



# FINAL DRAFT International Standard

## ISO/FDIS 27913

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

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

ISO/TC 265

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## 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 document 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)).

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This document was prepared by Technical Committee ISO/TC 265, *Carbon dioxide capture, transportation, and geological storage*.

This second edition cancels and replaces the first edition (ISO 27913:2016), which has been technically revised.

The main changes are as follows:

- the entire text has been editorially revised;
- normative references have been updated;
- a subclause about CO<sub>2</sub> stream flowrate and impurity measurement has been added;
- the level of impurities has been limited to 5 % and a set of 17 requirements are defined to ensure CO<sub>2</sub> stream pipeline integrity;
- [Annex A](#) has been added to show example compositions of CO<sub>2</sub> streams for gaseous and dense phase CO<sub>2</sub> streams which fulfil the requirements of the normative part of this document;
- [Annex D](#) has adopted the latest findings in fracture arrest design.
- [Annex F](#) has been added to describe decompression effects on pressure and temperature versus time.

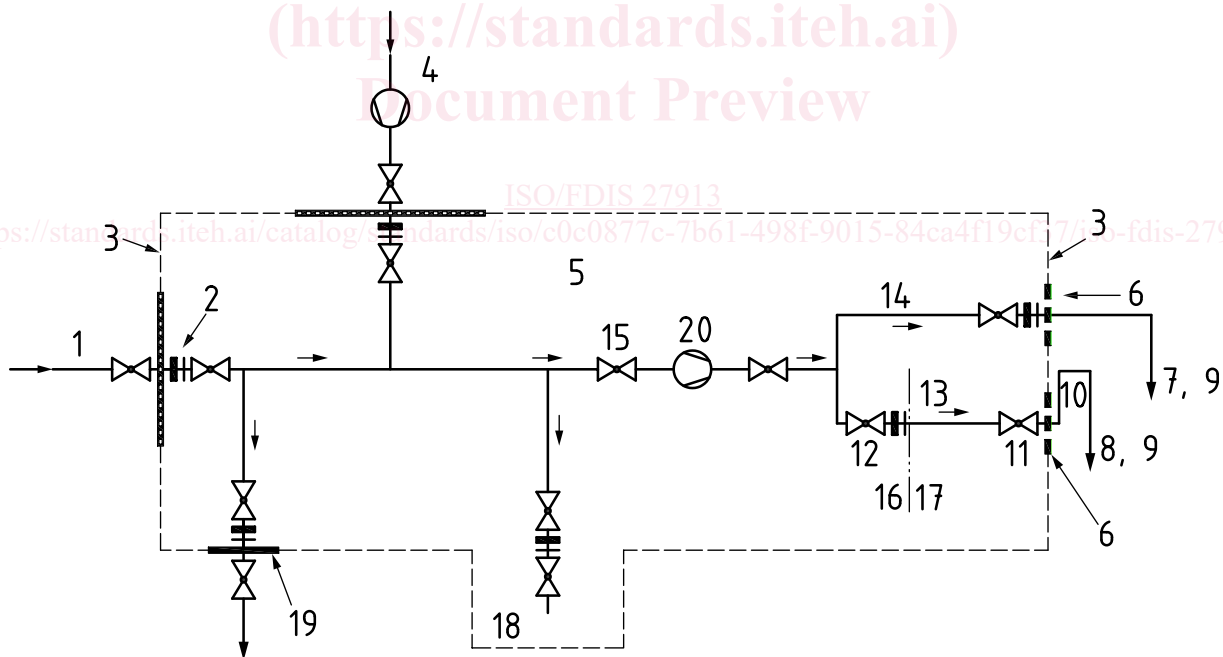
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## Introduction

Carbon dioxide (CO<sub>2</sub>) capture, carbon dioxide use (CCU) and carbon dioxide storage (CCS) have been identified as key abatement technologies 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 sites (e.g. depleted hydrocarbon formations, deep saline aquifers), or to usage points (e.g. enhanced oil recovery or utilization) 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 or CCU context, there is 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 specific 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, ASME B31.8, EN 1594, AS 2885 or other standards listed in the 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 (e.g. fracture arrest, internal corrosion protection) that are not adequately covered in these standards, but is addressed in this document. 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.

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 to meet the requirements for transportation as described in this document.



### Key

- |   |  |    |  |
|---|--|----|--|
| 1 | source of CO <sub>2</sub> from capture (e.g. from power plant, industry; see ISO/TR 27912) | 11 | subsea valve (inside transportation scope) |
| 2 | isolating joint  | 12 | beach valve                                |
| 3 | boundary limit   | 13 | offshore pipeline                          |
| 4 | other source of CO <sub>2</sub>  | 14 | onshore pipeline                           |
| 5 | transportation system inside given in this document  | 15 | valve                                      |
| 6 | boundary to storage facility or utilization  | 16 | landfall                                   |
|   |  | 17 | open water                                 |

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7	onshore storage facility	18	third party transport system
8	offshore storage facility	19	export to other uses than those of Keys 7, 8 and 9
9	enhanced oil recovery	20	intermediate compression or pumping
10	riser (outside transportation scope)		

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

The boundary between transportation and storage or utilization is the point where the CO<sub>2</sub> stream leaves the transportation pipeline infrastructure and enters the downstream infrastructure, which can be permanent geological storage, utilization or buffer storage prior to shipping.

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

## 1 Scope

This document specifies the requirements and recommendations 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 enhanced oil recovery or CO<sub>2</sub> use).

This document applies to the transportation of CO<sub>2</sub> streams by

- 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, and
- transportation of CO<sub>2</sub> streams in the gaseous and dense phases.

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 also considered in this document.

Transportation of CO<sub>2</sub> via ship, rail or on road is not covered in this document.

## 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, *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*

ISO/TR 27925, *Carbon dioxide capture, transportation and geological storage — Cross cutting issues — Flow assurance*

API SPEC 5L, *Line Pipe, 46th Edition*

## 3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

**3.1**

**aqueous phase**

liquid phase composed predominantly of water and other impurities that are not dissolved in the gaseous or dense CO<sub>2</sub> phase

**3.2**

**block valve**

full-bore valve inserted into a pipeline to reduce the total volume of the CO<sub>2</sub> stream (3.4) that would be emitted in the case of planned or unplanned depressurization of that section or in the case of a pipeline rupture

**3.3**

**bubble point pressure**

pressure of the saturated liquid at a given composition and temperature

**3.4**

**CO<sub>2</sub> stream**

stream consisting overwhelmingly of carbon dioxide

Note 1 to entry: usually >95 mol% CO<sub>2</sub>

**3.5**

**corrosion allowance**

additional wall thickness beyond that required by the mechanical design to compensate for any reduction in wall thickness by corrosion (internal/external) during the design operational life

**3.6**

**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 point curve and the dew point curve.

Note 2 to entry: The critical point is defined by the *critical pressure* (3.7) and *critical temperature* (3.8).

**3.7**

**critical pressure**

vapour pressure at the *critical temperature* (3.8)

Note 1 to entry: The critical pressure for pure CO<sub>2</sub> is 7,38 MPa.

**3.8**

**critical temperature**

pure substance 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 304,13 K (equivalent to 30,98 °C).

Note 2 to entry: For CO<sub>2</sub> streams (3.4), phase transitions can still occur above critical temperature.

**3.9**

**dense phase**

<engineering> CO<sub>2</sub> or CO<sub>2</sub> streams (3.4) in the single-phase fluid state above a density of 500 kg/m<sup>3</sup>

Note 1 to entry: For more details, see also ISO/TR 27925.

**3.10**

**dew point pressure**

pressure on the saturated vapour line

**3.11**

**ductile fracture**

shear fracture

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

**3.12**

**environmental cracking**

brittle fracture of a normally ductile material in which the corrosive effect of the environment is causing the embrittlement

**3.13**

**flow assurance**

engineering discipline that is required to understand the behaviour of fluids inside pipelines, at flowing and at static conditions

Note 1 to entry: The flow assurance provides input to design activities, such as pipeline design or risk analysis and operating philosophy development.

**3.14**

**fracture arrestor**

crack arrestor

additional pipeline component that can be installed around portions of a pipeline designed to resist propagating fractures

**3.15**

**hydraulic capacity**

maximum flow rate achievable in a system for a given pressure loss and given mechanical and operating constraints

**3.16**

**in-line inspection**

ILI

operation of sending an inspection tool inside a pipeline for the purposes of maintenance procedures such as pipeline cleaning, liquid removal, corrosion detection

**3.17**

**internal coating**

layer to reduce internal roughness and minimize friction pressure loss on the inside of the pipeline

**3.18**

**maximum allowable operating pressure**

MAOP

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

**3.19**

**minimum design temperature**

lowest possible temperature to which the equipment or system may reasonably be exposed locally during installation and operation

**3.20**

**multi-phase flow**

co-existence of more than one fluid phases (e.g. gas and *dense phases* (3.9) or two dense phases) in the same location of the pipeline

**3.21**

**non-condensable component**

component that, when pure, can be in gaseous form at possible CO<sub>2</sub> equilibrium conditions throughout the CO<sub>2</sub> value chain

Note 1 to entry: They include the following substances: N<sub>2</sub>, Ar, H<sub>2</sub>, CO, CH<sub>4</sub>, O<sub>2</sub> (excluding CO<sub>2</sub>).

**3.22**

**operating envelope**

limited range of parameters over which operations result in safe and acceptable performance of the equipment or system

**3.23**

**pipeline commissioning**

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

**3.24**

**pipeline dewatering**

removal of water after hydraulic testing of the pipeline system

**3.25**

**rapid gas decompression**

phenomenon brought about by pressurized fluid migrating at a molecular level into a polymer and then being released suddenly causing failure of polymeric materials

**3.26**

**saturation pressure**

saturation vapour pressure

pressure of a vapour which is in equilibrium with its liquid at a given temperature applicable to pure CO<sub>2</sub>

Note 1 to entry: For a CO<sub>2</sub> stream (3.4) containing impurities, the saturation pressure can either be the pressure on the saturated liquid line [*bubble point pressure* (3.3)] or the pressure on the saturated vapour line [*dew point pressure* (3.10)]. For CO<sub>2</sub> streams, both pressures are different for a given temperature.

**3.27**

**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

**3.28**

**single phase**

flow of a CO<sub>2</sub> or CO<sub>2</sub> stream (3.4) in a gas, or a *dense phase* (3.9), but not in any combination of them

**3.29**

**threat**

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

**3.30**

**triple point**

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

**3.31**

**vent station**

installation from which the contents of the pipeline or section of pipeline between *block valves* (3.2) can be vented

**3.32**

**network code**

set of rules, agreed by the operators and/or governments under which a CO<sub>2</sub> stream system is required to operate safely and in a way that allows the objectives of each party to be realised

Note 1 to entry: See Figure 1.

## 4 Symbols, abbreviated terms and units

### 4.1 Symbols

$A_C$	cross-section area of the notched-bar impact specimen equal to 80 mm <sup>2</sup>	mm <sup>2</sup>
$C_V$	Charpy V-notch absorbed energy value of the pipeline steel measured in the transverse direction	J
$D$	outer diameter of the pipe	mm
$E$	Young's modulus	MPa
$P$	pressure	MPa
$P_s$	bubble point pressure at given temperature and CO <sub>2</sub> stream composition	MPa
$R$	average pipe radius	mm
$t$	wall thickness of the pipe	mm
$t_{\min}$	minimum wall thickness	mm
$t_{\min DP}$	minimum wall thickness against internal pressure	mm
$t_{\min HS}$	minimum wall thickness against hydraulic shock	mm
$t_{\min DF}$	minimum wall thickness against fracture propagation	mm
$T$	temperature	°C
$\sigma_f$	flow stress	MPa

### 4.2 Abbreviated terms

BTEX	collective term for the highly volatile aromatic hydrocarbons benzene, toluene, ethylbenzene and xylene
BTM	Battelle Two Curve Method
CCS	carbon dioxide capture and storage
CCU	carbon dioxide capture and utilization
DEG	diethylene glycol
EOR	enhanced oil recovery
ILI	in-line inspection
IMP	integrity management plan
MAOP	maximum allowable operating pressure
MEG	monoethylene glycol
SSC	sulphide stress cracking
TEG	tri-ethylene glycol

NDMA	N-nitrosodimethylamine, also known as dimethylnitrosamine (DMN)
NMEA	N-methylethanolamine
NDEA	N-nitrosodiethylamine
NDELA	N-nitrosodiethanolamine
NPIP	N-nitrosopiperidine
NOMor	N-nitrosomorpholine
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinatedfurans

## 5 Properties of CO<sub>2</sub>, CO<sub>2</sub> streams and the mixing of CO<sub>2</sub> streams that influence pipeline transportation

### 5.1 General

According to ISO 20765-2, pure CO<sub>2</sub> and CO<sub>2</sub> streams 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 behaviours of pure CO<sub>2</sub> have been explored throughout literature (e.g. see Reference [50]). In the usual operating envelope for CCS or CCU, the temperature and pressure vary and are project-specific. CO<sub>2</sub> can be in the gaseous or dense phase. There can be a large change in properties when crossing a phase boundary and for this reason, normal operation close to the phase boundaries should be avoided if possible.

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

Subclauses 5.2 and 5.3 provide information for 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 affect the phase envelope and can result in negative impacts on the pipeline operation and 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. For more information, refer to [Annex A](#).

### 5.2 Pure CO<sub>2</sub>

#### 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 and operation of the pipeline. For a dense phase pipeline, the maximum saturation pressure resulting from isentropic expansion from within the operating envelope shall be used as the principal parameter in the design against running ductile fractures as described in 8.6. For gaseous transport, refer to 8.5.

The potential for inaccuracies in saturation pressure prediction and fluid properties should be taken into account when evaluating the design and operational philosophy of a CO<sub>2</sub>-transport system, and applying a margin of error to the maximum saturation pressure as a design criterion is recommended.

#### 5.2.2 Chemical reactions and corrosion

With pure CO<sub>2</sub>, there are no chemical reactions or internal corrosion in the pipeline.