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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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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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](http://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](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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](http://www.iso.org/iso/foreword.html).

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

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## Introduction

Carbon dioxide (CO<sub>2</sub>) capture and storage (CCS) has been identified as a key abatement technology for achieving a significant reduction in CO<sub>2</sub> emissions to the atmosphere. Pipelines are likely to be the primary means of transporting CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>. In a CCS context, there could be a need for larger CO<sub>2</sub> pipeline systems in more densely populated areas and with CO<sub>2</sub> coming from multiple sources. Also, offshore pipelines for the transportation of CO<sub>2</sub> to offshore storage sites are likely to become common.

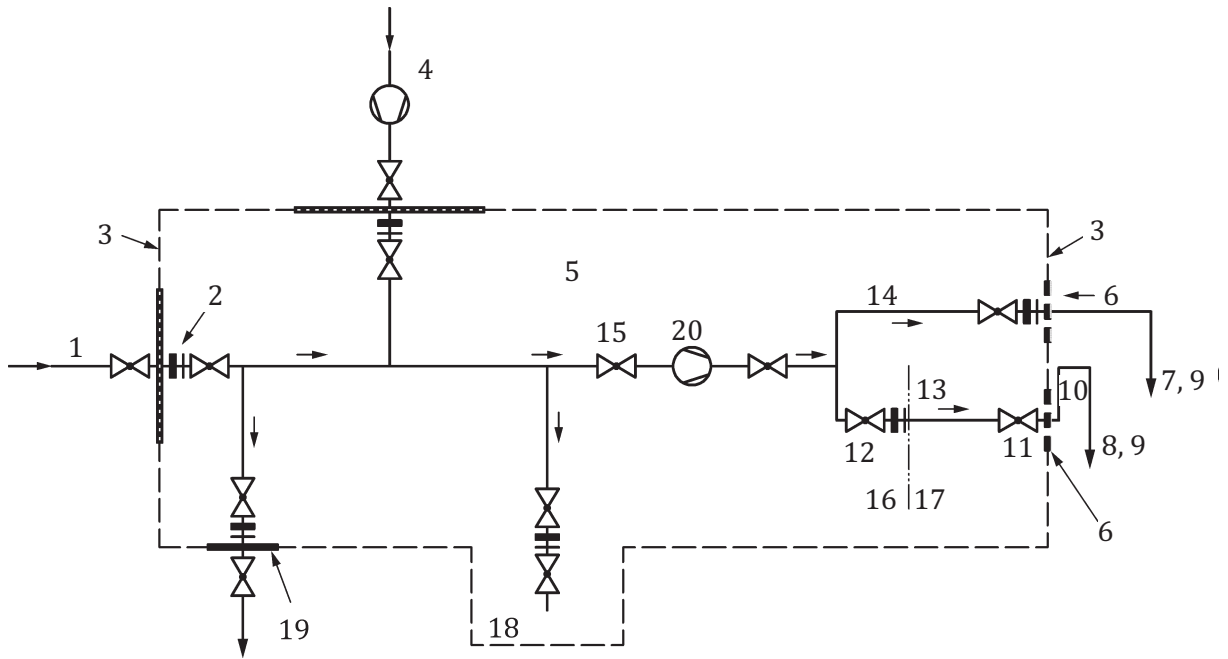
The objective of this document is to provide requirements and recommendations on certain aspects of safe and reliable design, construction and operation of pipelines intended for the large scale transportation of CO<sub>2</sub> that are not already covered in existing pipeline standards such as ISO 13623, 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<sub>2</sub> pipelines; however, there are some CO<sub>2</sub> 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<sub>2</sub> via ship, rail and road is not covered in this document.

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**Key**

- |   |   |    |                                       |
|---|---|----|---------------------------------------|
| 1 | source of CO <sub>2</sub> from capture, e.g. from power plant, industry; see ISO/TR 27912 (capture) | 10 | riser (out of transport scope)        |
| 2 | isolating joint   | 11 | subsea valve (inside transport scope) |
| 3 | boundary limit  | 12 | beach valve                           |
| 4 | other source of CO <sub>2</sub>   | 13 | offshore pipeline                     |
| 5 | ISO 27913 (transportation system inside)  | 14 | onshore pipeline                      |
| 6 | boundary to storage facility  | 15 | valve                                 |
| 7 | onshore storage facility  | 16 | landfall                              |
| 8 | offshore storage facility   | 17 | open water/sea                        |
| 9 | EOR   | 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**

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# 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<sub>2</sub> 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<sub>2</sub> use).

This document applies to

- rigid metallic pipelines,
- pipeline systems,
- onshore and offshore pipelines for the transportation of CO<sub>2</sub> streams,
- conversion of existing pipelines for the transportation of CO<sub>2</sub> streams,
- pipeline transportation of CO<sub>2</sub> streams for storage or utilization, and
- transportation of CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> stream leaves the transportation pipeline infrastructure and enters the storage infrastructure.

This document also includes aspects of CO<sub>2</sub> stream quality assurance, as well as converging CO<sub>2</sub> streams from different sources.

Health, safety and environment aspects specific to CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>) 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<sub>2</sub> is 7,28 MPa.

**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<sub>2</sub> is 304,03 K.

**3.7**  
**dense phase**  
CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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 <sup>2</sup>
$\sigma_f$	Flow stress (MPa)
$R$	Average pipe radius (mm)
$t$	Minimum wall thickness of the pipe (mm)
$\sigma_a$	Arrest stress (MPa)
$P_s$	Maximum saturation pressure (gauge pressure) in MPag; for pure CO <sub>2</sub> 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<sub>2</sub>, CO<sub>2</sub> streams and mixing of CO<sub>2</sub> streams influencing pipeline transportation

### 5.1 General

It shall be considered in accordance with ISO 20765-2 that pure and impure CO<sub>2</sub> 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<sub>2</sub> can be found in literature (see, for example, Reference [50]). In the usual operating envelope for CO<sub>2</sub> transportation, the temperature and pressure will vary and will be project-specific. CO<sub>2</sub> can be in the gaseous or dense phase. There is a large change in density between gaseous and dense phases when the CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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.

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**5.2 Pure CO<sub>2</sub>** <https://standards.iteh.ai/catalog/standards/sist/076d4bfl-c78d-46f8-9c5e-4ed8b55a21b5/iso-27913-2016>

#### 5.2.1 Thermodynamics

The thermodynamic properties of CO<sub>2</sub>, 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<sub>2</sub>, there will be no chemical reactions or internal corrosion in the pipeline.

### 5.3 CO<sub>2</sub> 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<sub>2</sub> stream composition, leading, amongst other things, to changed values of the saturation pressure compared to pure CO<sub>2</sub>. 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