VikingCCS

Viking CCS Pipeline

Technical Note: Repurposing and Life Extension Assessment Summary for the LOGGS Pipeline

Document Reference: EN070008/EXAM/9.15

Applicant: Chrysaor Production (U.K.) Limited,
a Harbour Energy Company
PINS Reference: EN070008
Planning Act 2008 (as amended)
The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 - Regulation 5(2)(q)
Date: April 2024

Harbour Energy | AECOM

Viking CCS - CO2 Transportation and Storage

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Revision	C1
Status	Issued for Use
Legacy Documents	N/A
Harbour Energy Document Number	HBR-GEN-P-XX-P-EN-11-00001
Total Number of Pages (Inc. Cover Page)	18

Approval page

Name	Position	Purpose	Signature	Date
Ryan Wallace	Senior Project Engineer	Author	[redacted]	19/04/24
Ewan Booth	Engineering Manager	Checker		19/04/24
Pat Dinan	Project Manager	Approver		19/04/24

Revision history

Revision	Issue date	Status	Originated by	Approval
A1	16-04-2024	Issued for Comment	Ryan Wallace	Pat Dinan
C1	19-04-2024	Issued for Use	Ryan Wallace	Pat Dinan

Document revision record

Revision No.	Revised section	Paragraph No.	Description of changes
C1	All	-	Per PIMS review.

Abbreviations & Acronyms

Term	Definition
LOGGS	Lincolnshire Offshore Gas Gathering System
CCS	Carbon Capture & Storage
CO_2	Carbon Dioxide
TGT	Theddlethorpe Gas Terminal
KP	Kilometre Point
LAT	Lowest Astronomical Tide
HAT	Highest Astronomical tide
CP	Cathodic Protection
ICCP	Impressed Current Cathodic Protection
CTE	Coal Tar Enamel
TOP	Top of Pipe
MPQT	Material Procedure Qualification Testing
ESDV	Emergency Shut Down Valve

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1 Summary

The LOGGS pipeline has been identified for reuse for the Viking CCS CO2 Transportation and Storage project. In-depth engineering assessment has been completed to evaluate the technical suitability to repurpose the pipeline and extend the life of the pipeline.
As documented in this technical note, the assessment has evaluated; the internal and external condition of the pipeline, the material properties of the pipeline, the welding used in original construction, the suitability for CO2 as the fluid within the pipeline and the time-dependent damage mechanisms that could impact the life extension.
It is the conclusion of this technical note that the LOGGS pipeline is suitable for reuse and life extension, subject to the successful completion of an inline inspection to verify that the line conditions remains suitable. The further inline inspection was executed in Q1-2024 and, at the time of writing, data from this inspection is under evaluation. Based upon this data evaluation the need for any further inspections prior to a Final Investment Decision shall be defined in due course.

2 Pipeline Overview

2.1 System Description

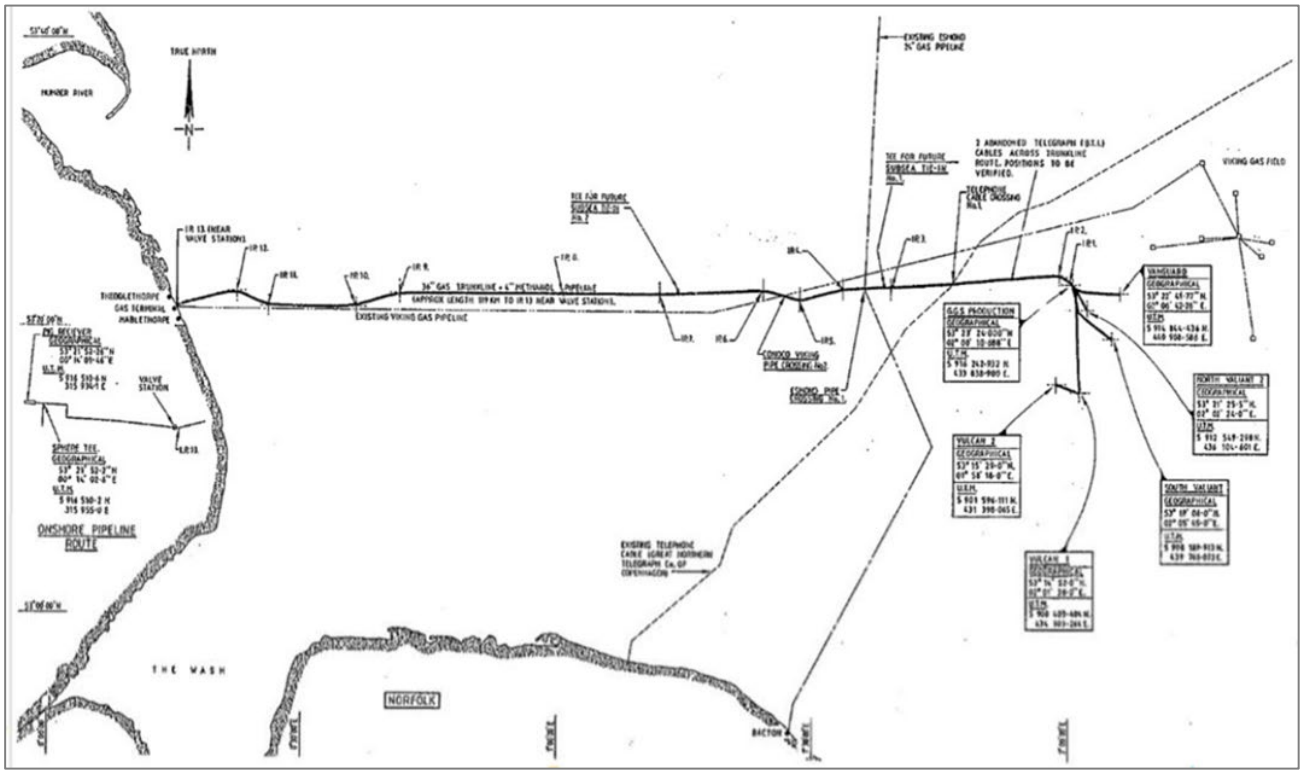
The 120 km, 36" LOGGS Pipeline transported wet natural gas from the LOGGS Production Platform (PP) to TGT until decommissioning in 2018. The pipeline was commissioned in 1987 and was designated number PL0454.
The LOGGS Pipeline comprises onshore and offshore sections:

- TGT onshore section: The 1.2 km onshore section runs from the beach tie-in at KP 118.724 to TGT. It incorporates a dunes isolation valve approximately 0.5 km outside of TGT towards the beach (KP 119.05) and a pipeline isolation valve at TGT.
- Offshore section: The 118.5 km offshore section runs from beach tie-in at KP 118.724 to LOGGS PP and included two inline 36" x 20" tees, each with two 20" valves and a protection structure at KP 26.2 and KP 51.6.

A 3" methanol pipeline, PL0455 was installed along with the wet gas pipeline. The methanol pipeline will not be reused for the Viking CCS project.

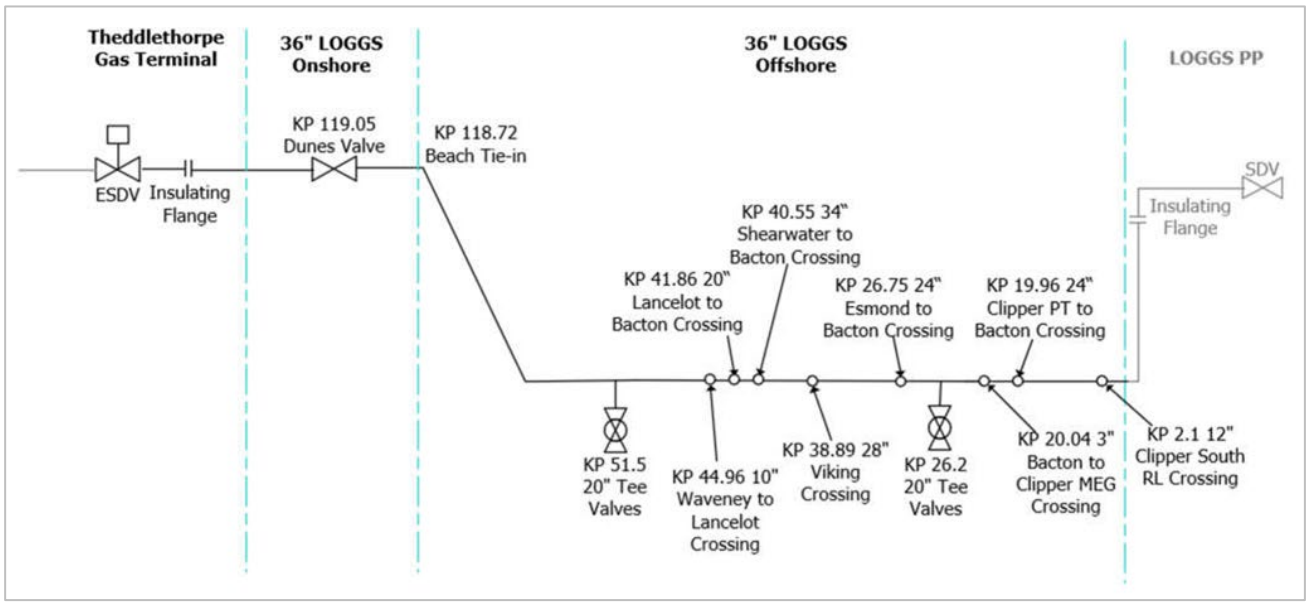
An overview of the LOGGS area and trunkline route is given in Figure 1

Figure 1 - LOGGS Route from Production Platform to TGT



The offshore platform, riser, tie-in spool and onshore pipework downstream of the ESDV have been decommissioned and removed. LAT is at located at KP118.224 and HAT is located at KP 118.724. The tie-in weld between the offshore and onshore pipeline sections was located at HAT (KP 118.724).

Figure 2 - Original LOGGS System Schematic



2.2 LOGGS Design

The primary design code for the offshore section of the LOGGS pipeline was:

- Institute of Petroleum Pipeline Safety Code Part 6 (IP6), 4th Edition 1982.

The primary design code for the onshore section of the LOGGS pipeline was:

- BS CP2010-2 Pipelines - Part 2: Design and Construction of Steel Pipelines in Land

The design code break was located at the tie-in weld which was coincident with HAT (KP118.724). The offshore and onshore sections of the LOGGS pipeline were designed by Brown & Root.

2.3 Pipeline Design Parameters

The original pipeline system design parameters and future repurposing design conditions are presented in Table 3.1.

Table 1 - LOGGS Pipeline System Parameters

Parameter	Original	CCS Service
Service	Natural Gas (Wet)	Dehydrated CO2
Design Life	40 years	25 years (to 2052)
Design Code – Offshore Section	IP6	PD 8010 Part 2 or DNV ST-F101
Design Code – Onshore Section	CP2010	PD 8010 Part 1

2.4 LOGGS Pipeline Details

The LOGGS pipeline system data is given in the table below:

Table 2 – LOGGS Pipeline System Data [8]

Parameter	Value
Length	119.89 km
Outside Diameter	914.4 mm (main line) 921.1 mm (shore approach from KP 117)
Wall Thickness	26.97 mm (main line) 30.3 mm (500m from platform, shore approach from KP 117.0 and tee locations KP 26.19 – 26.22 and KP 52.57 – 51.60)
Line Pipe	API 5L X65 DSAW
Bend Radius	5D
Internal Corrosion Allowance	6 mm
Coating	Onshore: 5.5 mm Coal Tar Enamel Offshore (KP 0 - 118.72): 5.5 mm Coal Tar Enamel + Concrete Weight Coating
Concrete Weight Coating Density	3040 (kg/m3)
Concrete Weight Coating Thickness	KP 0.0 – KP 4.85 89.0mm KP 4.85 – KP 36.75 64.0mm KP 36.75 – KP 38.75 89.0mm KP 38.75 – KP 114.22 64.0mm KP 114.22 – KP 118.72 89.0mm KP 118.72 – KP 119.89 0.0 mm
Field Joint Coating	Onshore: Cold applied anti-corrosion pipe wrap tapes Offshore: Cold applied anti-corrosion pipe wrap tapes with high density bituminous filler

The transition from thick wall to standard wall thickness is located 1.224 km from lowest astronomical tide (LAT) at a water depth of 6.0 m LAT.
The methanol pipeline is piggy-backed on the trunkline at the following locations:

- LOGGS PP for the initial 400 m; and
- before the beach tie-in point for approximately 2000 m.

Outside of these sections the pipelines were installed and trenched separately. The methanol pipeline transition from piggyback to separate trench was achieved with flexible tie-in spools after trenching. Rock was placed to protect the flexible spools.

2.5 Inline Tees

The LOGGS pipeline includes two subsea tees with 20" valve arrangements to allow future tie-ins, but these have not been utilised. The two subsea tees are located at:

- Tee 1 at KP26.200 in 26 m water depth.
- Tee 2 at KP51.565 in 18-20 m water depth.

The Tees were welded into the pipeline during installation whilst the valves are flanged. All 20" valves and flanges are rated to Class 900. All 2" flanges and valves are rated to Class 1500. The valve actuators were not fitted, and the Tees remain unpopulated (no import with other pipelines connections made during field life) with blind flanges installed at the end of the 20" pipework.

The protection structure framing is 13.0 m x 6.0 m in plan; the height is 3.0 m centres. The structures are piled and have two removable roof panels, along with sloping side panels.

2.6 Onshore Pipeline Section

The onshore section of the LOGGS pipeline is routed through the sand dunes and cultivated fields, this includes four 5D radius induction bends within the dunes. The location of each bend is as follows:

- KP 119.02 – 21.8° bend
- KP 119.00 – 16.2° bend
- KP 118.78 – 7.2° bend
- KP 118.74 – 7.0° bend

Within the dune crossing the pipeline is buried with cover varying from 2 m – 4.5 m. Within the farmland to TGT the pipeline is buried to provide a minimum of 1 m cover TOP.

The trunkline and methanol line are laid and buried separately onshore of the beach tie-in. The pipeline also includes a buried expansion spool with two 90 ° bends within the Theddlethorpe Gas Terminal boundary. There are also two 30 ° bends at the below/above ground transition. An isolation valve station is located within the Dunes at KP 119.05.

The pipeline is protected against external corrosion by a combination of corrosion coating and a Cathodic Protection (CP) system with sacrificial aluminium alloy segment anodes. The anodes were designed on the basis that the trunkline was 60% buried with a design life of 40 years. A nominal 5.5 mm glass reinforced coal tar enamel coating is provided along the line with the exception of field joint locations. Field joints are located every 12 m and are coated by cold applied anti-corrosion pipe wrap tapes, with infill by high density bituminous filler.

The external surfaces of the onshore section of the pipeline, including beach crossing, was initially protected through a combination of Coal Tar Enamel (CTE) coating and cathodic protection based primarily on impressed current (ICCP). An insulating flange is shown at TGT between the remaining onshore isolation valve and the Dunes Valve in LOGGS manual.

Impressed current cathodic protection was originally installed in 1972 to protect the fire main at TGT before upgrading the CP system to protect the pipelines installed over the years. The final system at TGT consisted of three transformer rectifier units and several ground beds. Enhanced protection and prevention of stray current interference was provided by bonding of the protected structures.

The ICCP was removed during TGT demolition phase and the shore approach sections of the offshore pipeline was retrofitted with a passive ground bed anode system in 2023 for temporary protection until permanent facilities are installed during the future VCCS project construction phase.

2.7 Protection & Trenching Design

The offshore pipeline was trenched to Top of Pipe (TOP) and was subsequently left to backfill by natural means. Exceptions to this are the two subsea tee connections and the Esmond and Viking pipeline crossings. A summary of the original design offshore trenching details is given in the table below.

Table 3 - Summary of Trenching and Burial Design along LOGGS

KP Range	Section Length (m)	Trenching Details
0.015 – 19.82	19,805	Trenched to TOP
19.82 – 20.32	500	Trenched to 0.5m cover
20.32 – 33.13	12,810	Trenched to TOP
33.13 – 33.63	500	Trenched to 1.0m cover
33.63 – 37.63	4,000	Trenched to TOP
37.63 – 38.13	500	Trenched to TOP
38.13 – 117.00	78,870	Trenched to TOP
117.00 – 118.22	1,220	2m cover to piggyback
118.22 – 118.72	500	Buried to min 3m cover
118.72 – 119.89	1170	Buried to 1m min cover U.N.O.

2.8 Pipeline Crossings

During installation, mattresses were placed over existing Esmond and Viking pipelines crossing points. Once the mattresses were placed 20 m square gravel blankets were added before the LOGGS pipeline was laid. Following the installation of the trunkline, stabilisation mattresses and further rock dumping was provided. During the operating life of LOGGS a further ten pipeline crossings (four of which were close to LOGGS PP) were constructed, all of which were protected by rock dumping unless stated otherwise. More recently, two cable crossings have been constructed.

2.9 Bathymetry

The 2010 ROV survey provided mean seabed levels for the LOGGS pipeline route from KP 0 to KP 96.51. The minimum water depth along the survey section of LOGGS was 13.88 m at KP 53.14, and the maximum water depth was 35.52 m at KP 29.45. Water depth at the decommissioned LOGGS pipeline end is approximately 20 m.

2.10 Original Construction, Installation and Pre-commissioning

The 36” linepipe and induction bends for both onshore and offshore sections was supplied by Mannesmann. The LOGGS pipeline was installed by Saipem’s Castoro Sei S-lay barge in 1987. The beach crossing, nearshore and platform approach sections of the methanol line were installed piggy-backed to the LOGGS pipeline. Over the majority of the route dual lay was carried out with a 20 m separation between the two lines. The beach tie-in location for the LOGGS pipeline is KP 118.729.

The LOGGS pipeline was hydrotested during pre-commissioning in accordance with Petroleum Code IP6 to a pressure of 196 bar. Prior to commissioning the line was dewatered by first running a pig train from shore using nitrogen then hydrocarbon gas. The line was then filled with gas at 5.5 bar.

2.11 Abandonment Status

The LOGGS pipeline was removed from service in December 2018. A solvent mixture, surfactant cleaning chemical and debris pick-up gel were flushed through the line in the cleaning pig train before final flushing with filtered, untreated seawater.

In summer 2020 diving activities were undertaken to cut and remove part of the pipeline, creating approximately 7m separation between the pipeline and LOGGS PP. No further work was undertaken on the cut end of the pipeline.

The TGT site has been partially decommissioned. The final isolation valve remains in situ whilst the pig receiver and isolation valves have been removed.

3 LOGGS Repurposing Assessment Key Conclusions

3.1 Integrity Assessment of External Pipeline Condition

What was assessed:

Annual integrity reports from 2007 – 2009, 2011 – 2014 and 2016 - 2017 have been reviewed for pipeline depth of cover, burial conditions, free spans, cathodic protection, objects in proximity to the pipeline, stability and general condition based on external inspections completed through a mixture of acoustic and visual (via remote operated vehicle) techniques.

In general, the seabed in the Southern North Sea is mobile, with areas of mega-ripples reported that change between reporting periods. In general, the pipeline was noted to be buried along 87% of the length, with 13% exposed through mobile seabed action (i.e. exposed in one survey and potentially buried again in the next).

The nearshore section of LOGGS was surveyed in 2014 and 2017. The survey reports indicates that the survey covered KP 103.581 to KP 118.263 and identified no spans and 13 exposures. Burial depths along the line had also been recorded with maximum burial depths of 3.4 m being reported.

What were the conclusions:

The review of the current integrity status does not identify any anomalies which would prevent the repurposing of the LOGGS pipeline for CO2 service.

Following TGT demolition where the ICCP was removed a new onshore passive anode cathodic protection system was installed in 2022 to protect the onshore pipeline sections from external corrosion.

3.2 Integrity Assessment of Pipeline Internal Condition

What was assessed:

The integrity assessment reviewed pipeline inspection reports to identify metal loss anomalies, considered anomaly growth since the inspections and evaluated the maximum operating pressure for the pipeline. Internal corrosion assessed calculated indicative worst case corrosion rates within the pipeline and extrapolated to 2024 based upon these rates to calculate pressure rating suitability.

The pipeline underwent ILI in 2008, 2014 and 2016 for 100% of the pipeline length. From review of the inspection run parameters (tool speed, temperature, and magnetisation levels) there are no indications of any significant issues that could affect the quality of the inspection data. No external corrosion anomalies were reported to be present on the pipeline in the 2016 ILI. The internal and external mill manufacturing anomalies and the girth weld anomaly detected in the ILI results are assessed as original construction features and as such acceptable up to the hydrotest pressure of 196 bar. Internal corrosion defects were detected in 2014 and 2016 ILI results in the first 3km of the pipeline. No internal corrosion defects beyond 5-to-10% of wall thickness, approaching the inspection tool's detection accuracy, were noted beyond the first 3km of the pipeline offshore end. The integrity assessment of defect suitability considered the period between assessment and where inhibited seawater would be added to the pipeline (2024) for potential corrosion via the seawater in the pipeline between decommissioning in 2018 and preservation in 2024.

Assessment of CO2 corrosion mechanisms for carbon steel and review of the Viking CCS CO2 specification were undertaken, including the impact of design controls such as dedicated dehydration facilities to remove water and the limitations within the permitted specification for control of other impurities such as oxides of nitrogen and sulphur.

What were the conclusions:

The assessed minimum safe operating pressure for the 2016 reported internal metal loss anomalies is predicted to be 250.7 bar in 2024, inclusive of those internal corrosion defects noted in the first 3km of the pipeline. To safeguard the pipeline for sustained long term service in CO2 service the first 3km of the pipeline has been removed, via a cut back operation performed in 2024 and will not be used in CO2 service.

A further inline inspection was completed in March 2024, to verify the condition of the LOGGS pipeline prior to repurposing, at the time of writing the data from this inspection is under assessment and will be used to determine any further inspection requirements.

Dehydration is the primary mitigation tool in ensuring the integrity of the LOGGS pipeline by preventing internal corrosion. Without water present, corrosion will not occur with pure CO2. Control of the composition of impurities such as oxides of nitrogen and sulphur shall be specified to prevent any corrosion mechanism in the absence of water. Viking CCS shall control the entry specification of CO2 from emitters by way of approval of the emitter project metering and verification equipment and plans. Viking CCS shall be able to shut in any emitters that cannot meet the specification for entry to the Viking CCS system and have appropriate monitoring in place to assure that CO2 entering the network meets the defined specification. These are rights granted to the Viking CCS network under the UK Government CO2 Network Access Code, as drafted by the Department for Energy Security and Net Zero.

3.3 Integrity Assessment of Pipeline Material Properties

What was assessed:

Evaluation of steel chemical composition, tensile properties, Charpy energy, drop weight tear tests, crack tip opening displacement, hardness, hydrogen sensitivity, and extend of non-destructive examination were assessed. The assessment compared the original linepipe supply against the requirements for repurposing to CO2 service.

As part of the demonstration that the LOGGS pipeline can be requalified to a contemporary design code (i.e. PD- 8010-2 or DNV ST-F101), the original linepipe specification and supply was assessed against the requirements associated to PD-8010-2 or DNV ST-F101. Comparison of the LOGGS pipeline specification with the more onerous DNV ST-F101 was assessed for Chemical and mechanical requirements, Sour service qualification – Supplementary Requirement S, Fracture Arrest – Supplementary Requirement F, Inspection and testing, Dimensional tolerances, NDE requirements, and Hydrostatic testing requirements.

The requirements for the line pipe were defined by Conoco:

- Conoco (U.K.) Ltd. Manufacture and Supply of Submerged Arc Welded Riser and Line Pipe. SBGD-B-QY- 50X-99-N00-002. Rev 2 [52]

The linepipe was manufactured by Mannesmann and the manufacturing data is reported in:

- Mannesmannrohren-Werke AG. Submerged Arc Welded Steel Pipes Data Books Vol. 1 – 9 [53]

The requirements for the induction bends were defined by Conoco:

- Conoco (U.K.) Ltd. Specification for the Manufacture of Induction Formed X65 Trunkline and Riser Bends. SBGD-B-QY-50X-99-N21-003. Rev 2 [56]

The induction bends were manufactured by Mannesmann and the manufacturing data is reported in:

- Mannesmann Large Diameter Bends Data Book A05 – 0003. Vol. 1 – 2

The original linepipe records above from Mannesmann were supplemented by two recent material testing scopes in 2016 and 2021:

- In 2016 Intertek undertook testing on a 36” x 30.3 mm pipe joint, Intertek Examination of X65 Linepipe Material. GC13348.

- In 2021 DNV undertook further testing of two 36” x 30.3 mm pipe joints.

All linepipe was manufactured by Mannesmann at the Mulheim (Ruhr) pipe mill using the Double Submerged Arc Welded (DSAW) UOE process. The plate and linepipe was manufactured using Thermo-mechanical Controlled Processing (TMCP), which corresponds to DNV ST-F101 delivery condition M.

The total produced quantities of linepipe are given in the table below:

Table 4 – Linepipe Production Quantities

Linepipe	No. of Pipes	Total Length (m)	Total Tonnage
36" x 26.97 mm	9,672	118,106	69,332
36" x 30.3 mm	322	3,937	2,590

What were the conclusions

For dense phase CO2 transport service, carbon steel pipeline is considered suitable, as stated by DNV RP-F104.

The LOGGS linepipe specification is considered to be comprehensive, and the manufacturing records indicate that the linepipe has characteristics of excellent weldability, ductility, low hardness and good toughness. The mean of the achieved Charpy Energies of around 270 J falls within typical requirements for fracture arrest for dense phase CO2.

The linepipe meets or exceeds all of the essential requirements of DNV ST-F101, and therefore API 5L / ISO 3183. Hence, the linepipe is considered suitable for the proposed requalification of the pipeline design to either PD 8010:1 and PD 8010:2 or DNV ST-F101.

The ConocoPhillips linepipe specification SBGD-B-QY-50X-99-N00-002 acts as a supplement to API 5L 33rd Edition, 1983. The linepipe specification is considered to be comprehensive, and particular requirements which are of relevance for repurposing for CO2 service are summarised below.

Required Charpy Energies were specified for hydrocarbon gas service are lower than is typically required for dense phase CO2 service. However, extensive testing was performed during manufacturing procedure qualification testing (MPQT) and production at a test temperature of -30 °C, and also Charpy energy transition curve testing was performed on the pipe body during MPQT and production. In conclusion although the LOGGS specified Charpy Energies are less than those of ST-F101 supplementary requirements F, the extensive mechanical testing completed and documented in the Mannesmann linepipe as-built records indicates that the achieved Charpy Energies in the pipe body exceed the requirements of supplementary requirement F from DNV-ST-F101.

The bend specification is considered to be comprehensive, and the manufacturing records indicate that the linepipe has characteristics of excellent weldability, ductility, low hardness and good toughness. The bends were specified for sour service and comprehensive testing was undertaken to demonstrate that the bends were suitable for sour service. As such, the bends are considered suitable for repurposing for CO2 service.

The bends meet or exceed all of the essential requirements of ST-F101. Hence, the bends are considered suitable for the proposed requalification of the pipeline design to either PD 8010:1 or DNV ST-F101.

3.4 Integrity Assessment of Offshore and Onshore Welds

What was assessed:

To confirm the suitability of the onshore and offshore girth welds for repurposing the following methodology is followed:

- Identification of available weld qualification data
- Review of the weld qualification data against the required weld properties for dense phase CO2 service
- Review of welding specification for compliance with welding requirements of contemporary codes including PD 8010-1, PD 8010-2, DNV ST-F101 and BS 4515.

The acceptance criteria for mechanical testing from the original LOGGS specification and from DNV ST-F101:2021 were compared and assessed. As were the offshore welding procedure and welding procedure qualification. Review of the original records for the welding trials for compliance with the original ConocoPhillips specification were assessed, as were the weld records for the weld material consumable certificates. The weld inspection and associated defect criteria were reviewed and assessed against the current version of BS 4515-1: 2009 which confirms that the defect acceptance criteria used in the original fabrication of the pipeline are unchanged and remain valid to modern standard.

The requirements for field welding were defined by Conoco:

- Specification of Field Welding of Pipeline doc. no: SBGD-B-QY-50X-99-NOO-015 [59]

The offshore welding was undertaken by Saipem onboard the Castoro Sei lay barge, and the Weld Procedure Qualification Records (WPQR) are given in:

- Installation Manual Section 6.9.1 C30 36” Trunkline/4” Methanol Line Vol 1 & 2 [60]

The fabrication of the onshore pipeline section appears to have been undertaken by NACAP Ltd. under contract to Saipem

What were the conclusions:

The specific requirements for girth welds for CO2 transportation are suitability for sour service including chemistry control, hardness control, adequate fracture toughness and Crack Tip Opening Displacement at or less than the minimum design temperature, and control of defects during construction verified by non-destructive examination.

The review of the qualification records for the onshore and offshore girth indicates that the LOGGS pipeline welds achieve these requirements, and hence the girth welds are considered suitable for CO2 service.

The general requirements of the LOGGS welding specification are in line with the general requirements of PD 8010 and DNV ST-F101.

The weld procedure mechanical test requirements of the LOGGS specification are in line with the contemporary requirements of DNV ST-F101 in terms of test types, test frequency and acceptance criteria. A review of the weld procedure qualification records indicates that the offshore and onshore weld procedures qualifications met the requirements of the LOGGS specification.

The weld inspection requirements (100% NDT) and acceptance criteria of the LOGGS welding specification (BS 4515: 1984) are in line with the contemporary requirements of BS 4515: 2019 and DNV ST-F101.

Based on the above, the LOGGS pipeline girth welds are considered to be compliant with contemporary code requirements and suitable for repurposing for CO2 service.

3.5 Integrity Assessment of CO2 service and fracture control

What was assessed:

A detailed review of the initiating events, overall risks and mitigations associated with running ductile fracture propagation within the LOGGS pipeline has been undertaken. The evaluation has considered and assessed all available full scale test data and a range of industry standards.

What were the conclusions:

Based on a thorough review of pipeline damage modes for the onshore section of the LOGGS pipeline, between TGT pipeline isolation valve and the Dunes valve station, there are no credible events that could result in the initiation of a ductile fracture. Based on the review of potential damage modes and existing controls for the pipeline operation, damage from 3rd party interference with the pipeline is the most common in industry. Assessment of impact energies indicates that even a very large (55Te) excavator impact would not have sufficient energy to penetrate the LOGGS pipeline to cause a defect capable of creating the onset of running ductile fracture. Based on robust CO2 specification control and existing corrosion control mitigations, internal or external corrosion is not deemed a credible fracture initiating event.

The Viking CCS specification has been defined such that the risk of running ductile fracture is controlled throughout the operational life. A robust, safe pipeline operating envelope has been defined via the control of the Viking CCS CO2 specification. Viking CCS shall control the entry specification of CO2 from emitters by way of approval of the emitter project metering and verification equipment and plans. Viking CCS shall be able to shut in any emitters that cannot meet the specification for entry to the Viking CCS system and have appropriate monitoring in place to assure that CO2 entering the network meets the defined specification. These are rights granted to the Viking CCS network under the UK Government CO2 Network Access Code, as drafted by the Department for Energy Security and Net Zero.

3.6 Integrity Assessment of Pipeline Components – Tees and Valves

What was assessed:

The LOGGS pipeline incorporates two subsea tee and 20” valve arrangement to allow future tie-ins. The two tee arrangements are identical and are located at:

- Tee 1 at LOGGS KP26.2 in 26 m water depth.
- Tee 2 at LOGGS KP51.2 in 18-20 m water depth.

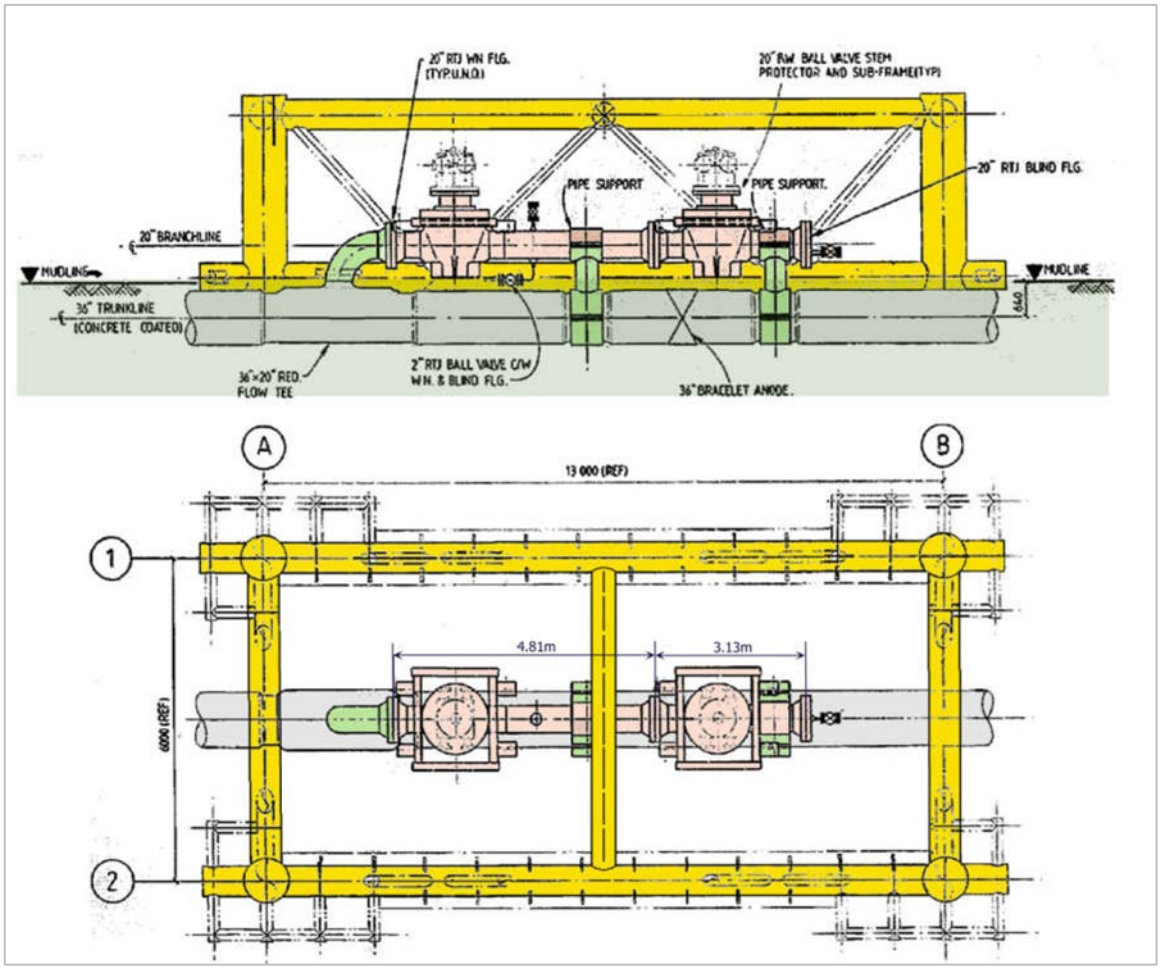
The LOGGS pipeline has an onshore 36” Dunes Valve, located near to the TGT site, and an onshore 36” isolation valve at the Theddlethorpe site.

DNV-RP-F104 Clause 5.3.4 requires that non-metallic materials such as seals and valve seats shall be qualified to ensure chemical compatibility with CO2 and other components in the CO2 stream.

What were the conclusions:

The subsea tee branch inclusive of valves shall be removed during the construction phase of the Viking CCS project, and a pressure rated flange installed on the connection point. Thereby removing any risk associated with the repurposing of the tie-in structures.

Figure 3 – Pipework to be Removed (shown in pink)



The two onshore ESDV & dunes valves shall be removed and replaced with newly constructed valves, during the construction phase of the Viking CCS project. Thereby removing any risk associated with the repurposing of the existing valves.

3.7 Integrity Assessment of Life Extension for the Viking CCS CO2 specification

What was assessed:

Review of the pipeline's original design, manufacturing, installation, and commissioning records against the latest applicable design codes to confirm if it remains in compliance to the current pipeline design codes.

Assessment to identify credible time-dependant threats to the pipeline's extended operating life, risk assessment of the threats to confirm pipeline acceptability and identify applicable mitigation measures to inform the future operating and maintenance strategy. Anomaly criteria for free spans was reassessed to the latest guidance of DNV-RP-F105.

Assessment of the life extension of the pipeline, focusing on time dependent threats included:

- Review of available Inline inspection data to determine the extent of current deterioration from prior service (refer to section 3.2 above).
- Defect assessment to understand the pipelines tolerance to corrosion over the extended life and demonstration that safe working pressure of defects is greater than the revised design pressure (refer to section 3.2 above)..
- Review of the coating degradation and cathodic protection design to assess the risk of external corrosion over the extended life.
- Fatigue assessment of seam and girth welds over previous hydrocarbon and future CO2 operation, and identification of requirements for more advanced fatigue or crack growth assessments

Assessment of the pipeline's operational fatigue life was performed by calculating the fatigue damage experienced from the pipeline historical and future stress cycles based on the latest guidance of DNV-RP-C203. The assessment considered operational trends from 1987 to 2018, including pressure and temperature averages and maximums. The normal operating pressure and temperature regime of the pipeline was noted as stable with no known excursions from the pipeline design limits. The life extension report has considered the mothballed period from 2018 to 2024 where the pipeline was filled with seawater, and the preservation period from 2024 to 2028 where the pipeline will be filled with inhibited seawater. The future service life for a 25-to-40 year further period of operation in dehydrated CO2 service has been considered.

What were the conclusions

The review of the current integrity status has not identified any anomalies or time-dependent damage mechanisms which would prevent the repurposing and life extension of the LOGGS pipeline for CO2 service.

Based on assessment of prior operating history the pipeline fatigue life is deemed suitable for life extension and CO2 service.

The conclusions of the assessment confirmed that existing LOGGS linepipe and bends specification and manufacturing quality control meet or exceed all of the key requirements of DNV-ST-F101 (and hence API SL/ISO 3183). The linepipe and bends are therefore considered suitable for the proposed requalification of the pipeline design to PD 8010-1, PD 8010-2 or DNV ST-Fl0l. Similarly, the girth welds are considered suitable for the proposed requalification of the pipeline design to PD 8010-1, PD 8010-2 or DNV-ST-F101.

No external corrosion features were found in the previous inline inspection works, subject to verification the 2024 inline inspection and the ongoing maintenance of the cathodic protection system it is concluded that external corrosion would not prevent the repurposing and life extension of the LOGGS pipeline for CO2 service.

It is concluded that current spans found on the pipeline are within the anomaly criteria and hence environmental fatigue from free span is not life limiting.

It is concluded that the majority of LOGGS pipeline has burial levels that are above the requirements for pipeline stability. Localised sections which are below the burial requirements are not considered a concern to stability of the pipeline. Ongoing survey via inline inspection or external means shall continue to monitor for any indications of lateral stability or movement at existing route bends where the existing burial condition is observed to change.

The Cathodic Protection system for the offshore pipeline is assessed in good condition based on prior external inspections prior to decommissioning and suitable for extended field life. External inspections have demonstrated that the pipeline anodes were found to be less than 25% depleted in 2010, from installation in 1987. Actual external anode wastage will continue to be monitored in service and replacements for any areas of the pipeline that may experience increased drain or may be more prone to coating degradation. Where required targeted anode replacements may be undertaken to ensure external cathodic protection remains suitable for the remaining life, which is a standard offshore industries activity and is not a limitation or constraint to life extension with a suitable inspection and maintenance regime.