Repurposing and design guidelines for carbon dioxide pipelines

energy institute

REPURPOSING AND DESIGN GUIDELINES FOR CARBON DIOXIDE PIPELINES

First Edition

December 2023

Published by
Energy Institute, London
The Energy Institute is a professional membership body incorporated by Royal Charter 2003
Registered charity number 1097899

The Energy Institute (EI) is the chartered professional membership body for the energy industry, supporting over 23 000 individuals working in or studying energy and 200 energy companies worldwide. The EI provides learning and networking opportunities to support professional development, as well as professional recognition and technical and scientific knowledge resources on energy in all its forms and applications.

The EI's purpose is to develop and disseminate knowledge, skills and good practice towards a safe, secure and sustainable energy system. In fulfilling this mission, the EI addresses the depth and breadth of the energy sector, from fuels and fuels distribution to health and safety, sustainability and the environment. It also informs policy by providing a platform for debate and scientifically-sound information on energy issues.

The EI is licensed by:
– the Engineering Council to award Chartered, Incorporated and Engineering Technician status, and
– the Society for the Environment to award Chartered Environmentalist status.

It also offers its own Chartered Energy Engineer, Chartered Petroleum Engineer, and Chartered Energy Manager titles.

A registered charity, the EI serves society with independence, professionalism and a wealth of expertise in all energy matters.

This publication has been produced as a result of work carried out within the Technical Team of the EI, funded by the EI's Technical Partners. The EI's Technical Work Programme provides industry with cost-effective, value-adding knowledge on key current and future issues affecting those operating in the energy sector, both in the UK and internationally.

For further information, please visit **http://www.energyinst.org**

The EI gratefully acknowledges the financial contributions towards the scientific and technical programme from the following companies:

ADNOC
BP Exploration Operating Co Ltd
BP Oil UK Ltd
Chevron North Sea Ltd
Chevron Products Company
CNOOC
DCC Energy
Drax Group
EDF Energy
ENI
Equinor
Exolum
ExxonMobil International Ltd
Harbour Energy
Ithaca Energy
Intertek
Kuwait Petroleum International Ltd
Neptune Energy
Ocean Winds
Ørsted
Phillips 66
Prax
Qatar Petroleum
Repsol Sinopec
RWE npower
Saudi Aramco
Scottish Power
SGS
Shell UK Oil Products Limited
Shell U.K. Exploration and Production Ltd
Siemens Gamesa Renewables
Spirit Energy
SSE
TAQA
TotalEnergies
Uniper
Valero
Vattenfall
Vitol Energy
Woodside
World Fuel Services

However, it should be noted that the above organisations have not all been directly involved in the development of this publication, nor do they necessarily endorse its content.

ISBN 978 1 78725 403 9

Published by the Energy Institute

Hard copy and electronic access to EI and IP publications is available via our website, **https://publishing.energyinst.org**.
Documents can be purchased online as downloadable pdfs or on an annual subscription for single users and companies.
For more information, contact the EI Publications Team.
e: **pubs@energyinst.org**

CONTENTS

Contents continued

Page

LIST OF FIGURES AND TABLES

Page

Figures

Tables

1 ACKNOWLEDGMENTS

This project was commissioned by the Energy Institute's (EI) Carbon Capture Usage and Storage Committee and steered by the EI CCS2002 Working Group chaired by Anthony Byrne from Protium. The research and drafting of the guideline were carried out by engineers from Xodus Group.

The guideline was updated with contributions and guidance from the following Steering Group members:

Yahya Al-Janabi	Aramco
M Faisal B Aziz	Petronas
Julian Barnett	National Grid
Andy Brown	Progressive Energy
Anthony Byrne	Protium
Vinod Chauhan	BP
Bob Conder	Neptune Energy
Graham Freeth	Shell
Derek Gall	Spirit Energy
Gareth Hinds	NPL
Hamish Holt	Independent
Hayati Hussien	Petronas
Kenneth Alasdair Macdonald	Equinor
Ian Matheson	Kent Plc
Prakash Patel	Marsh (Energy & Power)
Diana Rodriguez Barrera	Vallourec
Jillian Sandison	Wood Plc

Affiliations refer to the time of participation.

Further contributions were provided by the EI CCS2002 Working Group and others. This is not a complete list of all contributions.

The Energy Institute wishes to record its appreciation of the work carried out by the authors and also its gratitude for the valuable contributions made by the CCS2002 Working Group and CCUS Committee during the course of the project.

A draft version was distributed to industry stakeholders for technical review. Members from the following organisations generously gave of their time to provide feedback, which is greatly appreciated:

Carbon Capture and Storage Association
Equinor
Energy Institute
Health and Safety Executive
International Association of Oil and Gas Producers
Shell
TotalEnergies

Project coordination and technical editing were carried out by Marcela Betancur-Diaz and Eva Leinwather (EI).

2 FOREWORD

Carbon Capture, Utilisation and Storage (CCUS) has been identified as a key technology which will enable the Energy Transition and contribute towards the ability to meet Net Zero greenhouse gas (GHG) emissions. One of the proposed solutions for CCUS is to utilise infrastructure (for the present case being considered, pipelines) to transport and inject captured carbon dioxide, through the repurposing of existing pipeline assets.

The repurposing of existing steel pipeline assets to transport anthropogenic carbon dioxide rich mixtures is an appealing option as it could potentially reduce infrastructure costs. However, the characteristics of some pipelines may be uncertain and require a wide range of detailed work and remedial actions to ensure they can be safely repurposed.

The repurposing of existing onshore and offshore pipeline assets and the associated ancillary items (e.g. above ground installations (AGIs), block valves, subsea isolation valves, ground anchors, mattresses etc.) involves detailed assessment of the design and construction requirements in order to ascertain their suitability for the transportation of carbon dioxide and their potential for operation in different conditions.

Repurposing can only be performed following a detailed assessment and demonstration that the existing pipeline assets and associated ancillary items are suitable and safe to be operated with carbon dioxide under different operating conditions (e.g. pressure levels, temperature conditions, chemical compatibility (e.g. items such as internal painting compatibility), integrity challenges (e.g. mitigating against the running ductile fracture failure mode when in service) etc.). The assessments require detailed technical information on the existing assets.

The purpose of this guideline is to present a proposed approach to repurposing of onshore and offshore pipeline assets for use as carbon dioxide pipelines. However, it also provides the reader with the steps that would be required for design of a new pipeline as the principles are the same. The following is discussed within this guideline:

- The present 'state of the art' with regards to design codes, standards and recommended practices that cover carbon dioxide pipelines, outlining the approaches available to demonstrate a pipeline to be fit for purpose for carbon dioxide transportation.
- Providing an outline for specific risk assessments that should be carried out to demonstrate the health and safety (H&S) risks posed by a repurposed pipeline is as low as reasonably practicable (ALARP) and acceptable.
- A process for establishing viability of candidate pipelines for repurpose for carbon dioxide transportation during the upfront stage of a project is outlined. At this stage, the focus should be on determining the high-risk items for the development, with a full technical assessment happening later in the project process.
- Repurposing of a pipeline will require data to be gathered and reviewed, particularly for vintage pipelines with a long service history. An outline of the required data to perform a repurposing exercise is provided.
- Details of the full technical assessment that should be performed to fully establish viability of the pipeline for use as a carbon dioxide pipeline are provided.

The following definitions are used in this guideline:

Phases of Carbon Dioxide	The fluid state above the critical pressure is referred to as the dense phase, while that above both critical pressure and temperature is referred to as the supercritical phase. Dense phase is an umbrella terminology and encompasses both supercritical state and liquid state.
Pure CO_2	The term 'Pure CO_2' describes the pure form of CO_2 without any impurities.
Carbon Dioxide, CO_2 or CO_2 Stream	Within this guideline, the terms carbon dioxide, 'CO_2' or 'CO_2 stream' describe a stream of CO_2 with impurities, such as water, etc. The level of impurities varies depending on the source and capture process.
Aqueous Phase	The presence of water which could be on its own or bound to another molecule.