

BS EN 14161:2011+A1:2015



BSI Standards Publication

Petroleum and natural gas industries — Pipeline transportation systems (ISO 13623:2009 modified)

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National foreword

This British Standard is the UK implementation of EN 14161:2011+A1:2015. It is derived from ISO 13623:2009. It supersedes BS EN 14161:2011 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

The UK voted to abstain at the adoption stage for EN 14161 but BSI is obliged to publish it as a British Standard, in accordance with the CEN rules, as the result of the ballot was positive.

The members of Technical Committee PSE/17 and Subcommittee PSE/17/2 believe, however, that a more comprehensive approach to the design of pipelines is possible through using BS EN 14161 in association with the following Codes of Practice:

— PD 8010-1:2015, *Code of practice for pipelines — Part 1: Pipelines on land*;

— PD 8010-2:2015, *Code of practice for pipelines — Part 2: Subsea pipelines*

The UK participation in its preparation was entrusted to Technical Committee PSE/17/2, Materials and equipment for petroleum, petrochemical and natural gas industries.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

Petroleum and natural gas industries - Pipeline transportation
systems (ISO 13623:2009 modified)

Industries du pétrole et du gaz naturel - Systèmes de
transport par conduites (ISO 13623:2009 modifiée)

Erdöl- und Erdgasindustrie - Rohrleitungstransportsysteme
(ISO 13623:2009 modifiziert)

This European Standard was approved by CEN on 3 June 2011 and includes Amendment 1 approved by CEN on 5 March 2015.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

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Foreword

This document (EN 14161:2011+A1:2015) has been prepared by Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2015, and conflicting national standards shall be withdrawn at the latest by October 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes  EN 14161:2011 .

This document includes Amendment 1 approved by CEN on 2015-03-01.

The start and finish of text introduced or altered by amendment is indicated in the text by tags  .

The text of ISO 13623:2009 has been adopted by CEN/TC 12 with some modifications. These modifications are indicated by a vertical line in the left margin of the text.

Where the expression “International Standard” is used, it is understood as “European Standard”.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Significant differences exist between member countries in the areas of public safety and protection of the environment, which cannot be reconciled into a single preferred approach to pipeline transportation systems for the petroleum and natural gas industries. Reconciliation was further complicated by the existence in some member countries of legislation that establishes requirements for public safety and protection of the environment. Recognizing these differences, ISO/TC 67/SC 2 concluded that this International Standard should allow individual countries to apply their national requirements for public safety and the protection of the environment.

This International Standard is not a design manual; rather, it is intended for use in conjunction with sound engineering practice and judgment. This International Standard allows the use of innovative techniques and procedures, such as reliability-based limit state design methods, providing the minimum requirements of this International Standard are satisfied.

This second edition cancels and replaces the first edition, (ISO 13623:2000), which has been technically revised. Major revisions include replacement of various references to national standards with references to International Standards; replacement of sections on coatings and cathodic protection with ISO references; revision of design to accommodate line pipe above L555 in the new edition of ISO 3183; and the addition of a section on life extension.

ISO 13623:2009, developed within ISO/TC 67 SC 2, has been adopted as EN 14161:2011 (ISO 13623:2009 modified).

The scope of ISO/TC 67/SC 2 is pipeline transportation systems for the petroleum and natural gas industries without exclusions. However, in CEN the scopes of CEN/TC 12 and CEN/TC 234 overlapped until 1995. This scope overlap caused problems for the parallel procedure for the above-mentioned items. The conflict in scope was resolved when both the CEN/Technical Committees and the CEN/BT took the following resolution:

Resolution BT 38/1995: Subject: Revised scope of CEN/TC 12

"BT endorses the conclusions of the coordination meeting between CEN/TC 12 "Materials, equipment and offshore structures for petroleum and natural gas industries" and CEN/TC 234 "Gas supply" and modifies the CEN/TC 12 scope, to read:

"Standardization of the materials, equipment and offshore structures used in drilling, production, refining and the transport by pipelines of petroleum and natural gas, excluding on-land supply systems used by the gas supply industry and those aspects of offshore structures covered by IMO requirement (ISO/TC 8).

The standardization is to be achieved wherever possible by the adoption of ISO Standards."

In 2009, CEN/TC 12 changed its scope to be in coherency with the last CEN/TC 234's scope changes, as follows (resolution CEN/BTC 19/2009):

Standardisation of the materials, equipment and offshore structures used in the drilling, production, transport by pipelines and processing of liquid and gaseous hydrocarbons within the petroleum, petrochemical and natural gas industries, excluding on-land supply systems used by the gas supply industry excluding gas infrastructure from the input of gas into the on-shore transmission network up to the inlet connection of gas appliances. (covered by CEN/TC234) and those aspects of offshore structures covered by IMO requirements (ISO/TC8).

The standardisation is to be achieved wherever possible by the adoption of ISO standards.

[A₁] Resulting from these resolutions, "on-land supply systems used by the European gas supply industry from the input of gas into the on-land transmission network up to the inlet connection of gas appliances" are excluded from the scope of ISO 13623:2009 for the European adoption by CEN/TC 12. **[A₁]**

1 Scope

A1 This European Standard specifies requirements and gives recommendations for the design, materials, construction, testing, operation, maintenance and abandonment of pipeline systems used for transportation in the petroleum and natural gas industries.

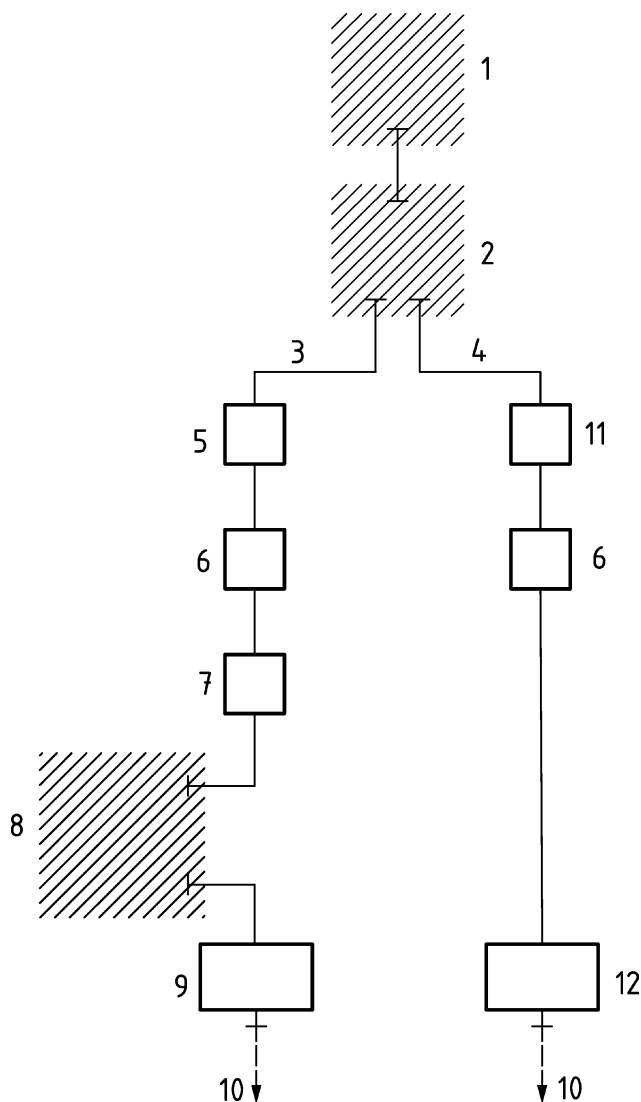
It applies to pipeline systems on land (see exclusion below) and offshore, connecting wells, production plants, process plants, refineries and storage facilities, including any section of a pipeline constructed within the boundaries of such facilities for the purpose of its connection. The extent of pipeline systems covered by this European Standard is illustrated in Figure 1.

This European Standard applies to rigid, metallic pipelines. It is not applicable for flexible pipelines or those constructed from other materials, such as glass-reinforced plastics.

This European Standard is applicable to all new pipeline systems and can be applied to modifications made to existing ones. It is not intended that it apply retroactively to existing pipeline systems.

It describes the functional requirements of pipeline systems and provides a basis for their safe design, construction, testing, operation, maintenance and abandonment.

On-land supply systems used by the European gas supply industry from the input of gas into the on-land transmission network up to the inlet connection of gas appliances are excluded from the scope of this European Standard. **A1**



Key

- | | | | | | |
|---|---|---|---------------|----|----------------------------|
| 1 | well site | 5 | pump station | 9 | depot |
| 2 | gathering station, treatment plant or process plant | 6 | valve station | 10 | distribution |
| 3 | liquid | 7 | tankage | 11 | compressor station |
| 4 | gas | 8 | refinery | 12 | pressure-reduction station |

- Pipeline elements covered by this International Standard
- Connections with other facilities. The pipeline system should include an isolation valve at connections with other facilities and at branches.
- Pipeline elements not covered by this International Standard.
- Station/plant area, offshore installation not covered by this International Standard.
- Station/plant area covered by this International Standard.

NOTE The pipeline system should include an isolation valve at connections with other facilities and at branches.

Figure 1 — Extent of pipeline systems covered by this International Standard

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 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 3183:2007, *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems*

ISO 3977 (all parts), *Gas turbines — Procurement*

ISO 10439, *Petroleum, chemical and gas service industries — Centrifugal compressors*

ISO 10474:1991, *Steel and steel products — Inspection documents*

ISO 13623:2009, *Petroleum and natural gas industries -- Pipeline transportation systems*

ISO 13707, *Petroleum and natural gas industries — Reciprocating compressors*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

ISO 13710, *Petroleum, petrochemical and natural gas industries — Reciprocating positive displacement pumps*

ISO 13847, *Petroleum and natural gas industries — Pipeline transportation systems — Welding of pipelines*

ISO 14313, *Petroleum and natural gas industries — Pipeline transportation systems — Pipeline valves*

ISO 14723, *Petroleum and natural gas industries — Pipeline transportation systems — Subsea pipeline valves*

ISO 15156-1, *Petroleum and natural gas industries — Materials for use in H₂S-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 H₂S-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 H₂S-containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

ISO 15589-1, *Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems — Part 1: On-land pipelines*

ISO 15589-2, *Petroleum and natural gas industries — Cathodic protection of pipeline transportation systems — Part 2: Offshore pipelines*

ISO 15590-1, *Petroleum and natural gas industries — Induction bends, fittings and flanges for pipeline transportation systems — Part 1: Induction bends*

ISO 15590-2, *Petroleum and natural gas industries — Induction bends, fittings and flanges for pipeline transportation systems — Part 2: Fittings*

ISO 15590-3, *Petroleum and natural gas industries — Induction bends, fittings and flanges for pipeline transportation systems — Part 3: Flanges*

ISO 15649, *Petroleum and natural gas industries — Piping*

ISO/DIS 21809-1, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 1: Polyolefin coatings (3-layer PE and 3-layer PP)*

ISO 21809-2, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 2: Fusion-bonded epoxy coatings*

ISO 21809-3, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 3: Field joint coatings*

ISO 21809-4, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 4: Polyethylene coatings (2-layer PE)*

ISO 21809-5, *Petroleum and natural gas industries — External coatings for buried or submerged pipelines used in pipeline transportation systems — Part 5: External concrete coatings*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*

API¹⁾ 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*

API 650, *Welded Steel Tanks for Oil Storage*

ASME B16.5, *Pipe Flanges and Flanged Fittings — NPS 1/2 Through NPS 24*

ASME Boiler and Pressure Vessel Code, Section VIII, Division I, *Rules for Construction of Pressure Vessels (BPVC)*

MSS²⁾ SP-25, *Standard Marking System for Valves, Fittings, Flanges and Unions*

MSS SP-44, *Steel Pipeline Flanges*

NFPA³⁾ 30, *Flammable and Combustible Liquids Code*

NFPA 220, *Standard on Types of Building Construction*

1) American Petroleum Institute, 1220 L Street, Northwest Washington, DC 20005-4070, USA.

2) Manufacturer's Standardization Society of the Valve and Fittings Industry, 127 Park Street, N.E., Vienna, VA 22180, USA.

3) National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101, USA.

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1

commissioning

activities associated with the initial filling of a pipeline system with the fluid being transported

3.1.2

design life

period for which the design basis is planned to remain valid

3.1.3

design pressure

maximum internal pressure of the pressure-containing components of the pipeline system designed in compliance with this International Standard

3.1.4

design strength

strength level to be used in design, based on material's specified minimum properties

3.1.5

fabricated assembly

grouping of pipe and components assembled as a unit and installed as a subunit of a pipeline system

3.1.6

fluid

medium being transported through the pipeline system

3.1.7

hot tapping

tapping, by mechanical cutting, of an in-service pipeline or piping

3.1.8

in-service pipeline

pipeline that has been commissioned for the transportation of fluid

3.1.9

lay corridor

corridor in which an offshore pipeline is being installed, usually determined prior to construction

3.1.10

location class

geographic area classified according to criteria based on population density and human activity

3.1.11

maintenance

all activities designed to retain the pipeline system in a state in which it can perform its required functions

NOTE These activities include inspections, surveys, testing, servicing, replacement, remedial works and repairs.

3.1.12

maximum allowable operating pressure

MAOP

maximum internal pressure at which a pipeline system, or parts thereof, is allowed to be operated in compliance with this International Standard

3.1.13

offshore pipeline

pipeline laid in maritime waters and estuaries seaward of the ordinary high water mark

3.1.14

pipeline

those components of a pipeline system connected together to convey fluids between stations and/or plants, including pipe, pig traps, components, appurtenances, isolating valves, and sectionalising valves

See Figure 1.

3.1.15

pipeline on land

pipeline laid on or in land, including lines laid under inland water courses

3.1.16

pipeline system

pipelines, stations, supervisory control and data acquisition system (SCADA), safety systems, corrosion protection systems, and any other equipment, facility or building used in the transportation of fluids

3.1.17

piping

pipe, fittings and components inside stations and terminals, but not part of the pipeline

3.1.18

primary piping

piping conveying or storing the fluid transported by the pipeline

3.1.19

right-of-way

corridor of land within which the pipeline operator has the right to conduct activities in accordance with the agreement with the land owner

3.1.20

riser

that part of an offshore pipeline, including subsea spool pieces, that extends from the sea bed to the pipeline termination point on an offshore installation

3.1.21

secondary piping

piping carrying fluids other than those of the primary piping and pipeline, such as fuel gas, water, or lube oil

3.1.22

specified minimum tensile strength

SMTS

minimum tensile strength required by the specification or standard under which the material is purchased

3.1.23

specified minimum yield strength

SMYS

minimum yield strength required by the specification or standard under which the material is purchased

3.1.24 station

facility for the purpose of increasing pressure, decreasing pressure, storage, metering, heating, cooling or isolating the transported fluid

3.2 Symbols

A_i	internal cross-sectional area of the pipe
A_s	cross-sectional area of pipewall
D	specified diameter (outside or inside)
$D_{\max}$	maximum measured diameter (outside or inside)
$D_{\min}$	minimum measured diameter (outside or inside)
D_o	nominal outside diameter
E	modulus of elasticity
f_h	hoop-stress design factor, obtained from Table 2 for pipelines on land and Table 3 for offshore pipelines;
F	pipe wall axial force
p_{id}	design pressure
p_{od}	minimum external hydrostatic pressure
O	ovality or out-of-roundness
$t_{\min}$	specified minimum wall thickness
T_1	installation temperature
T_2	maximum or minimum metal temperature during operation
ν	Poisson ratio
α	linear coefficient of thermal expansion
σ_{eq}	equivalent stress
σ_h	circumferential stress
σ_{hp}	circumferential hoop stress due to fluid pressure
σ_l	longitudinal stress
σ_y	specified minimum yield strength (SMYS) at the maximum design temperature
σ_D	design strength
τ	shear stress

4 General

4.1 Health, safety and the environment

The objective of this International Standard is that the design, material selection and specification, construction, testing, operation, maintenance and abandonment of pipeline systems for the petroleum and natural gas industries be safe and conducted with due regard to public safety and the protection of the environment.

4.2 Competence assurance

All work associated with the design, construction, testing, operation, maintenance and abandonment of the pipeline system shall be carried out by suitably qualified and competent persons.

4.3 Compliance

A quality system should be applied to assist compliance with the requirements of this International Standard.

NOTE ISO/TS 29001 gives sector-specific guidance on quality management systems.

4.4 Records

Records of the pipeline system shall be kept and maintained throughout its lifetime to demonstrate compliance with the requirements of this International Standard. Annex F can be used for guidance on records which should be retained.

5 Pipeline system design

5.1 System definition

The extent of the pipeline system, its functional requirements and applicable legislation should be defined and documented.

The extent of the system should be defined by describing the system, including the facilities with their general locations and the demarcations and interfaces with other facilities.

The functional requirements should define the required design life and design conditions. Foreseeable normal, extreme and shut-in operating conditions with their possible ranges in flowrates, pressures, temperatures, fluid compositions and fluid qualities should be identified and considered when defining the design conditions.

5.2 Categorization of fluids

The fluids being transported shall be placed in one of the following five categories given in Table 1 according to the hazard potential with respect to public safety.

Table 1 — Classification of fluids with respect to potential hazard to public safety

Category A	Non-flammable, water-based fluids.
Category B	Flammable and/or toxic fluids that are liquids at ambient temperature and at atmospheric pressure conditions. Typical examples are oil and petroleum products. Methanol is an example of a flammable and toxic fluid.
Category C	Non-flammable fluids that are non-toxic gases at ambient temperature and atmospheric pressure conditions. Typical examples are nitrogen, carbon dioxide, argon and air.
Category D	Non-toxic, single-phase natural gas.
Category E	Flammable and/or toxic fluids that are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases and/or liquids. Typical examples are hydrogen, natural gas (not otherwise covered in category D), ethane, ethylene, liquefied petroleum gas (such as propane and butane), natural gas liquids, ammonia and chlorine.

Gases or liquids not specifically included by name should be classified in the category containing fluids most closely similar in hazard potential to those quoted. If the category is not clear, the more hazardous category shall be assumed.

5.3 Hydraulic analysis

The hydraulics of the pipeline system should be analysed to demonstrate that the system can safely transport the fluids for the design conditions specified in 5.1, and to identify and determine the constraints and requirements for its operation. This analysis should cover steady-state and transient operating conditions.

NOTE Examples of constraints and operational requirements are allowances for pressure surges, prevention of blockage such as caused by the formation of hydrates and wax deposition, measures to prevent unacceptable pressure losses from higher viscosities at lower operating temperatures, measures for the control of liquid slug volumes in multi-phase fluid transport, flow regime for internal corrosion control, erosional velocities and avoidance of slack line operations.

5.4 Pressure control and overpressure protection

Provisions such as pressure-control valves or automatic shutdown of pressurizing equipment shall be installed, or procedures implemented, if the operating pressure can exceed the maximum allowable operating pressure anywhere in the pipeline system. Such provisions or procedures shall prevent the operating pressure from exceeding MAOP under normal steady-state conditions.

Overpressure protection, such as relief or source-isolation valves, shall be provided if necessary to prevent incidental pressures exceeding the limits specified in 6.3.2.2 anywhere in the pipeline system.

5.5 Requirements for operation and maintenance

The requirements for the operation and maintenance of the pipeline system shall be established and documented for use in the design and the preparation of procedures for operations and maintenance. Aspects for which requirements should be specified include:

- requirements for identification of pipelines, stations and fluids transported;
- principles for system control, including consideration of manning levels and instrumentation;
- location and hierarchy of control centres;
- voice and data communications;
- corrosion management;

- condition monitoring;
- leak detection;
- pigging philosophy;
- access, sectionalizing and isolation for operation, maintenance and replacement;
- interfaces with upstream and downstream facilities;
- emergency shut-in;
- depressurization with venting and/or drainage;
- shutdowns and restart;
- requirements identified from the hydraulic analysis.

5.6 Public safety and protection of the environment

National requirements that take precedence over the requirements in this International Standard shall be specified by the country in which the pipeline system is located. The requirements in this International Standard for public safety and protection of the environment shall apply where no specific national requirements exist.

On-land pipeline systems for category D and E fluids should meet the requirements for public safety of Annex B where specific requirements for public safety have not been defined by the country in which the pipeline is located.

6 Design of pipeline and primary piping

6.1 Design principles

The extent and detail of the design shall be sufficient to demonstrate that the integrity and serviceability required by this International Standard can be maintained during the design life.

Representative values for loads and load resistance shall be selected in accordance with good engineering practice. Methods of analysis may be based on analytical, numerical or empirical models, or a combination of these methods.

Principles of reliability-based limit state design methods may be applied, provided that all relevant ultimate and serviceability limit states are considered. All sources of uncertainty in loads and load resistance shall be considered and sufficient statistical data shall be available for adequate characterization of these uncertainties.

Reliability-based limit-state design methods shall not be used to replace the requirements in Tables 2 and 3 for the maximum permissible hoop stress due to fluid pressure.

NOTE 1 Ultimate limit states are normally associated with loss of structural integrity, e.g. rupture, fracture, fatigue or collapse, whereas exceeding serviceability limit states prevents the pipeline from operating as intended.

NOTE 2 ISO 16708 gives guidance on reliability-based limit state design.

6.2 Route selection

6.2.1 Considerations

6.2.1.1 General

Route selection shall take into account the design, construction, operation, maintenance and abandonment of the pipeline in accordance with this International Standard.

To minimize the possibility of future corrective work and limitations, anticipated urban and industry developments shall be considered.

Factors that shall be considered during route selection include:

- safety of the public, and personnel working on or near the pipeline;
- protection of the environment;
- other property and facilities;
- third-party activities;
- geotechnical, corrosivity and hydrographical conditions;
- requirements for construction, operation and maintenance;
- national and/or local requirements;
- future exploration.

Annex C provides guidance on the planning of a route selection. Annex D provides examples of factors that should be addressed during the considerations required in 6.2.1.1 to 6.2.1.7.

6.2.1.2 Public safety

Pipelines conveying category B, C, D and E fluids should, where practicable, avoid built-up areas or areas with frequent human activity.

In the absence of public safety requirements in a country, a safety evaluation shall be performed in accordance with the general requirements of Annex A for

- pipelines conveying category D fluids in locations where multi-storey buildings are prevalent, where traffic is heavy or dense, and where there can be numerous other utilities underground;
- pipelines conveying category E fluids.

6.2.1.3 Environment

An assessment of environmental impact shall consider as a minimum:

- temporary works during construction, repair and modification;
- the long-term presence of the pipeline;
- potential loss of fluids.

6.2.1.4 Other facilities

Facilities along the pipeline route that can affect the pipeline should be identified and their impact evaluated in consultation with the operator of these facilities.

6.2.1.5 Third-party activities

Third-party activities along the route shall be identified and should be evaluated in consultation with these parties.

6.2.1.6 Geotechnical, hydrographical and meteorological conditions

Adverse geotechnical and hydrographic conditions shall be identified and mitigating measures defined. In some instances, such as under arctic conditions, it can be necessary also to review meteorological conditions.

6.2.1.7 Construction, testing, operation and maintenance

The route shall permit the required access and working width for the construction, testing, operation and maintenance, including any replacement, of the pipeline. The availability of utilities necessary for construction, operation and maintenance should also be reviewed.

6.2.2 Surveys — Pipelines on land

Route and soil surveys shall be carried out to identify and locate with sufficient accuracy the relevant geographical, geological, geotechnical, corrosivity, topographical and environmental features, and other facilities such as other pipelines, cables and obstructions, that can impact the pipeline route selection.

6.2.3 Surveys — Offshore pipelines

Route and soil surveys shall be carried out on the proposed route to identify and locate

- geological features and natural hazards;
- pipelines, cables and wellheads;
- obstructions such as wrecks, mines and debris;
- geotechnical properties.

Meteorological and oceanographic data required for the design and construction planning shall be collected. Such data may include:

- a) bathymetry;
- b) winds;
- c) tides;
- d) waves;
- e) currents;
- f) atmospheric conditions;
- g) hydrologic conditions (temperature, oxygen content, pH value, resistivity, biological activity, salinity);
- h) marine growth;

- i) soil accretion and erosion.

6.3 Loads

6.3.1 General

Loads that can cause or contribute to pipeline failure or loss of serviceability shall be identified and accounted for in the design.

For the strength design, loads shall be classified as:

- functional; or
- environmental; or
- construction; or
- accidental.

6.3.2 Functional loads

6.3.2.1 Classification

Loads arising from the intended use and residual loads from other sources shall be classified as functional.

NOTE The weight of the pipeline, including components and fluid, and loads due to pressure and temperature are examples of functional loads arising from the intended use of the system. Pre-stressing, residual stresses from installation, soil cover, external hydrostatic pressure, marine growth, subsidence and differential settlement, frost heave and thaw settlement, and sustained loads from icing are examples of functional loads from other sources. Reaction forces at supports from functional loads and loads due to sustained displacements, rotations of supports or impact by changes in flow direction are also functional.

6.3.2.2 Design pressure

The design pressure at any point in the pipeline system shall be equal to or greater than the maximum allowable operating pressure (MAOP). Pressures due to static head of the fluid shall be included in the steady-state pressures.

Incidental pressures during transient conditions in excess of MAOP are permitted, provided they are of limited frequency and duration, and the MAOP is not exceeded by more than 10 %.

NOTE Pressure due to surges, failure of pressure control equipment, and cumulative pressures during activation of over-pressure protection devices are examples of incidental pressures. Pressures caused by heating of blocked-in static fluid are also incidental pressures, provided blocking-in is not a regular operating activity.

6.3.2.3 Temperature

The range of fluid temperatures during normal operations and anticipated blowdown conditions shall be considered when determining temperature-induced loads. Both a maximum design temperature and a minimum design temperature shall be established.

6.3.3 Environmental loads

6.3.3.1 Classification

Loads arising from the environment shall be classified as environmental, except where it is necessary that they be considered as functional (see 6.3.2) or when, due to a low probability of occurrence, as accidental (see 6.3.5).

EXAMPLE Loads from waves, currents, tides, wind, snow, ice, earthquake, traffic, fishing and mining are examples of environmental loads. Loads from vibrations of equipment and displacements caused by structures on the ground or seabed are also examples of environmental loads.

6.3.3.2 Hydrodynamic loads

Hydrodynamic loads shall be calculated for the design return periods corresponding to the construction phase and operational phase. The return period for the construction phase should be selected on the basis of the planned construction duration and season and the consequences of the loads associated with these return periods being exceeded. The design return period for the normal operation phase should be not less than three times the design life or 100 years, whichever is shorter.

The joint probability of occurrences in magnitude and direction of extreme winds, waves and currents should be considered when determining hydrodynamic loads.

The effect of increases in exposed area due to marine growth or icing shall be taken into account. Loads from vortex shedding shall be considered for aerial crossings and submerged spanning pipeline sections.

6.3.3.3 Earthquake loads

The following effects shall be considered when designing for earthquakes:

- direction, magnitude and acceleration of fault displacements;
- flexibility to accommodate displacements for the design case;
- mechanical properties under operating conditions;
- design for mitigation of stresses during displacement caused by soil properties for buried crossings and inertial effects for above-ground fault crossings;
- induced effects (liquefaction, landslides).

6.3.3.4 Soil and ice loads

The following effects shall be considered when designing for sand loads:

- sand-dune movement;
- sand encroachment.

The following effects shall be considered when designing for ice loads:

- a) ice frozen on pipelines or supporting structures;
- b) bottom scouring of ice;
- c) drifting ice;

- d) impact forces due to thaw of the ice;
- e) forces due to expansion of the ice;
- f) higher hydrodynamic loads due to increased exposed area;
- g) effects added on possible vibration due to vortex shedding.

6.3.3.5 Road and rail traffic

Maximum traffic axle loads and frequency shall be established in consultation with the appropriate traffic authorities and with recognition of existing and forecast residential, commercial and industrial developments.

6.3.3.6 Fishing

Loads and frequency from fishing activities shall be established based on the applied fishing techniques.

6.3.3.7 Mining

Loads due to ground vibrations from the use of explosives shall be considered. Loads from subsidence arising from mining activities shall be classified as functional.

6.3.4 Construction loads

Loads necessary for installation and commissioning shall be classified as construction loads. The effect of dynamic behaviour of installation vessels and equipment shall be considered where appropriate.

NOTE Installation includes transportation, handling, storage, construction and testing. Increases in external pressure during pressure grouting or sub-atmospheric internal pressure by draining and vacuum drying also give rise to construction loads. Dynamic effects from the movements of lay vessels are also construction loads that it can be necessary to consider for offshore pipelines.

6.3.5 Accidental loads

Loads imposed on the pipeline under unplanned but plausible circumstances shall be considered as accidental. Both the probability of occurrence and the likely consequence of an accidental load should be considered when determining whether the pipeline should be designed for an accidental load.

EXAMPLE Loads arising from fire, explosion, sudden decompression, falling objects, transient conditions during landslides, third-party equipment (such as excavators or ships' anchors), loss of power of construction equipment and collisions.

6.3.6 Combination of loads

When calculating equivalent stresses (see 6.4.1.2), or strains, the most unfavourable combination of functional, environmental, construction and accidental loads that can be predicted to occur simultaneously shall be considered.

If the operating philosophy is such that operations are reduced or discontinued under extreme environmental conditions, then the following load combinations shall be considered for operations:

- design environmental loads plus appropriate reduced functional loads;
- design functional loads and coincidental maximum environmental loads.

Unless they can be reasonably expected to occur together, it is not necessary to consider a combination of accidental loads or accidental loads in combination with extreme environmental loads.

6.4 Strength requirements

6.4.1 Calculation of stresses

6.4.1.1 Hoop stress due to fluid pressure

The circumferential stress, σ_{hp} , due to fluid pressure only (hoop stress), shall be calculated as given in Equation (1):

$$\sigma_{hp} = (p_{id} - p_{od}) \times \frac{(D_o - t_{min})}{2t_{min}} \quad (1)$$

where

p_{id} is the design pressure;

p_{od} is the minimum external hydrostatic pressure;

D_o is the nominal outside diameter;

t_{min} is the specified minimum wall thickness.

NOTE The specified minimum wall thickness is the nominal wall thickness less the allowance for manufacturing per the applicable pipe specification and corrosion. For clad or lined pipelines (see 8.2.3), the strength contribution of the cladding or lining is generally not included.

6.4.1.2 Other stresses

Circumferential, longitudinal, shear and equivalent stresses shall be calculated taking into account stresses from all relevant functional, environmental and construction loads. Accidental loads shall be considered as indicated in 6.3.5. The significance of all parts of the pipeline and all restraints, such as supports, guides and friction, shall be considered. When flexibility calculations are performed, linear and angular movements of equipment to which the pipeline is attached shall also be considered.

Calculations shall take into account flexibility and stress concentration factors of components other than plain straight pipe. Credit may be taken for the extra flexibility of such components.

Flexibility calculations shall be based on nominal dimensions and the modulus of elasticity at the appropriate temperature(s).

Equivalent stresses, σ_{eq} , shall be calculated using the von Mises equation as given in Equation (2):

$$\sigma_{eq} = (\sigma_h^2 + \sigma_l^2 - \sigma_h\sigma_l + 3\tau^2)^{1/2} \quad (2)$$

where

σ_h is the circumferential stress;

σ_l is the longitudinal stress;

τ is the shear stress.

Equivalent stresses may be based on nominal values of diameter and wall thickness. Radial stresses may be neglected when not significant.

6.4.2 Strength criteria

6.4.2.1 General

Pipelines shall be designed for the following mechanical failure modes and deformations:

- yielding;
- buckling;
- fatigue;
- ovality.

6.4.2.2 Yielding

The maximum hoop stress, σ_{hp} , due to fluid pressure shall be determined in accordance with Equation (3):

$$\sigma_{hp} \leq f_h \times \sigma_y \quad (3)$$

where

f_h is the hoop-stress design factor, obtained from Table 2 for pipelines on land and Table 3 for offshore pipelines;

σ_y is the specified minimum yield strength (SMYS) at the maximum design temperature.

Pipelines using steel grades above L555 should be designed using a reliability-based limit-state design approach in accordance with ISO 16708 or other recognized code or standard. If a limit-state design approach is not used, the maximum hoop stress due to fluid pressure shall be determined in accordance with Equation (4):

$$\sigma_{hp} \leq f_h \times \sigma_D \quad (4)$$

where σ_D is the design strength, which is the lesser of SMYS or the specified minimum tensile strength (SMTS) divided by 1,15 for grades above L555.

For temperatures above 50 °C, σ_y or σ_D shall be documented in accordance with 8.1.7.

σ_D characterizes the material strength at the maximum temperature for the analysed scenario. σ_D may be different in different phases; typically representing the ambient temperature during installation and pressure test and the design temperature during operation.

Table 2 — Hoop-stress design factors, f_h , for pipelines on land ^a

Location	f_h
General route ^b	0,77
Crossings and parallel encroachments: ^c	
— minor roads	0,77
— major roads, railways, canals, rivers, diked flood defences and lakes	0,67
Pig traps and multi-pipe slug catchers	0,67
Primary piping in stations and terminals	0,67
Special constructions such as fabricated assemblies and pipelines on bridges	0,67
^a The hoop stress factors of Table B.2 shall apply for category D and E pipelines to be designed to meet the requirements of Annex B. These factors apply to pipelines pressure-tested with water. Lower design factors may be necessary when tested with air. ^b The hoop stress factor may be increased to 0,83 for pipelines conveying category C and D fluids at locations subject to infrequent human activity and without permanent human habitation (such as deserts and tundra regions). ^c See 6.9 for the description of crossings and encroachments.	

Table 3 — Hoop stress design factors, f_h , for offshore pipelines

Location	f_h
General route ^a	0,77
Shipping lanes, designated anchoring areas and harbour entrances	0,77
Landfalls	0,67
Pig traps and multi-pipe slug catchers	0,67
Risers and primary piping	0,67
^a The hoop stress factor may be increased to 0,83 for pipelines conveying category C and D fluids.	

The maximum equivalent stress, σ_{eq} , shall be determined in accordance with Equation (5):

$$\sigma_{eq} = f_{eq} \times \sigma_y \quad (5)$$

where f_{eq} is the equivalent stress design factor, obtained from Table 4.

If a pipeline is designed using steel grade above L555, σ_y shall be replaced by σ_D in Equation (5).

Table 4 — Equivalent stress design factors, f_{eq}

Load combination	f_{eq}
Construction and environmental	1,00
Functional and environmental	0,90
Functional, environmental and accidental	1,00

The criterion for equivalent stress may be replaced by a permissible strain criterion where:

- the configuration of the pipeline is controlled by imposed deformations or displacements; or
- the possible pipeline displacements are limited by geometrical constraints before exceeding the permissible strain.

A permissible strain criterion may be applied for the construction of pipelines to determine the allowable bending and straightening associated with reeling, J-tube pull-ups, installation of a bending shoe riser and similar construction methods.

A permissible strain criterion may be used for pipelines in service for:

- a) pipeline deformations from predictable non-cyclic displacement of supports, ground or seabed, such as fault movement along the pipeline or differential settlement;
- b) non-cyclic deformations, where the pipeline is supported before exceeding the permissible strain, such as in case of a pipeline offshore that is not continuously supported but with sagging limited by the seabed;
- c) cyclic functional loads, provided that plastic deformation occurs only when the pipeline is first raised to its “worst-case” combination of functional loads and not during subsequent cycling of these loads.

The permissible strain shall be determined considering the fracture toughness of the material, weld imperfections and previously experienced strain. The possibility of strain localization, such as for concrete-coated pipelines in bending, shall be considered when determining strains.

NOTE BS 7910 provides guidance for determining the level of permissible strain.

6.4.2.3 Buckling

The following buckling modes shall be considered:

- local buckling due to external pressure, axial tension or compression, bending and torsion, or a combination of these loads;
- buckle propagation;
- restrained buckling due to axial compressive forces induced by high operating temperatures and pressures.

NOTE Buckling of restrained pipelines can take the form of lateral displacement for unburied pipelines or vertical upheaval of trenched or buried pipelines.

6.4.2.4 Fatigue

Fatigue analyses shall be performed on pipeline sections and components that can be subject to fatigue from cyclic loads in order to:

- demonstrate that initiation of cracking does not occur; or
- define requirements for inspection for fatigue.

Fatigue analyses shall include a prediction of load cycles during construction and operation and a translation of load cycles into nominal stress or strain cycles.

The effect of mean stresses, internal service, external environment, plastic prestrain and rate of cyclic loading shall be accounted for when determining fatigue resistance.

Assessment of fatigue resistance may be based on either S-N data obtained on representative components or a fracture mechanics fatigue life assessment.

The selection of safety factors shall take into account the inherent inaccuracy of fatigue-resistance predictions and access for inspection for fatigue damage. It can be necessary to monitor the parameters causing fatigue and to control possible fatigue damage accordingly.

6.4.2.5 Ovality

Ovality, or out-of-roundness, O , expressed as a percentage, is defined as given in Equation (6):

$$O = \frac{D_{\max} - D_{\min}}{D} \times 100 \quad (6)$$

where

- D is the specified diameter (outside or inside);
- $D_{\max}$ is the maximum measured diameter (outside or inside);
- $D_{\min}$ is the minimum measured diameter (outside or inside).

Ovality or out-of-roundness arising from manufacture, construction and installation shall be considered in relation to buckling and operational requirements.

6.5 Stability

Pipelines shall be designed to prevent horizontal and vertical movement, or shall be designed with sufficient flexibility to allow predicted movements within the strength criteria of this International Standard.

Factors which should be considered in the stability design include:

- hydrodynamic and wind loads;
- axial compressive forces at pipeline bends and lateral forces at branch connections;
- lateral deflection due to axial compression loads in the pipelines;
- exposure due to general erosion or local scour;
- geotechnical conditions including soil instability due to, for example, seismic activity, slope failures, frost heave, thaw settlement and groundwater level;
- construction method, including bundled or piggybacked lines;
- trenching and/or backfilling techniques.

NOTE Stability for pipelines on land can be enhanced by such means as pipe mass selection, anchoring, control of backfill material, soil cover, soil replacement, drainage and insulation to avoid frost heave. Possible stability improvement measures for subsea pipelines are pipe mass, mass coating, trenching, burial (including self-burial), gravel or rock dumping, anchoring and the installation of mattresses or saddles.

6.6 Pipeline spanning

Spans in pipelines shall be controlled to ensure compliance with the strength criteria in 6.4.2. Due consideration shall be given to:

- support conditions;
- interaction with adjacent spans;
- possible vibrations induced by wind, current and waves;
- axial force in the pipeline;
- soil accretion and erosion;
- possible effects from third-party activities;
- soil properties.

6.7 Pressure test requirements

6.7.1 General

Pipelines and primary piping shall be pressure-tested in place after installation but before being put into operation to demonstrate their strength and leak-tightness. Prefabricated assemblies and tie-in sections may be pretested before installation provided their integrity is not impaired during subsequent construction or installation. The requirements for pressure testing can govern the necessary pipe wall thickness and/or steel grade in terrain with significant elevations.

6.7.2 Test medium

Pressure tests shall be conducted with water (including inhibited water), except if low ambient temperatures prevent testing with water, if sufficient water of adequate quality cannot be made available, if disposal of water is not possible, if testing is not expedient or if water contamination is unacceptable. Pneumatic tests (when necessary) may be made using air or a non-toxic gas.

NOTE Rerouting of short pipeline sections or short tie-in sections for pipelines in operation are examples of situations for which pressure tests with water might not be expedient.

6.7.3 Pressure levels and test durations

The duration of strength and/or leak testing shall be determined taking into consideration ambient temperature changes and leak detection methods.

Pipelines and primary piping shall be strength-tested, after stabilization of temperatures and surges from pressurizing operations, for a minimum period of 1 h with a pressure at any point in the system of at least $1,25 \times \text{MAOP}$.

If applicable, the strength test pressure shall be multiplied by the following ratios:

- σ_y at test temperature divided by σ_y at the design temperature; and
- $t_{\min}$ plus corrosion allowance divided by $t_{\min}$ in case of corrosion allowance.

The strength test pressure for pipelines conveying category C and D fluids at locations subject to infrequent human activity and without permanent habitation may be reduced to a pressure of not less than $1,20 \times \text{MAOP}$, provided the maximum incidental pressure cannot exceed $1,05 \times \text{MAOP}$.