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Carbon dioxide capture, transportation and geological storage — Pipeline transportation systems

Captage du dioxyde de carbone, transport et stockage géologique — Systèmes de transport par conduites

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

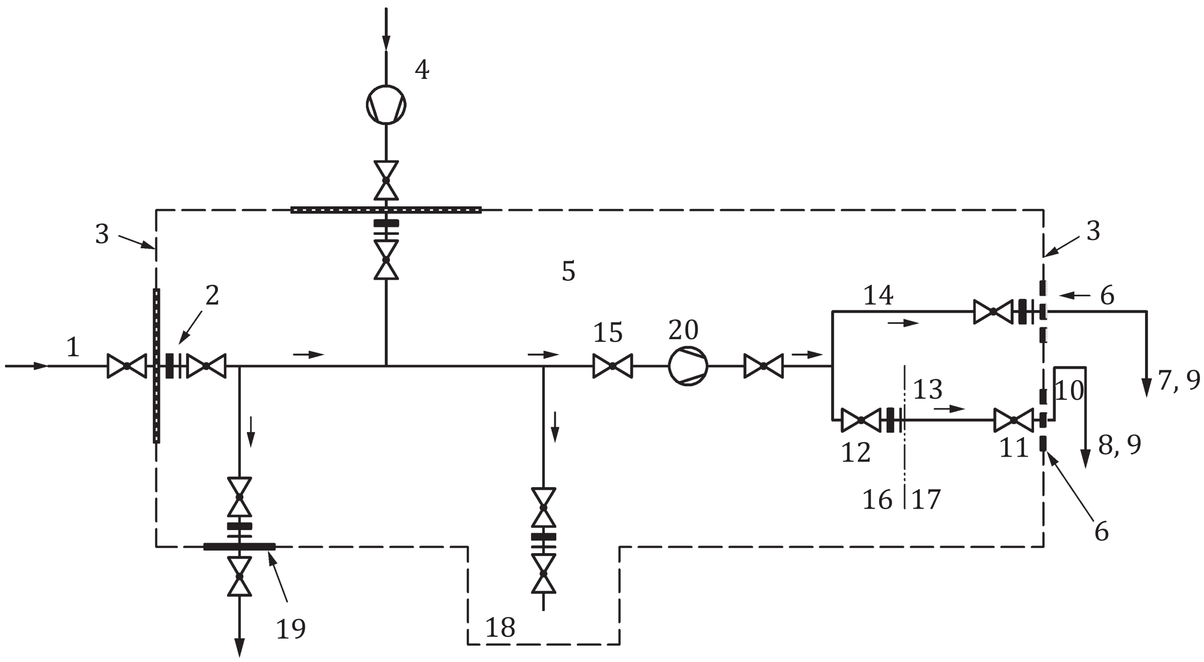
The committee responsible for this document is ISO/TC 265, *Carbon dioxide capture, transportation, and geological storage*.

Introduction

Carbon dioxide (CO_2) capture and storage (CCS) has been identified as a key abatement technology for achieving a significant reduction in CO_2 emissions to the atmosphere. Pipelines are likely to be the primary means of transporting CO_2 from the point-of-capture to storage (e.g. depleted hydrocarbon formations, deep saline aquifers), where it will be retained permanently or used for other purposes [e.g. Enhanced Oil Recovery (EOR)] to avoid its release to the atmosphere. While there is a perception that transporting CO_2 via pipelines does not represent a significant barrier to implementing large-scale CCS, there is significantly less industry experience than there is for hydrocarbon service (e.g. natural gas) and there are a number of issues that need to be adequately understood and the associated risks effectively managed to ensure safe transport of CO_2. In a CCS context, there could be a need for larger CO_2 pipeline systems in more densely populated areas and with CO_2 coming from multiple sources. Also, offshore pipelines for the transportation of CO_2 to offshore storage sites are likely to become common.

The objective of this document is to provide requirements and recommendations on certain aspects of safe and reliable design, construction and operation of pipelines intended for the large scale transportation of CO_2 that are not already covered in existing pipeline standards such as ISO 13623, ASME B31.4, EN 1594, AS 2885 or other standards (see Bibliography). Existing pipeline standards cover many of the issues related to the design and construction of CO_2 pipelines; however, there are some CO_2 specific issues that are not adequately covered in these standards. The purpose of this document is to cover these issues consistently. Hence, this document is not a standalone standard, but is written to be a supplement to other existing pipeline standards for natural gas or liquids for both onshore and offshore pipelines.

Transport of CO_2 via ship, rail and road is not covered in this document.



Key

1 source of CO_2 from capture, e.g. from power plant, industry; see ISO/TR 27912 (capture)
2 isolating joint
3 boundary limit
4 other source of CO_2
5 ISO 27913 (transportation system inside)
6 boundary to storage facility
7 onshore storage facility
8 offshore storage facility
9 EOR
10 riser (out of transport scope)
11 subsea valve (inside transport scope)
12 beach valve
13 offshore pipeline
14 onshore pipeline
15 valve
16 landfall
17 open water/sea
18 third party transport system
19 export to other uses than 7, 8 and 9
20 intermediate compression or pumping

Figure 1 — Schematic illustration of the system boundaries of this document

Carbon dioxide capture, transportation and geological storage — Pipeline transportation systems

1 Scope

This document specifies additional requirements and recommendations not covered in existing pipeline standards for the transportation of CO_2 streams from the capture site to the storage facility where it is primarily stored in a geological formation or used for other purposes (e.g. for EOR or CO_2 use).

This document applies to

— rigid metallic pipelines,

— pipeline systems,

— onshore and offshore pipelines for the transportation of CO_2 streams,

— conversion of existing pipelines for the transportation of CO_2 streams,

— pipeline transportation of CO_2 streams for storage or utilization, and

— transportation of CO_2 in the gaseous and dense phases.

The system boundary (see Figure 1) between capture and transportation is the point at the inlet valve of the pipeline, where the composition, temperature and pressure of the CO_2 stream is within a certain specified range by the capture process or processes to meet the requirements for transportation as described in this document.

The boundary between transportation and storage is the point where the CO_2 stream leaves the transportation pipeline infrastructure and enters the storage infrastructure.

This document also includes aspects of CO_2 stream quality assurance, as well as converging CO_2 streams from different sources.

Health, safety and environment aspects specific to CO_2 transport and monitoring are considered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3183:2012, *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems*

ISO 20765-2, *Natural gas — Calculation of thermodynamic properties — Part 2: Single-phase properties (gas, liquid, and dense fluid) for extended ranges of application*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
arrest pressure
internal pipeline pressure where there is sufficient mechanical strength to arrest or, there is not enough energy to drive a *ductile fracture* (3.8)

3.2
CO_2 stream
stream consisting overwhelmingly of carbon dioxide

3.3
corrosion allowance
extra wall thickness added during design to compensate for any reduction in wall thickness by corrosion (internal/external) during the design operational life

3.4
critical point
highest temperature and pressure at which a pure substance (e.g. CO_2) can exist as a gas and a liquid in equilibrium

Note 1 to entry: For a multicomponent fluid mixture of a given composition, the critical point is the merge of the bubble and the dew point curves.

3.5
critical pressure
vapour pressure at the *critical temperature* (3.6)

Note 1 to entry: The critical pressure for pure CO_2 is 7,28 MPag.

3.6
critical temperature
temperature above which liquid cannot be formed simply by increasing the pressure

Note 1 to entry: The critical temperature of pure CO_2 is 304,03 K.

3.7
dense phase
CO_2 in its liquid or supercritical phases

3.8
ductile fracture
mechanism which takes place by the propagation of a crack or stress-raising features, linked with a considerable amount of plastic deformation

Note 1 to entry: A “ductile fracture” is sometimes referred to as “shear fracture”.

3.9
flow coating
internal coating to reduce internal roughness, and hence minimize friction pressure loss

3.10
fracture arrestor
additional pipeline component that may be installed around portions of a pipeline designed to resist propagating fractures

Note 1 to entry: Fracture arrestor is also called crack arrestor.

3.11
free water
water (pure water, water with dissolved salts, water wet salts, water glycol mixtures or other mixtures containing water) not dissolved in the gaseous or dense CO_2 phase, i.e. a separate water phase

3.12
internal cladding
pipe with internal metal liner where the bond between the line pipe and liner is metallurgical

3.13
internal lining
pipe with internal coating where the bond between the line pipe and coating is mechanical

3.14
maximum design temperature
highest possible temperature to which the equipment or system may reasonably be exposed locally during installation and operation

3.15
maximum operating pressure
highest possible pressure to which the equipment or system may reasonably be exposed locally during installation and operation

3.16
minimum design temperature
lowest possible temperature to which the component or system may reasonably be exposed locally during installation and operation

3.17
minimum operating pressure
lowest possible pressure to which the equipment or system may reasonably be experienced locally during installation and operation

3.18
non-condensable gases
chemical substances that are partially in the vapour state at pipeline operating conditions

3.19
operating envelope
limited range of parameters over which operations will result in safe and acceptable performance of the equipment or system during operation

3.20
pipeline commissioning
activities associated with the initial filling and pressurization of the pipeline system with the fluid to be transported

3.21
pipeline dehydration
process of removing water from a *CO_2 stream* (3.2) to a level below saturation such that the design maxima for the transportation system can be achieved

3.22
pipeline dewatering
removal of water after hydraulic testing of the pipeline system

3.23
rapid gas decompression
phenomenon brought about by a fluid migrating at a molecular level into a polymer, and collecting as a bubble and bursting following pressure reduction

3.24
saturation pressure
pressure of a vapour which is in equilibrium with its liquid at a given temperature

Note 1 to entry: The term “saturation pressure” is also referred to as “saturation vapour pressure”.

3.25
short-term storage reserve
accumulation of the fluid in a pressurized section of a pipeline additional to the fluid that is extracted from the pipeline, for the purpose of temporary storage of that fluid

3.26
threat
activity or condition that alone or in combination with others has the potential to cause damage or produce another negative impact if not adequately controlled

3.27
triple point
temperature and pressure at which three phases (gas, liquid and solid) of a substance coexist in thermodynamic equilibrium

4 Symbols, abbreviated terms and units

4.1 Symbols

C_v Notched-bar impact value of the pipeline steel (J)

c_{cf} Correction factor (--)

E Young's modulus (MPa)

A_C Test patch = 80 mm^2

σ_f Flow stress (MPa)

R Average pipe radius (mm)

t Minimum wall thickness of the pipe (mm)

σ_a Arrest stress (MPa)

Ps Maximum saturation pressure (gauge pressure) in MPag; for pure CO_2 critical pressure = 7,28 MPag

OD External diameter of the pipe (mm)

4.2 Abbreviated terms

CCS Carbon dioxide Capture and Storage

EOR Enhanced Oil Recovery

GERG Groupe Européen de Recherches Gazières (European Gas Research Group)

IMP Integrity Management Plan

MAOP Maximum Allowable Operating Pressure

PIG Pipeline Inspection Gauge

SCADA Supervisory Control And Data Acquisition

SI Système International d'unités (International System of Units)

4.3 Units

All units used in this document are SI units.

5 Properties of CO_2, CO_2 streams and mixing of CO_2 streams influencing pipeline transportation

5.1 General

It shall be considered in accordance with ISO 20765-2 that pure and impure CO_2 have properties that can be very different from those of hydrocarbon fluids and can influence all stages of the pipeline life cycle.

The thermodynamic and chemical behaviour of pure CO_2 can be found in literature (see, for example, Reference [50]). In the usual operating envelope for CO_2 transportation, the temperature and pressure will vary and will be project-specific. CO_2 can be in the gaseous or dense phase. There is a large change in density between gaseous and dense phases when the CO_2 is close to the saturation pressure, and for this reason, operation close to the saturation condition should be avoided.

In case two-phase flow cannot be avoided for any reason, it should be given special consideration during design and operation (see References [25] and [52]).

The following subclauses are intended to inform the designer and pipeline operator on how to decide on the correct parameters to be used to avoid negative impacts on the pipeline integrity.

Impurities within the CO_2 stream can result in negative impacts on the pipeline integrity. As a part of the design process, limits shall be specified for the maximum levels of impurities within the CO_2 stream, and robust measurement equipment shall be installed to monitor the composition against this specification prior to its entry into the pipeline. Annex A provides further information on this.

5.2 Pure CO_2

5.2.1 Thermodynamics

The thermodynamic properties of CO_2, particularly the saturation pressure, shall be taken into account because they have a significant impact on the design of the pipeline. If the MAOP is above the critical pressure, then the critical pressure shall be used as the principal parameter in the design. This avoids ductile fracture in the wall of the line pipe unless the operating envelope with regard to pressure and temperature is such that it can be demonstrated that the pressure and temperature at the saturation line are always below the critical pressure and critical temperature. For other parameters, the MAOP shall be used as described in 7.3.

5.2.2 Chemical reactions and corrosion

With pure CO_2, there will be no chemical reactions or internal corrosion in the pipeline.

5.3 CO_2 streams

5.3.1 Thermodynamics

It shall be considered that the phase diagram and the physical and chemical properties will change depending on the CO_2 stream composition, leading, amongst other things, to changed values of the saturation pressure compared to pure CO_2. The highest value of the saturation pressure shall be the principal design parameter to avoid ductile fracture, unless the operating envelope with regard to pressure and temperature is such that it can be demonstrated that the pressure and temperature at the saturation line is always below the critical pressure and critical temperature. This saturation pressure for the specific stream may be determined by use of the GERG formula (see ISO 20765-2) or any other