
RV5.1	Simultaneous vent of 4 x CO_2 filters relief valves		From east		
RV6.1	Simultaneous vent of 4 x year 5-10 booster pump relief valves		From north		
RV7.1	Recycle cooler relief valve		From north		

B.3.21.4 Assessment Criteria

The criteria of interest in the venting dispersion analyses were as follows:

- Occupational exposure limits – 1.5% Short Term Exposure Limit (STEL) and 0.5% Long Term Exposure Limit (LTEL) concentration thresholds;
- SLOT DTL – 1.5 x 10^{40} ppm^8.min; and
- SLOD DTL –1.5 x 10^{41} ppm^8.min.

B.3.21.5 Results

Manual Venting of Equipment

The equipment manual venting dispersion modelling shows that in all cases when the wind speed is low, the releases exhibit blanketing behaviour around the stack tip. There is an initial peak release rate (lasting approximately 10s), after which the release rate drops and the plume slumps to ground. For worst case wind directions which produce sheltering effects at the vent stack location, the fully developed plume can affect large parts of the process area and may extend to the administration Building area at concentrations up to 0.5%. However, the dispersion modelling shows that in all equipment venting cases, the potential for long term exposure of personnel (up to 8 hours) is minimal. For the worst case venting scenario modelled (simultaneous venting of 1xpump and recycle cooler), there is potential for the LTEL envelope to just breach the security fence, however, as above, the potential for long term third party exposure (>8 hours is minimal).

Concentrations exceeding 1.5% (STEL) may occur in the plant area but the STEL threshold will not be exceeded at the administration Building and, due to limiting effects of the retaining walls, the STEL will not be exceeded beyond the site security fence. Concentrations within the plant area may reach 3% to 4%, however the plume will disperse to below 1.5% concentration in under 15 minutes.

No source blanketing and plume slump behaviour is observed for medium or high wind speeds (50% and 10% exceedance respectively). The modelling shows that the plume disperses freely and does not come to ground on site at concentrations exceeding the STEL. The plume may come to ground just offsite at concentrations up to 0.5%, however, as above, the potential for long term third party exposure (>8 hours is minimal).

Manual Venting of Offshore Pipeline

The pipeline manual venting dispersion modelling shows that when the wind speed is low there will be blanketing around the vent stack tip, with a subsequent plume slump to ground. For worst case low winds speeds and wind directions, which produce sheltering effects at the vent stack location, the fully developed plume will affect large parts of the process area. Cumulative exposure (SLOD and SLOT) envelopes over a one day period show that there is minimal potential for impact at the administration building area.

For worst case wind directions, the fully developed plume will also affect the administration Building area. Concentrations at the administration building area will not exceed the 1.5% STEL threshold; however concentrations will reach the LTEL threshold of 0.5%. The plume is also likely to extend beyond the security fence. Concentrations at the Security fence will not exceed the 1.5% STEL threshold; however, concentrations will reach the LTEL threshold of 0.5%.

No source blanketing and plume slump behaviour is observed for medium or high wind speeds (50% and 10% exceedance respectively). The modelling shows that the plume disperses freely and does not come to ground on site at concentrations exceeding the LTEL, however the plume may come to ground offsite.

Relief Valves

The relief valve dispersion modelling shows that the plumes become fully developed over the three minute release duration. When the wind speed is low (90% exceedance) the releases exhibit blanketing behaviour around the relief valve discharge pipe. The plumes slump to ground and in some cases, such as simultaneous lift of booster pump relief valves in the wake of the pump buildings, the plume can affect parts of the process area.

This behaviour is exacerbated with worst case wind directions, such as when the relief valve discharge pipe sits within a poorly ventilated zone in the wake of a large obstacle. However, in all cases the plumes disperse relatively quickly (within 10s to 20 s) once the relief valve comes to rest. This effect also means that the potential for the plumes from one cyclic relief valves lift to interact with the plumes from the next cyclic relief valves lift is minimal.

B.3.21.6 Recommendations

Recommendations from the venting dispersion study are included in sectionB.3.32.

B.3.22 CFD Flange Leak Cold Temperature Study

B.3.22.1 Introduction

A CFD analysis was conducted to determine the minimum possible metal temperature if an uncontrolled leak from a flange occurs. The CFD analysis was required to facilitate material selection as the potential risk of rapid cooling of material to below the minimum design temperature of -46°C was identified as a design concern.

B.3.22.2 *Assessment Approach*

The general purpose software ANSYS CFX (version 15) was used for the analysis, with fluid properties governed by GERG 2008 equation of state. A typical ring joint type flange model was constructed.

An initial screening exercise was conducted to determine the worst case flange sizes to be modelled. The basis for the screening exercise was identification of flange sizes with the highest leak area to metal mass ratio, as these were considered to have potential for worst case cold temperature impact on the metal.

Once, the screening exercise was completed, two leak locations were investigated with simulation cases as shown in Table B.22.

Table B.22: Flange Leak CFD Simulation Cases

Location of Leak	Scenario Tag	Flange Size and Rating	
Upstream of booster pumps	LP	6in	900#
			1500#
		8in	900#
Downstream of booster pumps	HP	6in	1500#
		8in	1500#

B.3.22.3 *Summary of Results*

The CFD analysis shows that temperatures at the flange surface and exposed bolting could be as low as -70^{O}C, however, temperatures increase with distance from the flange surface resulting in a mean temperature across the flange lower than -46^{O}C. This has some dependency on flange size and rating but a minimum mean temperature of -53^{O}C was calculated as a worst case (based on minimum material temperature through the flange thickness).

The requirements for selected flange materials are as outlined in section B.4.5.3.

B.3.23 EER Design Compliance

B.3.23.1 *Introduction*

The subsections that follow describe the design compliance assessment of the emergency response facilities. General compliance requirements are drawn from theCDM Regulations 2015.

B.3.23.2 *Detection and Alarm*

Requirement

Detection and Alarm [CDM 2015 Regulation 32(1)]

Assessment

Barmston Pumping Station is provided with a fixed F&G detection system which forms a part of the ICSS. Diverse detector types are provided including for detection of leaks, gas accumulation, gas migration and smoke. The detector layout is as shown on the CO_2 and Fire Detector Layout Drawings.

Primary emergency communication to personnel will be via the PAGA system. The PAGA system will provide audible and visual alarms (to be initiated automatically via interface with the F&G system including separate alarm tones for fire detection, CO_2 detection and evacuate facility. The locations of field devices will cover all working areas as shown on the CO_2 and fire detector layouts. Personnel in the plant will be able to communicate with each other using UHF hand portable radios. Communications with third parties will be facilitated by analogue landline and VOIP telephones.

Conclusion

No requirement for additional fixed systems is identified. However, it is recommended that personnel are equipped with personal CO_2 monitors.

B.3.23.3 Escape and Muster

Requirement

Escape and Muster [CDM 2015 Regulation 31(1, 3, 4 & 5)]

Assessment

Barmston Pumping Station is provided with access roads which run along the perimeter of the process areas, allowing ready access and escape from all main plant areas. Local primary escape routes are also provided at plant south of the pump houses and at the cooler area, leading onto the access roads. Local primary escape routes are designed with a minimum clear width of 1000mm. Internal escape routes have a minimum clear height of 2100mm.

Buildings and enclosed areas which may be manned during maintenance visits (including pump rooms, VSD rooms and administration building) are provided with diverse exists to facilitate ready escape and to minimise the potential for personnel to become trapped in the event of small local fires (see section B.3.17). Safety signs will be provided throughout the plant, including ‘safe condition’ signs to indicate exits, escape routes and the muster point.

The muster point is located adjacent to the main gate exit to facilitate emergency evacuation via vehicle. The site is also provided with three diverse personnel emergency escape gates provided.

Conclusion

As far as reasonably practicable, each process area of the Barmston Pumping Station is provided with diverse local escape routes leading to the personnel escape gates or the muster area. It is recommended that an assessment of escape route and muster impairment risk tolerability is conducted during detailed design to facilitate escape and muster layout optimisation and escape set requirements.

B.3.23.4 *Emergency Lighting*

Requirement

Emergency Lighting [CDM 1015 Regulation 35(3) and 31(4)]

Assessment

External areas, including roads, escape routes, approach to buildings and escape gates are provided with pole mounted LED luminaires, battery backed for 90 minutes. Process areas, including the pump houses and the package building, are provided with fluorescent luminaires (mounted at 2.7m) and exit signs, all of which will be battery backed (90 minutes). The battery backed luminaires will be wired with an inhibit contact to prevent discharge of batteries if power is lost when the facility is unmanned.

Conclusion

No requirement for additional mitigation is identified.

B.3.23.5 *Personal Protective Equipment*

Requirement

Escape and Muster [CDM 2015 Regulation 30(2) d&e]

Assessment

Personal safety equipment at the Barmston Pumping Station will include escape sets with a minimum 10 minute duration to allow personnel to reach the administration building (see conclusion). Spare sets will be provided in the administration building. Other safety equipment in the administration building will include a stretcher, a first aid kit and an electrical safety kit in the switch room.

Conclusion

It is assumed in the first instance that personnel will carry an escape set on their person. Escape set requirements (including type, location and requirement for personnel to carry an escape set) must be determined at detailed design based on a quantified Escape, Evacuation and Rescue Assessment (EERA). This should include a detailed escape time assessment (see also section B.3.24

B.3.24 Preliminary Escape Time Assessment

B.3.24.1 *Introduction*

In the absence of a detailed maintenance shift distribution, a preliminary escape time assessment was conducted, based on escape from potentially manned process areas to the muster area or the emergency exits. This high level escape time assessment does *not* include for:

- The time to CO_2 gas detection/alarm;
- Time to stop, react and secure work area;

- Time to don an escape set; and
- Movement within buildings.

B.3.24.2 Results

The estimated escape times are summarised in Table B.23 based on a horizontal surface transit speed of 1m/s. The muster and escape gate locations are detailed on the escape route and safety equipment layout drawings. A transit speed of 1m/s may be considered to be a conservative starting point as this order of transit speed typically represents vulnerable populations such as the very young or the elderly.

Table B.23 also shows the comparative escape times based on a reduced transit speed (40% reduction), to represent hindered movement due to injury or visual obscuration. This order of reduction in transit speed is typically applied when representing evacuation from smoke filled buildings and may be conservative for the external transit scenarios under consideration here.

The results of the high level escape time assessment show that when the hindered escape speed is applied, some personnel may not be able to reach a safe area within 10 minutes. It is recommended that quantified assessment of escape and muster facilities is conducted during detailed design.

Table B.23: Escape Time Assessment

	Escape Time (s) – Transit Speed 1m/s			
Start Location	**Muster Area**	**Emergency Exit 1**	**Emergency Exit 2**	**Emergency Exit 3**
Pump Houses (Year 1-5)	257	305	275	160
Pump Houses (Year 5-10)	186	236	343	229
Metering Package	357	269	170	208
Substation	38	303	493	392
Start Location	Hindered Escape Time (s) – Transit speed 0.6m/s			
	Muster Area	Emergency Exit 1	Emergency Exit 2	Emergency Exit 3
Pump Houses (Year 1-5)	508	508	458	267
Pump Houses (Year 5-10)	393	393	572	382
Metering Package	448	448	283	347
Substation	505	505	822	653

B.3.25 Supplementary FEED Assessments by NGCL

B.3.25.1 Assessment of Barmston Pumping Station Layout

NGCL commissioned a third party supplier to review the Barmston Pumping Station FEED layout including assessment of compliance against the requirements set out in NGCL specifications: CFD Venting Dispersion Model Independent Analysis.

An independent analysis of the Genesis CFD venting dispersion model validation study was conducted by NGCL's third party supplier.

B.3.26 Summary of Significant Risks

B.3.26.1 Overview

This section provides a summary of the primary risks identified during FEED, for which further consideration during detailed design is required. Identification of risk was based on a structured formal workshop approach which included HAZID workshops, HAZOP workshops and technical reviews.

B.3.27 Significant Risks/Risk Management

B.3.27.1 Feed Gas Composition from CPL (and Future Emitters)

The composition of feed gas into the onshore transport system including the Barmston Pumping Station will be assured by CPL and future emitters. The required feed gas specification is described in section B.4.2.2. Though the Barmston Pumping Station has analysis and metering facilities, detection of off-specification gas at Barmston would mean that the facility and onshore pipeline would already contain the off-specification gas. Exceedance of the feed gas impurity thresholds may result in:

- Corrosion, if free water (>50ppmv) is allowed into the system; and
- Adverse impact on the phase boundary if trace levels of N_2, O_2 and H_2 are exceeded.

The CPL production system includes a cold box which would freeze out any water and also provides product analysis to ensure the feed gas specification requirements. It is recommended that CPL (and future emitters) should be required to provide a continuous feed to NGCL of the product analyser and the upstream water analyser output.

B.3.28 Selection of Polymeric Materials

The process of material selection during FEED is detailed in section B.4.5.3.

Going forward, there is a requirement to ensure that suitable non-metallic polymeric material seals are used for all equipment components used in CO_2 service. Due to the solvent properties of CO_2 when in supercritical phase, commonly used polymers may absorb the CO_2 leading to swelling and changes in their physical properties.

Polymeric materials proposed for use in valves, flanges and isolation joint sealing should therefore be demonstrated (via testing) to be suitable for use in CO_2 service.

B.3.29 Minimum Temperatures on Depressurisation

The pipeline minimum design temperature is 0°C, however colder temperatures are likely to occur during pipeline depressurisation. Additional Charpy testing is required to ensure the pipeline can maintain integrity at lower temperatures down to -20°C.

Flanges which are specified ≤6in with a 900# rating, or ≤4in with a 1500# will need to be impact tested to -55°C for suitability. Bolts will need to be impact tested to the lowest temperature for the material selected (-80°C).

B.3.29.1 *Uncontrolled Venting*

The manual venting rate will need to be carefully controlled to mitigate the risk of the depressurisation cooling effects exceeding the minimum design temperature of the equipment and piping.

Operational procedures for the manual venting process are required to be developed. Development of physical limiters in the system should be considered during detailed design in preference to reliance on operator decision.

B.3.29.2 *Onsite Pipeline Loss of Containment*

The buried pipeline section just upstream of emergency shutdown valve 34-ESDV-003 is routed through the Barmston Pumping Station from plant west to the PIG receiver area at plant north-east. Loss of pipeline containment onsite would result in a very large inventory of toxic and asphyxiating gas being released into the process plant area which is sheltered by the landscape mounds. There is also a downstream section of pipeline that is partially routed through the Barmston Pumping Station from the PIG launcher area at plant south-east.

Onsite pipeline loss of containment contributors such as external impact and corrosion are mitigated. However, the requirement to determine the residual risk contribution to personnel at Barmston Pumping Station from pipeline incidents and to assess personnel individual risk against UK HSE risk tolerability criteria remains. The assessment should also include assessment of the potential impact at the nearest residential locations.

B.3.30 Process Loss of Containment

As far as reasonably practicable, measures have been implemented in design to mitigate the risk of process loss of containment.

However, the requirement to determine the residual risk contribution to personnel at the Barmston Pumping Station from process (and pipeline) loss of containment events and to assess personnel individual risk against UK HSE risk tolerability criteria remains. The assessment should include assessment of the potential impact at the nearest residential locations.

B.3.31 Actions List Status

B.3.31.1 *Introduction*

The SAMS register provides a record of all actions logged from formal workshops, audits and reviews, plus ad-hoc actions and includes background notes and references from the source documentation.

Use of the SAMS register ensured that:
- All design safety actions were recorded and notified to lead discipline engineers;
- All actions could be tracked;
- The method of resolving actions was recorded so that there was a clear and auditable trail;
- All action responses could be reviewed and reference documentation checked, before formal sign off by the engineering manager as part of the acceptance and closure procedure; and

- Any actions not closed at the end of FEED could be taken forward to detailed design.

The action List status at the time of issue of this report is as follows:

- Total raised (Genesis and NGCL) 80;
- Total closed 28;
- Total open with response under consideration 23;
- Total open and ready for NGCL sign-off 2;
- Total open with no response 10 (NGCL); and
- Total open – transfer to EPC 17.

17 Outstanding actions have been transferred to EPC for continued management during detailed design.

B.3.32 Outstanding Safety Design Actions Areas

B.3.32.1 Introduction

A number of safety design areas have been identified as requiring more detailed technical safety assessments as part of detailed design. The identification of these areas is based on:

- Outstanding actions which could not be closed out during FEED;
- Areas requiring detailed technical safety assessments (where those assessments were outside of the (Genesis) FEED scope of work); and
- Recommendations from the studies conducted during the (Genesis) FEED scope of work.

The safety design areas requiring further assessment are discussed in the sections that follow.

B.3.32.2 Detector Layout Design Optimisation

As far as reasonably practicable, the layout design of the CO_2 detectors followed the requirements of the gas leak detection and control philosophy.

However, as dispersion modelling data was unavailable at the time of development of the detector layout drawings, there remains a requirement to optimise the layout design.

The layout optimisation process should be as follows:

- Develop the full major accident dispersion scope for Barmston Pumping Station;
- Determine if the proposed layout design provides adequate coverage at the specified set points (in particular for the smallest leaks);
- Identify potential low points on site; and
- Adapt assessment recommendations into the layout design.

B.3.32.3 Escape and Muster Assessment

As far as reasonably practicable, the design of the escape and muster facilities followed the requirements of the CDM Regulations 2015 and the design safety philosophy.

A general compliance assessment was conducted, as outlined in section B.3.23. A limited major accident dispersion modelling scope of work was also conducted. The recommendations from these assessments are outlined below:

- It is recommended that a quantified technical assessment is conducted at detailed design. The assessment should include CFD dispersion modelling of all isolatable sections, leak sizes and wind conditions to allow a probabilistic analysis to be completed. The assessment should include:
  - Assessment of the escape route and muster layout design against impairment tolerability criteria;
  - Review of whether diverse and adequate escape routes are in place to enable personnel to reach the designated safe areas;
  - Determination of the required capacity, type and locations of escape set equipment (including confirmation of requirement to carry an escape set versus provision at fixed locations (in cabinets) across the process area;
  - Confirmation of requirement for personnel entering the pump buildings to wear a breathing apparatus set;
  - Review of administration building HVAC philosophy when gas is detected in the process plant;
- It is recommended that personnel are always equipped with personal CO_2 monitors; and
- It is recommended that NGCL develop local authority notification and third party emergency response procedures to be initiated in the event of major accident leak or rupture event.

B.3.32.4 Pump Building HVAC Design Optimisation

Identification of a potential flammable mist hazard inside the pump buildings, the associated hazardous area classification and the minimum HVAC air change requirements are described in section B.3.17.

Subsequent CFD dispersion modelling simulations of CO_2 major accident leaks inside the pump rooms is described in section B.3.20. The following is recommended based on the results of the CFD analysis:

- It is recommended that further CFD analysis is conducted during detailed design (to include the full scope of major accident cases) to facilitate optimisation of the HVAC design, including air intake and exhaust duct locations; and
- It is recommended that an HVAC philosophy is developed to include philosophy on detection of internal CO_2 leaks inside the pump rooms or external leaks in the process area.

B.3.32.5 Venting Philosophy

A venting dispersion analysis for Barmston Pumping Station was conducted and the procedural recommendations from the analysis are as follows:

- When conducting equipment manual venting operations, it is recommended that personnel entry into the process plant area is restricted. If personnel are required to enter the process plant area as part of the venting operations, then personnel must be equipped with a full self-contained breathing apparatus set;
- When conducting equipment manual venting operations, it is recommended that the HVAC system dampers at the administration building are closed;
- Given the required duration of a pipeline venting operation and the potential for the plume to breach the security fence at concentrations up to the LTEL, it is recommended that offshore pipeline venting operations are not conducted onshore; and
- Where practicable, it is recommended that manual venting operations in low wind speed conditions are avoided to mitigate the risk of the plume slumping to ground level.

B.3.32.6 *Determination of Residual Risk and Demonstration of ALARP*

As far as reasonably practicable, the results of formal safety assessments such as the formal workshops have been adapted into FEED. An assessment of risk including determination of residual risk to personnel and third parties and demonstration that the residual risk is ALARP was conducted.

B.3.32.7 *Layer of Protection Analysis*

The SIL determination workshop covering the onshore transport system (including the Barmston Pumping Station) was based on the risk graph approach.

One of the failure causes identified as having potential to lead to phase separation in the onshore pipeline is a prolonged failure of the pump control system at the Barmston Pumping Station. There is a requirement to conduct a Layer of Protection Analysis (LOPA) as this will allow for better representation of the mitigating factors that would prevent this sequence of events. The LOPA should be conducted during detailed design once NGCL have set a TMEL.

B.4 Summary of the Offshore Pipeline Process Safety Report

B.4.1 Overview

The report includes:

- A list of all formal process safety assessment activities undertaken during the offshore pipeline FEED;
- A summary of key themes and significant risks identified through the formal process safety assessment process; and
- A discussion around those key themes which remain a significant risk.

B.4.2 Process Description

B.4.2.1 *Process Design Parameters*

Process parameters on the pipeline are detailed in the Offshore Pipelines Infrastructure Design Report and summarised in Table B.24.

Table B.24: Pipeline and Riser Process Design Parameters

Parameter	Value	Units
Maximum Incidental Pressure (MIP)	200	barg
Design Pressure/Maximum Allowable Operating Pressure (MAOP)	182 (at LAT +6.84 m)	
Minimum Normal Operating Pressure	90	
Pipeline Maximum/Minimum Design Temperature	40/0	°C
Riser Maximum/Minimum Design Temperature	50/-46	

B.4.2.2 Gas Composition

The NGCL specification CO_2quality requirements for pipeline transportation specification sets out the maximum allowable impurity levels including water, nitrogen, argon, oxygen and methane, the exceedance of which adversely affects the phase boundary.

The anticipated first load (year 1) composition contains 99.7vol% CO_2 and up to 10ppmv of oxygen and 50ppmv of water. The balance of the fluid composition comprises nitrogen and argon. Year 5 and 10 compositions may also contain trace amounts of hydrogen, carbon monoxide, NO_x, SO_x and methane. The composition of the feed gas will be assured by the upstream OPP (and future emitters).

B.4.2.3 Design Flowrates

Camblesforth Multi-junction is designed as a manifold station to allow future tie-in of other emitters into the overall T&S system. The FEED basis for development is as outlined in Table B.25.

Table B.25: Development of Transport System

	Year 1 (First Load)	Year 5	Year 10
Flow Case	**Million Tonnes per Hour**		
Design	2.68	10.0	17.0
Normal	2.31	10.0	17.0
Minimum	0.58	0.58	0.90

B.4.3 Prevention, Control and Mitigation of Major Accidents

B.4.3.1 Introduction

As far as reasonably practicable, risk management in the offshore FEED was implemented through a risk based design approach, which typically involved the following:

- Identification of hazards and potential effects via formal workshops or via desktop studies;
- Quantified assessment of hazards;
- Determination of residual risk to personnel and third parties and to the asset;
- Determination of risk reduction measures where required – for example reinforcement or additional protection; and
- Re-evaluation of risks via quantified assessments (including cost benefit analysis if appropriate), following the iterative process outlined above.

The technical studies that supported this process are outlined in section B.4.9.

The risk based design approach was applied alongside the risk management framework set by the NGCL specifications and good engineering design practice and provided a basis for demonstration that residual risks associated with the FEED design are ALARP.

A description of the risk management measures implemented during the offshore pipeline FEED design are detailed in the sections that follow. Risk management measures were implemented in the following hierarchy:

- Legislation, codes and standards;
- Prevention;
- Control and mitigation; and
- Emergency response.

B.4.4 Legislation, Codes and Standards

B.4.4.1 Overview

The offshore pipeline FEED intent was that the design will comply with the highest regulatory, NGCL and industry standards for design safety. Safety design requirements were applied in the following hierarchy:

- UK legal requirements (laws, edicts, regional or local regulations, etc.);
- NGCL specifications;
- Data sheets/drawings (where applied);
- Project design philosophies;
- Primary project specifications;
- Contractor specifications and standards approved by NGCL; and
- International codes and standards.

A summary of the key legislation, FEED philosophies and specifications and normative and informative codes and standards utilised during FEED is outlined below. These and other, documents are referenced where appropriate in subsequent sections of this report.

B.4.4.2 UK Legal Requirements

The governing safety legislation in the development and implementation of safety principles in the onshore/landfall section of the offshore pipeline FEED is the HASAWA 1974.

The onshore/landfall section of the offshore pipeline is also notifiable under the CDM Regulations 2015.

The governing safety legislation in the development and implementation of safety principles in the offshore pipeline FEED is the Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 2013.

The offshore pipeline is not classed as a Major Accident Hazard Pipeline under the Pipelines Safety Regulations (PSR) 1996. However, the safety design principles of Part II of PSR (safe design and operation) are applicable.

The platform and associated pipeline section within the 500 m of the platform fall outside of the requirement for Safety Case regulatory submission as part of The Offshore Installations (Safety Case) Regulations 1995. However, as per NGCL requirements, the platform and associated pipeline within the 500 m zone of the platform must comply with the design requirements of the Safety Case Regulations.

B.4.4.3 Project Design Philosophies and Specifications

A number of project design philosophies, design basis documents and reports were developed to facilitate the offshore pipeline FEED.

B.4.4.4 International Codes and Standards

International codes, standards and industry guidance documents were referenced as appropriate.

Table B.26: International Codes, Standards and Guidelines

Reference	Title/ Description
PD 8010-1	Code of Practice for Pipeline – Steel Pipelines on Land
PD 8010-2	Code of Practice for Pipeline – Subsea Pipelines
IGEM/TD/1	Steel Pipelines and Associated Installations for High Pressure Gas Transmission
ASME B31.8	Gas Transmission and Distribution Piping Systems
ASME B36.10M	Welded and Seamless Wrought Steel Pipe
BSI BS EN ISO 3183	Petroleum and natural gas industries – Steel pipe for pipeline transportation systems
DNV-OS-F101	Submarine Pipeline Systems
DNV-RP-F107	Risk Assessment of Pipeline Protection

B.4.5 Prevention

B.4.5.1 Definition as Safety Critical Element and Development of Performance Standard

The Offshore Installations (Safety Case) Regulations 2005 define Safety Critical Elements as:

"Parts of an installation and such of its plant (including computer programs) or any part thereof, the failure of which could cause or contribute substantially to, or a purpose of which is to prevent or limit the effect of, a major accident event."

Performance standards are statements which outline the minimum functional, survivability and availability requirements that the safety critical element must achieve to meet its safety critical function.

CO_2 containment in the onshore/landfall pipeline, subsea pipeline and riser is defined as a safety critical element which has a preventive function. Performance standards have been developed for the safety critical elements.

B.4.5.2 Design Code

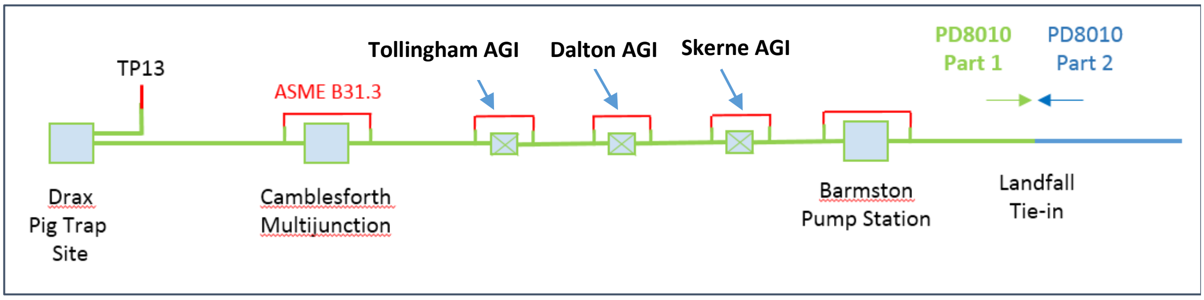
The onshore/landfall pipeline design was in accordance with the requirements of the primary design code: PD 8010-1:2004 (Code of Practice for Pipelines – Steel Pipelines on Land). Supplementary NGCL requirements were taken from NGCL/SP/PIP/28 (applicable to the onshore/landfall pipeline).

The subsea pipeline design was in accordance with the requirements of PD 8010-2 (Code of Practice for Pipelines – Subsea Pipelines).

The PD 8010-1:2004 and PD 8010-2:2004 design code interface is the landfall/subsea pipeline tie-in spool and the risers are also covered by PD 8010-2.

Within the requirements of PD 8010-1:2004 and PD 8010-2:2004, dense phase CO_2 was classed as substance type E, defined as *"Flammable and/or toxic fluids that are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases and/or liquids"*.

Figure B.4: PD 8010-1 Battery Limits



B.4.5.3 *Material Selection*

Selection of materials for use in the offshore transport system was based on the requirement to mitigate risk of material degradation and failure by ensuring:

- Selected materials are fit for service for the design life (40 years) based on corrosion assessments for both the internal and external environments;
- Selected materials are fit for service at maximum and minimum design temperatures;
- Selected material options minimise the requirements for inspection and maintenance as far as practicable; and
- Selected material options maximise equipment availability, reliability and safety.

A material selection study was conducted, with materials selected as follows:

- Carbon steel material grade BS EN ISO 3183 Grade L450 (X65) is selected for the offshore pipeline and riser. There will be no free water in the system, with control of water content and impurities assured by the upstream OPP (and future emitters);
- Monolithic isolation joints (onshore/landfall section) shall comprise Low Temperature Carbon Steel (LTCS) and HNBR-4007/glass reinforced epoxy tested under simulated operating conditions; and
- Selection of non-metallic soft seals should be based on historical data and satisfactory performance testing under the exact composition range, impurities and operating conditions of dense phase CO_2 transported.

B.4.5.4 *Corrosion Protection*

The potential for internal corrosion caused by the presence of free water will be mitigated via the protection measures in place at the OPP and future emitter installations (see also section B.4.20).

External corrosion protection on the onshore/landfall pipeline is specified as follows:

- The onshore/landfall pipeline will be coated with fusion bonded epoxy with an average thickness of 800µm;
- Buried components on the pipeline will be coated with a modified high build epoxy coating containing glass fibre; and

- A permanent Impressed Current Cathodic Protection (ICCP) system will provide a second layer of protection.

External corrosion protection on the subsea pipeline is specified as follows:

- The offshore pipeline will be coated with fusion bonded epoxy with an average thickness of 575μm; and
- A sacrificial anode cathodic protection system will provide a second layer of protection. The system requirements are detailed in the cathodic protection specification. An isolation joint is provided at the onshore/subsea pipeline interface to isolate the offshore cathodic protection system from the onshore ICCP system.

B.4.5.5 Wall Thickness and Design Factor

The wall thickness requirements for the onshore/landfall pipeline and the subsea pipeline were not pre-specified by NGCL provides a summary of the wall thickness and design factor parameters on the offshore pipeline.

A design factor of 0.5 was selected for the onshore/landfall section *inside* the Barmston Pumping Station fence in accordance with IGEM/TD1 and ASME B31.8. This specification extends a minimum of one pipe joint beyond the fence line.

Specification of the onshore/landfall pipeline wall thickness and design factor beyond the Barmston Pumping Station fence was based on a population density assessment in accordance with PD 8010-1:2004. PD 8010-1:2004 stipulates that for a type E substance, the design factor should not exceed 0.72 under normal operating conditions in Location Class 1 areas and in Location Class 2 areas, the design factor should not normally exceed 0.3, however this may be raised to a maximum of 0.72 if this can be justified via a QRA.

The population density assessment enabled definition of the Location Class, with the population density estimated from the number of normally occupied buildings within a defined lateral proximity to the pipeline (in accordance with PD 8010-1:2004 and IGEM/TD/1). The identification of buildings (mainly farm buildings) was facilitated by satellite imagery, with a normal occupancy of three assumed for each building. The population density per hectare was estimated to be 0.15. Within PD 8010-1:2004, the upper threshold for a Location Class 1 area is 2.5. The assessment showed therefore that the onshore/landfall pipeline area can be classed as Location Class 1 and that a design factor of 0.72 will not be exceeded. The population density assessment is detailed in the onshore pipeline mechanical design report. The FEED specification for the design factor on this pipeline section is 0.6, which aligns with the PD8010-1:2004 stipulated design factor for landfall.

Selected wall thicknesses for the subsea pipeline are based on ASME B36.10, SAWL pipe size. The specification satisfies the PD 8010-2:2004 safety requirements for containment, collapse, propagation buckling and local buckling. Details of the specification and assessment are provided in the offshore pipeline mechanical design report.

Table B.27: Wall Thickness and Design Factor

From	To	Diameter ("/mm)	Wall Thickness (mm)	Design Factor
KP0 (Barmston outlet)	KP0.03	24in/610mm	34.93mm (normal routing and crossings)	0.5 (inside Barmston fence)
KP0.03 (Barmston outlet)	KP0.439	24in/610mm	26.97mm (normal routing and crossings)	0.5 (inside Barmston fence)
KP0.439	KP1.320 (landfall)	24in/610mm	22.23mm (normal routing and crossings)	0.6 (outside Barmston fence)
KP0	KP1.3	24in/610mm	22.23mm	0.72 (hoop stress) 0.96 (equivalent stress)
KP1.300	KP46.49	24in/610mm	19.05mm	0.72 (hoop stress) 0.96 (equivalent stress)
KP46.49	KP88.349	24in/610mm	25.4mm	0.72 (hoop stress) 0.96 (equivalent stress)
Spool piece	Spool piece	24in/610mm	19.05mm	0.72 (hoop stress) 0.96 (equivalent stress)
Riser	Riser	24in/610mm	22.23mm	0.72 (hoop stress) 0.96 (equivalent stress)

Table B.28: Location Classes

Location Class	Description (Reference PD 8010-1:2004)
1	Areas with a population density less than 2.5 persons per hectare
2	Areas with a population density greater than or equal to 2.5 persons per hectare and which may be extensively developed with residential properties, schools and shops etc.
3	Central areas of towns and cities with a high population and building density, multi-storey buildings, dense traffic and numerous underground services

B.4.5.6 Pipeline Crossings

The pipeline crossing techniques for the onshore/landfall pipeline are as follows:

- Open cut – the onshore/landfall pipeline section crosses two tracks (TX 40/1 and TX 40/2); and
- Microtunnel and cofferdam – landfall. The preferred crossing design includes a 218m microtunnel from upstream of the cliff face to the beach, with the tie-in to the subsea pipeline constructed in a sheet piled cofferdam on the beach.

The subsea pipeline crosses the following third party facilities:

- Langeled pipeline (at KP37.603);
- (2 x future) Dogger Bank Creyke Beck HVDC cables; and
- Unidentified magnetic anomaly (at KP46.346).

A more detailed description of the subsea pipeline crossings is provided in the offshore pipeline third party crossing constraints report.

B.4.5.7 *Protection Against Impact/Third Party Interference*

Table B.29 provides a summary of the external interference protection measures on the pipeline route. A depiction of the protection measures is provided on the pipeline alignment sheets.

The subsea pipeline is also provided with concrete weighted coating (for hydrodynamic stability), with thickness ranging from 95mm minimum to 160mm. The impact energy specification for the concrete weighted coating is 1 tonne at a velocity of 2m/s.

Table B.29: External Interference Protection

From	To	km	Description	External Interference Protection
KP0	KP1.057	1.057	Onshore/landfall pipeline	Buried minimum depth 1.2 m; 2 m at track crossings with concrete slab
KP1.057	KP1.320	0.263		Buried minimum depth 4 m
KP0	KP9.2	9.2	Subsea pipeline	4.8m pre-dredge trench and post-lay backfill
KP9.2	KP16.25	7.05		2 m pre-dredge trench and post-lay backfill
KP16.25	KP16.6	0.35		None intended – however, 2 m post-lay trench is specified for pipeline stability and it is recommended that material is returned to the trench
KP16.6	KP17.781	1.181		2 m post-lay trench for pipeline stability + rock dump protection (Dogger Bank Crossing) Note 1
KP17.781	KP27.25	9.469		None intended – however, 2 m post-lay trench is specified for pipeline stability and it is recommended that material is returned to the trench
KP27.25	KP37.533	10.283		None intended
KP37.533	KP37.673	0.14		On seabed + rock dump protection (Langeled Pipeline Crossing) Note 2
KP37.673	KP88.349	10.283		None intended Note 3
Spool piece	Spool piece	0.049	Spool piece	Mattressed
Riser	Riser	-	Riser	Routed inside jacket structure

Note 1: The 2 x future Dogger Bank Creyke Beck HVDC cables currently have only a preliminary cable routing definition. As such, the White Rose pipeline has a large crossing area of size 10.5km x 7km designated for the crossing of the two future HVDC cables.

Note 2: The White Rose pipeline will span over the Langeled Pipeline leaving a 0.5m gap between the two pipelines. A minimum 0.5m rock dump over the pipeline is recommended to mitigate risk of trawl gear hooking in the span gap. Other technical requirements for the Langeled Pipeline crossing design are given by the pipeline operator (Gassco) and are summarised in the Offshore Pipeline Infrastructure Design Report.

Note 3: Further pre-construction survey is required to identify the actual nature of the magnetic anomaly feature at KP46.346. There is currently no ownership assigned to this feature and therefore no third party restrictions on potential crossing design and construction other than industry standard code compliance requirements

B.4.5.8 *Pipeline Markers (Onshore/Landfall)*

Marker posts are provided along the onshore/landfall pipeline to indicate pipeline location, which mitigates the risk of third party inadvertent interaction/impact. The marker post facilities are as follows:

- Aerial marker posts, the installation of which will be such that they are visible from the air or ground; and
- Boundary marker posts, to indicate crossings.

The locations of both aerial and boundary markers and cathodic protection marker posts are detailed on the pipeline alignment sheet.

B.4.5.9 Design and Operating Conditions

The PD 8010:2004 primary design codes specify that the MAOP of the pipeline should not exceed the design pressure and that the MIP should not exceed the design pressure by more than 10%.

The pipeline design pressure (182barg) is equal to the MAOP and the MIP (200barg) does not exceed the design pressure by more than 10%.

B.4.5.10 Overpressure Protection

A HIPPS is provided (located at the Barmston Pumping Station) to protect the offshore pipeline from the Barmston booster pump pressures. The HIPPS package will comprise two safety shut-off valves in series. Each valve will have a spring return actuator and a mechanical pressure measuring device to initiate activation of the shut-off valve. The valves will use 1oo2 voting. The HIPPS shall be SIL 3 rated.

B.4.5.11 Pipeline PIG Operations

The offshore pipeline is provided with PIG launcher and receiver facilities (at the Barmston Pumping Station and the platform respectively) to allow initial cleaning PIGs and subsequently intelligent PIGs to be run through the pipeline for inspection and monitoring. The pipeline will have minimum 5D bends to for allow intelligent PIG operations. Selected PIGs will be suitable to run through bends, tie-in spools and the barred tees.

B.4.6 Leak Detection and Alarm

Conditions on the pipeline will be continuously monitored from the NGCL control centre for transgression of operating conditions.

Leaks on the onshore/landfall pipeline should also be detectable via aerial or walking surveillance and maintenance activities as leaks are likely to leave a visible residue. Fixed leak detection and alarm systems are specified at the upstream and downstream facilities (Barmston Pumping Station and platform respectively).

B.4.7 Control and Mitigation

B.4.7.1 Pipeline Shutdown System

Project ESD Hierarchy

The project shutdown level hierarchy is defined as below:
- ESD Level 1: Total shutdown of the end to end CCS chain (inclusive of the onshore transportation AGIs and offshore storage facility);
- ESD Level 2: Entire process shutdown of each individual installation (onshore transportation AGIs and offshore storage facility) and partial utility shutdown at the facility; and

- ESD Level 3: Process system shutdown within an installation (onshore transportation AGIs and offshore storage facility).

To summarise overall control of the T&S Sections:

- Barmston is not a nominated control facility;
- Transportation assets would be controlled from the NGCL facility; and
- Storage assets would be controlled from the Carbon Sentinel Limited (CSL) control room.

There would be appropriate interfaces between NGCL/CSL/OPP to provide handshaking.

Isolation of Pipeline

Isolation of the offshore pipeline will be via closure of emergency shutdown valve 34-ESDV-004 at Barmston Pumping Station and emergency shutdown valve 34-ESDV-005 at the platform pipeline isolation (as part of ESD Level 1) may be initiated under the following conditions:

- Manually via a physical pushbutton at the Barmston Pumping Station local control room and the platform local electrical room; and
- Via the remote shutdown facility dedicated pushbutton in the NGCL control centre.

Once isolated, a manual local reset of the system will be required.

The ESDVs will be metal seated with maximum acceptable leakage rates to be confirmed during detailed design. A pneumatic actuator is specified for 34-ESDV-004 (at Barmston) and a hydraulic actuator is specified for 34-ESDV-005 (at the platform). Actuation will be possible at the maximum pressure drop across each valve. The ESVDs will fail closed in the event of a fault, loss of power or loss of control signal.

Definition as Safety Critical Element and Development of Performance Standard

The ESD system is defined as a safety critical element which has a control function. Performance standards have been developed for the safety critical elements.

B.4.7.2 Pipeline Depressurisation

Once isolated, the inventory will remain in the pipeline. If a requirement to depressurise the pipeline is identified, this will be a manual operation as follows:

- Via Barmston Pumping Station – A pipeline depressurising line is provided at the common year 1-5 permanent vent stack array. The pipeline depressurising line is sized to depressurise the offshore pipeline section from the CO_2 booster pump discharge ESDVs up to 34-ESDV-005 (at top of riser), though the line may also be used to depressurise the onshore pipeline section from the Skerne Block Valve Station up to 34-ESDV-004 (the onshore/offshore isolation ESDV); and
- Via the platform – A depressurising valve is provided at the low point on the injection manifold (sizing case is for pipeline depressurisation). The depressurising line vents inventory at the common vent boom. A globe valve is provided in the depressurising line to facilitate manual control of the depressurisation rate so that the minimum design temperatures are not breached. The common vent boom is located outboard of the cellar deck at platform north east. As for all the other vent lines, the pipeline vent line tip is angled at 45° downwards so that releases in unfavourable wind conditions are dispersed beneath cellar deck elevation. The vent system piping is LTCS.

The vent system design has been assessed by dispersion studies.

B.4.7.3 *Thermal Overpressure Protection*

Thermal relief is required to provide mitigation against the overpressure conditions which may arise if thermal expansion from solar gain occurs during a blocked in scenario, for example shut down for maintenance.

The onshore/landfall pipeline is buried and is therefore largely protected against atmospheric temperature variations. The subsea pipeline is also protected by location. There is, however a short section at the top of the riser (upstream of 34-ESDV-005, which falls within the offshore pipeline isolatable section) which is provided with a thermal relief valve (34-PRV-052). The discharge line from pressure relief valve 34-PRV-052 is oriented downwards and routed directly below the valve location, with the tip discharging at 3m below cellar deck elevation. The requirement for relief valve discharges to a safe location on the platform was assessed.

B.4.8 Emergency Response at Upstream and Downstream Facilities

In the event of a pipeline leak or rupture event in close proximity to the upstream or downstream facilities, emergency response arrangements at the Barmston Pumping Station and the platform respectively will be as described in the following reports:

- Process Safety Close Out Report - Onshore Pumping Station; and
- EER Assessment.

B.4.9 Formal Safety Assessments

B.4.9.1 *Introduction*

This section describes the technical safety assessments conducted to facilitate the offshore pipeline FEED.

B.4.9.2 *Formal Workshops*

Offshore HAZID Workshop

A HAZID workshop for the Offshore T&S system was conducted 29 October 2014. The scope of the offshore HAZID workshop included:

- Onshore/landfall pipeline, subsea pipeline and riser; and
- Platform.

A terms of reference document was developed and issued before commencement of the workshop to ensure all participants had a common understanding of the workshop format, methodology and means of reporting.

To ensure continuity in understanding of the system, the offshore HAZID workshop was facilitated by the same independent chairperson who facilitated the Onshore Transport System formal workshops. The workshop was attended by engineers from both NGCL and Genesis. The workshop was conducted on a system/subsystem basis to ensure that all the hazards were adequately identified. The workshop procedure was aligned with the requirements of the NGCL HAZID Specification NGCL/MP/HS/03/1 and was as follows:

- Identify hazards – guideword prompt;
- Identify failure mode/cause;
- Identify direct/Indirect consequences;
- Identify safeguards in place;
- Assess mitigating effect of safeguards;
- If required, recommend additional safeguards/risk reduction measures;
- Where a requirement for additional safeguards is identified, determine if safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of FEED.

The workshop proceedings were recorded on HAZID worksheets, which were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in HAZID report. Actions relating to the offshore pipeline were transferred to the formal process safety close-out assessment report register.

Offshore HAZOP Workshop

A HAZOP workshop for the offshore T&S system was conducted between 17th to19th November 2014. The scope of the offshore HAZOP workshop included the onshore/landfall pipeline and the subsea pipeline and riser.

A terms of reference document was developed and issued before commencement of the workshop.

The HAZOP workshop was facilitated by the same independent chairperson who facilitated the HAZID study and was attended by engineers from both NGCL and Genesis. The workshop procedure was aligned with the requirements of the NGCL HAZOP Specification NGCL/MP/HS/02/1.

The HAZOP study was conducted on the basis that the initial phase of the offshore transport system was in full operation. The HAZOP workshop was conducted on a nodal level, with the onshore/landfall pipeline, subsea pipeline and fine filters up to the manifold forming a single node. The HAZOP procedure was as follows for each node:

- Define the design intent;
- Confirm operating conditions for example pressure, temperature;
- Confirm mode of operation for example normal, start-up;
- Identify credible deviations (using guideword prompts);
- Consider the existing safeguards against the impact of a credible deviation and whether the existing safeguards are adequate;
- Propose actions (recommendations) as appropriate;
- Determine if any additional safeguard/action should be implemented;
- Assign actionee; and
- Manage actions until close-out or handover at the end of FEED.

The workshop proceedings were recorded on HAZOP worksheets, which were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the offshore T&S HAZOP report. Actions relating to the offshore pipeline are included on the SAMS register.

Offshore SIL Workshop

A SIL workshop for the Offshore T&S system was conducted 20 November 2014. The scope of the SIL assessment included all instrumented control loops identified as having a potential protective function . The SIFs requiring assessment were identified prior to the SIL workshop, based on a review of P&IDs, with confirmation during the Pipeline HAZOP workshop.

The primary objective of the SIL workshop was SIL determination. Determination of a SIL provides a statistical representation of the required availability of the SIF to act on demand in order to achieve functional safety. This therefore enforces a requirement for implementation of a programme of routine maintenance and testing as required to maintain the SIL rating.

A terms of reference document was developed and issued before commencement of the workshop. The SIL workshop was facilitated by the same independent chairperson who facilitated the HAZOP study and the HAZID study and was attended by engineers from both NGCL and Genesis.

The SIL workshop procedure was based on a semi-quantified Risk Graph approach, which follows the standard IEC 61511. This risk graph approach used a number of parameters, which together described the nature of the hazardous situation which could arise when SIFs fail or are not available. These parameters allow a graded assessment of the risks to be made and represent key risk assessment factors. The basic approach was as follows:

- Identify SIF control loops within the project scope and record the tag and P&ID numbers – identified during the pipeline HAZOP;
- Determine the functionality of the loop and the potential safety hazards against which the loop is protecting;
- Identify possible causes for demand on the loop being evaluated;
- Evaluate the consequences if the loop fails on demand. At this point no credit shall be taken for other relevant independent risk reduction measures for example mechanical protective systems;
- Determine the SIL target for each function;
- Agree the environmental loss parameter (E) and use the environmental risk graph to determine the Environmental Integrity Level required on environmental risk considerations;
- Agree the financial loss parameter (F) and use the asset risk graph to determine the Asset Integrity level required on financial loss risk considerations;
- Determine the overall SIL requirement (i.e. the greater of the three IL numbers from Safety, Environmental and Financial Impact is taken);
- Where independent risk reduction measures existed, for example PSVs, credit was taken for those measures and a reduction in the integrity level was applied; and
- Record the results and any associated assumptions or actions.

The SIL workshop proceedings were recorded on SIL worksheets. The worksheets were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the SIL workshop report.

Offshore ENVID Workshop

An ENVID workshop for the Offshore T&S system was conducted 25 November 2014. The scope of the ENVID workshop included the beach crossing and the subsea pipeline and riser, with workshop objectives as follows:

- Identify potential impacts that the project may have on the environment;
- Identify potential environmental risks and constraints to the project;
- Identify environmental controls to minimize or eliminate potential impacts/risks; and
- Produce an environmental aspects register of potential significant effects, along with associated mitigation actions identified to be considered and carried out during the next stage of design.

The ENVID workshop was facilitated by an independent chairperson and was attended by engineers from both NGCL and Genesis. A terms of reference document was developed and issued before commencement of the workshop. The workshop procedure was as follows:

- Pre-populate the assessment worksheets with available information on the activity, its aspect and associated environmental impacts related to the activity;
- During the workshop, complete the worksheets including information on all environmental impacts;
- Risk rank impacts (using a likelihood x severity score) into low, medium and high significance/risk score; and
- Identify controls and actions.

Risk rank impacts with consideration of controls and mitigation.

The workshop proceedings were recorded on ENVID worksheets, which were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the offshore ENVID report. Actions applicable to the offshore pipeline system are included on the SAMS register.

Additional HAZOP Workshop (Offshore Transport)

A second HAZOP workshop for the offshore transport system was conducted 27th January 2015 (additional HAZOP workshop). The objective of the additional HAZOP workshop was to review operation of the system in year 10.

The additional HAZOP workshop was facilitated by the same independent chairperson as the original HAZOP workshop and was attended by engineers from both NGCL and Genesis.

Following on from the original workshop the onshore/landfall pipeline, subsea pipeline and fine filters up to the manifold formed a single node. It was agreed that the original worksheets could be used as a basis for the additional HAZOP review; and that the worksheets could be revised and updated as necessary to take account of additional equipment and to reflect the increased throughput.

The workshop proceedings were recorded on HAZOP worksheets. The worksheets were projected onto a screen during the meeting so that the meeting record was visible to all participants. The worksheets were subsequently included in the additional HAZOP workshop report. Actions relating to the pipeline are included on the SAMS register.

B.4.10 Dropped Objects Assessment

B.4.10.1 Introduction

A dropped objects assessment was conducted for the offshore T&S facilities. This included assessment of potential risk to the riser and to the pipeline within the 500m zone of the platform (in particular the spool piece). The primary aim of the pipeline and riser risk assessment was to determine if additional mechanical protection or procedural mitigation was required.

B.4.10.2 Platform and Pipeline Configuration

The riser is protected by its location within the jacket structure. The riser exit and spool piece tie-in are routed from platform south-west.

The supply boat approach will be from platform east. The laydown areas and platform crane are located at platform east. The jack-up approach will be from platform south.

B.4.10.3 Basis for Assessment

The scope of the study included:

- Routine lifting operations using the platform crane – associated with maintenance and re-supply operations and well workover activities; and
- Complex lift operations using the platform crane – associated with expansion installation activities.

Routine lifts are expected to take place at platform east. The Dropped Objects Assessment showed that for objects dropped at platform east, the lateral excursion of objects through a water depth of 59.3m is insufficient to impact the pipeline spool piece and tie-in.

As a worst case, it was therefore assumed that all objects are dropped at platform south thus providing a conservative basis for assessment of pipeline risk.

The dropped objects assessment was based on a detailed probabilistic analysis of risk. The assessment methodology was aligned with DNV-RP-F107 (Risk Assessment of Pipeline Protection).

B.4.10.4 Results

The total *seabed* impact frequency is estimated to be 1.12E-02 per year.

The total residual risk of impact on the pipeline itself is low (2.5E-07 per year) because the pipeline is largely protected by routing/location. The majority of the pipeline impacts (76%) are in the range 0 to20kJ. Impact energies >100kJ represent approximately 2% of the total i.e. damage frequency is approximately 5E-09 per year which can be taken to be negligible. The frequency with which impacts exceeding 168kJ may occur is <1E-09 per year – i.e. impacts which may cause >20% dent depth and could result in loss of containment. The frequency with which impacts between 20-109kJ may occur is of the order of 6E-08 per year – i.e. impacts which may cause between 5-15% dent depth, with no loss of containment but with potential impact on PIG operations. The total pipeline impact frequency represents less than 1% of the total drop frequency of 1.92E-03 per year.

B.4.10.5 *Protection Requirements*

The residual risk to the pipeline will remain low provided that the risk is managed through operational controls including the following:

- No lifting operations should be conducted at platform west;
- Restrictions should be placed on lifting operations using the jack up crane over the west of the platform above the subsea pipeline. All jack-up lifts should be subject to individual risk assessment; and
- All heavy or unusual lifts should be subject to risk assessment.

If these conditions cannot be met, this may increase the residual risk of pipeline impact.

Since there is uncertainty at this stage of the project about the scope of lifts which may be conducted by the jack-up, concrete mattressing is specified for the spool piece. The specification details are provided on the platform approach drawing.

The dropped objects assessment will be reviewed during detailed design.

B.4.11 Trawl Gear Interaction Analysis

B.4.11.1 *Basis for Assessment*

Commercial fishing activity is known to occur along the pipeline route. In the UK, commercial trawling is dominated by demersal trawling which is on bottom trawling often using otter boards or doors to keep the net open laterally. Survey information indicates that intensive trawl scars are present from KP 33.415 to KP 38.100 which indicates past trawling in the area.

A trawl gear interaction assessment was conducted to assess the potential effects of trawl impact, pull-over and hooking and to determine if additional protection measures are required.

The assessment basis was in accordance with DNV-RP-F111 (Interference between Trawl Gear and Pipelines). In the absence of detailed information on trawling activities and types of trawlers in use, the analysis used default vessel and equipment parameters given by DNV-RP-F111, based on the most onerous North Sea fishing fleet data.

Details of the assessment methodology and assumptions are provided in the offshore pipelines infrastructure design report.

B.4.11.2 *Results*

The following conclusions were drawn from the study:

- The concrete weighted coating provides protection against trawl gear direct impact damage for pipeline sections on the sea bed. Concrete spalling is likely to occur after impact, however, due to the large specified concrete weighted coating thickness (up to 160mm) and 145mm of additional wire mesh, the majority of the concrete weighted coating thickness should be protected from spalling. The pipeline can be left on the sea bed without further protection against trawl gear impact provided the concrete weighted coating is not damaged during installation or due to the trawl gear impact. Regular pipeline survey should be carried out to check and assess the integrity of the concrete weighted coating. If

there are areas where the concrete weighted coating has been damaged, these areas should be protected by rock dumping;
- To avoid overstressing the pipeline during a pull-over event, the free spans should be limited; and
- To avoid hooking of clump weights and beam trawling equipment, a maximum free span gap of 0.5m is permitted. Gaps above this height should be rock dumped for protection. Warp line breaking strength and boat winching capacity should be reviewed for the area to assess the hooking potential of trawl board fishing type.

The effects of trawl gear impact loading, pullover and hooking should be reviewed when more detailed information on trawling activities is available including information on the intensity of the trawling activities and types of trawlers (size, mass, speed and warp line/boat capacity).

B.4.12 CFD Pipeline Venting Dispersion Analysis

B.4.12.1 Introduction

CFD models for the Platform and the Barmston Pumping Station were developed to enable venting dispersion and major accident dispersion modelling to be conducted, thus allowing more accurate representation of the interaction between the plume and the topography and local geometry. The CFD models were used for the pipeline venting dispersion analysis, with consideration of venting both onshore (at the Barmston Pumping Station) and offshore (at the platform).

B.4.12.2 Development of Venting Input Data

Depressurisation data for the pipeline was developed as part of the flow assurance transient report using OLGA v7.3, with fluid properties governed by Multiflash 4.1 and GERG 2008 equation of state. The data developed included the orifice size and the peak and plateau rates. The plateau rate describes the lower stepped down flowrate where the depressurisation rate plateaus from its initial peak rate.

The dispersion modelling input data associated with thermal relief valve 34-PRV-052 (on the piping section at the top of the riser) was developed using the AspenTech HYSYS Dynamics Package, with fluid properties governed by GERG 2008 equation of state. A peak relief rate was developed. The valve is provided for thermal expansion overpressure relief due to solar gain so the required orifice area is small. A standard relief valve orifice of an ASME 5 Crosby valve (with an area of 54.2mm^2) was selected for all the thermal reliefs. Dynamic simulation of a representative relief valve showed complex lift/rest cyclic behaviour over the course of an hour, with the lifts lasting approximately three minutes and the rest periods lasting 4 to 5 minutes. It is noted that the observed lift/rest behaviour is applicable to the representative relief valve type considered and may not be applicable to a different valve specification. However, for the purposes of the dispersion analysis, a release duration of three minutes at the peak rate was modelled. This provided a suitably conservative basis for assessment since, in practice, the discharge rate will decrease towards the end of the lift period.

Table B.30 provides a summary of the manual venting cases associated with the pipeline.

Table B.30: Pipeline Manual Venting Dispersion Cases

Case	Description	Discharge Location	Wind direction	Wind speed
V3.1	Manual Vent Pipeline	Offshore vent boom	From platform east	Low (90% exceedance)
V3.2				Medium (50% exceedance)
V3.3				High (10% exceedance)
V3.4			From platform north	Low (90% exceedance)
V3.5				Medium (50% exceedance)
V3.6				High (10% exceedance)
V4.1	Manual Vent Pipeline	Barmston Year 1-5 Permanent Stack	From plant south	Low (90% exceedance)
V4.2				Medium (50% exceedance)

B.4.12.3 *Development of Barmston and Platform CFD Models*

Barmston CFD Model

Barmston Pumping Station CFD model was based on the three dimensional PDMS model dated 15/01/2015, engineering drawings. One subsequent update to the initial CFD model was made to reflect design changes to the following vent stack arrangements:

- Venting of Barmston PIG Launcher – changed from discharge at a vent stack (6.5m tip height) to a local vent with tip height 3m; and
- Venting of offshore pipeline – permanent stack added at year 1 to 5 array.

The final CFD model explicitly represented all large geometrical details that have the potential to affect local airflow patterns and therefore dispersion behaviour. This included all buildings/shelters, equipment items, above ground large bore piping, primary structural supports, security fence, retaining wall and local topography. Smaller items (such as small bore pipework, stairs, ladders), were judged not to significantly influence local airflow and were therefore not included.

Platform CFD Model

The platform CFD model was based on the three dimensional PDMS model dated 26/02/2015 and additional engineering drawings. The CFD model explicitly represented all large geometrical details that have potential to affect local airflow patterns and therefore dispersion behaviour including the helideck, crane, accommodation building, structural supports, process and utility equipment, large bore pipework, decks and staircases. Smaller items such as small bore pipework were excluded.

B.4.13 Ventilation Analyses

B.4.13.1 *Barmston Pumping Station*

A ventilation analysis was conducted to:

- Assess the effects of the site topography on local airflow patterns inside the landscape mounds; and
- Identify stagnant areas and the conditions under which they develop, as these areas may in turn adversely affect local dispersion behaviour during venting operations or under major accident event conditions.

An analysis of wind rose data from the Leconfield Station (November 2009 to October 2014) was conducted. A wind speed probability distribution was derived, with average omni-directional values as follows:

- 90% annual exceedance wind speed – 1.2m/s;
- 50% annual exceedance wind speed – 3.9m/s; and
- 10% annual exceedance wind speed – 7.9m/s.

The probability of wind speeds exceeding 1 m/s was found to be very low (occurring approximately 1% of the time). The predominant wind direction is from plant west-southwest (occurring approximately 55% of the time). A total of 12 wind directions were simulated in the ventilation analysis (0 to 330°). 10%, 50% and 90% exceedance wind speeds were simulated in each of the 12 wind directions.

In general, large low-velocity recirculation zones were observed in the wakes of large structures such as the landscape mounds and the pump buildings. The extent of the stagnant zones was particularly significant when the wind direction was from plant north or south and less so when the wind direction was from plant west. When the wind direction is from plant north, the vertical extent of the recirculation zone in the wake of the pump buildings may extend up to approximately 7m to 9m. Above this recirculation zone elevation, the wind flow will be relatively undisturbed.

The conclusions of the ventilation analysis were as follows:

- The local geometry of Barmston Pumping Station (buildings and retaining walls) induces large stagnant areas with recirculation of air for all wind directions that could lead to larger gas accumulation under those ambient conditions;
- This effect could be more pronounced for smaller (or buried) releases which have a lower initial jet momentum;
- The worst case scenarios in terms of volume of stagnant regions were observed for winds coming from the plant north, east and south;
- Winds coming from the plant west were found to give slightly better natural ventilation; and
- The stagnant regions can vertically extend to an elevation of up to around 7 to 9m, which is similar to the elevation of the vent stack tips. This could hamper gas dispersion from controlled venting, in particular when winds are from the plant north.

The potential effects of stagnant areas on local dispersion were studied as part of the dispersion analysis in section B.4.13.5.

B.4.13.2 Platform

An analysis of wind rose data for the field was conducted. A wind speed probability distribution was derived, with average omni-directional values were as follows:

- 90% annual exceedance wind speed – 3.4m/s;
- 50% annual exceedance wind speed – 7.8m/s; and
- 10% annual exceedance wind speed – 13.6m/s.

The predominant wind directions are from the platform west-southwest sectors (approximately 40% of the time). The remaining wind directions show a fairly uniform occurrence probability distribution.

B.4.13.3 *Venting Dispersion Model Validation*

Field scale experiments for vertical vent releases and horizontal releases from shock tube of dense phase CO_2 were commissioned by National Grid as part of the COOLTRANS research program. The COOLTRANS tests were conducted at the Spadeadam Test Site.

A CFD dispersion model validation study was conducted for the Barmston venting dispersion model, using test case data from two of the COOLTRANS field scale experiments (Test 7 and Test 11). Both COOLTRANS test cases involved vertical vents.

The CFD simulations used similar initial discharge and ambient conditions as the test cases. For the purposes of the CFD modelling, with the primary interest being mid to far field dispersion, the initial discharge conditions from the test cases were recalculated into an equivalent vapour source located a short distance downstream of the discharge location. Calculation of an equivalent vapour source allowed a reduction in computational time because phase changes and behaviours in the near field including high-speed compressibility effects, expansion and liquid flashing, solid particle formation and sublimation are not modelled.

The equivalent vapour source was modelled as a cylindrical momentum source with known exit velocity, vapour mass flow rate, initial air entrainment, mixture temperature and initial turbulence parameters.

The conclusions of the CFD venting dispersion model validation study were as follows:
- There is reasonable alignment between the CFD dispersion model predictions and the COOLTRANS test cases in terms of both vertical penetration of the plume and ground level concentrations; and
- The level of accuracy of the CFD dispersion model is suitable when modelling vertical vent releases.

B.4.13.4 *Definition of Dispersion Modelling Limits*

The criteria of interest in the venting dispersion analyses were as follows:
- Occupational exposure limits – 1.5% Short Term Exposure Limit (STEL) (15 minutes) and 0.5% Long Term Exposure Limit (LTEL) (8 hours) concentration thresholds;
- SLOT DTL – 1.5×10^{40} ppm^8.min; and
- SLOD DTL –1.5×10^{41} ppm^8.min.

B.4.13.5 *Dispersion Modelling Results*

Pipeline Venting at Barmston Pumping Station

The pipeline manual venting dispersion modelling shows that when the wind speed is low there will be blanketing around the vent stack tip, with a subsequent plume slump to ground. For worst case low winds speeds and wind directions, which produce sheltering effects at the vent stack location, the fully developed plume will affect large parts of the process area. Cumulative exposure (SLOD and SLOT) envelopes over a one day period show that there is minimal potential for impact at the administration building area.

For worst case wind directions, the fully developed plume will also affect the administration building area. Concentrations at the administration building area will not exceed the 1.5% STEL threshold; however concentrations will reach the LTEL threshold of 0.5%. The plume is also likely to extend beyond the security fence. Concentrations at the security fence will not exceed the 1.5% STEL threshold; however, concentrations will reach the LTEL threshold of 0.5%.

No source blanketing and plume slump behaviour is observed for medium or high wind speeds (50% and 10% exceedance respectively). The modelling shows that the plume disperses freely and does not come to ground on site at concentrations exceeding the LTEL, however the plume may come to ground offsite.

The pipeline dispersion modelling results are provided in the Barmston pumping station CFD venting dispersion analysis report.

Pipeline Venting at Platform

When conducting pipeline venting operations under low and medium wind speed conditions, the discharge will slump to the sea surface, with significant spread of the gas plume at the STEL concentration level (up to 300m). The LTEL envelope may exceed 400 m (400m was the limit of the computational domain).

The SLOD and SLOT envelopes (based on a duration of one day) also have potential to extend 50m and 100m respectively from the platform. Venting the pipeline under these conditions could therefore affect supporting activities such as supply vessels located in the vicinity of the platform or standby vessel located within the 500 m zone of the platform. However, in practice supply boats should not be present during manual venting operations and the use of a standby vessel would not be required for the duration of the venting operation (which could be up to several days). The pipeline manual venting discharge does not affect the topsides under any wind conditions.

The pipeline venting dispersion modelling results are provided in the offshore topsides CFD venting dispersion analysis.

Relief Valve Venting at Platform

The dispersion modelling shows that due to routing, location and orientation of the discharge line, the relief valve discharge will freely disperse underneath the platform in all wind conditions. The plume does not impact the topsides.

The relief valve dispersion modelling results are provided in the Offshore Topsides CFD Venting Dispersion Analysis.

B.4.14 Pipeline Assessment

B.4.14.1 Introduction

An assessment was conducted for the Offshore T&S scope of design, including the onshore/landfall pipeline and the subsea pipeline.

The purpose of the Pipeline assessment was to:
- Determine the residual risk associated with the offshore pipeline FEED;
- Assess the residual risk against UK HSE risk tolerability criteria; and

- Identify opportunities for risk reduction in design and, where relevant, assess the potential risk vs cost benefit of design implementation.

The basis for the assessment was agreed prior to commencement of the study and an assumptions register was included in the final report.

The subsections that follow focus on the pipeline assessment, including the onshore/landfall pipeline and subsea pipeline and riser. The full assessment, including the platform, is detailed in the platform and offshore pipeline assessment Report.

B.4.14.2 Assessment Basis

Failure Case Definition

A desktop study was conducted to identify the pipeline major accident hazards/accident events that required assessment. The results of the desktop study are presented in Table B.31.

Table B.31 shows the pipeline process failure case, defined by pipeline isolation valves 34-ESDV-004 at Barmston Pumping Station and 34-ESDV-005 at the platform.

Table B.31: Desktop Review

Hazard	Potential Causes	Potential Consequences	Include in Assessment?
Process Hazards – Pipeline Onshore/Landfall			
Process release – buried pipeline (within Barmston site)	Material/fabrication defect Ground movement	Near field impinged jet Toxic/asphyxiating gas Personnel injury/fatality Third party injury/fatality	Yes
Process release – buried pipeline (offsite Barmston to Landfall)	Material/fabrication defect Ground movement Third party excavation	Near field impinged jet Toxic/asphyxiating gas Third party injury/fatality	Yes
Process Hazards – Pipeline Subsea			
Process release offshore – near shore	Material/fabrication defect Ground movement Vessel grounding	Diffuse source at sea surface Toxic/asphyxiating gas Third party injury/fatality	Yes
Process release offshore – open water	Material/fabrication defect Ground movement External impact (for example trawl board impact, pull over or hooking, dropped anchor)	Diffuse source at sea surface Toxic/asphyxiating gas Minor stability impact on vessels in the area	Yes
Process release offshore – within exclusion zone up to tie-in spool	Material/fabrication defect Ground movement Dropped object	Diffuse source at sea surface Toxic/asphyxiating gas Injury/fatality at platform Minor stability impact on attendant vessels within exclusion zone (for example standby vessel)	Yes

Hazard	Potential Causes	Potential Consequences	Include in Assessment?
Process Hazards – Riser			
Import riser release – below water	Material/fabrication defect (External impact unlikely as riser is routed within jacket structure)	Diffuse source at sea surface Toxic/asphyxiating gas Personnel Injury/fatality	Yes
Import riser release – above water including splash zone	Material/fabrication defect Exposure/brittle fracture (for example topsides release) (External impact unlikely as riser is routed within jacket structure)	Toxic/asphyxiating gas Personnel Injury/fatality Cryogenic/abrasive jet Topsides equipment damage/escalation	Yes

Table B.32: Pipeline Failure Case

Isolatable Section	Description	From	To	Volume (m^3)
15	Offshore Pipeline (including onshore/landfall pipeline, subsea pipeline and riser)	34-ESDV-004	34-ESDV-005	23496

B.4.14.3 Hole Size Basis

The selected major accident hole size basis was as follows:

- 10mm – to represent small leaks; and
- 20mm – to represent medium leaks.

Full bore – to represent pipeline rupture.

Leaks smaller than 10mm, typically associated with corrosion related failures, were considered to be less credible for this pipeline. Use of a three-hole size basis is reasonable for the pipeline, the assumption being that the medium hole size provides a limit beyond which a leak will quickly propagate into a full bore rupture.

B.4.14.4 Wind Speed Data

The onshore and offshore wind speed conditions are as described in section B.4.13.

B.4.14.5 Consequence Modelling

Initial leak conditions (10mm and 20mm) were developed using AspenTech HYSYS dynamics package, with fluid properties governed by GERG 2008 equation of state. Leak rates were modelled as constant. Discharge conditions for the pipeline rupture cases were modelled using DNV PHAST v.6.7 to facilitate modelling of transient release from the two open pipeline ends.

On the onshore/landfall section, it was assumed that all leak sizes have potential to cause displacement of soil resulting in formation of a crater. Predictive models for crater size modelling were based on those developed for the COOLTRANS research programme.

It was assumed that subsea releases would expand as they rise through the water to form a diffuse source on the sea surface. Calculation of the initial source term was based on a simple cone model which assumes that the resulting plume occupies a cone of fixed angle such that the radius of the diffusing area at the sea surface is a fixed proportion of the water depth. The simple model does not take into account potential effects of interaction with water currents (the extreme current speed for a return period of 1E-04 per year is 1.16m/s at mid-depth. For releases near the platform, it was assumed that the diffuse source will form above the point of release.

The discharge models provided input into development of the equivalent vapour sources for use in the CFD modelling cases. The major accident dispersion model was also subject to model validation against experimental data from the CO2PIPETRANS JIP. This analysis is described in detail in the CFD atmospheric dispersion model validation report.

Table B.33: Pipeline Major Accident Dispersion CFD Simulations

Isolatable Section	Description	Release Location	Hole Size Basis	Wind Direction	Wind Speed
15	Onshore/landfall section	Crater – Barmston Pumping Station (plant south east)	10mm 20mm Full bore rupture	From (Barmston) plant south	Low (90% exceedance)
15	Onshore/landfall section	Crater – rupture approximately 700m downstream of Barmston	10mm 20mm Full bore rupture	From true north-east, From west	High, Medium, Low (10%, 50%, 90%)
15	Onshore/landfall section	Beach	10mm 20mm Full bore rupture	From true north-east	High and Low (10% and 90%)
15	Subsea section	Bottom of riser (-60m depth)	10mm 20mm Full bore rupture	From south-west	
15	Subsea section	Halfway up riser (-30m depth)	10mm 20mm Full bore rupture	From south-west	
15	Riser	Splash zone	10mm 20mm Full bore rupture	From platform south	High and Low (10% and 90% exceedance)
15	Platform section	Cellar Deck (upstream of 34-ESDV-005)	10mm 20mm Full bore rupture	From platform south	High and Low (10% and 90% exceedance)

B.4.14.6 Consequence Modelling Limits and Harm Criteria

The consequence modelling limits were defined by harm and fatality criteria, which are summarised in Table B.34.

Table B.34: Modelling Limits and Fatality Criteria

Pipeline Location	Criteria/Limit	Basis
Onshore/Landfall	SLOT = 1.5 x 1040 ppm8.min SLOD = 1.5 x 1041 ppm8.min	Potential impacts based on dose criteria
Open water subsea	0.5%	Impacts based extent of LTEL contour due to potential receptor being transient
Riser/pipeline within exclusion zone	8.6%	Impacts on personnel based on short term exposure fatality rule-set as per assumptions register
	9.4%	
	10.8%	
	12.3%	

B.4.14.7 Frequency Assessment

Statistical pipeline leak frequency data was based on the following:

- Onshore/landfall section – 9th EGIG report (1970-2013) (gas transmission pipelines); and
- Offshore section – International Association of Oil and Gas Producers (IAOGP) Risk Assessment Data Directory, which is based on an re-analysis of PARLOC data (gas pipelines).

EGIG does not include data from fittings/components on the pipeline. The IAOGP data does include component contributions although further analysis of component frequencies is not provided in the PARLOC database. Leak frequency contributions from fittings/components at the upstream and downstream ends of the pipeline were based on data from the UK Offshore Hydrocarbon Release Database which provides data from all reported incidents in the North Sea in the period since 1992. Data up to 2013/2014 was included.

The detailed frequency assessment is provided in the platform and offshore pipeline assessment report.

B.4.14.8 Risk Results

Pipeline Section Inside Barmston Fence

The offshore pipeline is routed partially through Barmston Pumping Station from plant south-east to south-west. The results show that if there is a pipeline loss of containment, there should be no SLOD or SLOT exceedance at the nearby process area from small or medium (10mm or 20mm leaks). The process area is taken to be a nominal point near the recycle cooler. However, there is potential for exceedance of the dose criteria at the process area from full bore releases. In developing the risk transect, no credit was taken for wind directionality. The distance to the process area is approximately 22m (exceedance frequency 2E-04 per year).

Onshore/Landfall Section

As for the Barmston Pumping Station pipeline section, exceedance of SLOD and SLOT criteria from onshore/landfall pipeline releases will only occur within close proximity of the release. No credit is taken for wind directionality.

Based on a nominal rupture location upstream of the cliffs, the results show that there should be no exceedance of concentrations above the LTEL at the nearest population centres.

Subsea Section

Risks from a leak or rupture on the subsea section of pipeline have been considered within the context of potential impacts on personnel on an attendant vessel (for example standby vessel), with potential impacts on third party vessels (for example fishing trawler) assumed to be similar. The nominal impact height is assumed to be approximately 6m above the sea surface, with the standby vessel height taken as 5m above sea surface (based on Genesis' experience on another project) and the average height of a person in a range of postures assumed to 1m.

The results show that there is potential for the plume elevation from full bore releases to extend to the assumed deck elevation of a standby vessel. The total frequency (over the full pipeline length) with which a full bore release event may occur is 4.5E-04 per year. However, the personnel or third party exposure probability (and therefore associated risk) is likely to be orders of magnitude lower because the presence of a vessel and proximity to the pipeline will be transient. This is particularly true of third party vessels. An attendant vessel such as a standby vessel is likely to be aware of the pipeline location and is unlikely to anchor in close proximity to the pipeline.

Table B.35: Impacts from Subsea Releases

Hole Size (mm)	LTEL Contour Elevation (Low Wind Speed 90% Exceedance)	Total Event Frequency/Year	Potential for Impact on Person at Vessel Deck Level
10	4.2 m	–	No
20	5.2 m	–	No
FB	12 m	4.5E-04	Yes

Spool Piece, Riser and Topsides Section

The modelling results show that the plume from a leak or rupture on the spool piece or the bottom of the riser (~60m water depth) will not reach cellar deck elevation at concentration exceeding 0.5% CO_2 (LTEL), even under low wind speed conditions.

The plume from small to medium leaks on the wetted section of the riser (at approximately ~30m water depth) will not reach cellar deck elevation at concentrations exceeding 0.5% CO_2 (LTEL). The plume from a full bore release at this location does have potential to affect the topsides at concentrations up to 4% CO_2 but will not exceed the concentration-fatality levels. A concentration level of 4% is used as one of the impairment thresholds in the platform EERA and this event has been included in the platform EERA.

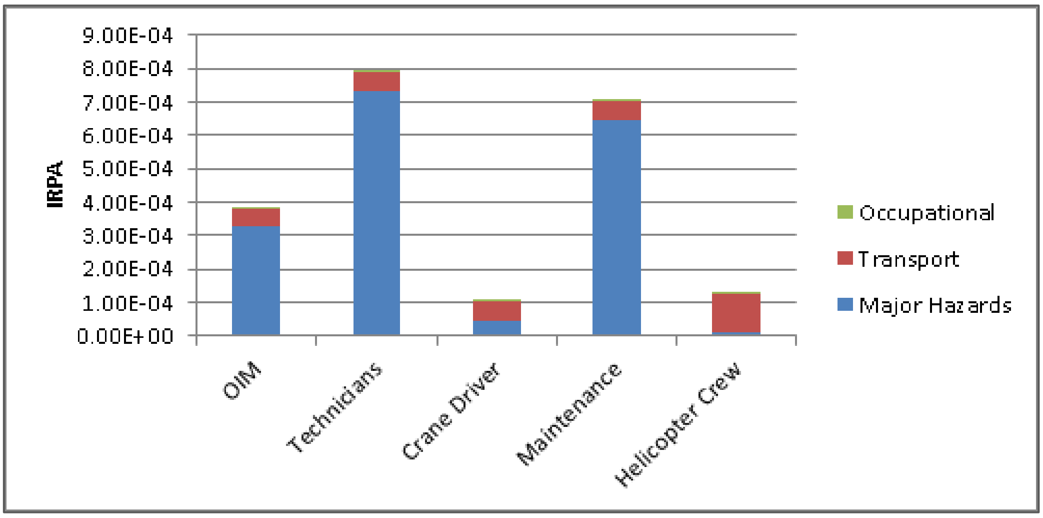
The plume from leak and rupture events on the riser section above the splash zone has potential to affect the topsides at concentrations exceeding the concentration-fatality levels. These events have been included in the platform and offshore pipeline assessment. Leak and rupture events on the pipeline section on the cellar deck (just upstream of 34-ESDV-005) have also been included in the platform and offshore pipeline assessment.

B.4.14.9 Residual Risk to Personnel on Platform

The residual risk to personnel on the platform, including from riser releases have been assessed as part of the platform and offshore pipeline assessment.

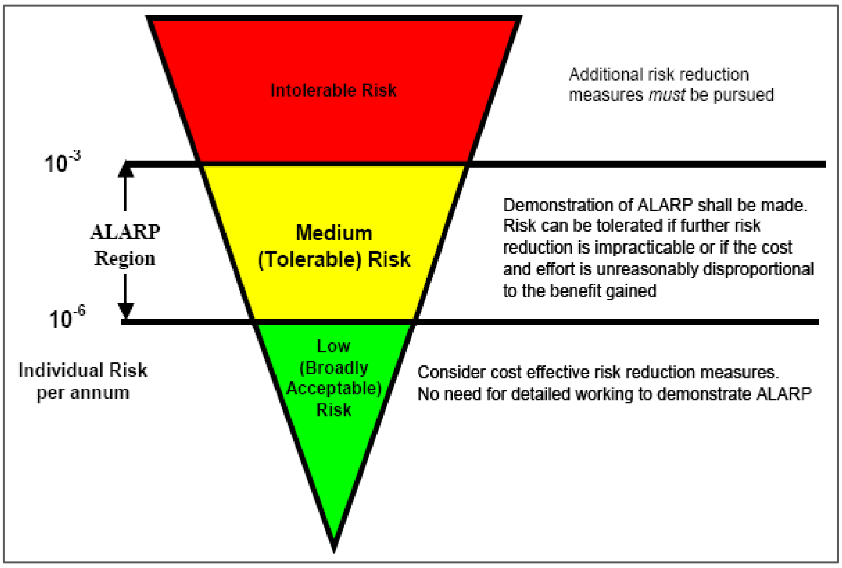
Figure B.5 provides a summary of the residual risks to personnel by worker group. The most exposed worker group are the technicians with a total (process and non-process) individual risk per annum (IRPA) level of 7.9E0-4 per year. The individual risks for all worker groups are the UK HSE risk tolerability criterion of 1E-03 per year. For all worker groups, the risk levels lie within the tolerable region of the ALARP triangle (depicted in Figure B.6), with demonstration of ALARP required. The ALARP summary is provided in the design integrity and risk overview report.

Figure B.5: Individual Risk per Annum (IRPA) by Worker Group



Note: the Major Hazards category includes process, vessel impact and helicopter impact risk.

Figure B.6: ALARP Triangle



B.4.15 Requirement for Subsea Isolation Valve

The requirement for a subsea isolation valve on the pipeline was assessed as part of the offshore pipeline assessment to determine if there is a potential risk benefit of provision of a subsea isolation valve on the pipeline. For the purposes of the analysis, it was assumed that the subsea isolation valve would be located at the bottom of the riser thus limiting the inventory available for release as that between the subsea isolation valve and 34-ESDV-005 (which isolates the pipeline from the topsides).

The assessment results show that the potential risk reduction gained from installation of a subsea isolation valve on the pipeline would be negligible; there is a reduction in evacuation fatality risk of the order 0.002%. On this basis, this option is ruled out.

B.4.16 Safety Critical Elements and Performance Standards

B.4.16.1 Introduction

The process of safety critical element management involves:

- Identification of safety critical elements; and
- Development of performance standards.

Ensuring that the minimum performance standards are achieved and maintained throughout the design life (verification scheme).

The safety critical elements in the offshore T&S system were identified and outline (high level) performance standards for each safety critical element have been developed. This process is described in the subsections that follow. Assurance and verification are outside the FEED scope of work and are typically required towards the end of detailed design.

B.4.16.2 *Identification of Safety Critical Elements*

Assessment Procedure

Identification of safety critical elements in the offshore T&S system was based on a structured approach as shown in the flowchart in Figure B.7. The flowchart illustrates how major accident hazards have been identified and analysed and measures taken to prevent, detect and mitigate their consequences, leading to the identification of safety critical elements. The assessment process is detailed in the safety critical elements and performance standards report; and outlined below:

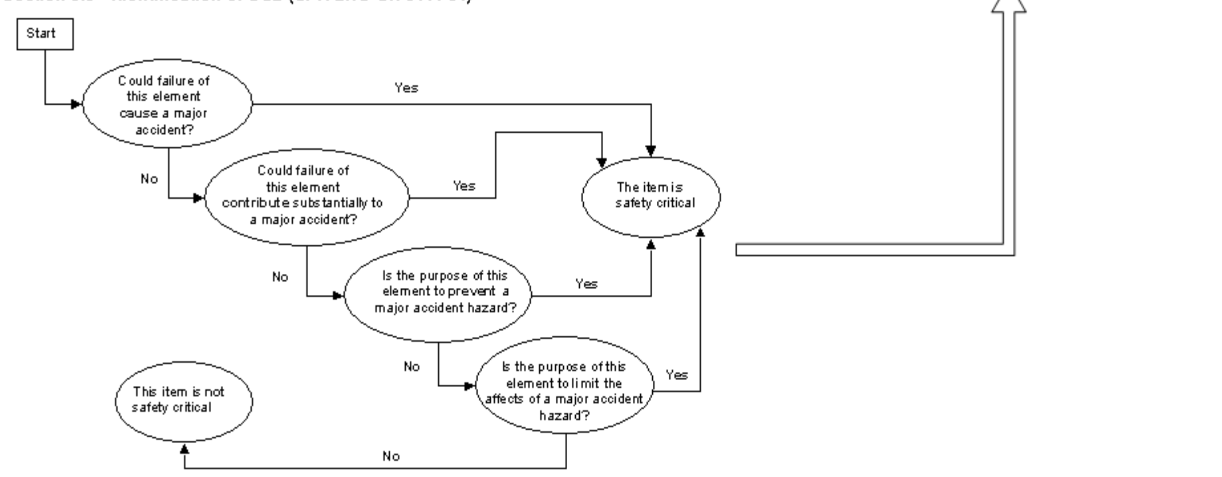
- Step 1 (planning) – A desktop review was conducted in lieu of a formal safety critical element identification workshop;
- Step 2 (identification of major accident events) – This step involved identification of major accident hazards and assessment of their potential to develop into major accident events. A generic list of major accident hazards was developed based on the definition of a major accident given by The Offshore Installations (Safety Case) Regulations 2005 [Note 1]. The formal workshop (HAZID and HAZOP) reports were reviewed to identify the project specific hazards, and then the project specific hazards were assigned to the generic hazard categories. Each project specific hazard was then considered in turn to assess the factors that affect the nature of the major accident events. For example, for loss of containment events the review included the nature of dense phase CO_2, the release location and the discharge conditions; and
- Step 3 (identification of safety critical elements) – Step 2 also facilitated understanding of measures that are in place to prevent, control and mitigate the consequences of major accident events and whether the identified measures are safety critical.

Figure B.7: Safety Critical Element Identification Procedure

1: Planning	2: Identify MAE			3: Identify SCE
1.1 Req. to identify SCE & PS 1.2 Plan SCE workshop 1.3 Define boundaries 1.4 Establish docs req. 1.5 Form team (conduct studies)	2.1 Review MAH	2.2 Define & Describe MAE	2.3 Develop MAE 2.4 Record MAE	3.1 Document SCE process 3.2 Identify Prevention measures 3.3 Identify Control measures 3.4 Identify Mitigation measures 3.5 Define SCE 3.6 Identify SCE (See Flowchart) 3.7 Review SCE

Study	Worksheet	Major Accident Hazard (condition - potential for harm)	MAE Potential (cause of concern)	Major Accident Event	Safety Critical Measures		
HAZID.	- Guideword - Concern - Conseq. - Safeguard - Recomm.	- Hydrocarbon inventory - CO2 inventory - Lifting operations - etc.	- Description - Material released - Location - Pressurised / Non-press.	- Fire - Explosion - Toxic / Asphyx. Release - etc.	Prevent	Control	Mitigate

Section 3.6 - Identification of SCE (CPR-ENG-GN-0114-01)



Report			
Section 3.1 & 5.1.1	Section 6 (& Appendix A)	Section 7 (& Appendix A)	Section 8 (& Appendix B)

Note 1: Major accident" means:

a) A fire, explosion or other release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it

b) Any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installation

c) The collision of a helicopter with the installation

d) the failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations;

e) Any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity in connection with it

B.4.16.3 Safety Critical Elements Affecting the Pipeline

The safety critical elements affecting the pipeline system are as follows:

- CO_2 Containment (Pipeline and Riser) – preventive function; and
- Emergency Shutdown System – control function.

B.4.16.4 *Development of Outline Performance Standards*

Outline (high level) performance standards have been developed for the pipeline and the emergency shutdown system. The performance standards outline the minimum functional, survivability and availability requirements that the safety critical elements must achieve to meet its safety critical function.

B.4.17 Emergency Systems Survivability Assessment

B.4.17.1 *Introduction*

An Emergency Systems Survivability Analysis (ESSA) was conducted to:

- Identify emergency systems that should be considered for analysis within the ESSA;
- Assess the ability of the emergency systems to survive and control the Major Accident Event (major accident events) or facilitate emergency response actions; and
- For any systems found to be vulnerable to major accident events damage without being fail safe or fully redundant, provide recommendations for further assessment or risk reduction.

B.4.17.2 *Assessment Basis*

The first stage in the ESSA involved identification of emergency systems, defined as:

"Those systems that are required to operate in the period immediately after an accident so that the required emergency response actions can be executed and risk to personnel who survive the initial event is as low as reasonably practicable (ALARP)"

The starting point for identification of emergency systems was the list of safety critical elements, developed as described in section B.4.16. A further screening exercise was then conducted to identify which safety critical elements have system components which are required to remain functional immediately after a major accident event in order that the consequences of the incident can be minimised. From the screening exercise:

- CO_2 Containment (Pipeline and Riser) – not required to remain functional following a major accident events; and
- Emergency Shutdown System – has components which are required to remain functional and is therefore subject to ESSA.

B.4.17.3 *Results*

The assessment conclusion was that the acceptance criteria are met and no requirement for additional mitigation is identified. The basis for this conclusion was as follows:

- 34-ESDV-004 (at Barmston) – Valve is not significantly vulnerable to process release impact and is designed to fail closed;
- 34-ESDV-005 (top of riser) – Valve may be vulnerable to abrasive/cryogenic impact from high pressure process releases, but is designed to fail closed; and
- ESD panel, local cabling and ICSS interface – No significant vulnerability to major accident events is identified and alternative means of activating ESD are provided.

B.4.18 Summary of Significant Risks

B.4.18.1 Overview

This section provides a summary of the primary risks identified during the offshore pipeline FEED, for which further consideration during detailed design is required. Identification of risk was based on a structured formal workshop approach which included HAZID workshops, HAZOP workshops and technical assessments.

B.4.18.2 Significant Risks/Risk Management

Minimum Temperature during Depressurisation

Minimum fluid temperatures during the offshore pipeline depressurisation process will not be as low as for the onshore pipeline. This is primarily because the surrounding ambient fluid is seawater, which is a far better heat source than soil due to the significantly higher heat capacity.

The flow assurance transient report shows that a minimum fluid temperature of approximately -5°C is reached during pipeline depressurisation through a 1in orifice at the platform. Additional Charpy testing is required to ensure the pipeline can maintain integrity at lower temperatures down to -2° C.

B.4.18.3 Third Party Activity on Pipeline Route

Mining Activity

FEED documentation supplied by NGCL does not indicate any mining activity on the pipeline route. However, route surveys should be conducted during detailed design to provide confirmation of local conditions along the route. The pipeline way leave allows for minor, local adjustments of pipeline route if necessary. This requirement is recorded in the FPSA register under HSE action number 127.

B.4.18.4 Magnetic Anomaly

A magnetic anomaly has been identified west of the existing Wollaston–Whittle gas assets. There is no seabed surface indication of this feature, which may potentially represent a chain, wire, umbilical or pipeline resulting in a possible need for an additional crossing. A further pre-construction survey is required to identify the nature of the magnetic anomaly. There is currently no ownership assigned to this potential feature and therefore no third party restrictions on potential crossing design and construction. This requirement is detailed in the offshore pipeline third party crossing constraints report.

B.4.18.5 Dogger Bank Cable Crossings

The offshore pipeline FEED includes a proposed design for the pipeline crossing of the future Dogger Bank Creyke Beck HVDC cables. However, information on cable design, number, actual crossing locations and installation schedule is not yet available. The cable specification is required to be established during detailed design in order to ensure the final crossing design takes into consideration the cable design, installation and operational requirements.

This requirement is detailed in the offshore pipeline third party crossing constraints report.

B.4.19 Selection of Materials

There is a requirement to ensure that suitable non-metallic polymeric material seals are used for all components used in CO_2 service. Due to the solvent properties of CO_2 when in supercritical phase, commonly used polymers may absorb the CO_2 leading to swelling and changes in their physical properties. Polymeric materials proposed for use in valves, flanges and isolation joint sealing should therefore be demonstrated (through testing) to be suitable for use in CO_2 service.

This requirement is recorded on the SAMS register under HSE action number 66 which was raised during the onshore pipeline HAZOP, however the action is also applicable to components on the upstream and downstream ends of the offshore pipeline isolatable section.

B.4.20 Composition of Gas from CPL (and Future Emitters)

The composition of feed gas will be assured by CPL and future emitters. Exceedance of the feed gas impurity thresholds may result in:

- Corrosion, if free water (>50ppmv) is allowed into the system; and
- Adverse impact on the phase boundary if trace levels of N_2, O_2 and H_2 are exceeded.

The CPL production system includes a cold box which would freeze out any water and also provides product analysis to ensure the feed gas specification requirements. It is recommended that CPL (and future emitters) should be required to provide a continuous feed to NGCL of the product analyser and the upstream water analyser output.

This requirement is recorded on the SAMS register under an HSE action.

B.4.21 Actions List Status

All actions, including those required to mitigate the risks, were transferred to the formal process safety assessment close-out report register.

The register provides a record of all actions logged from formal workshops, audits and reviews and includes background notes and references from the source documentation.

Use of the formal process safety assessment close-out report register ensured that:

- All design safety actions were recorded and notified to lead discipline engineers;
- All actions could be tracked;
- The method of resolving actions was recorded so that there was a clear and auditable trail;
- All action responses could be reviewed and reference documentation checked, before formal sign off by the engineering manager as part of the acceptance and closure procedure; and
- Any actions not closed at the end of FEED could be taken forward to detailed design.

The offshore actions list status (including the pipeline and platform) is provided in the formal process safety assessment close-out report.

B.4.21.1 *Outstanding Safety Design Actions Areas*

A number of safety design areas have been identified as requiring more detailed review and technical safety assessment to aid design optimisation during detailed design. The identification of these safety design optimisation areas is based on:

- Review of outstanding actions which could not be closed out during FEED; and
- Areas requiring technical safety assessments where those assessments were outside of the Genesis FEED scope of work.

The safety design areas requiring further assessment are discussed in the sections that follow.

Fishing Gear Interaction

A detailed trawl gear interaction analysis has been conducted as detailed in the offshore pipelines infrastructure design report.

In the absence of detailed information on trawling activities and types of trawlers in use, the analysis used default vessel and equipment parameters given by DNV-RP-F111, based on the most onerous North Sea fishing fleet data.

The effects of trawl gear impact loading, pullover and hooking should be reviewed when more detailed information on trawling activities is available including information on the intensity of the trawling activities and types of trawlers (size, mass, speed and warp line/boat capacity).

Layer of Protection Analysis

One of the hazards considered in the onshore transport system SIL workshop was overpressure of the offshore pipeline, for example due to a stuck PIG or spurious closure of 34-ESDV-005 at the platform, resulting in loss of containment. This scenario was included in the onshore workshop because the HIPPS package is located at the Barmston Pumping Station.

The SIL workshop procedure was based on the risk graph approach. There is a requirement to conduct a Layer of Protection Analysis (LOPA) to allow for better representation of the mitigating factors that could prevent the failure sequence of events. The LOPA should be conducted during detailed design once NGCL have set a TMEL. This requirement is recorded as an action on the SAMS register.

B.4.22 Performance Standards

There is a requirement to develop a complete and comprehensive set of design performance standards during detailed design, covering COMOPS, construction, commissioning and operations. Compliance with the performance standards will provide assurance that the safety critical elements have been suitably designed, constructed and commissioned and will be suitably maintained.

Appendix C T&S Project Health and Safety Plan

C.1 Overview

This section presents for the project health and safety plan for the Implementation Phase.

C.2 Onshore Project H&S Requirements for Detailed Design and Construction

C.2.1 Summary

The Project HS & E requirements for Detailed Design and Construction document is a Contract document. The CDM Principal Designer, CDM Principal Contractor, CDM Designer and CDM Contractor must allow for all its requirements in their Tender.

It should be noted that the employer's requirements are supplementary to the requirements of legislation.

Where legislation is more onerous than the requirements of this document, then the requirements, duties and obligations in legislation shall be complied with.

C.2.1.1 General Requirements

The EPCm contractor will act as the CDM PD as defined in the CDM (Construction and Design Management) Regulations 2015 (CDM 2015) for the overall co-ordination and management of the design works. The CDM PD shall co-ordinate all appointed CDM Designers, including those nominated by the employer, to complete the design works. Survey teams in the provision of information shall also be deemed as CDM Designer's under CDM.

The CDM PD and CDM Designers shall fulfil the duties and requirements set out for the CDM Principal Contractor (CDM 2015) for all survey works, including those arranged and/or being undertaken by the employer.

Project Objectives and Targets

Project specific health and safety objectives and targets shall be agreed by the employer and the CDM Principal Designer, CDM Designer's, CDM Principal Contractor and CDM Contractor's for inclusion in the design plan, survey phase plan and construction phase plan.

Objectives and targets are set both at the employer's Group level and also by the employer at a subsidiary level.

The project manager shall ensure the employer's health and safety objectives and targets are included when agreeing the project specific objectives and targets with all above mentioned parties.

Progress towards health and safety objectives and targets shall be monitored, measured and reported to the project manager by the CDM Principal Designer, CDM Designer's, CDM Principal Contractor and CDM Contractor's on a monthly basis or more frequently as requested.

Competence

The CDM Designer and CDM Principal Contractor shall implement and record a process to evaluate the competence of their project team (includes consultants, Contractors and agency workers) for management, discipline engineers, supervisors, surveyors and technical support staff.

Competency criteria for each role within the project team shall be established that specifies a suitable level of health and safety training with qualification, construction knowledge, relevant risk awareness and qualifications aligned to their responsibilities.

C.2.1.2 Design Works

For the design work, it is a NGCL requirement that all levels of management and senior engineers within the design team, that influence health and safety within the design process, have recognised health and safety training with a suitable qualification. As a minimum the following will apply:

- Managers shall have a recognised 5 day Managing Safety qualification, have undertaken a recognised CDM Awareness course and have 3 years' experience managing designs and surveys for construction projects;
- Health & Safety Manager shall have a recognised Health and Safety Diploma and CDM Awareness training;
- Health and Safety Advisers shall have a recognised Health and Safety Certificate. Engineers and Survey Team Supervisors shall have a recognised 2 or 3 day Supervising Safety‟ qualification and hazard and risk awareness training;
- Survey teams and Contractors will hold a suitable and accredited health, safety and environmental passport, valid for the duration of their work;
- Design Manager shall be professionally qualified in a relevant engineering discipline, shall have CDM training, be on a recognised Designer Register and have 5 years managing design experience;
- Design Co-ordinator shall be professionally qualified in a relevant engineering discipline, shall have CDM training and have 3 years design experience in engineering;
- Lead Discipline Engineers and Independent Design Checkers shall be professionally qualified in a relevant engineering discipline, shall have CDM training, be on a recognised CDM Designer Register and have 3 years design experience; and
- All members of the design team, commissioning team and project managers, including those of supporting CDM Designers, shall undertake the employer's CO_2 and CCS induction awareness course.

C.2.1.3 Construction Works

For the construction work, it is a NGCL requirement that all levels of management and supervision within the CDM Principal Contractor's management team that influence and manage health and safety have recognised health and safety training with a suitable qualification. As a minimum, the following roles shall meet such requirements:

- Managers shall have a recognised 5 day "Managing for Safety‟ qualification (e.g. CITB, NEBOSH, IOSH or equivalent) and a CDM awareness qualification (e.g. APS). A minimum of 5 years relevant experience is required and is subject to a project specific induction being completed;
- Health and Safety Manager shall have a recognised Health and Safety Diploma or a recognised Health and Safety certificate and 5 years relevant experience ;
- Health and Safety Advisers shall have a recognised Health and Safety Certificate;

- Engineers, Supervisors, Foremen and Gangers shall have a recognised 2 or 3 day Supervising Safety" qualification (e.g. EUS, CITB, NEBOSH, IOSH or equivalent) and temporary works awareness training. A minimum of 3 years relevant experience is required and engagement is subject to a project specific induction being completed; and
- Labourer, Pipeline Operatives will hold a suitable and accredited health, safety and environmental passport, valid for the duration of their work and a project specific induction being completed.

C.2.2 Inspections and Audit

The management arrangements will be reviewed during the project by NGCL's Project Manager or his nominee.

NGCL's Project Manager or his nominee's will monitor and audit the activities of the CDM Designer and CDM Principal Contractor in accordance with NGCL Procedures, to ensure that the duties as prescribed in the current legislation and the requirements of this document are being fulfilled.

An Inspection and Audit Programme, based on a suitable template, shall be jointly developed by NGC, the CDM Designer and/or CDM Principal Contractor. Members of both project teams shall be nominated to carry out designated compliance monitoring, inspections and audits as detailed on the programme.

C.2.2.1 Design Works

As a minimum, the CDM Designer's Project Manager shall undertake and record a monthly management inspection and systems compliance check of the design works. The Design Manager shall undertake and record a monthly compliance check of the effectiveness of the design procedures and risk management.

Lead discipline CDM Designers shall undertake and record weekly reviews to ensure continuous hazard identification and risk mitigation. All compliance records shall be reviewed by the CDM Designer's H&S Adviser and non-compliances recorded on an Action Log. Issues recorded on Action Log shall be monitored until satisfactorily addressed by the nominated person. The Action Log shall be tabled at every Project Progress Meeting and H&S Meeting.

C.2.2.2 Construction Works

As a minimum, the CDM Principal Contractor's Project Manager shall undertake and record a monthly management inspection and systems compliance check of the construction works. The Construction Manager shall undertake and record a monthly inspection of the working areas and compliance check of the method statements.

Foremen shall undertake and record weekly inspections of their work areas. All inspection records shall be reviewed by the CDM Principal Contractor's H&S Adviser and non-compliances recorded on an Action Log. Issues recorded on Action Log shall be monitored until satisfactorily addressed by the nominated person. The Action Log shall be tabled at every Project Progress Meeting and H&S Meeting.

The nominated site based NGCL representative shall undertake an initial project health and safety inspection on the CDM Principal Contractor's systems on the day that construction commences.

C.2.3 Project Meetings

A pre-start meeting will be held immediately after Contract Award, the date for which will be arranged. The programme would be:

- Project Progress Meetings will be held and minuted on a monthly basis;
- Design Meetings will be held and minuted on a monthly basis; and
- Construction Meetings will be held and minuted on a weekly basis.

Health and Safety Meetings will be held on a monthly basis. Dependant on the nature of the project, the Progress and H&S monthly meetings may be combined.

The CDM Designer and/or CDM Principal Contractor shall prepare and submit to the NGCL's Project Manager a Risk and Safety Performance Report three days prior to the monthly Project Progress Meetings.

A Project Progress Meeting shall be held monthly at which the progress, status, performance and compliance across all disciplines is discussed. The Risk and Safety Performance Report including, H&S performance statistics, the status of key H&S documents, significant hazards/risk issues and accident/incident occurrences and investigation findings.

C.2.3.1 During Design Works

A Health and Safety Meeting shall be held monthly to discuss safety performance, inherent design risk issues, compliance with legislation, survey activities, the Action Log and the like. The H&S Meeting shall be chaired by the Design Manager.

C.2.3.2 During Construction Works

A Health and Safety Meeting shall be held monthly to discuss safety performance, compliance with safe systems of work, compliance with legislation, the Action Log, accident/incident findings and the like. The H&S Meeting shall be chaired by the CDM Principal Contractor's Project Manager.

The CDM Principal Contractor shall hold a formal weekly Construction Meetings to discuss the following week's programme of work. At these meetings the potential risks and proposed controls shall be reviewed and discussed with actions tasked to further mitigate the risks.

A Meeting Schedule shall be jointly developed by NGCL and the CDM Designer and/or CDM Principal Contractor. Members of both project teams shall be nominated to attend the meetings shall be detailed on the Schedule.

The CDM Designer shall attend the Construction Phase Pre-Tender Meeting to:

- Formally identify and explain key risk documents;
- Identify which key risk documents will transfer and become the responsibility of the appointed CDM Principal Contractor;
- Explain the key design decisions taken;
- Clarify the key assumptions made and any remaining assumptions;
- Explain suggested and/or essential methods of working;

- Explain recommended or essential sequences of work and/or control measures; and
- Communicate any significant design issues that may impact on construction safety.

The CDM Designer shall also identify at the Construction Phase Pre-Tender Meeting any remaining designs to be completed or likely changes to the design. If designs are to continue after Construction commences, the NGCL's Project Manager, the CDM Designer and CDM Principal Contractor's Project Manager shall establish a practical design strategy to co-ordinate and complete the on-going designs and to handle any design changes. Accordingly, the CDM Designer shall support the CDM Principal Contractor in the development of key risk documents after their hand-over.

C.2.4 CDM Risk Register

C.2.4.1 Design Works

A project specific CDM Risk Register has been issued by NGCL that records the known significant or unusual hazards and risks at the time of Contract Award.

Only perceived significant, difficult and/or unusual hazards, risks and concerns shall be included. Day to day low risk construction hazards should not be recorded on the CDM Risk Register. It is essential that the User expands the descriptive text as other related hazards and risks may be subsequently identified by other disciplines from the description given. The descriptive text does not have to be extensive, but brief enough and clear enough to clarify the nature and context of the hazard, risk and/or concern to be controlled and managed; and its location within an element of work or project.

More detailed information relating to the management of the CDM Risk Register can be found on the "User Guide" tab found at the bottom of the Risk Register.

At the Pre-Start Meeting the CDM Risk Register shall be formally handed over to the CDM Designer for continual development and mitigation of project risk.

During the design works of the project, the CDM Designer shall take responsibility for the project CDM risk register. The CDM Designer will implement a procedure for the continual development and management of the CDM Risk Register. The procedure shall set out how the Register is disseminated to all relevant persons/parties (including other CDM Designers, Surveyors, Material Suppliers etc.), how hazard/risk contributions are incorporated, the means to progress recorded issues, the means to monitor effectiveness and the person responsible for implementing the procedure and for the Register itself.

A reviewed and updated CDM Risk Register shall be submitted to the NGCL Project Manager and CDM PD a week before each Project Progress Meeting. The content of the Register shall be an agenda item at the Progress and Design Meetings. New significant risks and risk issues that are not being resolved shall be raised at the Progress and Design Meetings.

The CDM Risk Register shall be made available immediately at any time when requested by the NGCL Project Manager and CDM Principal Designer.

For issues recorded on the CDM Risk Register that are no longer relevant, such entries maybe hidden but not deleted. At scheduled design completion, the Register shall be thoroughly reviewed by the Design

Manager and the CDM Principal Designer. Issues and risks that remain shall be clearly identified for communication on to those affected and to the CDM Principal Contractor. The CDM Risk Register shall be a design deliverable for inclusion into the Handover Documentation (H&S File).

The CDM Designer shall ensure the register is issued to all planners, CDM Designers, survey teams, Contractors, lead roles within the design team and lead roles within the employer's project Delivery Team involved in the project - on a frequency that reflects the planning, design and survey activities; and as a minimum at least monthly. The CDM Designer shall ensure contributions from all design support services, such as prefabrication CDM Designers, environmentalists, surveyors, temporary works CDM Designers, ground investigators and pipeline routers, are added to the project CDM risk register. The CDM Designer shall ensure contributions from the owner/operator are considered from design outset and throughout the planning and design phases.

CCS chain interface hazards and risks that are of significance, and/or where risk mitigation must be aligned and co-ordinated across the project as a whole, shall be recorded on the CDM risk register. These entries shall be clearly denoted as a CCS chain interface issue.

C.2.4.2 Construction Works

A project specific CDM Risk Register has been issued by NGCL that records the known hazards and risks at the time of Contract Award. The CDM Risk Register also incorporates issues and risks identified by the CDM Designer.

Only perceived significant, difficult and/or unusual hazards, risks and concerns shall be included. Day to day low risk construction hazards should not be recorded on the CDM Risk Register. It is essential that the User expands the descriptive text as other related hazards and risks may be subsequently identified by other disciplines from the description given. The descriptive text does not have to be extensive, but brief enough and clear enough to clarify the nature and context of the hazard, risk and/or concern to be controlled and managed; and its location within an element of work or project.

More detailed information relating to the management of the CDM Risk Register can be found on the "User Guide" tab found at the bottom of the Risk Register.

At the Pre-Start Meeting the CDM Risk Register shall be formally handed over to the CDM Principal Contractor for continual development and mitigation of project risk.

The CDM Principal Contractor shall implement a procedure for the continual development and management of the CDM Risk Register. The procedure shall set out how the Register is disseminated to relevant persons/parties (including Sub-Contractors where necessary), how hazard/risk contributions are incorporated, the means to progress recorded issues, the means to monitor effectiveness and the person responsible for implementing the procedure and for the Register itself.

A reviewed and updated CDM Risk Register shall be submitted to the NGCL Project Manager and CDM PD a week before each Project Progress Meeting. The content of the Register shall be an agenda item at the Progress Meetings. New significant risks and risk issues that are not being resolved shall be raised at the Progress Meetings.

The CDM Risk Register shall be discussed at the weekly Construction Meetings. The recorded risks and outstanding issues for the forthcoming works shall be raised as an agenda item. Where the risks and controls are considered unacceptable, then appropriate actions, those designated to address such and timescales, shall be agreed by the managers and supervisors present.

The CDM Risk Register shall be made available immediately at any when requested by the NGCL Project Manager and CDM Principal Designer. A copy of the Risk Register shall be on each site and shall be managed by a person nominated in the Construction Phase Plan. The CDM Risk Register should be continually reviewed and updated on site throughout the Construction Phase with each hazard being closed as required and new hazards being added to the register as necessary.

For issues recorded on the CDM Risk Register that are no longer relevant, such entries maybe hidden but not deleted. At project completion, the Register shall be thoroughly reviewed by the person responsible for the Register and the CDM Principal Designer. Issues and risks that remain shall be clearly identified for communication on to those affected. The CDM Principal Contractor shall include the CDM Risk Register into the Handover Documentation (H&S File).

C.2.5 CCS Chain Interface Risks

- The different sections of the CCS chain will have different hazards and risks that are to be identified, mitigated and/or controlled through the design, commissioning and construction works;
- Design solutions developed in isolation by the CDM Designer may not be the optimum, nor the engineering, process or operationally preferred solution for the CCS chain as a whole;
- The CDM Designer shall attend and proactively partake in all CCS chain interface meetings, Formal Process Safety Assessments (FPSA)s and reviews when requested; providing the relevant competent resource to ensure hazards and risks, including engineering, process, commissioning and operational issues, are identified that may impact and/or alter the developing design solution;
- The CDM Designer shall prepare and maintain relevant technical interface documents. The CDM PD shall review and comment on technical interface documents prepared by others within the CCS chain, to identify and determine design conflicts and to ensure alignment of the works;
- The CDM PD shall review and comment on safety management systems prepared by others within the CCS chain, to identify and determine conflicts and where there is misalignment; and
- It is a key requirement of the employer, that the CDM PD and CDM Designer be proactive in identifying key interface alignment issues and proposing alignment options and solutions.

C.2.6 CO_2 Information

The employer has carried out an extensive research and development (R&D) programme with regard to the physical and chemical performance and impacts associated to the transportation of CO_2 in its different states. The interpretation and analysis of the data and findings will be an on-going process.

C.2.7 Process Safety Management

In order to provide a service to its customers National Grid owns and operates a number of major hazard assets, which have the potential to cause many injuries and major damage to property and the local environment. Through effective Process Safety Management we can ensure that the assets remain safe and reliable.

The Group Process Safety Team has been established to support the business in the management of major hazard assets through the development and implementation of Process Safety Management System.

The Framework and Risk Control Standards have been developed to ensure consistent approach to the management of Major Hazard facilities and networks across National Grid. They are not intended to replace existing management systems but strengthen accountability and set minimum standards for process safety management across National Grid.

Scope – they apply to the Major Hazard assets; LNG Facilities, High Pressure Pipelines and Installations (UK >7Barg) (US >125Psig), Compressed Natural Gas, Gas Storage, Generation, Gas Storage Sites, Transportation of hazardous substances, CO_2transportation and Drilling Operations .

C.2.8 The Health & Safety File

The Health and Safety File is a record of information for NGCL and end-user operator which focuses on provisions for health and safety, key structural elements and risks that must be communicated to allow consideration by others during maintenance, repair, future works and decommissioning.

The format of the File shall be in accordance with NGCL's Handover Document requirements and its content shall be agreed by NGCL's Project Manager or his nominee and the CDM Principal Designer. This shall be recorded and shall be handed to the CDM Designer / CDM Principal Contractor.

For the Design works, the CDM Designer shall collate and compile the design information to be included within Handover Document throughout the planning and design works of the project. A person shall be specifically nominated who shall take responsibility for the continual update and management of the records until submission to NGC.

The CDM Designer shall allow for the collation and inclusion of all NGCL and design project information.

The CDM Designer shall prepare one (1No.) paper copy and one (1No.) electronically scanned and formatted onto CD copy of each Handover Document.

All Approved for Construction issue drawings; specifications, reports, documents and records shall be signed and dated by the Design Manager.

For the Construction works, the CDM Principal Contractor shall collate and compile the Handover Document throughout the construction and commissioning works of the project. A person shall be specifically nominated who shall take responsibility for the continual update and management of the records until submission to NGC.

The CDM Principal Contractor shall allow for the collation and inclusion of all NGCL and CDM Designer project information.

One Handover Document for each Above Ground Installation, pumping station and one for the Pipeline shall be prepared.

The CDM Designer shall prepare one (1No.) paper copy and one (1No.) electronically scanned and formatted onto CD copy of each Handover Document.

All As Built drawings, reports, documents and records shall be signed and dated by the CDM Principal Contractor as a 'true record'.

C.2.8.1 Design Specific Requirements

The CDM Designer shall fulfil the duties as set out in the CDM regulations and implement the concept of 'Safety by Design'. The CDM Designer will discharge the CDM Designer's obligations whilst having regard to requirements of the employer as set out within this document.

C.2.9 Health and Safety Policies

A copy of the National Grid PLC Group policies for safety and well-being, process safety and the environment can be found in Appendix D, E and F respectively. All staff will be expected to comply with the requirements of their company's policy health and safety statement and the requirements of their health and safety management systems. In addition, the CDM Designers, staff, CDM Designers, survey teams, Contractor staff and workers, are expected to comply with the requirements of the employer's group policy statement.

C.2.10 Health and Safety Legislation

It is an employer requirement that planning and design development activities shall comply at all times with all relevant statutory or legislative requirements, in order for the employer to meet their legal obligations.

The interface between onshore and offshore pipeline, at the coastline, is referred to as "landfall", and it is at this location that the application of onshore and offshore legislation requires clear interpretation. The CDM Regulations relate to the design of onshore projects requiring construction, and in this document CDM shall be construed accordingly. The spirit and obligations of onshore and offshore legislation is in principle the same; though in many aspects it is more onerous in offshore legislation. It is on this parity that the following shall apply:

a. The 'landfall' section from Barmston Pumping Station to the cofferdam located at the mean low waterline shall be designed as a pipeline special crossing, under the CDM 2015 Regulations (CDM);
b. CDM shall apply up to and including the cofferdam which will be situated at the mean low waterline. The cofferdam will be the break point between on and off-shore pipeline design codes;
c. The landfall crossing shall be subject to a separate F10 project notification to the HSE; and
d. The design of the landfall crossing will require a fully integrated approach between both the onshore and offshore CDM Designers, and the employer.

The application of onshore and offshore engineering standards and specifications has been set out in a technical interface document as referenced within the works information.

Applicable offshore legislation is set out in the Project Health, Safety & Environment Requirements for Detailed Design and Construction Document (Offshore)

C.2.11 Health and Safety Management Systems

The project manager, CDM PD and health and safety adviser are responsible for reviewing the basis of the CDM Designer's management of occupational health and safety, and ensuring that it complies with the employer's requirements.

The design plan, the survey phase plan, Formal Process Safety Assessments (FPSAs), temporary works procedure, driver's plan (for survey works) and CDM risk register must be reviewed by the project manager (or delegate) and CDM Principal Designer. All health and safety documentation must be specific to the project and duly signed and dated by the CDM Designer.

C.2.12 Design Strategy

The EPCM appointed to undertake the management of the design works shall do so as CDM PD as required by the CDM 2015 Regulations (CDM). The CDM PD shall establish the overall strategy and procedures for the approach to design risk management that all other CDM Designers, consultants, survey team and the employer's Project Delivery Team (PDT) shall adhere to.

The CDM PD is reminded that the strategies, procedures, competencies, studies, deliverables and the like are different for pipeline design and Installation design. The design plan shall clearly set out the differences between pipeline and Installation design; to ensure the optimum design solution that has the desired functionality and performance.

Prior to carrying out any design works all members of the design team, including all appointed CDM Designers and consultants, will have undertaken the CDM Principal CDM Designer's design induction.

The CDM PD/CDM Designer shall evaluate the survey works undertaken, and those proposed by the employer, in order to establish any additional survey works required to complete the designs.

The CDM PD/CDM Designer shall ensure that safety by design, human factors and the proposed operating procedures interact from design outset in the iterative and progressive development of the management systems and supporting procedures.

The CDM PD/CDM Designer shall communicate to the employer the inherent hazards and risks, the provisions for safety, all relevant risk assessments, the basis of the assumed management system, the relevant procedures, the required training and relevant safety compliance monitoring - to enable the employer to comply with legal obligations as an employer and operator. The employer will undertake risk assessments to establish safe systems of work as an employer or operator, prior to operating the Installations and/or pipeline, based on the intentions and information provided by the CDM Designer.

The inherent requirements for safety by design, human factors and operating philosophies are incorporated within this health and safety requirements document, the works information and the employer's referenced procedures

C.2.13 Design Outset Challenge and Review

Sufficient time shall be allowed for the CDM Designer to critically appraise the works information contained within the RFP provided by the employer, including the resolution of information gaps and shortfalls. This critical appraisal shall be undertaken immediately after contract award. Any gaps or shortfalls in information identified or perceived by the CDM Designer shall be addressed using the NGCL technical query procedure.

A short period of time after the critical appraisal, as agreed with the project manager, the CDM Principal Designer/CDM Designer shall prepare sufficient design information for a 'Design Management and CDM Induction' challenge and review, conducted by the employer. The challenge and review shall:

a. Demonstrate the CDM Designer's technical understanding of the work scope;
b. Address any remaining information gaps and shortfalls;
c. Define the discipline resources and competency management;
d. Define the approach to design risk management; and
e. Define their approach for the development of the CDM risk register.

The CDM PD/CDM Designer shall allow for the specified design reviews as determined by the employer's project manager.

Following the challenge and review, the CDM PD/CDM Designer shall address any issues raised and submit a project specific design plan.

C.2.14 Design and Survey Plans

The defined and required design plan and survey phase plan shall be developed and implemented by the CDM Designer; and they shall be maintained throughout the lifecycle of the design and survey works of the project.

The design plan and survey phase plan shall be live documents in which the CDM Designer shall set out the arrangements for securing the health, safety and welfare of all those carrying out the work and all others who may be affected by it.

When developing project specific arrangements and documentation, the CDM Designer shall identify the hazards and assess the risks at each of the key stages of planning, design, survey, construction and commissioning, including but not necessarily limited to those identified in this document. The CDM Designer shall also identify the organisation and arrangements for managing health, safety and welfare.

The project specific arrangements and documentation shall be reviewed, kept up to date, modified and altered in the light of changing circumstances. As the planning, design and survey work progresses, the arrangements will need to be amended and updated as a result of hazard identification, risk assessments, mitigation and methods of working proposed. Reviews of the arrangements and documentation may also need to be made if there are for example design changes, unforeseen circumstances, preferred construction methods and operational constraints. It is vital that such changes are notified to all those working on the project who may be affected.

It is a requirement of the CDM Regulations for CDM Designers to mitigate risks to health and safety to those affected by their designs and to co-operate with other CDM Designers. The CDM Designer shall prepare, and submit to the employer for acceptance, a design plan that sets out the design policy, organisation, management, arrangements, procedures and monitoring; to demonstrate compliance of the philosophies of risk management from design outset; and requirements that are embedded within legislation, BS 7000 Part 4 and in this health and safety requirements document.

The design plan shall also include for design deliverables and shall take into account temporary works design, lifting operations required for construction, commissioning and considerations for operation and maintenance.

The CDM Designer shall prepare and submit to the employer, for acceptance, a survey phase plan that sets out the management, arrangements and controls for the survey works.

It is a requirement that no survey works commence until the survey phase plan has been accepted by the project manager.

The CDM Designer shall establish change registers to list and record all changes made to the design plan and survey phase plan. The design plan, the survey phase plan and their change registers will be reviewed periodically by the project CDM PD.

The CDM Designer's design plan and survey phase plan shall detail arrangements for the implementation of project objectives and targets.

The project manager, in liaison with the Health and Safety Manager/Adviser and CDM PD, shall ensure that the basis of the CDM Designer's design plan and the survey phase plan is acceptable for the design and survey works of the project.

C.2.15 Human Factors Integration

The CDM PD/CDM Designer shall produce a relevant Human Factors Integration Plan (HFIP) for acceptance by the employer. The HFIP shall cover the pipeline, installations and associated control centre. The CDM PD/CDM Designer shall update and maintain the HFIP throughout the lifecycle of the project. In support of the HFIP the CDM PD/CDM Designer shall produce and maintain:

a. A human factors issues log;
b. Target audience descriptions;
c. Usability scenarios;
d. Task analysis and assessments;
e. Workload analysis and assessments;
f. Operating procedures;
g. Maintenance procedures;
h. Emergency procedures;
i. Skills and competence matrix;
j. A training matrix; and
k. A human factors integration audit log.

Refer to the HSE guidance: Human factors integration: Implementation in the onshore and offshore industries – INO No. 843300/001 and HSG 48 – Reducing Error and Influencing Behaviour.

The CDM PD/CDM Designer shall determine with the employer, the operator resource requirements, the organisational structure and any operating constraints as a basis for design – and for continuous development and iteration throughout the design process.

The CDM PD/CDM Designer shall determine and agree with the employer the full range of human factor issues and safety critical tasks/systems that shall be subject to analysis, assessment and mitigation; that must be subsequently tested for effectiveness.

The CDM PD/CDM Designer shall ensure that performance and process requirements are included in their procurement procedures and/or design specification in the provision, supply and functionality of the permanent materials, systems and fabrications.

The CDM PD/CDM Designer shall collate data and maintain a record on the expectations and demands of the operator's resource and their interactions with the designed system(s).

The CDM PD/CDM Designer shall identify and record where operator error has a significant hazardous potential and risk.

The CDM PD/CDM Designer shall produce and maintain a skills and competence matrix and a training matrix to support the development of the operator's resource pool; based on the requirements and demands inherent within the design solution.

The CDM PD/CDM Designer shall ensure he engages or has access to a human factors specialist to ensure interaction and integration of the key issues and assessments throughout the project lifecycle.

C.2.16 Operator's Operation and Maintenance Procedures

The CDM PD/CDM Designer shall from design outset list and progressively develop a safe working design layout register, itemising all single item components or permanent-materials, items of equipment, plant and fabrications designed in to the permanent works, including the associated remote control centre.

The CDM PD/CDM Designer shall from design outset obtain all relevant information and data from permanent material, prefabrication and system suppliers.

The CDM PD/CDM Designer shall from design outset produce and maintain a brief summary of relevant data and requirements for each single item component/material, item of equipment, plant and fabrication (including single items making-up the fabrication) on a component summary sheet.

CDM PD/The CDM Designer shall produce and maintain a high level operating schedule, maintenance schedule that are aligned to each other, and will be used to ensure the management and development of operating, maintenance and emergency procedures.

The CDM PD/CDM Designer shall ensure that by design solution and permanent material selection, the maintenance schedule meets the employer's availability to function and operate.

The CDM PD/CDM Designer shall develop and produce operating and maintenance procedures for adoption by the employer as an operator; and shall base such on the inherent requirements and criticality of a design solution.

The operating procedures shall be developed and structured in conjunction with employer and the operator's representative(s). The procedures shall take cognisance of the various operating procedures.

The proposed maintenance procedures shall clearly set out the sequence of work, frequency required, the level of resource required, the likely duration, the specific tools required, necessary equipment required for the activities, spare parts required, safety critical tasks to be undertaken, the limitations or constraints to be adhered too, the associated hazards and risks, the provisions for safety and risk control, and information on potential waste or by-products.

In developing the proposed maintenance procedures, the maintenance requirements and frequencies of all elements of the CCS chain will need to be taken into consideration and aligned to ensure CCS system availability. The CDM Principal Designer/CDM Designer shall inform the employer where material and equipment specifications have been enhanced to meet the requirements of other CCS stakeholder's demands and to align maintenance.

The employer is mindful that the production of operating and maintenance procedures is an iterative process, which may influence the developing design solutions and will require proactive inclusion of the employer's project delivery team and stakeholders; and potentially other parties within the CCS chain.

The employer draws to the CDM Designer's attention, that proactive and progressive development of these requirements will support the evolving safe working design layout reviews and registers as required by the employer.

The CDM PD/CDM Designer is reminded that to develop suitable and relevant procedures in an effective and expeditious manner, interaction with safety by design processes, human factor considerations and design philosophies is essential.

C.2.17 Permanent Materials

The CDM PD/CDM Designer shall ensure health and safety requirements are detailed within the design specifications and data sheets; such as the provision of manufacturer's information within seven days of confirmation of purchase, weight labels on permanent materials storage requirements, and the like.

The CDM PD/CDM Designer shall ensure health and safety requirements forms part of the procurement and evaluation process for permanent materials, systems and prefabrications.

The CDM PD/CDM Designer should ensure that manufacturers and suppliers are Building Information Modelling (BIM) compliant and are committed to a collaborative approach to reduce risk, cost and carbon emissions throughout the whole lifecycle of the project.

The CDM PD/CDM Designer shall ensure that specified permanent materials are suitable and adequate for the design intention; and integrate into the design solution.

The CDM PD/CDM Designer shall refer to the contract requirements for the permanent materials required within the permanent works detailed within the works information.

C.2.18 Prefabrications and Supplied Fittings

Suppliers of prefabricated arrangements and fittings of the permanent works that are supplied on the basis of a functional specification; and where the Supplier subsequently completes the detail design to ensure performance compliance with the functional specification; shall be regarded as CDM Designers in accordance with the CDM Regulations. Design cooperation, co-ordination and risk mitigation with such Suppliers shall be an inherent aspect of the design process; and as part of the design review by the CDM PD shall be demonstrable.

Suppliers of packaged systems such as; meter/filter skids, valve control arrangements, instrument buildings; operational buildings; CO_2 composition analysis and cooling systems shall ensure that health and safety be considered in performance, installation, operation, maintenance and removal; and shall communicate such issues to the CDM Designer and other CDM Designers.

C.2.19 Design of Temporary Works

Temporary works are structures and systems that provide support to the construction of the permanent works, are short term and do not form part of the permanent works. Temporary works are designed to take varying loads dependant on the intended purpose and function. Temporary works include for example; ground support systems, ground water management systems, scaffold, access structures, lifting frames, electrical supplies, lighting systems, cathodic protection, security measures and services supports.

The CDM Designer shall set out in the design plan the design procedures to identify and make provision for temporary works design. Where possible the CDM Principal Designer/CDM Designer by planning and design shall avoid the need for temporary works. The CDM Principal Designer/CDM Designer shall take responsibility for the co-ordination, development, design and provision of information for temporary works.

The CDM Designer shall, as part of the design of the permanent works, identify the locations where temporary works are needed. The type, extent and purpose of the temporary works shall be recorded on temporary work register(s). In determining the need the for temporary works the CDM Designer shall take into consideration adjacent existing structures, close proximity excavations, lifting operations and any other features and activities that may affect the type and design of the temporary works. The need and identification for temporary works shall be on a progressive basis throughout the design process. In the first instance recording the need for temporary works may be acceptable; and as the design advances through its different stages, more information and greater detail is recorded against the need to allow temporary works to be an inherent part of the design process.

Where temporary works are of such design criticality or form an integral part of the permanent works then the designs shall be undertaken by the CDM Designer during the design works.

The CDM Designer when planning for excavations at pipeline crossings and when establishing details of any temporary works design for these excavations, shall ensure the entire excavation is designed to prevent collapse. All such excavations and temporary works shall be recorded on the temporary works register.

The CDM Designer shall identify and record all potential deep excavations and shall ensure collated information on ground conditions, groundwater conditions, the temporary works, access/egress requirements and risk assessments, in line with planning and design considerations, are communicated. Potential deep excavations shall recorded be on the temporary works register.

The CDM Designer is reminded that deep excavations in certain ground strata conditions and in mining and landfill areas, may encounter ground gases that could result in the excavation being classed as a confined space.

C.2.20 Hazardous Materials and Substances

The CDM Designer shall clearly identify all materials, chemicals, substances and mixtures that are specified in the permanent works design, the quantities relating to application/component and note those that are hazardous to health. The CDM Designer shall issue with their designs, substance data sheets and chemical safety assessments to allow the Contractor in planning for the construction phase to carry out a Control of Substances Hazardous to Health (COSHH) assessment implement controls and manage any necessary health surveillance.

The CDM Designer shall nominate a person within the design team to identify all substances designed into the permanent works; collate manufacturer's safety data sheets, chemical assessment sheets, product name and quantities; and record such on a substances register.

All such information shall be included within the handover documentation / health and safety file for communication to the operator.

C.2.21 Elastomers and Lubricants

CO_2 has the potential to damage elastomers (materials that have the ability to stretch easily and return to their original shape when stress is removed) through a process known as rapid gas decompression. Rapid gas decompression occurs when CO_2 is absorbed into the elastomer material at high pressure and rapidly expands when the seal is returned to atmospheric pressure. The causes of rapid gas decompression are complex and are dependent upon a range of factors such as the type of elastomer material, hardness, system pressure, temperature and seal design.

The HSE Research Report No 485. Elastomeric Seals for Rapid Gas Decompression Applications in High - Pressure Service provides further details. Elastomers can also suffer from a range of other failure mechanisms, such a low temperature embrittlement, extrusion, and chemical attack, for example hydrogen sulphide.

In addition CO_2 can act as a solvent for lubricants and greases.

To ensure the integrity of the design the CDM Designer shall identify any elastomer material or other materials and substances that in isolation, or in combination, could be in contact or exposed to CO_2 and shall fully assess and certify as fit for purpose.

The CDM Designer shall record on a seals register all elastomers, or other materials that could suffer degradation when exposed to CO_2. The register shall list the location, nature of exposure, exposure pressures, physical details and properties, failure consequences and secondary impacts associated with the 'seal' or material. For each of the identified seals or materials the CDM Designer shall fully assess and certify as fit for purpose and provide evidence of certification where available.

The CDM Designer shall identify where an arrangement of seals and the like which cannot meet the integrity performance criteria. The CDM Designer shall adopt an iterative approach to identify and assess the 'at-risk' barriers.

C.2.22 Method Statements and Procedures

- If by design, the construction work or a particular aspect of the works requires a specific approach or control to construct the works, then the CDM Designer shall specify the method or procedure to be adopted. The level of detail given within the specification shall depend on the complexity or nature of the works requiring control;
- If by design, the permanent works or a particular aspect of an installation requires a specific approach or control to operate, maintain or clean, then the CDM Designer shall specify the method or procedure to be adopted. The level of detail given within the specification shall depend on the complexity or nature of the works requiring control; and
- If the residual risks or significant hazards identified are of a high nature, then the CDM Designer shall recommend the method or procedure necessary to control the works and/or element of the work. The level of detail given within the recommendation shall depend on the complexity or nature of the works requiring control.

C.2.23 Formal Process Safety Assessments

Safety and operability is delivered in the design process through a number of assessment techniques referred to as Formal Process Safety Assessments (FPSAs). The employer's requirements are set out in a suite of supporting FPSA management procedures. Further details can be obtained from NGC/MP/HS/01.

Formal design reviews and FPSAs shall be undertaken by the CDM Designer throughout the design process.

The CDM Designer shall undertake further design reviews in line with their design plan and to support the delivery of the employer's requirements. The CDM Designer shall establish the additional FPSA's they deem necessary, over and above the employer's minimum requirements. Prior to any FPSA being conducted, the CDM Designer shall undertake their own thorough challenge and review of the information and documents being provided; to ensure they are relevant, suitable and sufficiently advanced to be of benefit to the FPSA being undertaken. The FPSA shall not be conducted as an evaluation or checking exercise.

The CDM Designer shall manage and maintain a register to track FPSA, updated monthly.

The CDM Designer shall give advance notice, of four weeks, to the employer of forthcoming FPSAs.

The CDM Designer shall prepare all relevant design documentation to support an effective FPSA; all such documents shall be specifically noted as 'FPSA Issue' and issued to all attendees seven days prior to the commencement of the scheduled FPSA.

The FPSA chairperson(s) shall be suitably competent and independent form the project, and approved in accordance with the employer's management procedure NGC/MP/HS/01. The employer reserves the right to appoint and nominate the FPSA chairperson(s). In this instance the CDM Designer shall work with the employer's appointed chairperson to prepare, deliver and close-out the FPSA.

Where such design reviews and FPSAs generate actions, then a formal close-out procedure shall be implemented by the CDM Designer to ensure the issues arising have been suitably addressed, that any secondary matters are taken forward and that any residual hazards and risks are recorded on the CDM risk register.

Safe Working Design Studies (SWDS) studies shall be carried out and will not be a one-off study. Multiple SWDS studies will be required and in a planned and co-ordinated manner. The SWDS register shall be pre-populated prior to the studies being undertaken. The register shall be progressively developed throughout the lifecycle of the project.

A preliminary hazard analysis and safety review shall be undertaken during the early stage of the design work. This review seeks to identify and agree the project hazards and risks, put them into context for mitigation and determine in principle the options for design risk management.

A high level HAZCON review(s) shall be undertaken prior to the completion of the design works that identifies all significant and residual hazards and risks.

All design reviews and FPSAs are deliverables that shall form part of the design plan and detailed on the design programme.

C.2.23.1 CCS Chain FPSAs

The CDM Designer shall attend and proactively partake in all CCS chain interface FPSA's as requested; providing the relevant competent resource to ensure hazards and risks, including engineering, process and commissioning issues, are identified that may impact and/or alter the developing design solution.

Where the CDM Designer has been allocated an action during an Interface FPSA, the response shall be submitted to the employer who shall forward it on to the FPSA chairperson.

C.2.24 Communication and Co-ordination

The CDM Principal Designer/CDM Designer shall actively co-ordinate and communicate with other CDM Designers and external design service providers during the course of their scoped design works and design responsibilities in the pursuance of mitigating health and safety hazards and risks; especially where design works will remain outstanding.

The project design plan, project CDM risk register and this health and safety requirements document shall be formally issued to all other CDM Designers and external design service providers on the commencement of their duties within the project.

The CDM Designer shall ensure that all personnel involved in the design are able to liaise, discuss and offer advice on matters affecting health and safety within the design that impacts construction, operation and demolition.

The CDM Principal Designer/CDM Designer shall ensure that health and safety matters arising from personnel involved in the design are considered and co-ordinated with all other pertinent CDM Designers, Contractors and support services.

The employer shall periodically audit and inspect the design process and monitor the approach being implemented to effect health and safety aspects into the designs. When so requested the CDM Designer shall demonstrate compliance with the CDM regulations. At design scope completion, the design information produced shall be reviewed, with regard to health and safety issues, by the employer.

C.2.25 Lifting Operations

The CDM Designer shall consider lifting operations as part of the design process; including within the constructability review, HAZCON(s) and SWDS.

During the planning and design stages of an installation, the CDM Designer shall take into account all lifting operations required for construction, commissioning and operation. The layout of the Installation shall be set out to allow sufficient working space for all lifting operations. Individual layout drawings shall be prepared for construction lifts and for operational lifts that details the location of all lifting appliances; and it shall further detail information on the items to be lifted, their loads, reach, imposed ground loads and affected buried services.

The CDM Designer shall prepare a lifting schedule in conjunction with the lifting layout drawing for operational lifts. This schedule shall be included within handover documentation to enable the employer to test and maintain all installed lifting equipment and appliances.

C.2.26 Plot Plans at Pipeline Crossings

The CDM Designer shall produce a specific plot plan for each trenchless crossing based on minimum requirements. The employer has developed a generic site layout for trenchless pipeline crossings (C001-06-27-99-GD000-0011 - Typical Trenchless Foreign Service Crossing) that sets out the minimum expectations and standards to be included in the layout/design solution. The CDM Designer shall enhance and develop these minimum requirements to ensure the required construction area is a ‘safe place of work’ for all activities and tasks, and to enable the safe construction of the crossing. The generic site layout is contained within the works information.

The CDM Designer shall also produce specific plot plans for each pipeline access/egress point and crossing point. These plot plans shall take into consideration traffic management considerations for the construction phase.

These plot plans shall be suitably detailed for the site area immediately associated to each pipeline crossings and access point shall be developed during the design works. The plot plan drawings shall include for example information and dimensions with regard to: - the pipeline position; location of excavations; the position of the working areas for machinery, plant and vehicles; ground strata conditions;

land gradients; ground water and provisions for control; discharge points; temporary works; angles of excavation batter; overhead hazards; right of way fencing; vehicle standing areas; material storage areas; car parking; welfare facilities; the route of the Right of Way; the position of access/egress points with regard to the right of way; types of vehicles accessing/egressing; turning circles; services protection; temporary road construction details.

The CDM Designer shall identify on the plot plan the overall dimensions and the land take requirements.

On the basis that the information provided is suitable, sufficiently detailed and legible, the CDM Designer may incorporate the plot plan into the strip maps for the pipeline.

C.2.27 Pipeline Special Structural Sections

A pipeline special structural section is defined as a section or length of pipeline that requires additional or special support, flexibility or strength in order to maintain the integrity of the pipeline. The pipeline route proposed will cross areas with a variety of contrasting terrains and which are categorised by differing geological and ground conditions.

NGC/PR/PIP/03 provides additional information of the requirements for special sections.

C.2.28 Design for Operational Traffic

As part of the safe working layout review, the layout shall be configured to ensure safe access and egress to all equipment requiring vehicular support. The layout shall endeavour to keep distances travelled to frequently accessed areas and equipment to a minimum. Buried services and chambers shall be sited away from the kerb line to minimise the potential for vehicles tracking over or parking on them. Road radii will be specified such that foreseeable vehicle movements will not mount the kerb in transit.

The CDM Designer shall ensure that pedestrian routes are offset a safe distance from the kerb line and proposed road crossings are clearly demarked with no obstructions to the driver’s line of sight.

All designed-in ‘give way’ junctions will require clear lines of sight from the ‘set-back’ position of the driver.

Light vehicle parking, such as operative’s cars, shall be external to the Installation.

C.2.29 Designing for Construction Traffic

As part of an environmental assessment for the project the employer will take in to account the impacts of construction phase traffic movements, usage and management. The CDM Designer shall develop traffic management arrangements in a Traffic Management Plan (TMP) for review and adoption by the CDM Principal Contractor. Whilst the TMP shall consider the environmental aspects and impacts of an integrated transport policy, the key driver is to ensure the safety of the public, persons associated to the project and on-site personnel and workers.

The TMP shall be duly developed to allow a fully detailed route map showing permitted traffic routes and restrictions, traffic rules, emergency procedures and Right of Way (ROW) restrictions.

The TMP route map and the traffic rules shall be based on hazard identification and risk assessment of the affected infrastructure and local highways.

The CDM Designer shall identify ROW restrictions shall be based on for example; the working conditions, public rights of way, steep slope ascents and descents and restricted areas.

Hazardous steep slopes shall be subject to risk assessment and where necessary traffic control measures shall be proposed within the TMP. These hazardous slopes identified by risk assessment shall be marked on relevant strip maps.

All access/egress points to the ROW, crossing points and all road junctions up to and including the first A class road shall be subject to risk assessment.

In addition, the CDM Designer shall identify the need for escort vehicles especially for narrow roads, difficult bends, third party pipe deliveries, slow vehicles and large pre-fabrications.

C.2.30 Overhead Hazards

The CDM Designer shall identify, by survey and consultation, all overhead hazards along the pipeline route, within Installations and local traffic routes and shall be recorded on a suitable overhead hazard register by the CDM Designer.

By planning and design, overhead hazards shall be avoided for example by reroute, realignment and cable diversions. Where such hazards cannot be avoided, mitigation and control measures shall be developed.

For all overhead cables that are to be crossed, and for those running parallel in close proximity, a specific risk assessment shall be undertaken and recorded for each cable by the CDM Designer in line with GS6 requirements.

C.2.31 Utilities Co-ordinator and Management

The CDM Designer should develop and implement a design procedure to research, identify, locate and record utility, private and third party services.

The CDM Designer should appoint a utilities co-ordinator within the design team to:
- Ensure that the design considers the presence of all existing services;
- Communicate and co-ordinate with utility companies and private service owners for existing and new proposed services as part of the design works;
- Arrange associated trial holes and surveys as part of the design works; and
- Prepare and maintain records of all the utilities impacted by the proposed design.

The CDM Designer shall ensure a CDM combined services drawing for each installation and the pipeline strip maps detail all new and existing services, above and below ground.

The CDM Designer shall record within the TMP being developed for the construction phase, any known utility, private and third party services, permanent materials and equipment at risk; as well as any overhead features that may also be at risk.

No service trial holes shall be undertaken without the prior acceptance of the utilities permit to work system, If applicable, by the project manager or a nominee.

C.2.32 Construction Noise

Whilst it is recognised that most construction noise can be reduced and controlled by the noise generating Contractor, CDM Designers shall consider the noise generation, propagation and transmission within their design process. Perceived noise risks arising from foreseeable construction activities in unusual scenarios shall be identified and recorded for mitigation in the construction phase. Environmental noise, sensitive issues and receptors, affecting species and the public, shall also be identified, recorded and mitigated within the planning and design stages; and the risks, constraints and controls specified for the subsequent construction phase.

C.2.33 Operational Noise

The CDM Designer by the layout configuration, selection of permanent materials and equipment, assessment and means of attenuation shall mitigate noise (control as far as reasonably practical) to its lowest practical level. Sufficient information on the remaining potential operational noise shall be provided to allow the employer to complete the relevant risk assessments and implement suitable risk controls. This information shall also be suitable for the employer to demonstrate ALARP or to meet compliance with any planning authority constraints.

The CDM Designer shall establish and record:

a. The permanent material, equipment and process noise the design will generate;
b. The predicted noise levels;
c. The octave band frequencies;
d. The sound power data;
e. The predicted site Leq level; and
f. Duration for each item and process predicted to generate noise over 79dB (occupational only).

The CDM Designer shall further identify:

a. Which areas are at risk from noise over 79dB;
a. Which areas exceed 80dB and 85dB;
b. Which areas will have a peak sound pressure of 135dB or over;
c. Where tonal noise will/may occur; and
d. Which work areas will require noise measurements to be taken to verify the design expectations.

If noise reduction at source cannot be achieved and provisions for noise control (attenuation) are to be specified by design; the CDM Designer shall ensure the means of attenuation do not compromise normal operational activities. The CDM Designer shall further ensure the means of attenuation do not increase the difficulty or risk to carrying out normal operational and maintenance activities of the permanent material and equipment being attenuated. Where noise attenuation has been specified, the CDM Designer shall provide information on the noise level and octave band frequency reductions that are to be achieved by the attenuation measures to be installed. The CDM Designer shall ensure the means of attenuation can be removed and reinstated with minimal risk to the operator. NGC-SP-MECH-05 – NGCL specification for venting noise shall be adhered to.

C.2.34 Noise Information

The CDM Designer shall take into account and record:

a. Noise risks during any plant start-up procedures;
b. The various operating parameters;
c. Venting operations;
d. The audibility of alarms at quiet spots;
e. The audibility of alarms at all site locations over process noise;
f. The location, type and fixing details of essential noise attenuation;
g. Which permanent material, equipment and processes can generate sudden noise;
h. Process functions that will require an on-going strategy of noise measurements; and
i. What permanent materials and equipment, if faulty, would generate increased noise.

The CDM Designer shall record the findings in a noise report supported by a noise layout drawing(s). The drawings shall detail:

a. The zones of noise above 80dB (and 85dB for mandatory protection) supported by the relevant noise data;
b. The designated hearing protection zones;
c. The signage necessary for restricted access and required hearing protection;
d. Noise levels at the site boundaries and sensitive receptors;
e. Noise levels at operator positions;
f. Noise levels at noise generating permanent material and equipment; and
g. Noise levels along pedestrian routes.

C.2.35 ATEX Compliance

The Explosive Atmospheres Directive 99/92/EC (ATEX) Directive is implemented in the UK through the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations (EPS) and the Dangerous Substances and Explosive Atmospheres Regulations 2002 - (DSEAR).

The CDM Designer shall take full cognisance of the EPS Regulations and DSEAR within his design of Installations.

The CDM Designer shall specify all ATEX certified equipment, protective systems and devices in accordance with the EPS Regulations to support the requirements of DSEAR.

A Hazardous Area Equipment Register listing all ATEX certified equipment, protective systems and devices shall be prepared, maintained and issued by the CDM Designer.

The CDM Designer shall fulfil the Employer's design obligations as set out in DSEAR, especially regulations 6, 7, 8 & 9 and Schedules 1, 2 and 3. In addition the CDM Designer shall provide a preliminary DSEAR risk assessment based on design decisions, considerations and layouts; to support the Employer's design obligation set out in regulation 5.

Within the assessment, the CDM Designer shall also specify the volume/quantity of the dangerous substance that may support an explosive atmosphere mixture and the points of isolation to which that inventory has been calculated. The CDM Designer shall also detail any key equipment, protective systems, devices, cabling and pipework that may be at risk as a consequence of a fire or explosion occurring from an identified explosive atmosphere.

The CDM Designer shall contribute to the requirements of regulation 8 for emergency arrangements by undertaking a study of potential consequences of a fire and/or explosion and determine the safe means of escape. The CDM Designer shall take into account his findings from his design activities and submit an escape assessment as key document supporting the DSEAR risk assessment process.

DSEAR deals only with risks to people from dangerous substances but such substances could also harm the environment during disposal or in the event of a spill. In undertaking any risk assessment, or developing emergency arrangements, the potential for environmental harm should also be considered.

C.2.36 Lightning Protection

The CDM Designer shall undertake and record a lightning risk assessment within his design of Installations. Where required, protective systems shall be specified for communication, electrical and telemetry systems. Where required, lightning conductors and rods shall be located to provide protection to structures, plant and pipework fittings in accordance with NGCL document C001-08-10-99-GD000-0002 - Electrical Earthing & Lightning Protection Specification.

C.2.37 Verification and Validation of Design

The CDM Designer shall develop and submit to the employer, for acceptance, a suitable design verification and validation plan with potential supporting arrangements. The primary objective of the plan is for the CDM Designer to set out the procedures, activities and information necessary to validate the correct performance and functioning of the Installations and or pipelines in compliance with the employer's scope; especially safety critical equipment, systems and processes. The arrangements shall set out the necessary requirements for specification compliance, inspections, testing and commissioning of the constructed design solution.

The CDM Designer shall nominate a commissioning engineer within the design team who shall, from design outset, ensure commissioning criteria aligns to the specified design criteria; and that it forms an integral part of the design process. By design, sufficient safe working space shall be allowed for safe zones, the siting of test permanent materials and equipment, the need for temporary works, and the like.

Typical requirements of design validation may include: - provision of specific information; review of manufacturer's documentation; verification of certification; necessary site inspections; performance tests, factory acceptance tests; site acceptance tests; cable loop tests; cable end to end tests; permanent material and equipment function checks; performance criteria compliance trials; sequencing of key tasks and the like.

The verification and validation plan should identify the tests that need to be carried out to prove the design to its maximum and minimum parameters. For example, if a standby generator is part of the design, identify a test to establish how long it takes the generator to ramp up and supply power to the site and is the time period specified within the design parameters; and observe the effect on all permanent material and equipment after a power failure.

The CDM Designer shall also include within the verification and validation planning arrangements to inspect and accept permanent materials, procured by the employer, as compliant with the design specifications.

Once all specified tests are carried out and the verification and validation process is complete, the employer can be assured the system works as per the design.

C.2.37.1 Construction Specific Requirements

The CDM Principal Contractor/Contractor shall fulfil the duties as set out in the CDM regulations. The CDM Principal Contractor/Contractor will discharge their obligations whilst having regard to requirements of the employer as set out within this document.

C.2.38 CDM Principal Contractor Management Arrangements

The Construction Phase Plan developed by the Principal Contactor must detail the methods of managing, controlling and monitoring all health, safety, and welfare aspects of the Project.

The CDM Principal Contractor is responsible for managing the health and safety aspects of construction on a day-to-day basis.

The CDM Principal Contractor appointed to do the work will qualify his H&S procedures to employer satisfaction; such procedures are to be employed during the work.

The CDM Principal Contractor shall nominate a Project Manager for the Contract who will take overall responsibility for all health and safety matters.

The CDM Principal Contractor shall nominate a site based person who is responsible for reporting to the Project Manager, for the duration of the construction phase who will take responsibility for the day to day management and control of all health and safety matters.

The CDM Principal Contractor shall nominate a H&S Manager/Advisor, reporting to his Project Manager, responsible for monitoring safety compliance on site, reporting non-conformances and supporting accident investigations. The H&S Manager/Adviser shall monitor the effectiveness and relevance of the Construction Phase Plan and propose changes to the Construction Manager as necessary. Changes to the Plan shall be submitted to the employer Project Manager for acceptance and be re-issued to all authorised holders of such.

The CDM Principal Contractor shall include within the Construction Phase Plan a detailed organisation chart showing all management and supervisory levels down to nominated work area supervisors/foremen for each construction activity; including those of Contractors. The organisation chart should specify communication links between the CDM Principal Contractor and other Contractors, CDM Principal Designer/CDM Designers (as necessary) and key members of the Client team.

This does not relieve the Contractor acting as CDM Principal Contractor of his obligation to observe all legislative requirements and guidance with regard to health and safety including preparation of method statements for all activities carried out on their part of the work and ensuring a similar compliance by all his Contractors.

C.2.39 Construction Risk Management

The CDM Principal Contractor has duty to manage and mitigate the identified and foreseeable risks. The CDM Principal Contractor shall set out in the Construction Phase Plan his procedures for identifying, mitigating and controlling construction risks; and identify those with responsibilities for doing such.

C.2.40 Construction Phase Plan

The CDM Principal Contractor shall develop and implement a Construction Phase Plan taking cognisance of the requirements in this document and of the CDM Regulations. The Plan shall be kept and maintained by the CDM Principal Contractor in such a manner as it will be readily available to site personnel and all other entitled persons. The CDM Principal Contractor's Project Manager shall take responsibility for review, compliance and update of the Construction Phase Plan. Audits shall be undertaken by employer.

The CDM Principal Contractor shall have in place adequate systems and procedures vetted and accepted as suitable by employer and which must be included in the Plan. Sufficient detail must be provided in the Plan to ensure identification and compliance with such systems and procedures.

It will be essential for the CDM Principal Contractor to liaise with any other relevant Contractors and third parties.

The developed Construction Phase Plan will be assessed by the employer, CDM PD and NGCL H&S Adviser. The construction phase shall not commence until the Construction Phase Plan is in place and considered suitably and sufficiently developed by the employer.

A documented (recorded) review of the Construction Phase Plan shall be undertaken on a regular basis by the Construction Manager or their nominated representative; this is to be shown on the front sheet of the plan.

C.2.41 Security of the Site

Security of the construction working areas, associated off-easement areas and site establishment areas are the responsibility of the CDM Principal Contractor and as a minimum be in accordance with HSE Guidance Note, Protecting the public HS(G)151.

The CDM Principal Contractors arrangements for security of the site areas and the provision at access and egress points must be clearly indicated within the developed Construction Phase Plan.

Security of Contractor's vehicles, plant, equipment, substances and materials stored on the site is the CDM Principal Contractor's responsibility. Consideration should be given to the hazard and risk in accordance with DSEAR. COSHH, etc.

Where excavations are left open overnight and in close proximity to public areas, the CDM Principal Contractor shall secure the perimeter of the excavation with Heras fencing, and appropriate notices and signs, in accordance with Health and Safety (Safety Signs and Signals) Regulations 1996.

Details and requirements for ensuring security shall be set out in the Construction Phase Plan and may include but will not be limited to:

- Protection of the public;
- Protection of private and public areas;
- Removal of old materials;
- Passage of new permanent materials and delivery to Site;
- Site security – covering yards, offices, excavations, site areas; and 24 hour as required;
- Maintenance of public rights of way;
- Maintenance of existing physical features; and
- Adjacent sites and premises.

C.2.42 Welfare Provision

The CDM Principal Contractor shall provide welfare facilities in accordance and in compliance with the CDM Regulations 2015; and the HSE's construction information sheet No. 59 'Provision of welfare facilities during construction work'. Details of the project welfare provisions and the management arrangements to monitor and maintain them must be clearly defined within the Construction Phase Plan.

All cabins and containers must have door restraints fitted to them to ensure that they cannot accidentally close and injury anybody. Any cabin or container arriving at site without door restraints should be replaced immediately.

The Contractor shall erect, in a prominent position available to all personnel, a health and safety notice boards. The notice boards shall display as a minimum:

- Health and Safety Law poster;
- F10 Project Notification Form;
- Fire and emergency procedures; including emergency telephone numbers;
- Hospital Route and First Aiders;
- Safety bulletins, relevant best practices (as necessary); and
- Client and Contractor Health and Safety, Quality, Environment Policies and Insurance Certificates can be put in a folder and hung from the wall where wall space is limited.

C.2.43 Traffic Management

The CDM Principal Contractor shall develop and implement a Traffic Management Procedure back to the nearest "A" road which shall locate all highway restrictions; to assess highway and traffic route risks; locate safe access/egress points; co-ordinate and communicate with the Local Authority (as required).

The Traffic Management Procedure shall result in a succinct Driver's Traffic Pack that includes:- a project specific traffic route map; traffic route restrictions; locations of specific high risk areas; driver's rules; emergency procedures and contacts; and plot plans of all working areas including; welfare areas, laydown areas, storage areas, other Contractors areas etc.

The CDM Principal Contractor shall issue the Driver's Traffic Pack to all drivers of any vehicle or plant associated to the project, including those of suppliers.

It is an employer requirement that all highway accidents or incidents involving any vehicle or plant associated to the project be reported to the employer immediately.

Vehicles and plant associated with the project must report to the CDM Principal Contractor's site office prior to being used. The CDM Principal Contractor shall inspect and check all vehicles and plant and their associated records before allowing their use on site. The CDM Principal Contractor shall maintain a Plant Register of all vehicles, plant, MEWPs and lifting appliances used on the project. The drivers of all vehicles and plant shall retain a copy of the Driver's Traffic Pack with the vehicle/plant.

The CDM Principal Contractor must provide prominent highway signage indicating the direction to be taken by vehicles for delivery and offloading. Signage indicating the speed limit along the access tracks and on the pipeline route must also be clearly positioned. Signage shall also comply with NRSWA requirements as necessary.

CDM Principal Contractor shall notify other users of the approach lanes of the project works and of any critical delivery dates likely to cause access or traffic disruptions.

The CDM Principal Contractor shall make suitable provision to ensure:

- All roads and tracks are kept clean of mud and other a risings;
- That no tracked vehicles or plant be allowed to cross roads or tracks that are unprotected; and
- No vehicles or plant park on the highway, verges or private land.

Vehicle and pedestrian routes on site must be clearly identified, well lit and with physical separation provided and maintained where practicable. A qualified, competent Banksman must be used whenever a vehicle is reversing.

C.2.44 CDM Principal Contractor's Permit to Work Systems

The CDM Principal Contractor shall implement a Permit to Work Systems for:- opening and closing excavations; installing and removing of temporary works; lifting operations over 1 tonne; hot works; and for the permission to pump ground water, and electrical permit to work, isolations, re-energising, and sanction for test.

The CDM Principal Contractor shall nominate a Permit Controller, who shall take responsibility for the management, issue of permits and compliance monitoring of the Permit to Work Systems.

Before a Permit is issued, the Permit to Works System controller shall verify that key controlling documents have been approved and are available, competent persons are present, plant/equipment certification checked, all necessary materials are present on site, current and near future adjacent site activities pose no additional risks and that all monitoring/inspection requirements are identified.

C.2.45 Fire Precautions

The CDM Principal Contractor shall carry out a fire risk assessment of all site premises and storage areas. A suitable Fire Policy shall be developed, communicated and implemented accordingly; that includes for testing of the evacuation procedures at regular intervals throughout the contract period (frequency will depend on the construction programme).

Site establishment and yard plot plans shall be developed that fully details accommodation facilities, welfare provisions, storage, parking, pedestrian routes, emergency routes, muster points, fire alarm points, location of firefighting facilities and the like.

The CDM Principal Contractor shall ensure that suitable and sufficient supply of firefighting equipment is available for use by the Contractor's personnel at workplace locations, particularly when carrying out hot works.

C.2.46 Emergency Arrangements

The CDM Principal Contractor shall develop, communicate and implement suitable Emergency Arrangements based on the potential emergency scenarios.

The CDM Principal Contractor shall empower site managers and foremen to make critical decisions during the occurrence of a major incident. Accordingly, those identified to control emergency events and make critical decisions shall be suitably trained.

Emergency Arrangements, including first aid provisions, shall be included within the CDM Principal Contractor's Construction Phase Plan.

C.2.47 First Aid Provisions

The CDM Principal Contractor shall undertake a first aid risk assessment and establish suitable First Aid Provisions for the nature and extent of the project.

As a minimum, at least two trained first aiders shall be present at each site location whilst works are being undertaken.

It is an employer requirement that suitably stocked first aid kits be available in each construction vehicle.

The CDM Principal Contractor shall maintain a project specific Accident Book.

C.2.48 Smoking and Sources of Ignition

Smoking on all NGCL construction sites is prohibited. Smoking will only be allowed at designated off site locations.

All hot works shall be authorised under a Permit to Work.

The CDM Principal Contractor shall undertake a DSEAR risk assessment for dangerous substances under his control, such as butane, propane, acetylene, petrol and the like.

Where potentially explosive atmospheres and oxygen depletion or enrichment may occur, the CDM Principal Contractor shall provide suitable Monitoring Devices. Those required to use them shall be suitably trained.

All personnel shall wear appropriate flame retardant PPE on a top layer basis, and ensure long sleeve T shirts are worn (to cover exposed skin in the event of a flash fire).

C.2.49 Hydrostatic Testing

All pre installation hydrostatic testing will be carried in accordance with employer specifications and procedures.

The CDM Principal Contractor shall obtain all consents to abstract and discharge test water.

C.2.50 Movements over Buried Pipelines

The CDM Principal Contractor shall agree all crossing points over buried pipelines with the statutory owner or his nominee. The CDM Principal Contractor shall undertake all agreed activities to locate the pipeline and provide all necessary ground protection and ensure restriction to the crossing point by use of appropriate fencing and signage.

C.2.51 Accident and Incident Reporting

The CDM Principal Contractor shall develop and implement an Accident/Incident Reporting Procedure and have access to an approved means of recording accidents on site. All accidents, incidents, near misses and dangerous occurrences are to be reported to the employer to be inputted through the National Grid NGUK/SHE/INV/1 system.

The CDM Principal Contractor is to ensure prompt remedial action following an accident or incident and take all necessary action to ensure any remaining risks are made safe.

All accidents, incidents and dangerous occurrences shall be investigated by the CDM Principal Contractor relevant to their seriousness. The findings of all investigations shall be communicated to the employer within 48 hours of the event.

HSE Notices and EA Notices are to be reported to the employer immediately.

C.2.52 Personal Protective Equipment

Unless prior exemption is obtained from the employer, and on the basis of a risk assessment, the PPE requirements set out in National Grid procedure Personal Safety Equipment and Personal Protective Equipment (NGUK/PM/SHE/11) must be adhered to.

Personal protective clothing and equipment including coveralls or work wear, safety helmets, eye protection, safety boots with ankle support and high visibility jackets shall be worn at all times; and a glove policy shall be implemented to allow suitable and task specific work gloves to be available for use at all times.

Other PPE based on activity risk assessment shall be worn, such as – double layered fire suits with hoods (Nomex or equivalent), fall arrest harnesses, breathing apparatus and the like.

The CDM Principal Contractor shall state in the Construction Phase Plan which site activities require additional specific PPE to be worn.

C.2.53 Project Specific Site Rules

The CDM Principal Contractor shall develop, communicate and display project specific Site Rules for compliance by all persons working on the site or visiting.

The Site Rules shall be signed and dated by the CDM Principal Contractor's Project Manager and shall be reviewed monthly for continuing suitability.

C.2.54 Project Specific Inductions

The CDM Principal Contractor shall develop a project specific induction, that as a minimum includes:- the management arrangements for the project; the significant project hazards and risks; the safe systems of work to be adhered to; the emergency arrangements; specific PPE requirements; driver's traffic pack; and the welfare provisions.

All workers and management personnel involved in the project shall be inducted prior to entering the construction sites and associated areas. Visitors who are to be shown around the site must be accompanied by an authorised person at all times.

An additional Supervisors Induction shall be given to all Supervisors / Foremen that sets out their management responsibilities, the duties expected of them and the records that are to be kept with regard to health, safety and welfare.

The CDM Principal Contractor shall maintain an induction register and record sheet of all Inductions undertaken.

C.2.55 Safety Passports

All workers and management personnel shall hold a valid Health and Safety Passport prior to entering the construction sites and associated areas. The CDM Principal Contractor shall be responsible for arranging and facilitating all passport training as necessary.

The CDM Principal Contractor shall extend the Induction Register to record holders of Passports identification number or the current status of passport training.

C.2.56 Substance Management

No substances shall be brought onto site and used without a relevant manufacturer's product data sheet and a verified COSHH assessment being submitted and approved by the CDM Principal Contractor.

The CDM Principal Contractor shall nominate a COSHH Co-ordinator for the duration of the project; who shall ensure suitable procedures are implemented for the management of all substances. The COSHH Coordinator is responsible for developing and maintaining the COSHH Register which shall contain all COSHH substances on site, including those of Contractors.

The manufacturer's product data sheet and COSHH assessment for all substances incorporated into the permanent works shall be retained and included into the Health and Safety File collated for the project.

C.2.57 Utilities Obstacle Register

The CDM Principal Contractor shall nominate a Utilities Co-ordinator for the duration of the project; who shall ensure all utility service information is obtained, existing services locations verified and documented records and photographs kept.

A Utilities Obstacles Register shall be developed and maintained for all buried and overhead services encountered.

Each overhead service shall be subject to a risk assessment in conjunction with the utility owner and all mitigation measures agreed.

Crossing of utility services shall be subject to the CDM Principal Contractor's Permit to Work System.

C.2.58 Temporary Works

The CDM Principal Contractor shall develop and adhere to his own temporary works procedure and shall ensure temporary works are suitably controlled.

The CDM Principal Contractor shall nominate in writing to the employer, a Competent Temporary Works Co-ordinator, who shall take responsibility for the design and management of all temporary works.

The CDM Principal Contractor shall provide a competent onsite Temporary Works Supervisor that has the relevant up-to-date technical and H&S training together with the relevant qualifications and experience appropriate to the operations for which they are responsible and undertaking.

Temporary works includes that of ground support systems, battered excavations, ground dewatering systems, loaded platforms/scaffold, mechanical frames, electrical systems and site establishment facilities.

Unless a scaffold is a basic configuration described in recognised guidance e.g. NASC Technical Guidance TG20 for tube and fitting scaffolds or manufacturers' guidance for system scaffolds, the scaffold should be designed by calculation, by a competent person, to ensure it will have adequate strength and stability – for further guidance see http://www.hse.gov.uk/construction/scaffoldinginfo.htm

Scaffold platforms that do not fall into the 'Basic Scaffold' shall be deemed temporary works and shall be designed, managed, recorded and inspected accordingly.

Temporary Works Register(s) shall be developed and maintained for all types of temporary works.

Construction activities requiring temporary works shall not commence until an approved design, approved installation/removal procedures and all necessary materials are available.

The installation and subsequent removal of temporary works shall be over seen by the site temporary works supervisor, and be in line with the CDM Principal Contractor's Permit to Work System.

C.2.59 Excavations

The CDM Principal Contractor shall implement their Permit to Work System to approve and manage the commencement of any excavation.

C.2.60 Lifting Operations

The CDM Principal Contractor shall nominate a Lifting Co-ordinator, who shall take responsibility to ensure all lifting operations are competently planned and supervised, including those of Contractors. Lifting plans for all lifts over 1 ton and difficult, awkward and contract lifts shall be submitted in advance to the employer for acceptance when requested to do so.

The CDM Principal Contractor shall implement a means of 'in-date' inspections and recording for all lifting equipment, such as colour tagging.

The CDM Principal Contractor shall implement a 'quarantine area' for all out of date, damaged and faulty lifting equipment. Equipment may only be held in the quarantine area for a short period of time before it is revalidated or removed from site.

C.2.61 Safety Inspection and Testing of Mechanical Equipment

C.2.61.1 Receiving Mechanical Equipment and Construction Vehicles at Site.

All mechanical equipment brought to the Site, including that of Contractors, shall be inspected by the Contractor to:

- Ensure it is in good operational condition;
- Confirm it has all statutory certification, e.g. lifting certificates, MOT"s etc;
- Confirm it is the correct type of equipment for the work to be done, and in the case of equipment owned/ordered by the Contractor meets the requirements of the requisition of order;
- Ascertain that for equipment supplied with an operator, the operator is conversant with the duties and type of work to be done, and is competent and familiar with the equipment to be used;
- Ensure that equipment provided without an operator, has a competent person allocated as responsible for operating the equipment, and who is familiar and trained for the equipment to be used; and
- Ensure it is fit for purpose and has been fully serviced prior to delivery to the Site.

The Employer particularly requires the Contractor to comply with the requirements as follows:

- **Recording -** the Contractor shall maintain a register of all equipment inspected and further ensure that a system of regular auditing of inspected equipment is initiated;
- **Non Mechanical Equipment -** shall be subjected to appropriate inspection and recording in line with the foregoing. The CDM Principal Contractor shall maintain a PAT Register of all Portable Appliance Equipment on site (including SubContractors). PAT test records should be maintained onsite at all times; and
- **Operation of Equipment –** the Contractor shall ensure that site equipment is used only by trained and competent operators; and monitored and directed by a trained and appointed banksman when in use; and where risk assessment and method statement identifies this requirement. As a minimum requirement, Banksmen will be required for all operations involving excavation, lifting and plant movement. The Contractor will adopt a system to ensure that Banksmen are instantly recognisable.

C.2.62 Radiography

The CDM Principal Contractor shall seek to undertake as much off-site radiography as possible and shall comply with the requirements of the Ionisation Radiations Regulations 1999.

C.2.63 Noise

Prior to the works commencing, the Contractor shall identify and record the potential sources of noise, carry out risk assessments and propose the controls. The risk assessment and controls shall be verified by onsite measurement at the location or source. They shall, as required by the risk assessments, implement additional training and health surveillance to the persons affected. Information and advice regarding the health effects from noise shall be incorporated into the Supervisor's / Foremen's Safety Folder.

The Contractor when configuring an Installation and positioning all plant, permanent materials, equipment and operational activities during the design works, shall take into consideration the noise and noise levels that will generated.

Prior to the construction phase the Contractor shall identify and record the potential sources of construction plant and equipment noise and carry out risk assessments. They shall, as required by the risk assessments, implement additional training and health surveillance to the persons affected. Information and advice regarding the health effects from noise shall be incorporated into the Supervisor's / Foremen's Safety Folder.

All construction plant and equipment generating noise levels over 79dB shall have suitable signage fixed to the item, displaying the relevant noise information and mandatory hearing protection signage where applicable.

C.2.64 Public Rights of Way

Where 'closures' cannot be obtained the CDM Principal Contractor shall secure and manage the means to maintain the public right of way and ensure the safety of the public.

Where rights of way are to remain open they shall be deemed temporary works and shall be designed, managed, recorded and inspected accordingly.

C.2.65 Project Specific Hazards and Risks

Issues regarding the local environment, and the known hazards and risks have been recorded within the Risk Register.

The CDM Principal Contractor shall review and take full cognisance of these issues when planning for the management of health and safety and for the implementation of suitable risk controls at each site and workplace location.

C.2.66 Risk Assessments and Work Procedures

The CDM Principal Contractor shall undertake risk assessments of: - each of the issues recorded on Hazard documents; those required by legislation; and of each construction activity. Suitable safe systems of works shall be developed and implemented accordingly. A nominated competent supervisor shall take responsibility for each construction activity, the immediate work area and effective implementation of the safe systems of work.

For routine activities and tasks 'model' risk assessments and work procedures may be adopted, providing they are reviewed to ensure they are relevant to the works and amended accordingly.

All safe systems of work and risk assessments shall be verified at the workplace immediately prior to the construction activity commencing. This verification is required to ensure there are no additional risks or changes required to the controls; the verification and any perceived changes shall be recorded on the relevant documents.

The CDM Principal Contractor shall implement a procedure to review, approve and provide document control to all other Contractors risk assessments and safe systems of work prior to forwarding to the employer for review. A copy of the review sheet used by the CDM Principal Contractor shall be sent through with the risk assessment and work procedure.

All risk assessments and requirements of the safe system of work shall be briefed to the relevant and affected groups of workers; all workers shall sign a record to state they have understood the risks involved and safe systems of work to be adhered to.

C.2.67 Hazard in Construction (HAZCON) Study

A HAZCON Study is a FPSA to be arranged, and managed by the CDM Principal Contractor prior to the commencement of the construction phase. The employer's management procedure NGC/MP/HS/01 is to be adhered to.

A HAZCON Study shall be undertaken three weeks prior to the commencement of the construction phase. The HAZCON Study is a systematic review of the known hazards and risks, and an evaluation of the safe systems of work proposed by the CDM Principal Contractor. Actions will be generated where risk management can be improved, does not meet employer requirements or fails to meet accepted industry practices.

All Actions generated must be addressed and ‘closed out’ by the HAZCON Chairperson prior to the construction phase commencing with any residual hazards and risks are recorded on the CDM Risk Register.

The HAZCON chairperson(s) shall be suitably competent and independent form the project, and approved in accordance with the employer’s management procedure NGC/MP/HS/01. The employer reserves the right to appoint and nominate the FPSA chairperson(s). In this instance the CDM Principal Contractor shall work with the employer’s appointed chairperson to prepare, deliver and close-out the FPSA.

The CDM Principal Contractor’s Project Manager, Construction Manager, Temporary Works Coordinator, Environmental Adviser and H&S Adviser shall attend this Study.

Attendees from the employer project team shall be identified by the employer Project Manager and are likely to include Project Supervisor’s, H&S Adviser’s, Environmental Advisor’s, CDM Principal Designer, and the Design Manager.

C.2.68 Look Ahead Risk Mitigation

The CDM Principal Contractor shall hold a formal weekly Construction Meeting to discuss following week’s programme of work. At these meetings a review of the CDM Risk Register, the forthcoming construction risks, suitability of proposed controls and lessons learnt shall be an agenda item of the Construction Meetings.

A ‘weekly look ahead’ programme with the significant risks noted and controls shall be submitted to the employer. The employer or his nominee shall be invited to attend these meetings.

C.2.69 Safety Briefings

The Supervisor/Foreman shall brief the details of the relevant safe system of work and risk assessment to the workers affected. Any changes to the safe systems of work shall be immediately briefed to the workers. A record of the briefings shall be kept.

The Permit Controller shall brief the requirements and limitations of the permit to the Supervisor/Foreman receiving the permit.

Tool Box Talks shall be delivered to the work force to raise and maintain safety awareness; they shall be topical and aligned to the programme of works.

Lessons learnt, investigation findings, best practices and safety alerts may be delivered as tool box talks.

In the event of a serious event, the CDM Principal Contractor shall undertake a ‘safety stand down’, where all works are briefly stopped to enable the safe systems of work and importance of safety management to be re-emphasised; and where necessary focused training delivered; to the workforce and management team.

C.2.70 Supervisor's Safety Pack

The CDM Principal Contractor shall develop and issue to all Supervisor's/Foremen a Safety Pack containing relevant management responsibilities, safety procedures, information, safe systems of work and relevant record sheets. This Safety Pack shall typically contain the following:

- Emergency Procedures;
- First Aid Arrangements;
- Emergency Contact details;
- The Site Rules;
- Driver's Traffic Pack;
- Tool Box Talks topics, register and record forms;
- GS6 – Overhead Electricity Lines;
- HSG 47 – Underground Services;
- Specific safe systems of work and risk assessments; and briefing forms;and
- Permit to Works requirements.

C.2.71 Employer's Compliance Audits and Inspections

The employer shall undertake compliance audits and inspections of the project delivery team engaged to manage the design works, survey works and construction works on their behalf; the CDM Designer/Contractor shall provide the support and evidence necessary, when requested, to demonstrate the effective and safe management of their contract and delivery of services.

The employer shall identify certain key aspects of the CDM Designer's/Contractor's activities, deliverables and services they deem of sufficient importance and criticality where they will need to undertake independent audits and inspections. The CDM Designer/Contractor shall provide the support and evidence necessary, when requested, to demonstrate the effective and safe delivery of services, compliant with their scope of work and this document.

C.2.72 Employer's Audits and Inspections

The employer maintains a 'rolling' two year CDM Designer and Contractor audit programme; and depending on timescales/previous results, a formal ISO 9001 quality management audit of the CDM Designer's/Contractor's quality system may be undertaken by the employer.

C.2.73 Design Works Audits and Inspections

Before the design works commences, the employer in conjunction with the CDM Designer shall produce a programme of design compliance audits and inspections.

The CDM Designer's audit and inspection procedures shall be strictly adhered to and a copy of the internal and external inspection/audit reports shall be issued to the project manager.

The CDM Designer shall be responsible for ensuring, and be able to demonstrate that, non-compliance reported by the employer and from inspection/audit procedures are closed-out expeditiously.

The CDM Designer shall ensure that the schedule of internal and external audits and inspections covers the planning, design, site and construction phases (supporting role).

The CDM PD shall ensure design compliance checks are undertaken as per the programme. Health, safety and CDM matters identified as being non-compliant with the design plan, the employer's quality management plan and legislation shall be submitted to the project manager.

C.2.74 Survey Works

Before survey works commences, the employer in conjunction with the CDM Designer shall produce a programme of survey work audits and inspections. These shall include compliance audits and weekly and monthly inspections.

The issued audit and inspection programme will be included in the employer's project control manual and the CDM Designer's survey phase plan.

The project manager (or a nominee) should manage the weekly and monthly inspections during the survey works. Health and safety matters identified as being non-compliant with the survey phase plan, the CDM Designer's design plan, the employer's contract quality plan and legislation shall be submitted to the project manager.

C.2.75 Construction Works

Before construction works commences, the employer in conjunction with the CDM Principal Contractor shall produce a programme of construction work audits and inspections. These shall include compliance audits and weekly and monthly inspections.

The issued audit and inspection programme will be included in the employer's Quality Management Plan and the CDM Principal Contractor's construction phase plan.

The project manager (or a nominee) should manage the weekly and monthly inspections during the construction works. Health and safety matters identified as being non-compliant with the construction phase plan, the employer's quality management plan and legislation shall be submitted to the project manager.

C.2.76 Non-Conformances

All non-conformances shall be recorded on the action log and maintained throughout the life of design works. Progress of the outstanding actions shall be reported to the design meetings and where required escalated to the project progress meetings.

C.3 Offshore Project H&S Requirements for Detailed Design and Construction

Reference to the use of specific employer documents may be supported by CCS specific local working procedures referenced in the project control manual.

C.3.1 General Requirements

The employer will act as the principle contact for all enquiries related to the content of this document. All project contractors will ensure they familiarise themselves and their employees with the contents of this document and ensure compliance with its requirements. Where any gaps are identified between safety management systems these shall be brought to the attention of the employer who will determine the action to be taken in order to obtain successful resolution.

When developing project specific arrangements and documentation, contractors shall identify the hazards and assess the risks at each of the key stages of planning, design, survey, construction and commissioning, including but not necessarily limited to those identified in this document. Contractors shall also identify the organisation and arrangements for managing health, safety and welfare.

The project specific arrangements and documentation shall be reviewed, kept up to date, modified and altered in the light of changing circumstances. As the planning, design and survey work progresses, the arrangements will need to be amended and updated as a result of hazard identification, risk assessments, mitigation and methods of working proposed. Reviews of the arrangements and documentation may also need to be made if there are for example design changes, unforeseen circumstances, preferred construction methods and operational constraints. It is vital that such changes are notified to all those working on the project who may be affected.

C.3.1.1 Project Goals, Objectives and Targets

This document prescribes the minimum QHSE requirements for CCS project offshore activities. In this instance offshore working includes all project activities associated with the transport, installation, hook-up, commissioning and hand-over of the CCS topsides, jacket structure and wells along with all associated subs sea, sub surface and support facilities located with the platform 500 m zone. CCS contractors shall develop their own project/work scope specific QHSE plans that are aligned with the requirements of this document. All CCS project QHSE queries in relation to the contents of this document should be directed to the CCS QHSE manager.

This document establishes the minimum expectations for the offshore QHSE management and details the controls that should be in place for specific hazards or risks. All offshore work shall be carried out in compliance with this and other CCS offshore QHSE standards and procedures.

A contractor pre-qualification and selection process has been applied by the project to ensure all contractors operate a QHSE management system that aligns to the standards and expectations of NGCL. The pre-qualification process has also assisted the QHSE team in developing a suitable QHSE management plan for those contractors selected

C.3.1.2 Goals

In line with the National Grid QHSE policies, the following offshore project goals have been set as a minimum:

- To reduce risks to health, safety and the environment from the new facilities to ALARP through correct design, material and equipment selection, fabrication, installation and commissioning;
- To eliminate all accidents and incidents which could occur during the course of the project;

- To provide a safe and healthy work environment with a focus on zero accidents/ incidents, zero dropped objects and zero environmental releases;
- To actively manage QHSE and in so doing improve the awareness of all personnel connected with the project;
- To comply with all relevant QHSE legislation, regulations, safety procedures, etc;
- To establish safe working practices for all personnel associated with the CCS project;
- To provide training for all personnel to enable them to work safely; and
- To provide within the project, the means necessary for the collection, discussion and dissemination of up-to-date, authoritative and reliable information on QHSE matters.

These goals shall be achieved by the implementation of existing procedures, standards and specifications as appropriate, with the development and implementation of project specific procedures as required. Project QHSE goals shall be reviewed on a 12 monthly basis in order to assess the QHSE project performance and also ensure that they remain valid as the project progresses.

C.3.1.3 Objectives and targets

The objective is to ensure an effective and coordinated approach between all stakeholders throughout all phases of project execution. The project objectives that have been adopted include the following:

- Total recordable rate <0.1;
- No serious injuries;
- No serious accidents;
- No enforcement action;
- No significant procedural violations;
- No high or significant potential dropped object incidents; and
- No unintentional releases to the environment.

C.3.2 Hazard Identification and Control

C.3.2.1 Risk Assessment

All stakeholders will take due cognisance of the environmental, organisational and job factors and human and individual characteristics, which may influence behaviour at work in a way which can affect any aspect of the inherently safe design principles of the offshore facilities.

Dynamic risk assessments shall be carried out during all project phases that will consider normal, abnormal and emergency operating conditions. The project assessment process will utilise a multi-discipline team consisting of members from both client and contractors management teams. Once the assessment process is complete, all relevant personnel shall be informed of the risks identified and the control measures necessary to eliminate, reduce or control the risks. The assessment output and resulting action plans shall be documented. Implementation of effective control measures shall be audited on a regular basis to ensure that they are effective.

C.3.2.2 Inherently Safe Design

The project design principles shall follow the principles of inherently safe design, which is one that avoids hazards instead of controlling them. All aspects of the design shall be assessed with overall risk levels demonstrated to be within recognised acceptable levels and reduced to as low as reasonably practicable (ALARP). The demonstration of ALARP will be based on established principles of safety engineering and good engineering practice. The following approach provides guidance as to how a demonstration of ALARP is to be achieved:

- Quantitative Risk Assessments for on and offshore processes. This risk assessment provides the basis for demonstrating that the selected design is capable of achieving acceptable levels of safety once operational;
- A Hazard Management Plan to be implemented during detail design to define the full range of safety and environmental hazards and consequences for input to the engineering;
- Continual assessment of HSE aspects to ensure that risk levels remain at acceptable levels through the various project phases and ALARP solutions are achieved;
- Progressive HSE definition to ensure that by the time of operations start-up, an effective Safety Case has been established through all the required deliverables and associated operating procedures; and
- A goal of zero workplace incidents.

With a focus on major accident hazards, the hazard management philosophy for the development of the project considers:

- Lessons learned from previous projects;
- Inherent safety/safety by design;
- Fire and CO_2 release strategy;
- Escape and evacuation strategy;
- Emergency response arrangements; and
- Minimizing the exposure of personnel to risks in hazardous areas.

C.3.2.3 Safety Critical Elements

Safety critical elements have been identified for the offshore platform and pipeline along with (high level) performance standards for each safety critical element.

Safety critical element identification and performance standard development will progress as the offshore design matures. The impairment or safety critical element’s should be avoided at all times during normal operations, however during construction and commissioning activities the impairment of safety critical element’s may be unavoidable. In this instance a Safety Critical Element Impairment Risk Assessment (SCEIRA) will be carried out by a multi-discipline team with all findings recorded on the relevant worksheets.

C.3.2.4 Process Safety Management

In order to provide a service to its customers National Grid owns and operates a number of major hazard assets, which have the potential to cause many injuries and major damage to property and the local environment. Through effective process safety management we can ensure that the assets remain safe and reliable.

The group process safety team has been established to support the business in the management of major hazard assets through the development and implementation of process safety management system.

The framework and risk control standards have been developed to ensure consistent approach to the management of major hazard facilities and networks across National Grid. They are not intended to replace existing management systems but strengthen accountability and set minimum standards for process safety management across National Grid.

Scope – they apply to the major hazard assets; liquefied natural gas facilities, high pressure pipelines and installations (UK >7barg) (US >125psig), compressed natural gas, gas storage, generation, gas storage sites, transportation of hazardous substances, CO_2transportation and drilling operations.

C.3.2.5 Corrective Actions

Mitigating strategies shall be assigned to responsible parties and target closeout dates established using project action tracking systems (currently SAMS). These shall be subject to periodic review and update as required throughout the project lifecycle. All actions resulting from these studies shall be closed out in an auditable manner prior to commencement of the related works.

C.3.2.6 Installation, Hook-Up, Commissioning and Handover

Multi-discipline workshops (HAZID, constructability review, three dimensional model review, etc.) will be conducted during detailed design in order to carry out preliminary assessments of the hazards that may be foreseen during the offshore phases of the project.

The aim of these workshops will be to identify the hazards associated with the installation activities and ensure that the required risk reduction measures are put in place.

C.3.3 Structure and Responsibility

C.3.3.1 New Starter

All new starters to the project will be provided with an induction, which covers as a minimum, the following subjects:

- Project overview;
- Project QHSE goals and objectives;
- QHSE standards, expectations and communication;
- Golden rules;
- Site layout, location of muster area, first aid facilities, welfare facilities, etc;
- Emergency response procedures;
- Behavioural based safety programme;
- STOP/good spot card system;
- PPE requirements; and
- Hazard recognition.

All personnel travelling offshore will have completed the following as a minimum:

- Pre-mobilisation brief (including project induction);
- Basic Offshore Safety Induction and Emergency Training (BOSIET);
- Minimum Industry Safety Training (MIST); and
- Current OGUK medical.

C.3.3.2 Roles and Responsibilities

A successful project depends on having an effective organisation, with clearly defined roles and responsibilities, good communication, effective controls and experienced personnel in key positions. Whilst full job descriptions are available, this section details the QHSE responsibilities for project personnel. Health and safety requirements are line management as well as an individual's responsibility:

- Ensure all project related activities meet or exceed corporate QHSE and ethical policies;
- Enforce corporate core values;
- Manage project resources;
- Develop and implement project strategy and objectives;
- Implement agreed project metrics and benchmarking;
- Lead and motivate project personnel;
- Incorporate lessons learned from similar projects within the organisation;
- Ensure all accidents/incidents are thoroughly investigated to identify causes and prevent recurrence;
- Ensure that any deficiencies in equipment, standards and operating procedures within his control are corrected;
- Review and comment on key engineering deliverables;
- Promote a high degree of safety and environmental awareness among all contractors;
- Assure awareness of CCS project within NGCL and act as an information conduit for project queries;
- Review and comment on key engineering design deliverables and ensure relevant discipline engineers are consulted as required;
- To represent and communicate the views of respective NGCL disciplines at project meetings; and
- Discipline representation (as required) at HAZOPs, HAZIDs, risk assessments, etc.

C.3.3.3 Key Project Personnel

An important part of QHSE management is the provision of competent personnel. CCS employee selection and training processes provide the appropriate controls to ensure that only personnel who are deemed competent are permitted to perform work on the CCS project.

Selected contractors will produce a suitable training plan which shows the training available, the delivery method and competency requirements of all members of the workforce. Training records for all members of the workforce shall be available for audit and inspection purposes. Supervisors, team leads and above shall be able to demonstrate the attendance at formal safety management training for example MIST, IOSH, NEBOSH, etc.

All personnel new to offshore for the first 30 days shall be made distinctive by a specific hard hat colour, decal or means of identification.

C.3.3.4 Job Descriptions

Personnel on the CCS team have their position, QHSE, quality and technical responsibilities formally defined within individual job descriptions. Job responsibilities and accountabilities are outlined for all key project members in the CCS project RACI chart.

The project manager/director shall ensure that personnel assigned to the project have the necessary experience, training and qualifications to perform their intended function. The QHSE plan identifies the QHSE requirements for the project. Project personnel shall familiarise themselves with the plan.

C.3.4 QHSE Programs and Procedures

NGCL has an established set of company procedures and method statements relating to offshore working, which are applicable to all projects.

C.3.4.1 Pro-active QHSE Initiatives

Owing to the demanding nature of offshore working environments it is important to pro-actively prevent all accidents. In a drive to eliminate incidents, a programme of positive QHSE promotion will be applied throughout the project. Wherever it is appropriate, environmental aspects will be included within campaigns. The project shall participate in safety initiatives that are undertaken to promote safety awareness.

Safety initiatives shall be utilised both in the project offices, offshore and at contractor's sites and incorporate an aspect of recognition and reward. All hazard recognition submissions will be reviewed as they are received with suitable corrective action taken to eliminate or mitigate the hazard. The recognition and reward aspect of the scheme will be managed at each location with awards presented on a monthly basis with the selected nominee decided by the location based safety committee. Special recognition awards will also be made to personnel who show exceptional commitment to the project safety management principles.

In order to maintain focus on the CCS project goals the project initiative will focus on raising safety awareness, for example; in the areas of "Hand injury prevention", "safe working at Height" and "Housekeeping" (HHH). Short training packages will be developed and delivered to all project personnel.

Behavioural based safety programmes can be useful in raising awareness of the risks we may be exposed to; it allows workers to anticipate risks and hazards before they occur, so that they do not put themselves and others in a vulnerable position. We must accept that safety is the personal responsibility of all members of the project and always be proactive regarding safety. The use of behavioural based safety shall be required throughout all stages of the project. Adequate training shall be provided to all personnel as required. A minimum project target of 95% of workforce personnel will be trained in the use of behavioural based safety.

C.3.4.2 Environmental Care

CCS shall minimise the potential impact on the environment by using sound environmental management principles. Product and material selection shall be reviewed with regard to environmental impact in its intended use and ultimate disposal.

Environmental objectives for the project are to:
- Minimise airborne emissions where practicable;
- Minimise and control waste streams both on and offshore; and
- Eliminate the likelihood of discharges to sea.

C.3.5 Oil Pollution Emergency Plan (OPEP)

C.3.5.1 Offshore – Platform

Operators are responsible for and must be able to respond to, pollution incidents relating to their installations or infrastructure. All installations, infrastructure and activities that could give rise to an oil pollution event on the UKCS must be covered by an OPEP. This requirement applies to fixed and floating installations, including MODUs (Mobile Offshore Drilling Units); gas, condensate and oil pipelines; and subsea facilities, including any connected third party infrastructure that is not the subject of a separate OPEP.

During the activities on the platform, NGCL will ensure an adequate level of emergency response preparedness in line with the current OPEP requirements. All personnel undertaking work on the platform will be expected to be aware of and comply with this plan and the associated procedures at all times. Prior to mobilisation offshore, all personnel will be provided with pre-mobilisation briefing covering the emergency procedures for the platform. This is a mandatory requirement and is provided by CCS managers and supervisors.

C.3.5.2 Offshore – 500 m Safety Zone

It is anticipated that the project shall require non-routine marine operations in the form of heavy lift barges. A specific operating and emergency procedure shall be written, which clearly identify the interfaces and the chain of command for normal operations and an emergency situation. This bridging documentation shall be reviewed and approved by representatives from all parties involved prior to commencement of operations. In support of this a suitable hazard identification and risk assessment workshop shall be completed covering all planned operations.

The primary objectives for both the platform and the 500 m zone are presented in the project escape, evacuation and rescue assessment.

C.3.6 HSE Performance

QHSE performance against the goals and objectives established in this report shall be monitored throughout the life of the project. Offshore daily and weekly reports shall provide a sufficient level of QHSE information which includes but is not limited to the following:

- Man-hours;
- Employee;
- Contractor;
- Inductions;
- Toolbox talk attendees;
- Behavioural based safety submissions (copies of reports to be submitted to the onshore QHSE team);
- Accidents/incidents and near misses details;
- Safety meetings/workshops/time out for safety sessions;
- Lessons learned; and
- Success stories.

C.3.6.1 *Incident Reporting*

Accident/Incident reporting and investigation is considered to be of prime importance for the maintenance of a safe working environment and follows strict guidelines. Investigations focus on determining root causes with the objective of correcting deficiencies, preventing recurrence and broadly sharing lessons learned, all in a timely manner.

Incident reporting and investigation shall be carried out in accordance with NGCL procedures. A QHSE alert will be produced following all accidents, incidents and near misses within 24hrs of the occurrence.

Accidents/incidents on the platform should be reported immediately to the offshore safety advisor, with the CCS project QHSE manager informed as soon as possible.

C.3.6.2 *Lessons Learned*

Information and lessons learned from any incident shall be freely shared across the CCS project and with all contractors and similar organisations. It should be noted that all incidents, accidents and near misses should be reported without fear of reprimand.

Lessons learned workshops shall be carried out on a frequent basis to enable project team members to share information relating to each relevant phase of the project. The lessons learned register shall be populated with the findings from each workshop with the aim of using the information in the project final close out report.

C.3.7 Communications

Communication is considered to be of prime importance in maintaining a safe and efficient operation. Close interface with all relevant contractors is considered to be a major part of maintaining safe working conditions. This section addresses the communication of project-related QHSE issues, both internally and externally.

Internal QHSE communication in this context refers to the transmittal of information within the CCS project team and the NGCL organisation. QHSE issues will be communicated to project personnel primarily by means of e-mail, meetings and presentations. Team meetings will be held involving all core CCS project personnel in order to ensure integration across all disciplines. Project progress for all disciplines will be discussed and any safety related issues raised. Types of QHSE related issues to be communicated internally include, but are not limited to:

- QHSE goals and objectives;
- Safety alerts;
- Incident reports;
- QHSE policy/procedure developments; and
- QHSE progress reports.

External QHSE communications in this context refers to the formal transmittal of information outside the project team. External communications will occur by means of e-mail, written reports, meetings and presentations. Types of issues to be communicated externally include, but are not limited to:

- Project information to government/non-government authorities;

- Project information to contractors; and
- Project updates.

CCS monthly and weekly project reports will be regularly presented and made available to all project personnel.

C.3.7.1 External/internal interfacing

Contractors have their own management systems and shall prepare project specific plans and procedures based on their own company systems and the contents of this document.

Interface documents shall detail responsibilities and how risk will be managed in order to ensure that all contractors apply QHSE policies and standards that are compatible with CCS requirements and to ensure that all contractors' personnel are competent to perform their tasks safely.

The CCS QHSE manager shall remain the focal point for all the QHSE enquiries from external agencies and for all liaison with the EBD QHSE manager as required.

C.3.8 Review

QHSE review is a means of effectively assessing the project's QHSE performance. QHSE reviews shall be aimed at evaluating the project QHSE Plan, its implementation and results to date. Improving the Plan and/or its implementation is the continued goal of these reviews. Reviews will also include any significant issues arising from risk assessments, changes in legal or regulatory requirements and the project's QHSE risk register.

Each contractor will prepare and submit an audit plan covering each aspect of the safety management system.

Appendix D NGCL’s Safety and Well-being Policy

Safety and Well-being Policy

National Grid's vision

We, at National Grid will be the foremost international electricity and gas company, delivering unparalleled safety, efficiency and reliability, vital to the well-being of our customers and communities. We are committed to being an innovative leader in energy management and to safeguarding our global environment for future generations.

The communities that we serve include all those who have a stake in or are affected by National Grid. This policy states the key actions that we take to ensure the safety and well-being aspects of our operations.

Success is beyond just avoiding harm or injuries — it enhances the well-being of the individual. Achieving this will minimise the impact of physical and emotional harm on elements of safety performance and improve employees' work experiences.

Our belief

We recognise that our operations potentially give rise to risk. We believe that we can eliminate or minimise those risks to achieve zero injuries or harm, and to safeguard members of the public. We further believe that everyone in National Grid, collectively and individually, has a part to play to achieve that.

We are committed to:

- using the best designs, processes, tools and training to ensure that risks are eliminated or minimised
- ensuring that our employees and contract partners have the expertise to work safely and without harm
- using our collective knowledge and experience to innovate new ways of working safely and healthily, and to identify and implement best practices
- fostering collaboration by openly sharing and incorporating best practices into consistent global standards, while retaining flexibility to deliver standards consistent with local needs and constraints — these standards form an important part of our safety management systems
- holding line management accountable to deliver high standards of safety performance, but also recognizing that all have a part to play in influencing their own personal safety and health outcomes, and once equipped are trusted to do so
- actively encouraging our employees to make a more positive impact on their well-being and the well-being of those around them.

We can only achieve these goals if the company and individuals actively work together, that is the power of action.

Steve Holliday
Chief Executive

nationalgrid
The power of action.℠

Appendix E NGCL’s Process Safety Policy

Process Safety
Our commitment

Our vision

To be an industry leader in managing the process safety risks from our assets throughout the world.

Our belief

That safety is paramount and we can protect our people and the public by putting in place an effective safety management system and culture.

Our approach

- We assess and manage the major hazards arising from our assets and operations.
- We ensure our employees and contractors have the necessary expertise to manage and operate our assets safely.
- We consider inherent safety and apply relevant laws, codes and standards to ensure our assets are designed and constructed to be safe throughout their lifetime.
- We operate within defined safe operating limits and ensure that any deviations are properly assessed and controlled.
- We maintain and inspect our assets to ensure their integrity.
- We maintain up to date documentation detailing our assets and the procedures for their safe operation.
- We take into account human factors and implement controls to reduce errors and their impact.
- All changes in our operations are assessed and managed to ensure we continue to operate safely.
- We monitor our safety critical systems and procedures.
- We have emergency plans for our major hazards which are regularly tested to ensure we remain in a state of preparedness.
- We investigate and analyse any incidents and near misses to determine the root causes and prevent a recurrence.
- We encourage everyone to identify and act upon process safety hazards they find.
- We independently audit our management systems and technical arrangements and respond to any findings.
- We review our process safety performance on a regular basis and update our plans to ensure continuous improvement.

Steve Holliday
Chief Executive

Safety Health Environment Security

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Appendix F NGCL’s Environment Policy

National Grid and the environment

We, at National Grid, will be the foremost international electricity and gas company, delivering unparalleled safety, reliability and efficiency, vital to the wellbeing of our customers and communities.

We are committed to being an innovative leader in energy management and to safeguarding our global environment for future generations.

Investing in, and operating a safe, and reliable gas and electricity supply network uses energy and raw materials, and produces waste. Our effect on the environment and the communities we serve depends on how we and our supply chain work.

We will face these challenges by deploying best practice throughout our operations, by engaging on national and international energy issues and by supporting renewable energy targets. We will show leadership by working with others to deliver a more sustainable future.

We are committed to:

- **reducing the effect our activities have on the environment by considering whole life environmental costs and benefits in our business decisions**
- **using resources efficiently through good design, using sustainable materials, responsibly refurbishing existing assets, and reducing and recycling waste**
- **reducing the effect our business has on climate change by decreasing our emissions of greenhouse gases by 45% by 2020 and by 80% by 2050**
- **respecting the environmental status and biodiversity of the places we work, aiming to enhance areas for the benefit of local communities or the natural environment**
- **managing the risks associated with sites where we have responsibility for dealing with contamination associated with past operations**
- **helping consumers reduce their dependency on fossil fuels by giving them access to more sustainable energy and through innovative energy efficiency programmes**
- **working with governments and regulators to help them develop and deliver more effective environmental polices and targets**
- **continually improving our management systems to prevent pollution, reduce the risk of environmental incidents, and comply with environmental laws, policies, charters and other commitments to which we subscribe**
- **making sure that our employees have the training, skills, knowledge and resources they need to meet our environmental commitments**
- **openly sharing our performance with employees, members of the public and others, and giving them the opportunity to comment on our performance**
- **requiring those working on our behalf to demonstrate at least the same level of commitment to the environment and creating a culture where best practice can be shared.**

Steve Holliday
Chief Executive

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April 2009