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Petroleum and natural gas industries — Guidelines for offshore platforms handling streams with high content of CO2 at high pressures

Pétrole et plates-formes en mer de gaz naturel — Courants contenant des niveaux élevés de CO2 sous haute pression et débits élevés — Lignes directrices

ICS: 75.020

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 17349 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

Introduction

In recent years, the oil industry has been facing challenges in developing and operating high CO_2 content offshore fields. The CO_2 rich streams, separated from the produced natural gas, may be injected to enhance oil recovery from the reservoirs. Even in cases where the oil recovery increase is not so significant, operators have to consider the CO_2 rich stream compression and injection, in order to avoid its venting to the atmosphere.

Main concerns comprise surface safety system and material selection areas, which lack specific standards and regulations for this scenario. The commercial tools available, for instance, to model the dispersion of gases, need to be validated for CO_2 and CO_2/hydrocarbon mixtures, which have distinctive thermodynamic behavior. This will affect the choice of materials and plant design.

This document is intended for guidance only, to improve the industry's knowledge and to assist developers and operators to address the issues raised.

Petroleum and natural gas industries — Guidelines for offshore platforms handling streams with high content of CO2 at high pressures

1 Scope

This International Standard provides guidelines for design of topside facilities for offshore plants handling CO_2 rich streams at high pressures. The surface systems include usual offshore process unit operations, e.g. compression, dehydration, hydrocarbon dew point control and CO_2 separation. Cryogenic CO_2 separation processes are not covered. The actual concentration of CO_2 and other components present in the CO_2 rich streams is determined case by case, based on reservoir characteristics, topside plant process selection, economical evaluations and appropriate regulations. This standard intends to address concepts and criteria about process with CO_2 rich streams that should be considered as a supplement to existing standards for offshore installations.

In this document the term “Streams containing high levels of CO_2”, henceforth referred to as CO_2 rich streams, designates streams with CO_2 molar concentration above 10 %. Pure CO_2 streams and CO_2 streams from combustion processes are not covered.

This International Standard is applicable only to topside facilities of fixed and floating oil and gas production offshore units. Subsea production systems are not covered. Figure 1 shows an example of Oil and Gas Platform Process and the highlighted scope of this International Standard.

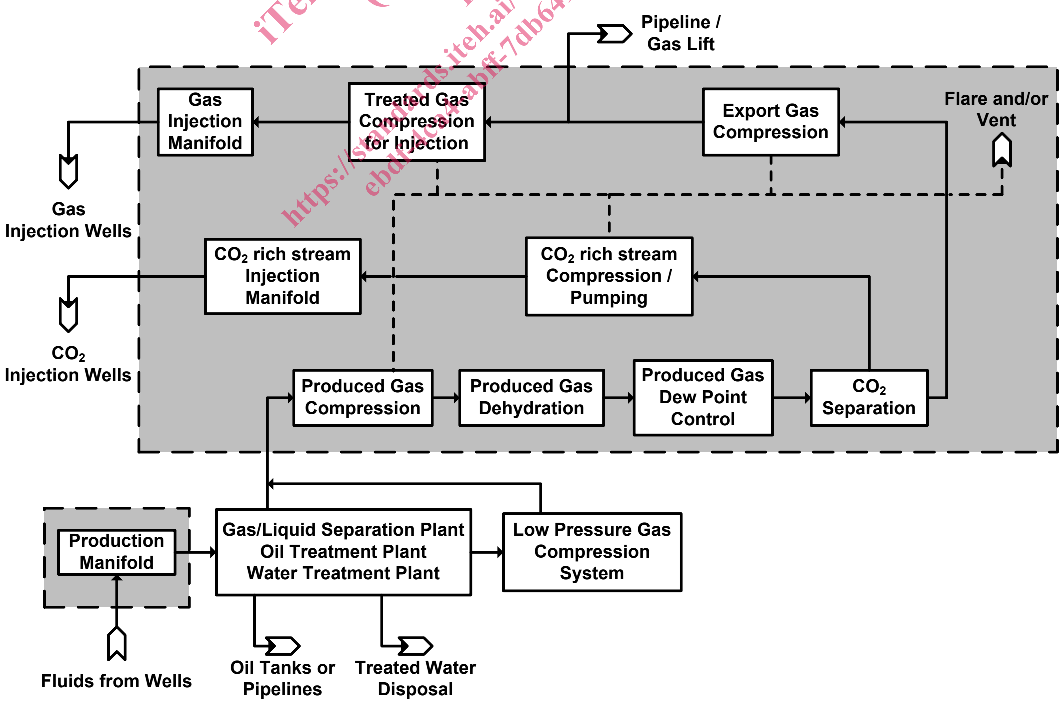

Figure 1 — Example of a Process Flow Diagram that is within Scope of this Standard (in grey zone)

2 Normative references

The following referenced documents are indispensable for the application 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 13702, *Petroleum and natural gas industries — Control and mitigation of fires and explosions on offshore production installations — Requirements and guidelines first edition*

ISO 15156-1, *Petroleum and natural gas industries — Materials for use in H_2S–containing environments in oil and gas production — Part 1: General principles for selection of — cracking-resistant materials*

ISO 15156-2, *Petroleum and natural gas industries — Materials for Use in H_2S–containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons*

ISO 15156-3, *Petroleum and natural gas industries — Materials for Use in H_2S–containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

ISO 15544, *Petroleum and natural gas industries — Offshore production installations — Requirements and guidelines for emergency response*

ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 21457, *Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems*

ISO 23251, *Petroleum and natural gas industries — Pressure relieving and depressuring systems*

ISO 25457, *Petroleum, petrochemical and natural gas industries — Flare details for general refinery and petrochemical service*

3 Terms, definitions and abbreviations

3.1 Terms and Definitions

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

3.1.1
charpy test
test for determining the energy absorbed in an impact test of metallic materials, also referred as Charpy V-notch test

3.1.2
compressibility factor
Z
thermodynamic property for modifying the ideal gas law to account for the real gas behavior

3.1.3
critical point
critical point is defined by the critical pressure and temperature of the fluid composition above which the substance exists as a supercritical fluid

3.1.4
critical pressure
defined as the vapor pressure at the critical temperature

3.1.5
critical temperature
defined as the temperature above which liquid cannot be formed by a pressure increase

3.1.6
dense phase
fluid state (supercritical or liquid) above critical pressure

3.1.7
equation of state
EOS
thermodynamic equation describing the state of matter under a given set of physical conditions such as temperature, pressure and volume

3.1.8
free water
water not dissolved in the CO_2 rich stream, i.e. water exists as a separate phase

Note 1 to entry: This can be pure water, water with dissolved salts, water wet salts, water glycol mixtures or other mixtures containing water.

3.1.9
gas-assisted flare
flare with gas assistance system in order to increase gas net heating value

3.1.10
high velocity tip flare
flare with gas exit velocities higher than 122 m/s

3.1.11
high velocity vent
vent with gas exit velocities higher than 150 m/s

3.1.12
hydrate
solid, crystalline compound of water and light hydrocarbons or CO_2, in which the water molecules combine with the gas molecules to form a solid

3.1.13
internal cladding
metallic coating of CRA in which the bond between the parent metal and liner is metallurgical

3.1.14
low velocity tip flare
flare with gas exit velocities lower than 122 m/s

3.1.15
low velocity vent
vent with gas exit velocities lower than 150 m/s

3.1.16
minimum design temperature
minimum temperature below which the application limits for the materials involved are exceeded

3.1.17
platform
complete assembly including structure, topsides and, where applicable, foundations

[ISO 19900:2002, definition 2.23]

3.1.18
rapid gas decompression
RGD
depressurization
explosive decompression
rapid pressure-drop in a high pressure gas-containing system which disrupts the equilibrium between external gas pressure and the concentration of gas dissolved inside any polymer, with the result that excess gas tries to escape from the solution at points throughout the material, causing expansion

[ISO 23963-2:2011, definition 3.1.10]

3.1.19
supercritical phase
the fluid state above critical pressure and temperature

3.1.20
topsides
structures and equipment placed on a supporting structure (fixed or floating) to provide some or all of a platform's functions

[ISO 19900:2002, definition 2.38]

3.1.21
triple point
the temperature and pressure where CO_2 exists as a gas, liquid and solid simultaneously

3.2 Abbreviated terms

ACGIH	American Conference of Governmental Industrial Hygienists
AIV	acoustically induced vibration
BLEVE	boiling liquid expanding vapor explosion
BDV	blow down valve
CO_2	carbon dioxide
CCR	central control room
CFD	computational fluid dynamics
CRA	corrosion resistant alloy
EERS	evacuation, escape and rescue strategy
EOS	equation of state
ESD	emergency shut down
FEA	finite element analysis
FES	fire and explosion strategy
GHV	gross heating value
H_2S	hydrogen sulfide

HC	hydrocarbon
HP	high pressure
HSE	health, safety and environment
HVV	high velocity vent
IDLH	immediately dangerous to life or health
LP	low pressure
MMSCF	million standard cubic feet gas (60 °F & 1 atm)
NHV	net heating value
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
OSHA	Occupational Safety & Health Administration
Pa	ambient pressure
Pc	critical pressure
PEL	permissible exposure limit
pha	Preliminary Hazard Analysis
ppmv	parts per million, volumetric basis
PR	EOS Peng-Robinson
PR-HV	Peng-Robinson EOS modified by using mixing rule of Huron-Vidal and Peneloux factor
PR-SV	Peng-Robinson-Stryjek-Vera
PSV	pressure safety valve
PVT	pressure, volume, temperature
RGD	rapid gas decompression
RO	restriction orifice
SCF	super critical fluids
STEL	short term exposure limit
SRK	EOS Soave-Redlich-Kwong
Ta	ambient temperature
Tc	critical temperature
TLV	threshold limit value
TWA	time weighed average

V_{max} maximum permitted velocity, expressed in m/s

WEL workplace exposure limits

Z compressibility factor

4 Overview of CO_2 rich streams behavior

4.1 General

In an offshore plant design, CO_2 rich streams may be handled close to or above its critical pressure (dense phase) or above its critical pressure and temperature (supercritical phase) [5]. In the latter, some of its properties are similar to that of a liquid (e.g. density) and other similar to that of a gas (e.g. viscosity). The physical and thermodynamic properties of the CO_2 rich streams will have an impact on issues like hydrate formation and depressuring.

The design of a plant handling CO_2 rich streams at high pressures should be conducted using an EOS supported by experimental data in the range of operations. Examples of this approach are shown in Annex A. If experimental data are not available, data from thermodynamic based models, including readily available EOS, may be used taking into account any related uncertainties therefore allowing for sufficient safety margins.

Particular attention should be given when performing simulations near the critical point due to strong variation on stream properties and uncertainty on the description of the existing phases. For that reason, equipment normal operation envelope should avoid critical point region.

4.2 Hydrate formation

CO_2 rich streams may present a potential risk for hydrate formation similar to sweet natural gas, if water is present (as free water or in gas phase).

For high pressures, CO_2 has an inhibitor effect on hydrate formation, since an increase on the CO_2 concentration shifts the hydrate equilibrium curve towards low temperatures, as it can be seen in Annex B.

Dehydration unit design should take into account all operational conditions, including low temperatures that might occur in process systems and pipeline segments downstream from the offshore plant. Special attention should be given to the fact that CO_2 tends to increase water holding capacity at higher pressures.

For that reason, depending on CO_2 content in the stream, it is not safe to set a water dew point specification based on higher pressure requirements only, since water condensation may occur at lower pressures (see Figure B.1).

As a first approach, a margin of 10 °C on water dew point or a reduction down to 50 % of the water saturation content should be considered.

An example of moisture content specification for Dehydration Unit is presented in Annex C.

4.3 CO_2 solid formation

Solid formation may be observed in a CO_2 rich stream depending on temperature and pressure. Low temperatures which lead to solid formation may be achieved during planned and unplanned depressuring operations, for equipment maintenance purposes and emergency conditions as well. Annex D presents phase diagram for CO_2 rich streams and discusses solid formation based on experimental and theoretical calculations.

The influence of methane content in solid formation temperature has already been evaluated and published [6]. The frost point is presented for a CO_2-CH_4 mixture in a wide range of concentrations, showing that increasing CH_4 content shifts the frost point curve toward lower temperatures, as shown in Annex D.

According to available references [6] and [7], there is an indication that solid formed from a CO_2 rich stream in low temperature operations may be considered as composed of pure CO_2. Therefore, in the absence of experimental data and specific phase diagrams for mixtures with the solid region represented, available phase diagrams for pure CO_2 may be used as conservative approach, in order to predict the low temperatures in which solid formation is expected in an offshore plant design.

Process plant design should take into account the predicted low temperatures with additional design margin in order to specify suitable mitigation measures to avoid or deal with solid formation. More details are presented in Clause 5.

4.4 Flow metering

Design of metering systems has to take into account the peculiarities of behavior of CO_2 rich streams. Preferably, metering systems should be located in plant sections where physical and transport properties are stable and predictable, i.e., far from critical point or phase transitions. Depending on the process, this means some meters may be designed for gas phase, while others for liquid phase [8].

Flow computers with input for composition as well as temperature and pressure online measurements using the AGA-8 method, commonly used for natural gas, may be extended to CO_2 rich streams as long as conditions guarantee gas phase [9]. AGA-8 method also shows good predictability of supercritical phase as shown in Annex A.

Differential pressure flow meters such as orifice plates, Venturi or V-Cone are well suitable and robust, especially when working at very high pressures. Coriolis meters, being mass flow meters, are less susceptible to the variation of fluid properties or phase changes as long as no solids are formed but can be limited to operational pressures due to meter body construction.

Special care should be taken regarding changes in the CO_2 rich stream properties and potential flashing, so meter sizing and location should be properly selected.

5 Blow down, depressuring and relieving of plant and equipment

Temperature decrease observed in CO_2 rich streams during depressuring depends upon the initial and final pressures, initial temperature and stream composition.

In order to avoid brittle fracture, minimum temperatures achieved during an isenthalpic depressuring should be considered for material selection of letdown pressure devices (PSVs, BDVs, ROs) and for the entire low pressure system. Piping sections upstream the letdown pressure device may also be subjected to low temperatures and should be designed for co-incident high pressure at minimum temperature.

Apart from low temperature effects, designing relief systems of process plants (equipment or piping) should consider solid CO_2 formation, hydrate formation, adhesion and two-phase flow analysis.

5.1 Depressuring

Plant design should avoid operational conditions that lead to the triple point and solid formation in order to prevent plugging, piping erosion and vibration. Annex D presents examples of depressuring route in a phase diagram for CO_2 rich streams.

Designer should evaluate:

- control of blowdown rate (such as manual assisted operations, restriction orifice or automatic control in steps);