Northern Endurance Partnership

CO_2 Pipelines Entry Specification

June 2024

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Definitions

NEP/T&SCo	T&SCo (Transportation & Storage Company) means in relation to each T&S (Transportation & Storage) Network, the entity that is the holder of a Licence authorising it to operate that T&S Network. The Northern Endurance Partnership (NEP) has stood up an Incorporated Joint Venture (IJV) known as Net Zero North Sea Storage Limited (NZNSSL). NZNSSL acts as the T&SCo and will be the regulated TRI Licence holder. NEP will continue to be the 'brand' that Users associate with the T&SCo.
User	Entity feeding anthropogenic CO_2 into the Teesside gas gathering network or the Humber pipeline transportation system. A User means an entity other than T&SCo who is bound by the provisions of the UK CCS Network Code and delivers carbon dioxide into the T&S Network at a Delivery Point.
Contractor	Entity appointed to carry out the engineering design of the project, procure the equipment and materials necessary and then construct the infrastructure required.
Shall	Is to be understood as mandatory.
Should	Indicate best practice and is the preferred option. If an alternative method is used then a suitable and sufficient risk assessment and or cost benefit analysis must be completed to show that the alternative method delivers the same, or better, level of protection.

Abbreviations

AGI	Above Ground Installation
ALARP	As Low as Reasonably Practicable
CCP	Carbon Capture Plant
CCS	Carbon capture and storage
CO_2	Carbon Dioxide
COD	Commercial Operation Date
EMC	Electromagnetic Compatibility
ESDV	Emergency Shutdown Valve
EU	European Union
FEED	Front End Engineering Design
HAZOP	Hazards and Operability
HP	High Pressure

HSE	Health and Safety Executive
IJV	Incorporated Joint Venture
ISD	Inherently Safer Design
ISO	International Organisation for Standardisation
LOPA	Layers Of Protection Analysis
MTPA	Million Tonnes Per Annum
NEP	Northern Endurance Partnership
NPS	Nominal Pipe Size
NZNSSL	Net Zero North Sea Storage Limited
PSSR	Pressure Systems Safety Regulations
ROV	Remotely Operated/ Actuated Valve
RTU	Remote Terminal Unit
SIF	Safety Instrumented Function
T&S	Transport and Storage
T&SCo	Transport and Storage Company
TMEL	Target Mitigated Event Likelihood
UKAS	United Kingdom Accreditation Service

1 Introduction

The Northern Endurance Partnership (NEP) is developing onshore and offshore infrastructure needed to transport CO_2 from carbon capture projects across Teesside and the Humber – collectively known as the East Coast Cluster - to secure storage under the North Sea. The infrastructure will be key to delivering net zero in the UK's most carbon intensive industrial regions. NEP, via the Endurance saline aquifer and adjacent stores, has access to up to 1 billion tonnes of CO_2 storage capacity. NEP is an incorporated joint venture between shareholders bp, Equinor and TotalEnergies, established solely to develop and operate CO_2 transportation and storage infrastructure in the Teesside and Humber regions.

By mid-2025, NEP aims to start constructing the Teesside Carbon Capture Pipeline, the infrastructure to transport CO_2 from industrial carbon capture projects across Teesside to a compression facility and out to the Endurance carbon store via an offshore pipeline. NEP aims to commence commercial operations in 2028.

NEP is also progressing development work for the Humber Carbon Capture Pipeline - the proposed infrastructure that would transport CO_2 from carbon capture projects in the Humber region to secure offshore storage under the North Sea. This infrastructure will enable a connection to carbon capture projects in the Humber, subject to selection by DESNZ through the Track 1 expansion process.

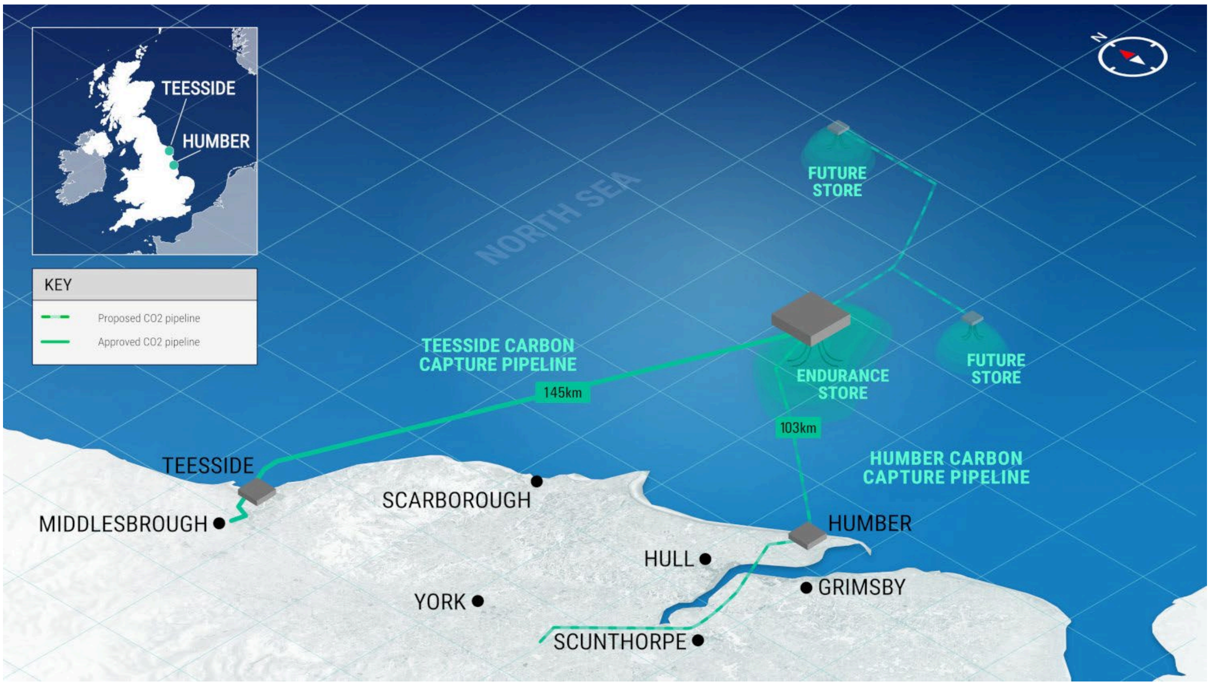

Figure 1: Overview of Northern Endurance Partnership

2 Purpose of this document

The purpose of this document is to specify pipeline entry requirements for NEP network users additional to those in the UK Carbon Capture and Storage (CCS) Network Code. These requirements are based on NEP specific technical and operating conditions.

The document includes:

- Export Process Conditions
- Export Contaminant Limits
- Overview of Data and Signals to be transferred between a User and T&SCo.
- Overview of network safeguarding requirements.

3 Introduction

This document specifies NEP (herein referenced as T&SCo) specific technical entry requirements for all Users within the East Coast Cluster. It should be read in conjunction with the UK CCS Network Code and any Connection and Construction agreement in place between the User and the T&SCo.

3.1 Order of Precedence

In the event of any conflict between this specification and the documents listed herein, the decreasing order of precedence shall be:

1. UK legal requirements (laws, edicts, regional or local regulations, etc.)
2. UK CCS Network Code
3. Individual T&SCo and User code, connection, and construction agreements
4. T&SCo requirements / specifications
5. Other T&SCo or user requirements including design philosophies, specifications, datasheets and drawings

3.2 HOLDs

Hold Number	Design Hold Description
HOLD 1	Closed
HOLD 2	Closed
HOLD 3	Data sharing procedures - to be developed in Detailed Design phase
HOLD 4	Closed
HOLD 5	Closed
HOLD 6	Pipeline Operating Procedure – to be developed in Detailed Design phase
HOLD 7	Humber Operating Pressures and Temperature to be developed in FEED
HOLD 8	User nominated quantity ramp up/ ramp down times - to be developed in Detailed Design phase

3.3 Reference Documents

Document Number	Design Hold Description
NS051-IC-SPE-000-00001	NEP - Teesside Emitter Gas Metering & Analysis Requirements Specification
HOLD 3	Data sharing procedures

3.4 Applicable Codes and Standards

The following international and national codes and standards are relevant as per their latest editions and inclusive of any addendums.

Document Number	Design Hold Description
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety related systems
IEC 61511	Functional safety - Safety instrumented systems for the process industry sector

4 Safety in Design

The East Coast Cluster Projects are based around an Inherently Safer Design (ISD) approach supported, where hazards cannot be eliminated or prevented, by control and mitigation hazard management measures to ensure risks can be demonstrated as either Broadly Acceptable or As Low As Reasonably Practicable (ALARP) in accordance with UK onshore Regulatory requirements and guidance.

Each User shall be responsible for ensuring a safe design within their carbon capture treatment and compression plant, but also shall ensure that conditions including upsets and excursions within their plant do not have adverse consequences on the downstream pipelines and facilities.

The main hazards associated with CO_2 include:

- Toxicological impact to human health in concentrations > 5% v/v
- At concentrations >50 % v/v in air, CO_2 displaces the oxygen in air to dangerously low levels acting as an asphyxiant and posing an immediate threat to life.

The impact severity of CO_2 exposure on people depends on the dose that they receive which is a combination of gas concentration and the exposure duration.

CO_2 is denser than air. The combination of its density and the Joule Thomson cooling effect which takes place following a release from pressure containment means that a dense cloud is formed which will in many cases slump towards the ground. Additionally, solidification of CO_2 and intensely cold temperatures are other hazards that can persist following a release of CO_2.

4.1 User safety studies

The User shall provide the T&SCo with a list of key safety studies to be conducted at each project stage to demonstrate how consequences to the T&S system have been assessed and incorporated into their design. As a minimum these should include:

- HAZID
- Interface HAZOP
- LOPA
- Functional Safety Assessments
- Interface studies including pressure and temperature interfaces and cause and effect schedules.

The T&SCo shall be invited to attend as a participant in Industry accepted Process Safety Assessments, such as HAZOP/LOPA workshops, for the user carbon capture, compression, treatment, and export facilities to allow any consequences to downstream operations to be fully understood.

Integrated safety studies such as a full chain LOPA shall also be conducted where required.

5 Users' Responsibilities

The T&SCo users are responsible for:

- Ensuring CO_2 is delivered in line with the pipeline entry specification and all steps are taken to ensure any deviations from the specification are mitigated such that they do not result in an adverse impact to any downstream capture plant or T&SCo facilities.

- Providing baseline analysis of the untreated and treated CO_2 stream as requested by the T&SCo, identifying all components in normal operation and process upset conditions.

- Developing an evergreen analysis plan for identified contaminant risks and to confirm that no new contaminants are present. This shall be reviewed regularly and include for independent analysis upstream and downstream of the CO_2 stream treatment facilities and allow verification of online analysers. Frequency of independent analysis will be determined by the T&SCo.

- Developing highly reliable and available systems that shall take all possible corrective and preventative actions needed if the quality of the CO_2 is either out of specification or varying significantly, to ensure compliance with the defined quality requirements.

- Assessing on a regular basis or following a change to the carbon capture process/design, the operation of the Carbon Capture Plant (CCP), process controls and analysis systems to ensure the quality of the CO_2 stream is in accordance with the plant design and the quality requirements of this specification.

- Advising the T&SCo of any change to the carbon capture process or any other changes that may lead to non-conformance with this entry specification, to allow the T&SCo to advise/require enhanced monitoring or change to the protection system provided by the User. If changes are to be made to the User CCP after export has started, the User must seek prior approval from the T&SCo. The T&SCo reserves the right to request the User conduct an independent engineering risk assessment and risk quantification exercise to determine the impacts of the proposed changes. The T&SCo reserves the right to revoke User's access to the pipeline if it is determined that protection systems will not provide the required level of protection or that the risk to the overall safe operation of the T&S network will be compromised if the proposed changes are implemented.

- Conducting maintenance and inspection on the CCP, process controls, metering, and analysis systems to ensure they are operating effectively and in accordance with the design conditions. All maintenance and corrective records shall be kept for the life of the assets and made available to the T&SCo on request.

- Undertaking validation and / or calibration of process controls, metering, and analysis systems in accordance with analysis plan agreed with the T&SCo and provide T&SCo with a completed validation /calibration report following completion of the work.

- Facilitating the T&SCo, or their delegate (such as Independent Verifier), requests for access to perform auditing, inspection, gather manual samples for laboratory testing, witness testing of the custody transfer metering and analysis systems.

6 Design Conditions

This section details the T&S design conditions to enable individual Users to design their capture, conditioning, and compression systems to provide a CO_2 stream at the required conditions to enter the network.

6.1 CO_2 Composition

The CO_2 at the User battery limit (connection point) shall be of a purity ≥ 96 mol%. Excursion below this figure is not allowed due to the effect of contaminants on the downstream facilities. Refer to section 6.2 for specific contaminant limits.

6.2 Contaminant Limits

Table 1 below defines the contaminant limits for entry to the Teesside and Humber pipeline systems.

Table 1: Contaminant limits for delivered CO_2 Stream

Contaminant	Limit	Additional Information
Water H2O	≤50 ppm mol	Sec 6.2.1
Hydrogen H2	≤0.75 mol%	Sec 6.2.2
Nitrogen N2	Combined limit of ≤ 4mol% - See Notes 1 & 2 below	Sec 6.2.2
Argon Ar		Sec 6.2.2
Methane CH4 / Ethane C2H6		Sec 6.2.2
Oxygen O2	≤10ppm mol	Sec 6.2.3
Oxides of Sulphur SOx	≤10ppm mol	Sec 6.2.4
Oxides of Nitrogen NOx	≤5ppm mol	Sec 6.2.5
Hydrogen Sulphide H2S	≤5ppm mol	Sec 6.2.6
Carbon Monoxide CO	≤1000ppm mol	Sec 6.2.7
Mercury Hg	≤0.0025ppm mol	Sec 6.2.8
Glycols	≤1ppm mol	Sec 6.2.9
Amines	≤1ppm mol	Sec 6.2.10
Ammonia	≤10ppm mol	Sec 6.2.11
Formaldehyde	≤20ppm mol	Sec 6.2.12
Acetaldehyde	≤20ppm mol	Sec 6.2.12
Cadmium	≤0.005ppm mol	-
Thallium	≤0.012ppm mol	-

Methanol/ Cumulative methanol & Ethanol	≤350ppm mol	-
Ethanol	≤50ppm mol	-
Heavy Hydrocarbons	See Note 3 below	

NOTE 1 – Cumulative inerts and non-condensable limit (including light hydrocarbons).

NOTE 2 – Additionally for Humber onshore pipeline system the saturation pressure of the mixture shall not exceed 80 barg. This is an estimate and subject to review by the T&SCo upon completion of Humber onshore pipeline FEED.

NOTE 3 – Heavy hydrocarbons should not shift the dew point below that of pure CO2 [e.g., n-C4: ≤0.25mol%, n-C6: ≤250ppm, n-C10: ≤5ppm].

6.2.1 Water

Water shall be removed from the CO_2 stream by User before metering. Water within the stream will quickly become saturated with CO_2 and form carbonic acid which is corrosive. Contaminants such as SOx, NOx and H_2S will react with the water to form other corrosive acids. In addition, the presence of water can result in the formation of hydrates which have the potential to reduce flow in the pipeline or block small bore pipework. To reduce the threat to pipeline integrity from acid formation and subsequent corrosion, the water concentration shall not exceed the limit stated.

6.2.2 Non-Condensables

Nitrogen, hydrogen, methane/ ethane and argon are non-condensable at the pressures and temperatures associated with the pipelines and so will have an impact downstream of the Teesside main compression facilities where the CO_2 is transported offshore in the dense phase and throughout the Humber pipeline system. To ensure two phase flow is kept to a minimum in dense phase pipelines, the combined flow of non-condensables such as N_2, H_2, CH_4, C_2H_6 and Ar shall not exceed the limits stated.

6.2.3 Oxygen

Oxygen is non condensable (refer to 6.2.2) and is one of the reactive components participating in the formation of sulphuric and nitric acids. It also causes corrosion in the presence of water (e.g., a possible condition downhole in the wells). Oxygen levels shall not exceed the limit stated.

6.2.4 Oxides of Sulphur

SOx can react with other contaminants and result in deposition of elemental sulphur or the creation of strong acids such as sulphuric acid which are corrosive. SOx levels shall not exceed the limit stated.

6.2.5 Oxides of Nitrogen

NOx is toxic and can also react with other contaminants to form nitric and sulphuric acid which are corrosive. NOx levels shall not exceed the limit stated.

6.2.6 Hydrogen Sulphide

H_2S is toxic at low concentrations and even at trace levels it has a noxious odour. The limit declared is to ensure that there is no danger of sour conditions occurring if free water is present. The limit also reduces the risk of reaction with contaminants such as SOx and NOx producing corrosive acids. H_2S levels shall not exceed the limit stated.

6.2.7 Carbon Monoxide

Due to concerns with CO-CO_2 stress corrosion cracking and the toxicity of CO should a leak occur, the CO concentration shall not exceed the limit stated.

6.2.8 Mercury

Mercury could condense out in the pipeline system and create operational issues as well as implications for storage. Mercury levels shall not exceed the limit stated.

6.2.9 Glycols

Glycols, for example Triethylene glycol (TEG), shall not be utilised in Users carbon capture as any carried-over glycol may condense out especially in gaseous phase CO_2 stream potentially causing corrosion issues.

6.2.10 Amines

Amines have low solubility in CO_2. To prevent liquid drop-out at low temperatures in the pipeline systems, Amine levels shall not exceed limit stated.

6.2.11 Ammonia

Ammonia can react with CO_2 and H_2O and form ammonium salts which are solid at pipeline operating temperatures. Ammonia level shall not exceed limit stated.

6.2.12 Formaldehyde & Acetaldehyde

Formaldehyde and Acetaldehyde may present a risk of polymerisation and solids formations. Formaldehyde and Acetaldehyde levels shall not exceed the limits stated.

6.3 Trace Impurities

All other impurities/contaminants, not listed in section 6.2 (Table 1), shall be declared and agreed with the T&SCo. User shall advise their expected maximum concentrations if they may be present within the stream during operation, start-up, shutdown or any emergency or upset scenarios. These may include, but not limited to:

- Arsenic
- Benzene
- Hydrochloric acid
- Sodium chloride
- Selenium
- Selexol
- Hydrogen fluoride
- Hydrogen cyanide
- Carbonyl sulphide

Users shall develop plans to demonstrate that the impurities remain at trace levels (i.e., level below measurable limits) for as long as access to the respective pipeline system is required. This may include online analysis or periodic samples analysed under laboratory conditions at a frequency agreed with the T&SCo. Users shall retain all historical analysis (online or laboratory) for auditing and submission on request by the T&SCo or Regulator.

6.3.1 Solid Contaminants

User shall ensure solid matter, extraneous material, oil/grease or particulates are not entrained in the CO_2 stream to prevent clogging or erosion of downstream facilities.

Particles shall be ≤5 micron in size and with a maximum occurrence of ≤1 mg/Nm^3.

6.4 Network Design & Operating Pressures and Temperatures

The design conditions for the CO_2 gathering network are given in Table 2 for Teesside Users entering the onshore gathering network and Table 3 for Humber Users [HOLD 7].

Table 2: Design and operating pressures and temperatures for Teesside Users

Parameters	Units	Value	Notes
Design Conditions			
Design Pressure	barg	44	
Maximum Design Temperature	°C	75	
Minimum Design Temperature	°C	-29	
Operating Parameters			
Typical Operating Pressure Range	barg	15-30	Note 1
Maximum normal operating temperature	°C	50	At User's tie-in point
Minimum normal operating temperature	°C	15	At User's tie-in point

NOTE 1 – 15 barg is the minimum normal operating pressure at the inlet to the HP compression facilities. 30 barg is the estimated maximum operating pressure at the connection point for a user at the furthest end of the Teesside onshore gathering network at full rates. Users closer to the Teesside HP Compression Facilities will have a lower maximum operating pressure requirement. Users shall also design their export system to allow for fluctuating pressure within the pipeline system. As additional Users feed into the pipeline systems the pressure required for forward flow through the pipelines will change. Life of field pressure envelopes for Users based on their location will be developed by T&SCo.

Table 3: Operating pressures and temperatures for Humber Users [Note 1], Hold 7

Parameters	Units	Value	Notes
Maximum Allowable Operating Pressure	barg	136	Note 2
Minimum operating pressure	barg	90	Note 3
Maximum normal operating Temperature	°C	40	Note 4
Minimum normal operating Temperature	°C	5	

NOTE 1 – The values presented in Table 3 are estimates and will be updated by the T&SCo upon completion of the Humber onshore pipeline FEED.

NOTE 2 – This is the maximum operating pressure at the connection point for the User at the furthest end of the Humber onshore pipeline. Users closer to the Humber Pump Facility will have a lower maximum operating pressure requirement. Maximum operating pressure will be agreed with each User during design development.

NOTE 3 – Minimum operating pressure for Humber is set to prevent two phase flow in the Humber pipeline system.

NOTE 4 – For the Humber onshore pipeline system, the maximum design temperature is 50 deg C. This temperature level shall be protected by a suitable upstream SIL rated protection system/device(s) located on the User export system.

6.5 Flows

Users shall ensure the CO_2 flowrate does not exceed instantaneous flow limits stated in the connection agreements.

Users shall design their export facilities such that the export flow can be ramped up and ramped down in a controlled manner during start-up / controlled shutdown. Ramp up of flow from zero to the nominated quantity into the Teesside gathering network shall be conducted in a controlled manner over a minimum 15-minute duration to prevent pressure surges while also ensuring the minimum operating temperatures stay within the limits in Table 2. Ramp down of flow from nominated quantity to zero during planned User's shutdown shall occur over a period of 20-30 mins to minimise the impact to the other users and avoid upset of downstream HP Compression and onward offshore transportation. The T&SCo shall provide the required ramp up/down rates specific to each User for action in their own control systems during detailed design [HOLD 8].

Users shall provide all necessary facilities to ensure no unintentional reverse flow from the pipeline systems to the User during operation, start-up, shutdown or any emergency or upset scenarios.

7 Interface Facilities

The gathering network is defined as commencing downstream of any compression, gas analysis and fiscal metering at each User site. Figure 2 below shows a typical interface with a third-party User.

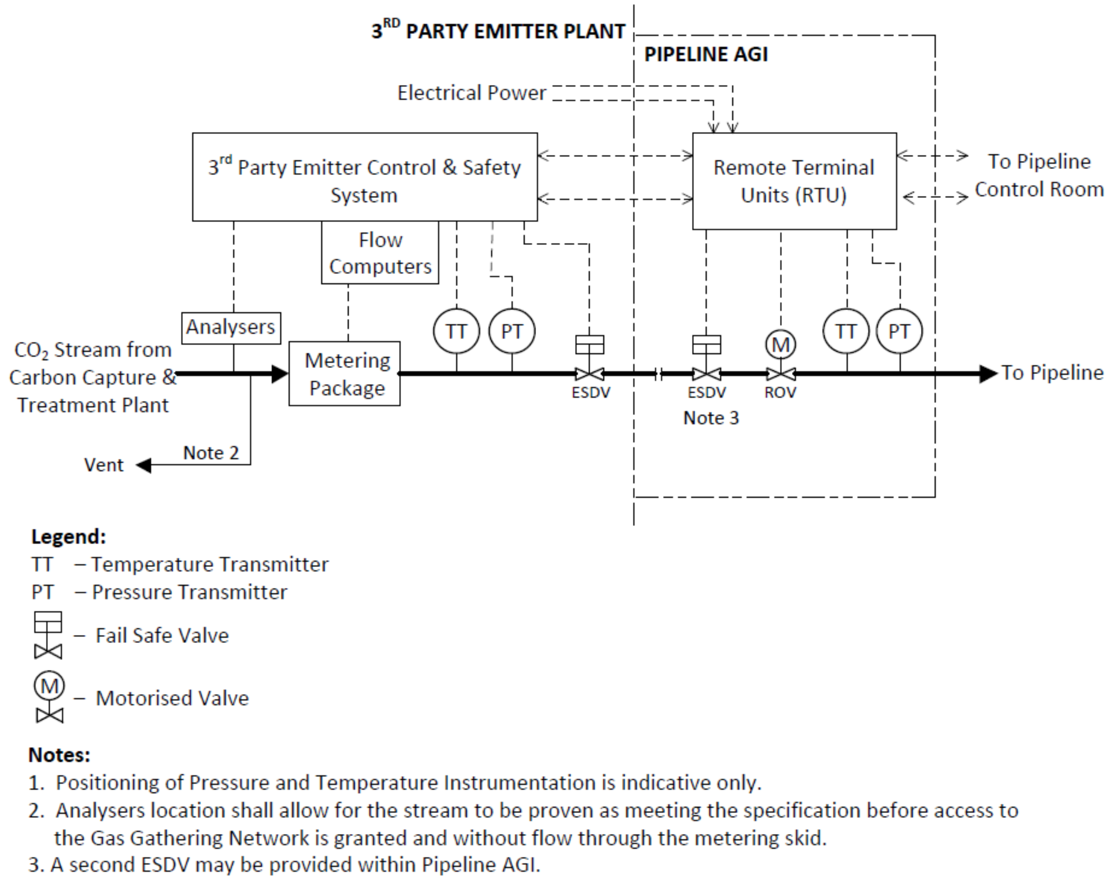

Figure 2: T&SCo and user typical interface facilities

7.1 T&SCo Facilities at Interface

The CO_2 gathering network will have an AGI at each user's site consisting of the following T&SCo owned and supplied equipment:

- A Remotely Actuated Valve (ROV) - an on/off valve that is operated by the T&SCo control room.
- One or more Emergency Shut down Valve (ESDV) - failsafe valve that is connected to the T&SCo safety instrumented and control and trip systems and may be shut without operator intervention.
- A telemetry/data transmission unit back to the T&SCo control room.

AGIs at some User locations may also site pigging facilities within the T&SCo AGI scope (potentially within the user's site boundary).

AGIs shall be sited in a designated non-hazardous area, with respect to Flammable Gas, unless a suitable location meeting this requirement is not practicable.

Where a User requires a connection to take off CO_2 from the network; User shall apply for a re-use connection to the T&SCo during User's FEED. If the User has an approved CO_2 re-use system, the CO_2 take-off location shall be downstream of the T&SCo boundary Isolation valve. The take-off location shall also include a boundary isolation valve within the T&SCo system. If approved, any flow out of the pipeline system shall be metered and reported to the same standard as the export flow metering.

7.1.1 Signal Interface

A Remote Terminal Unit (RTU) shall be supplied and installed by the T&SCo within the Above Ground Installation (AGI) where the point of connection/tie-in is located. The RTU shall allow the T&SCo to receive signals from, and send signals to, the User and to interface with the actuated valves and instrumentation downstream of the point of connection/tie-in within the AGI. It will:

- Allow the ROV and ESDV(s) to be operated and their status monitored.
- Monitor process conditions at the connection arrangement.
- Receive and transmit signals to/from User
- Receive and transmit signals to/from the Control Room managing the respective carbon dioxide pipeline transportation systems.

The connection between the RTU and the User Control System shall be dual redundant, utilising diverse routes. The connection type and signal protocol utilised shall be agreed between T&SCo and User. Refer to Figure 2: T&SCo and user typical interface facilities, for Interface Schematic.

An indicative list of signals from user meters and analysers is provided in Section 7.2.1 and 7.2.3.

A “Network Available” signal linked to the status of the ESDV(s) and ROV shall be made available to the User. This shall be treated as a signal for information only.

User shall provide repeat signals to the T&SCo relating to their operated boundary ESDV for opened, closed, travelling and fault status.

Final listing of signals to be exchanged shall be agreed during detailed engineering phase [HOLD 3].

7.1.2 Power Supply

The AGI requires two permanent three phase, 400V power supplies, ideally fed from two different distribution / switchboards. The supplies shall be in accordance with The Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002. These will be connected to a changeover switch and redundant UPS within the AGI kiosk to provide maximum availability. An approximate 10 kVA electrical power supply with surge protection is required. Cables to the AGI should run in diverse routes if possible.

User and T&SCo shall agree during detailed design requirement of feeder pillars/ junction boxes at the interface point. Where required and agreed, User shall procure and install, at an agreed location, within 2.5m of the proposed Pipeline AGI boundary fence, two electrical feeder pillars. Where the pillars are installed outside of the Pipeline AGI fence a 100mm PVC duct shall be installed by User from the pillar towards the boundary fence.

Feeder pillars shall have the following requirements:

- 3mm minimum 316 Stainless Steel
- Containing 100A BS88 Cut-out fuses, coordinated with upstream feeder
- Pre-wired to four pole lockable isolator
- Yale lock (3 spare keys to be provided to the T&SCo)
- Engraved phenolic label (WHITE-BLACK-WHITE) attached by stainless steel rivets

During FEED, the User shall identify supply locations, route lengths and provide supply characteristics for the power supply and feeder pillars. This shall include:

- Measured fault level at supply, calculated maximum and minimum levels.
- Cable type, size and length

The supply must not cause a drain on the corrosion/cathodic protection system or cause a short across the insulation joint incorporated in the connection arrangement.

Further specific electrical requirements will be confirmed during the detailed design stage of the project when more detailed information becomes available.

7.1.3 Hotlines

Users shall be free issued with Hotline phone for installation within User carbon capture facility control room. User shall supply and install necessary cable between control room and the RTU / Communications panel located in the AGI at the point of connection/tie-in. Further details of requirements shall be developed during detailed design phase.

7.2 User facilities at interface

User treatment and dehydration plant shall be designed such that export stream at the battery limit/point of connection shall be below the contaminant limits specified in Table 1 at all times.

Each User is required to install metering and monitoring equipment to measure the CO_2 throughput and ensure that it achieves the required specification (detailed in Section 6.2) before entry into the gathering network. These are anticipated to consist of:

7.2.1 Metering

All users shall comply with the metering requirements set out in the UK CCS Network Code.

Users in Teesside shall additionally comply with requirements stated in the NEP - Teesside Emitter Gas Metering & Analysis Requirements Specification NS051-IC-SPE-000-00001. Additional requirements for Humber users will be defined upon completion of Humber onshore pipeline FEED.

Flow meter readings shall be in mass flow units.

Signals regarding flow metering shall be repeated to the T&SCo via the RTU. These shall include but not be limited to:

- Current Instantaneous mass flow – tonnes/hr
- Previous day totalised mass flow (for the last 24 hours between daily cutoffs) – tonnes
- Totalised mass flow since daily cutoff - tonnes
- Pressure - barg
- Temperature - deg C
- Density - kg/m3
- Metering Fault alarm
- The fault alarm signal shall be triggered when the components of the metering system are reporting any fault that affects the reliability of the flow metering flow signal.

If the metering signals from the User are not received at the Teesside Control Room / Humber Pipeline Control Room, the quantity of gas cannot be accurately logged by T&SCo. The User shall be required to submit a mis-measurement report which will be checked against the other metering on the pipeline systems.

Sampling period for all datapoints shall be agreed during detailed engineering phase.

7.2.2 User Vent

Users shall install a vent(s) that is suitably designed to meet the following requirements:

- Venting gas at start-up to ensure it is on-spec before forward feeding to the T&SCo. The vent connection shall be between the analyser and the metering package.
- Venting requirements during initial commissioning and start-up to ensure:
    - User does not export off spec CO_2 to the Pipeline System during initial commissioning and start-up
    - User can reach its Commercial Operation Date (COD) independently, without a requirement to export to the Pipeline system
- Used to depressurize the spur line between Users and the main T&SCo gathering line.

- Can handle maximum flows/ pressures in the event the T&SCo boundary ESDVs are shut unless another vent within the User's plant has been designed to protect the T&SCo network for this scenario.

7.2.3 Composition Monitoring Requirements

Online analysers shall be provided by the Users based on a risk assessment of the potential challenges to the pipeline system and storage operation created by contaminants in the emission stream. As a minimum, the following components should be monitored using online analysers:

- Carbon dioxide content
- Water
- Oxygen
- NOx
- SOx

During the FEED phase, Users shall provide a full breakdown on potential components in their process streams (pre and post treatment) backed up by laboratory analysis where available. Based on this analysis, the T&SCo may set additional limits and analysis requirements in addition to those covered by this specification.

As per the CCUS Network Code, analysers selected shall be subject to review and approval by the T&SCo.

For further details for Teesside users refer to the NEP - Teesside Emitter Gas Metering & Analysis Requirements Specification NS051-IC-SPE-000-00001. Requirements for Humber users will be defined upon completion of Humber onshore pipeline FEED.

The User shall develop an Analysis Verification Plan that will detail the periodic taking of samples for laboratory analysis to independently verify measurements from online analysers and to confirm no new contaminants are present in the CO_2 stream. Frequency of laboratory testing will be advised by the T&SCo.

Signals regarding analysers shall be repeated to the T&SCo via the RTU. These shall include but not be limited to:

- Component concentration (e.g., mol%; ppm mol, etc.)
- Analyser Fault alarm

The fault alarm signal shall be triggered when the components of the analyser system are reporting any fault that affects the reliability of the flow metering flow signal.

T&SCo shall have, upon giving a minimum 5 business days' notice, the right to inspect the User's export system process controls, metering, and analysis systems.

If analysis signals from the User are not received at the Teesside Control Room / Humber Pipeline Control Room or Analysers are reporting fault signals, the T&SCo may shut the ROV as the export stream quality cannot be determined. In this scenario the T&SCo will aim to inform the User of the impending ROV closure so a controlled shutdown of the User system can be initiated. It is therefore in the best interest of the

User that their analysis systems remain highly reliable and available. In addition, users shall ensure all data from analysers are stored for a minimum of 10 years and made available to the T&SCo on request.

7.3 Safeguarding Measures

All users shall install suitable control measures to ensure the CO_2 fluid delivered to the T&S network stays within the design conditions listed in Section 6. These should include consideration of potential failure mechanisms and provision of multiple independent barriers where required.

Users shall install appropriate safeguarding barriers such that the likelihood of failure resulting in an excursion with an adverse consequence on the downstream facilities stays below the target frequency specified. The emitter design should ideally 'eliminate' the risk of hot gas (> 75°C) entering the pipeline by installing redundant coolers that will ensure cooling from natural convection even when fans unavailable due to power / controller failure. This would be an inherently safe design.

This section provides Target Mitigated Event Likelihood Levels (TMEL) to meet for key parameters where an exceedance may result in an adverse safety and/or environmental impact to downstream facilities. Users shall ensure any engineered safety instrumented systems in combination with other protection layers meet or exceeds the target mitigated event likelihood.

A full system integrated HAZOP and LOPA shall be carried out evaluating combined barriers within the User facilities and T&SCo to confirm the TMEL requirements specified in Table 4.

Higher TMEL requirements or additional safeguarding measures (e.g., for additional components) may be required following evaluation of User facilities designs, and User specific hazards and subsequent impacts to the full chain systems.

Table 4 lists the safeguard TMEL requirements for Teesside users.

Requirements for Humber users will be defined upon completion of Humber onshore pipeline FEED.

Table 4: Safeguard Target Mitigated Event Likelihood (TMEL) values for Teesside Users

Parameter	TMEL	Notes
High Pressure	1x 10^{-4} / yr	Typical safeguards may include full flow pressure relief valve(s) and SIL 2 high pressure trips as per IEC-61508/ 61511.
High Temperature	1 x 10^{-5} / yr	Typical safeguards may include a SIL 1 or SIL 2 high temperature trip as per IEC-61508/ 61511.
Low Temperature	1 x 10^{-5} / yr	Typical safeguards may include a SIL 1 or SIL 2 low temperature trip as per IEC-61508/ 61511.
Credible excursions of contaminants in Table 2	1 x 10^{-3} / yr	Typical safeguards may include a SIL 1 moisture analyser trip as per IEC-61508/ 61511, temperature trips on oxygen removal facilities, etc.

7.3.1 Demonstration of Safeguarding Requirements

Users shall share key design, installation (including as-built data), and commissioning documents with the T&SCo for review and approval to demonstrate how the above limits have been met. Users shall also inform the T&SCo about planned studies, assessments, and field and site tests as per IEC-61508/61511 to allow T&SCo participation.

8 Pipeline Operation

Procedures for startup and shutdown of flow from Users into the Teesside and Humber pipeline systems shall be detailed in the respective Pipeline Operating Procedures [HOLD 6] developed in detailed design.

8.1 Shutdown Requirements

The T&SCo shall endeavour to provide advanced warning of the closure of the remote operated valve (ROV) and Emergency Shutdown Valve (ESDV) downstream of the point of connection. However, the valves may close with no warning to allow the T&SCo to ensure the integrity of the network.

User plant shall therefore be designed to safely manage the consequences of this sudden loss of access to the pipeline, and subsequent loss of export flow, without over pressurising the tie-in pipework, pipeline and upstream plant.

Examples of events that may trigger shutdown of the ESDV at Teesside User's boundary include:

- A confirmed toxic gas alarm in event of a leak/ loss of containment at the HP compressor site.
- A power failure or process upset resulting in shut down of the HP compressor.
- Wider unforeseen disruption within the T&SCo T&S network.

As described in Section 7.2.3, loss of analysis signals or a fault in analyser signal may result in the T&SCo shutting the ROV as the export stream quality cannot be determined. It is therefore in the best interest of the User to ensure highly reliable and available analysis systems to maintain continuous operation.

8.2 Teesside Onshore Pipeline CO_2 Dropout Prevention

The Teesside onshore pipeline system is designed to ensure the CO_2 stays in the vapour phase. At high pressure coincident with cold temperature, there is a potential for liquid dropout resulting in potential liquid carryover to downstream HP Compression System risking the system integrity.

As a result, a 2oo3 high-high pressure trip has been implemented on each pipeline with the sensors located at the HP Compression end to prevent significant CO_2 liquefaction in the pipeline being carried forward to the HP compressors. Activation of confirmed high-high pressure trip will automatically close the ESDVs at the User boundary.

In addition, the pipeline will not be operated at ambient temperatures below -11°C due to the risk of CO_2 liquefaction. There are low temperature alarms provided on the pipeline to alert the T&SCo who will advise Users of imminent network shutdown or close the ROV at the User boundary upon activation of alarm.