LBA CCS TRANSPORT AND STORAGE PROJECT

POINT OF AYR TO SATELLITE PLATFORMS

SUBSEA PIPELINE CONNECTION STUDY - DOUGLAS CCS

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HOLD RECORD

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ASSUMPTIONS RECORD

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CONTENTS

1.0 SCOPE OF THIS DOCUMENT

The scope of this document is to present the finding for the possible options for the connections of existing repurposed pipeline with new offshore spools at new Douglas CSS Platform for the transportation and storage of CO_2 as part of LBA CCS T&S Project. This document provides input into the FEED phase to enable completion of engineering activities at the FEED level.

The scope of this document covers connection with Five (5) new spools of various lengths and sizes at new Douglas CSS platform:

- New 20in spool with Existing repurposed pipeline PL1030 at new Douglas CSS Platform
- New 14in spool with Existing repurposed pipeline PL1041 at new Douglas CSS Platform
- New 16in spool with Existing repurposed pipeline PL1035 at new Douglas CSS Platform
- New 12in spool with Existing repurposed pipeline PL1036A at new Douglas CSS Platform
- New 20in spool with Existing repurposed pipeline PL1039 at new Douglas CSS Platform

2.0 BATTERY LIMITS

The following figure provides an overview of the CO_2 injection system from Offshore Pipeline to Spools Offshore.
The tie-in scope battery limits considered in this report are limited to the spool tie-in point at the existing repurposed pipelines. The proposed approximate tie-in location is marked out with blue rectangle on the figure below.

Nominal Size	Description	Easting Note1	Northing Note1	Nominal Design Capacity
20in	20in Tie-in Connection on PL1039 near new Douglas CSS Platform	461784.24	5932627.10	4.5 MTPA Gas Phase
14in	14in Tie-in Connection on PL1041 near new Douglas CSS Platform	461679.84	5932613.32	4.5 MTPA Gas Phase
16in	16in Tie-in Connection on PL1035 near new Douglas CSS Platform	461738.49	5932616.47	4.5 MTPA Gas Phase
12in	12in Tie-in Connection on PL1036A near new Douglas CSS Platform	461818.75	5932622.27	4.5 MTPA Gas Phase 4.5 MTPA Dense Phase
20in	20in Tie-in Connection on PL1030 near new Douglas CSS Platform	461775.81	5932229.40	4.5 MTPA Gas Phase 4.5 MTPA Dense Phase 10 MTPA Dense Phase
Note 1: Coordinates are approximate and subject to confirmation				

Table 2-1 Battery Limits

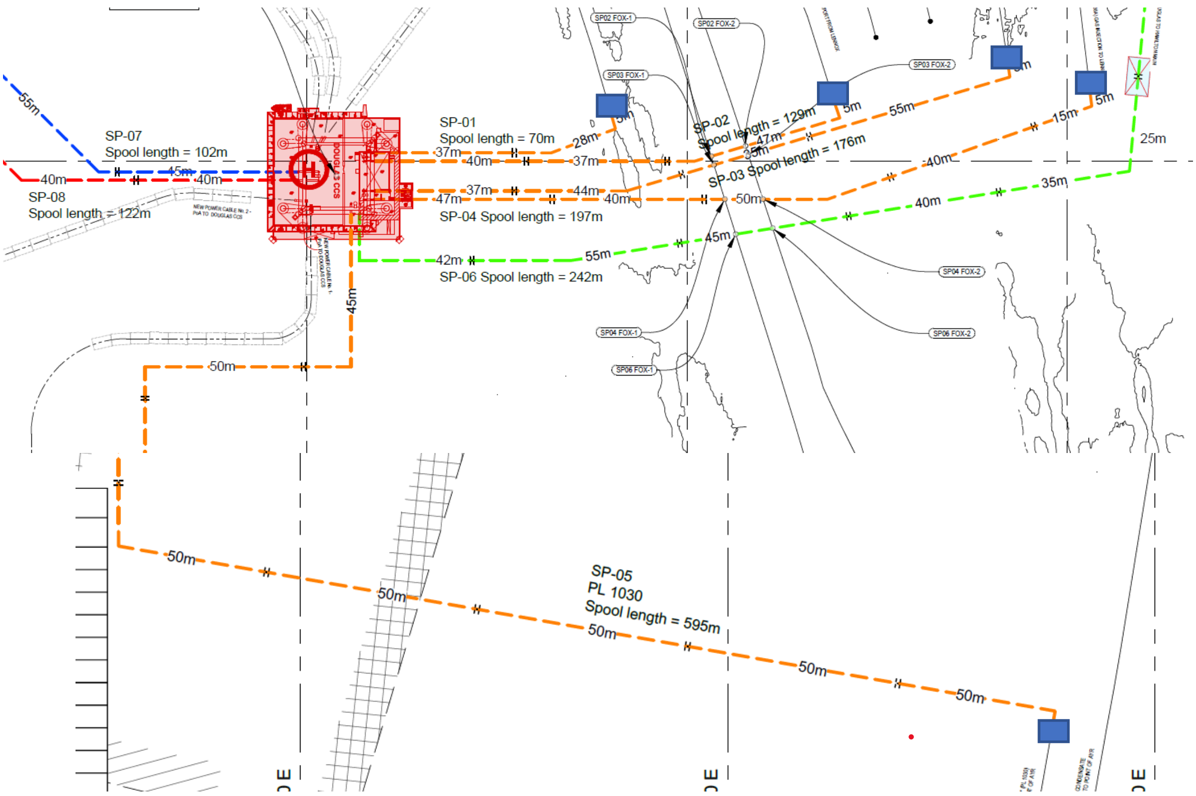

Figure 2-1: Tie-in Location

3.0 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

The following definitions, terminology and abbreviations are applicable for the Project and used throughout this document:

COMPANY/CLIENT	The party that initiates the project and ultimately pays for its design and construction i.e., Eni UK. The COMPANY will generally specify technical requirements. The term "COMPANY" also includes agents or consultants authorized to act for and on behalf of COMPANY. Eni UK is the Client for LBA CCS Transport and Storage
CONTRACTOR	A person or organisation that undertakes responsibility for the execution of a CONTRACT. EniProgetti is responsible for execution of the Scope of Work agreed with the COMPANY
CONTRACT	An acceptance of legal relations between two or more parties for the transfer of goods or services for value.
Project or Plant:	LBA CCS Transport and Storage
WORK	Shall mean all work that CONTRACTOR is required to carry out in accordance with the provisions of CONTRACT including all related services and resources to be provided in accordance with the CONTRACT
Shall	A mandatory provision
Should	An advisory provision

3.2 Abbreviations

API	American Petroleum Institute
BOP	Bottom of Pipe
CCS	Carbon Capture and Storage
CS	Carbon Steel
DNV	Det Norske Veritas
EOI	Expression of Interest
FEED	Front End Engineering Design
HM	Hamilton
HOC	Hamilton Oil Company
PLFT	Platform
POA	Point of Air
ISO	International Organization for Standardization
LAT	Lowest Astronomical Tide
LBA	Liverpool Bay Asset
Min	Minimum
Max	Maximum
MSL	Mean Sea Level
OD	Outside Diameter
PTFE	Polytetrafluoroethylene
TBC	To be confirmed
TOP	Top of Pipe
TRL	Technological Readiness Level
WT	Wall Thickness

4.0 REFERENCES

4.1 Project Documents

[Ref.1]	1025H0BGRB09002, Basis of Design Offshore 4.5 MTPA (Gas Phase) – FEED &10 MTPA (Dense Phase) – Feasibility
[Ref.2]	102100BESB09003, Project List of Applicable Codes and Standards
[Ref.3]	1025H0BSDN84002, Overall Facility Schematic
[Ref.4]	1023DSBSDN84003, Offshore New Pipelines Field Layout
[Ref.5]	1023DSBSRV84008, Offshore Pipeline Preliminary Routing Report
[Ref.6]	1025H0BSRF84028, Offshore Pipelines Pre-Feed Feasibility Report
[Ref.7]	102327D0BLPU80026, Existing Pipelines Cleaning and Preservation Philosophy

4.2 Company Specifications

Company Specifications to comply with [Ref.2].

[Ref.8]	23025.ENG.PLI.PRG, Design of Offshore Pipelines

4.1 International Codes and Standards

International Codes and Standards to comply with [Ref.2].

[Ref.9]	ISO 27913, Carbon Dioxide Capture, Transportation and Geological Storage Pipeline Transportation Systems
[Ref.10]	DNV-ST-F101, Submarine Pipeline System
[Ref.11]	DNV-RP-F104, Design and Operation of Carbon Dioxide Pipelines
[Ref.12]	DNV GL RP-F113, Pipeline Subsea Repair
[Ref.13]	ASME B16.5, Flange and Flanged Fittings Specification
[Ref.14]	ASME B31.8, Gas transmission and distribution piping systems
[Ref.15]	ASME B31.4, Pipeline Transportation Systems for Liquids and Slurries
[Ref.16]	API 6H, Specification on End Closures, Connectors and Swivels
[Ref.17]	API 570, Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping System
[Ref.18]	API 574, Inspection Practices for Piping System Components
[Ref.19]	ISO 27913, Carbon Dioxide Capture, Transportation and Geological Storage Pipeline

4.2 Other

	Field Layout
[Ref.20]	D-200-UC-001, Overall Field Chart LBA, Rev C, BHP, 2002

4.3 Order of Precedence

Should conflict arise between the statements of different rules, codes or standards, the following list of precedence shall be respected:

1. Law and National Standards
2. Design Basis, Project Specifications and Drawings
3. COMPANY Specifications
4. International Codes and Standards

If conflicts arise the most stringent requirement shall apply in its entirety of the specific topic. In all cases of conflict, the COMPANY shall be informed.

5.0 SUMMARY AND CONCUSION

5.1 Summary

Three different solutions have been considered for the connections of existing repurposed pipelines with the new offshore pipelines and new spools envisaged at the new Douglas CSS Platform for the transportation and storage of CO_2 as part of LBA CCS Transport & Storage Project.

Three (3) options have been evaluated for each tie-in connection point between the new spools and the corresponding existing repurposed pipeline considering both cost and technical acceptability:

- **OPTION 1: Flange Connection:** use of existing flange on the existing repurposed pipeline for a connection with the new spool
- **OPTION 2: Mechanical Connector**: use of mechanical connector to connect existing repurposed pipeline with the new spool
- **OPTION 3: Hyperbaric welding**: welding the new flange on the existing repurposed pipeline for a connection with new spool

Dedicated in-house workshops were undertaken to evaluate the merits of each option and to list out points of actions for further evaluation. Due to the first of a kind application of these options with CO_2 service, a further preliminary vendor engagement was undertaken. Appendix A outlines the extend of the vendor engagement on technical feasibility level.

On the basis of data gathered in-house within various department and with vendors, this report presents a topic based comparative discussion of each option and further ranks each of the option, to allow for preliminary conclusion of best feasible option at this stage of the project.

5.2 Conclusion

Based on the ranking and discussion presented in this study, Subsea Mechanical Connectors have the highest ranking and shall be nominated as the base case solution to be taken forward for further engineering. This option, compared to Flange connection, doesn't require pipeline to be recovered and it can be performed completely subsea. This avoids issues conserving the structural integrity of the existing pipelines during lifting as well as minimizing the excavation required for the tie-in connection. Compared to Hyperbaric Welding option is has lower cost and more vendors minimizing the potential impact on schedule.

Hyperbaric welding option is ranked second due to higher cost and further investigation to confirm the feasibility and acceptability.

The Flange connection could be used however, the condition of the existing flanges needs to be evaluated first. Furthermore, this option requires longer excavation of the existing reproposed pipelines (up to 300m) and recovery of pipeline aboard the installation vessel which impact total cost. Finally, detailed installation analysis needs to be performed to verify acceptability of this option.

5.3 Recommendations

Below recommendations are made to firm up the selection of the tie-in connection option;

- Further detailed engagement with subsea mechanical connector vendors to understand product compliance and regulatory requirements.
- Continue engagement with hyperbaric welding companies to understand schedule and cost implications.
- Include the procurement and installation timeline of the selected tie-in option onto the project overall schedule.
- Confirm the current status of the existing repurposed pipeline at the tie-in location for both inside and outside pipe surfaces and reference with [Ref.7].

6.0 OPTIONS DESCRIPTIONS

Three (3) different possible options were evaluated:

- **OPTION 1: Flange Connection:** use of flange on the existing repurposed pipeline for a connection with the new spool
- **OPTION 2: Mechanical Connector**: use of mechanical connector to connect existing repurposed pipeline with the new spool
- **OPTION 3: Hyperbaric welding**: subsea welding the new flange on the existing repurposed pipeline for a connection with new spool

6.1 OPTION 1: Flange Connection

This option considers joining of two sections, the new spool and existing repurposed pipeline, using Flange to Flange connection. The existing flanges has been installed and in operation for 20 years and would need for disconnection, recovery and detailed cleaning before making new flange connection.

Section of the pipeline, along with the flange, is to be lifted to installation vessel. Common practice is either to perform the above-water tie-in (lifting with davits) or by reverse lay method (recovering the pipeline to firing line). In both cases there is a need to perform extensive analysis to confirm that the pipeline can be lifted safety without overstressing it. Similarly, the condition of the existing flange needs to be validated. Recovery of the pipeline onto construction vessel would necessitate exposing of the buried pipeline subsea for approximate length of 300m and removal of 1.0-1.2m burial cover top of pipe. Exposing of such lengths of buried pipeline would have a significant impact on the subsea environment.

The flange connectors are to design to relevant codes, and it should meet the ASME B16.5 [Ref.13], API 570 [Ref.16] API 574 [Ref.18] design code, and shall be NACE compliant.

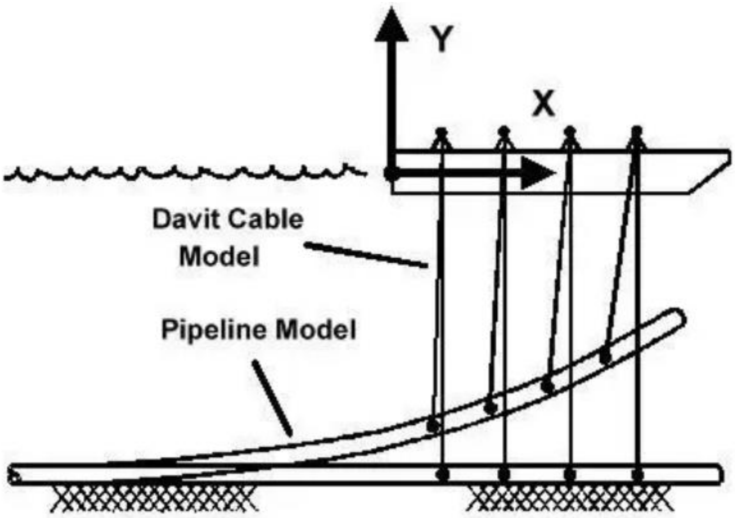

Figure 6-1: Schematic of Above Water Tie-in

6.2 OPTION 2: Mechanical Connector

Mechanical connectors are commonly used for pipeline repairs, pipeline re-route and pipeline abandonment. Mechanical connectors are compact steel cast with a flanged outlet for connecting plain end pipe to a pre flanged termination. Mis-alignment flange interface may be used if required.

The design is compatible with a wide range of pipe materials including carbon steel, stainless steel and duplex. All the vendors provide a seal assembly to eliminate flow leak

Mechanical connectors are easy to install and commissioned either by divers or diver-less using ROV or remote tooling installation. There is no need to lift the pipeline, all operation can be performed subsea.

All connectors are delivered to be used together with vendor qualified and field proven tie-in systems using external seal test ports (back seal testing) to ensure the integrity after connected subsea. Mechanical connector can withstand the full structural loads of the pipeline's design and test conditions. There is no post installation maintenance required.

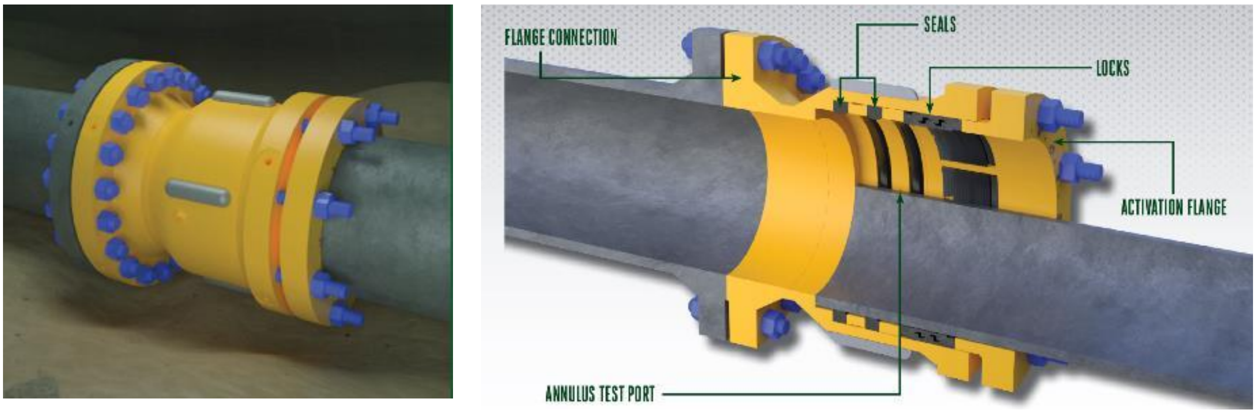

Figure 6-2: Typical diver assisted Mechanical connector

The installation of the mechanical connector can either be diver-less or diver assisted. The diver-less assisted is shown in Figure 6-3.

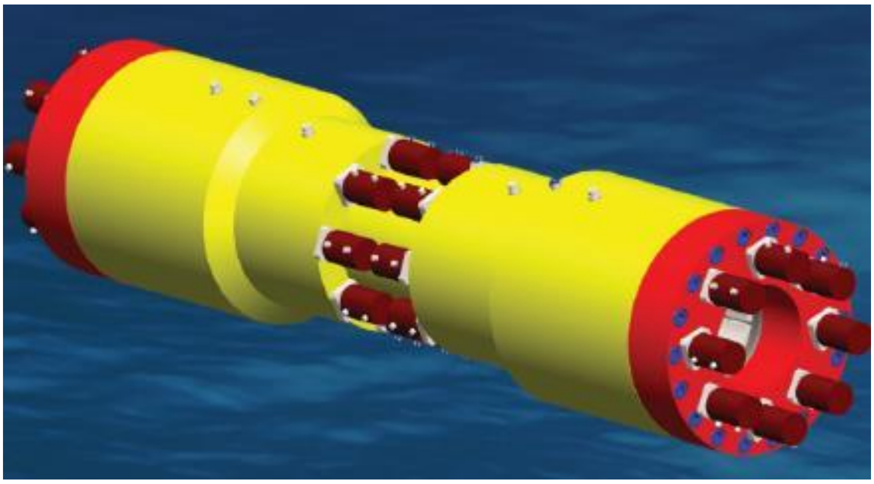

Figure 6-3: A typical diver-less Mechanical connector

A typical installation sequence is shown in Figure 6-4 below.

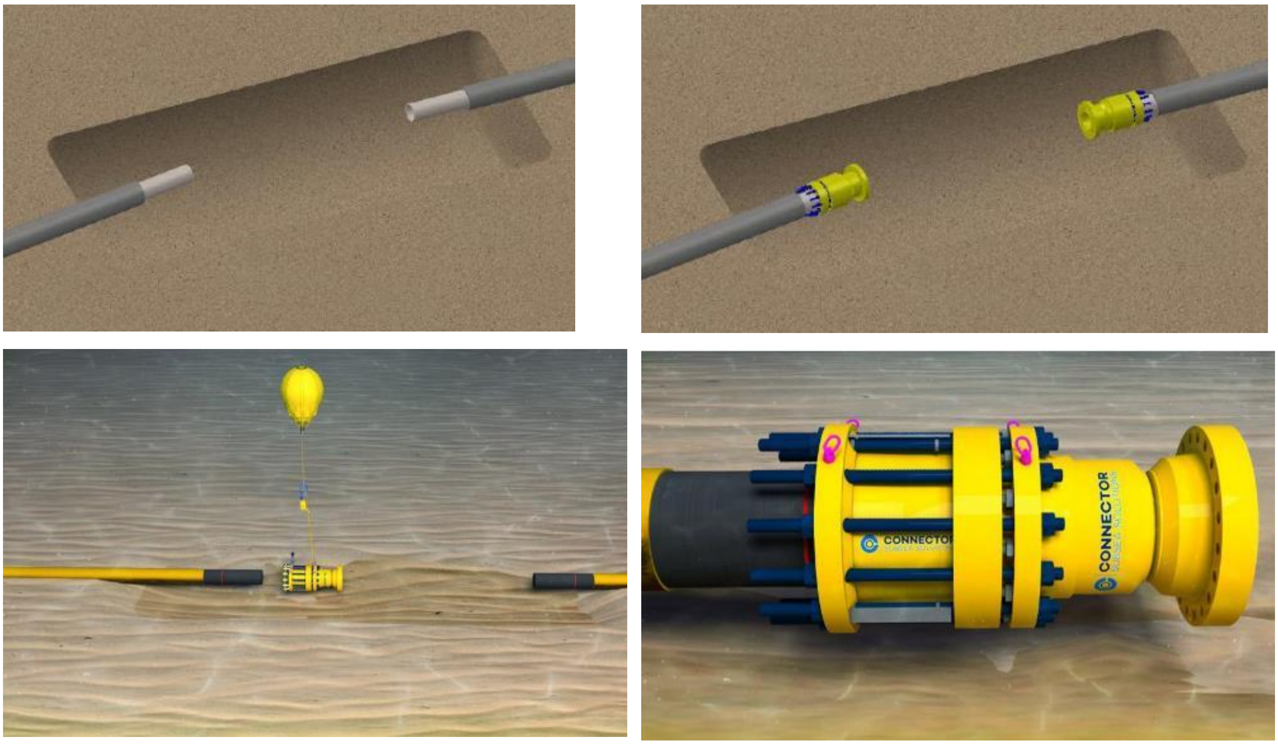

Figure 6-4: A typical installation of Mechanical connector

Mechanical connectors are designed to either to DNV-ST-F101 [Ref.10], ASME B16.5 [Ref.13], ASME B31.8 [Ref.14], ASME B31.4 [Ref.15], and or API 6H [Ref.16]. The external coating are yellow to facilitate subsea visibility. The studs and nuts are coated with Polytetrafluoroethylene (PTFE).

Mechanical connector procurement can take 16 to 35 weeks and the construction will take between 1 day up to 10 days for each connections excluding mobilization and demobilisation.

6.3 OPTION 3: Hyperbaric welding

Hyperbaric welding is the process of welding at elevated pressures, normally underwater. Hyperbaric welding can either take place wet in the water itself or dry inside a specially constructed positive pressure enclosure and hence a dry environment. There is no need to recover the pipeline as all operation can be performed subsea.

The three most common hyperbaric welding technics includes:

- **Shield Metal Arc Welding:** This is the most common type of underwater welding, used more than 90% of the time especially when performing "Wet welding". It is known as stick welding; it involves cylindrical nodes to create an electric arc.
- **Flux-Cored Arc Welding**: uses a spool that provides a constant feed, giving welders vital fillers metal, including cast-iron and nickel alloys.
- **Friction welding**: This uses friction to generate the heat necessary for successful hyperbaric welding. It is used for various thermoplastics and metals. The welding process can either be by utilising a Dry habitat or by atmosphere welding i.e., utilising cofferdam attached to Suction pile. (The monopile is clearly suited, both commercially and technically.)

The interior of hyperbaric welding chamber is shown in following figure.

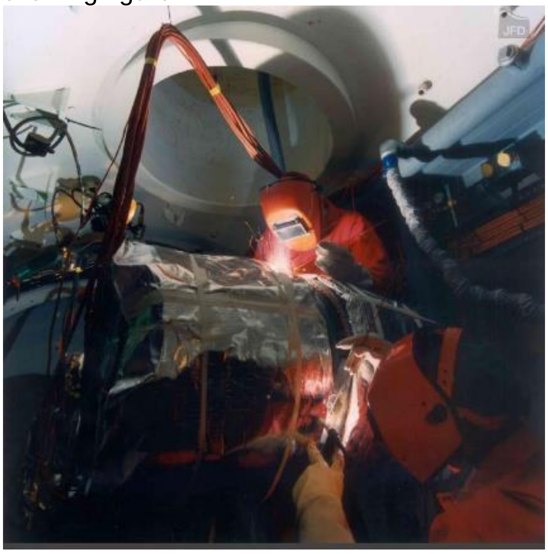

Figure 6-5: A typical installation of Mechanical connector

The Hyperbaric welding and testing of production weld shall be as in accordance to DNV-ST-F101 [Ref.10].

The schedule for the hyperbaric welding from pre-engineering, project management, mobilization, welders' qualification, hyperbaric welding operation and testing and mobilization can take 26 weeks.

7.0 EVALUATION CRITERIA

Tie-in connection options have been evaluated based on the feasibility and technical readiness including:

- Compatibility with CO_2 for both gas phase and dense phase
- Constructability,
- Safety,
- Design and code compliance,
- Technological Readiness level,
- Installation schedule,
- Design life,
- Cost,
- Gasket design,
- Corrosion,
- Piggability,
- Material procurement lead time (schedule),

8.0 RANKING

All three options have been ranked and evaluated according to criteria described in Section 7.0. Ranking system consider numerical values from 0 to 5, where 0 is poor/non-compliant and 5 is excellent.

Criteria Description	Option 1 Flange Connection	Option 2 Mechanical Connector	Option 3 Hyperbaric Welding
Compatibility with CO_2	4	3	4
Constructability	3	5	4
Safety	3	4	4
Design/Code Compliance	5	5	5
Technological Readiness level	4	3	4
Installation Schedule	1	4	2
Design Life	5	5	5
Cost	3	5	2
Corrosion	4	4	4
Piggability	4	4	4
Procurement Lead time	4	3	4
Total	**40**	**45**	**42**

Table 8-1 Evaluation Summary

8.1 Compatibility of the options with CO_2

Flanges and line pipes can be designed for compatibility with CO_2.

Similarly for hyperbaric welding of the pipelines same flange as above would be made use for the tie-ins, the main consideration is the welding qualification and the welder's qualification.

For Mechanical connectors, none of the vendors contacted had confirmed that connector has been used for CO_2 service in the past. However they have confirmed that the mechanical connector is made from carbon steel, and it can be designed to ensure compatibility with CO_2. The main challenge with the mechanical connector is the seals. The seal compatibility with the dense phase needs to be evaluated. Vendors have recommended the use of graphite seals. Furthermore, the Vendors are open to investigate compatibility of graphite or elastomer seals with CO_2 to ensure the seal meet the TRL standard required.

8.2 Safety

All option should follow highest safety standards both during installation and in operation. Any deviations from safe operation should be flagged and addressed. Flange Connection, due to complex operation, present higher safety risk compared to other two. Furthermore, operation that is diver assisted present higher safety concerns compare to diver-less.

8.3 Design And Technical Feasibility

Several design and technical feasibilities were considered in the assessment of the different methods of connecting the existing repurposed pipeline and the new spools for utilization in the CO_2 pipeline network.
The design code, material, design pressure, CO_2 compatibility, design life (durability), technological readiness level of the option, corrosion, diameter restriction, seals where applicable, operability (piggability), and constructability were all evaluated and considered in the assessment.

All three options shall be designed to industry design codes. The flange tie-in option are design to relevant codes, in this case the flange meet the ASME B16.5 [Ref.13], API 570[Ref.16] API 574 [Ref.18], and shall be NACE compliance. Hyperbaric welding of the existing pipeline to new spool will be performed in accordance to DNV-ST-F101 [Ref.10].

All the vendors contacted indicated that the mechanical connectors are designed to either to DNV-ST-F101 [Ref.10] or ASME B16.5 [Ref.13], ASME B31.8 [Ref.14], ASME B31.4 [Ref.15], and or API 6H [Ref.16], the coating are design to exterior surface are yellow to facilitate subsea visibility. The studs and nuts are coated with Polytetrafluoroethylene (PTFE).

8.4 Material

Mechanical connectors can be carbon steel, stainless and duplex SS/ANSI/ASME and ASTM A694. The pressure rating ranges from ANSI 600 to 2500.

8.5 Design Life

The design life for the three option is an average of 25 years. However, it is important to note that the design life for the mechanical connect is based on pipeline repairs.

8.6 Technological Readiness Level (TRL)

The flange connection and the weld connection are traditional pipeline connection methods that have been tested and proved to meet at least TRL 7. Both options are tested and trusted technology for pipeline connection.

However, not all the mechanical connector vendors have provided a TRL level. The vendors that provided a TRL level, provided a TRL level of 7 and 9. None of vendors have provided a documentation to justify this, only an assumption that their product meets these requirements.

The information provided by vendor needs to independently verify, since the TRL has not been independently certified to a specific product technology readiness level.

None of the mechanical connector vendor has a track record of the connector usage for CO_2.

8.7 Water Dept

The water depth at the proposed tie-in location (new Douglas CSS Platform location) is 29m LAT with maximum tidal range of 10m (HAT). Flange Connection and Mechanical Connector options can be installed both by diver assisted or diver-less installation method.

8.8 Piggability

All three options there are no foreseen restriction for the piggability.

9.0 TIE-IN CONNECTION FEASIBILITY

9.1 Flange connection

Flange connection is commonly used and considered cheaper than other options. It has a track record of use for the CO_2 transportation.

However, this option presents some drawbacks. The most significant one is that it is required to make up the face of existing flange to allow for installation of new gasket and flange tie-in. Such make up of flange face requires the flange and significant section of existing pipeline to be recovered onto an installation vessel. In this case up to 300m of the pipeline will need to be excavated first, impacting technical feasibility, cost and schedule. Based on the inspection of the flange it may be deemed that flange is too corroded for future use and need to be replaced. Excavating and lifting the pipeline may cause damage to the pipeline itself. Furthermore, detailed analysis will need to be performed first to verify that pipeline can withstand this operation.

Typically flange connections are weakest point in system, with lowest load capacity. Divers may be required if it is diver assisted installation.

9.2 Mechanical Connector

Use of mechanical connector have multiple advantages in comparison with the other options. Mechanical connecter and its sleeve can withstand higher loads and stresses than flange connection while having lower total weight. Construction is relatively easy and it requires lower bolting torque. It requires a small dig up top of pipe and bottom of pipe, with enough clearance to install mechanical connector. All operations are to be performed subsea and there is no need to recover the pipeline. Operation can either diver-less or using divers

To allow for a correct connector installation, the exposed cut pipe section will require a proper cleaning and removal of any coating to achieve a clean bare pipe metal ready for connector installation. Such removal of pipe coating would extend beyond the length of mechanical connector for about 200-300mm. This exposed section would become part of the pipeline system and would need to be protected with cathodic protection as post connector tie-in coating repair would not be possible.

No vendor, up to the point of concluding this assessment, has provided proof of seals compatibility for CO_2 transport and technological readiness level requires more work. The technology has been tested on repair works only. However, vendors claim it is suitable for new pipeline design based on the design life. Also, this option is more expensive compared to the flange connection

9.3 Hyperbaric Welding

Hyperbaric welding is a proven technology with good track record. Welded joints can withstand higher loads compared to the other options. Similar to mechanical connector, only a small section of the pipeline needs to be excavated to perform the welding operation. All testing is carried out by qualified personnel on the surface and welder qualifications require no diving.

However, this option is more expensive than both flanged or mechanical connector. There are only few contractors available due to the high level of required expertise.

APPENDIX A: CONNECTOR TYPE COMPARISON

Vendor Engagement.xlsx

APPENDIX B: FIELD LAYOUT DETAIL - NEW DOUGLAS CSS PLATFORM