

Petroleum and natural gas industries — Pipeline transportation systems

The European Standard EN 14161:2003 has the status of a
British Standard

ICS 75.200

National foreword

This British Standard is the official English language version of EN 14161:2003. It supersedes BS 8010-1:1989, BS 8010-2.8:1992 and BS 8010-3:1993 which are withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries, to Subcommittee PSE/17/2, Transmission pipelines, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Additional information

The UK voted against EN 14161 at the adoption stage 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 8010-1:2004, *Code of practice for pipelines — Part 1: Pipelines on land*;
- PD 8010-2:2004, *Code of practice for pipelines — Part 2: Subsea pipelines*

For example, BS EN 14161 excludes pipeline systems for the transportation of oxygen. This subject is addressed in PD 8010-1.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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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Summary of pages

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English version

**Petroleum and natural gas industries - Pipeline transportation
systems (ISO 13623:2000 modified)**

Industries du pétrole et du gaz naturel - Systèmes de
transport par conduites (ISO 13623:2000 modifiée)

Erdöl- und Erdgasindustrie - Rohrleitungstransportsysteme
(ISO 13623:2000 modifiziert)

This European Standard was approved by CEN on 3 November 2003.

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 Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.



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Explanatory Note

ISO 13623:2000, developed within ISO/TC 67 SC 2, has been taken over as a European Standard EN 14161 (ISO 13623:2000 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 item. 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.”

Resulting from Resolution BT 38/1995, “**gas supply on land**” has been excluded from the scope of ISO 13623:2000 for the European adoption by CEN/TC 12.

Equivalence with European standards is provided in annex ZA.

Foreword

The text of the International Standard ISO 13623:2000 has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" of the International Organization for Standardization (ISO) and has been taken over as EN 14161:2003 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 June 2004, and conflicting national standards shall be withdrawn at the latest by June 2004.

Annexes A, B and ZA form a normative part of this European Standard.

Annexes C, D, E and F are for information only.

This document includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

Significant differences exist between member countries in the areas of public safety and protection of the environment, which could not 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 which establishes requirements for public safety and protection of the environment. Recognizing these differences, TC 67/SC 2 concluded that this International Standard, ISO 13623, should allow individual countries to apply their national requirements for public safety and the protection of the environment.

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

1 Scope

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 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.

On-land supply systems used by the gas supply industry are excluded from the scope of this Standard.

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 may be applied to modifications made to existing ones. It is not intended that it should 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.

This European Standard does not apply to pipeline systems for the transportation of oxygen.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ISO 148:1983, *Steel $\frac{3}{4}$ Charpy impact test (V-notch).*

ISO 3183-1:1996, *Petroleum and natural gas industries $\frac{3}{4}$ Steel pipe for pipelines $\frac{3}{4}$ Technical delivery conditions $\frac{3}{4}$ Part 1: Pipes of requirement class A.*

ISO 3183-2:1996, *Petroleum and natural gas industries $\frac{3}{4}$ Steel pipe for pipelines $\frac{3}{4}$ Technical delivery conditions $\frac{3}{4}$ Part 2: Pipes of requirements class B.*

ISO 3183-3:1999, *Petroleum and natural gas industries $\frac{3}{4}$ Steel pipe for pipelines $\frac{3}{4}$ Technical delivery conditions $\frac{3}{4}$ Part 3: Pipes of requirement class C.*

ISO 7005-1:1992, *Metallic flanges $\frac{3}{4}$ Part 1: Steel flanges.*

ISO 10474:1991, *Steel and steel products $\frac{3}{4}$ Inspection documents.*

ISO 13847, *Petroleum and natural gas industries $\frac{3}{4}$ Pipeline transportation systems $\frac{3}{4}$ Welding of pipelines.*

ISO 14313, *Petroleum and natural gas industries $\frac{3}{4}$ Pipeline transportation systems $\frac{3}{4}$ Pipeline valves.*

ISO 14723, *Petroleum and natural gas industries ¾ Pipeline transportation systems ¾ Subsea pipeline valves.*

IEC 60079-10:1995, *Electrical apparatus for explosive gas atmospheres ¾ Part 10: Classification of hazardous areas.*

IEC 60079-14:1996, *Electrical apparatus for explosive gas atmospheres ¾ Part 14: Electrical installations in hazardous areas (other than mines).*

API¹⁾ Std 620:1996, *Design and construction of large, welded, low-pressure storage tanks.*

API Std 650:1993, *Welded steel tanks for oil storage.*

ASME²⁾ B16.5:1996, *Pipe flanges and flanged fittings ¾ NPS 1/2 through NPS 24.*

ASME B31.3:1996, *Process piping.*

ASME Boiler and Pressure Vessel Code:1998, Section VIII, Division I, *Rules for construction of pressure vessels.*

ASTM³⁾ A193/A 193M:1998, *Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service.*

ASTM A194/A 194M:1998, *Standard specification for carbon and alloy steel nuts for bolts for high pressure or high temperature service, or both.*

MSS⁴⁾ SP-25:1998, *Standard marking system for valves, fittings, flanges and unions.*

MSS SP-44:1996, *Steel pipeline flanges.*

NFPA⁵⁾ 30, *Flammables and combustible liquids code.*

NFPA 220, *Standard on types of building construction.*

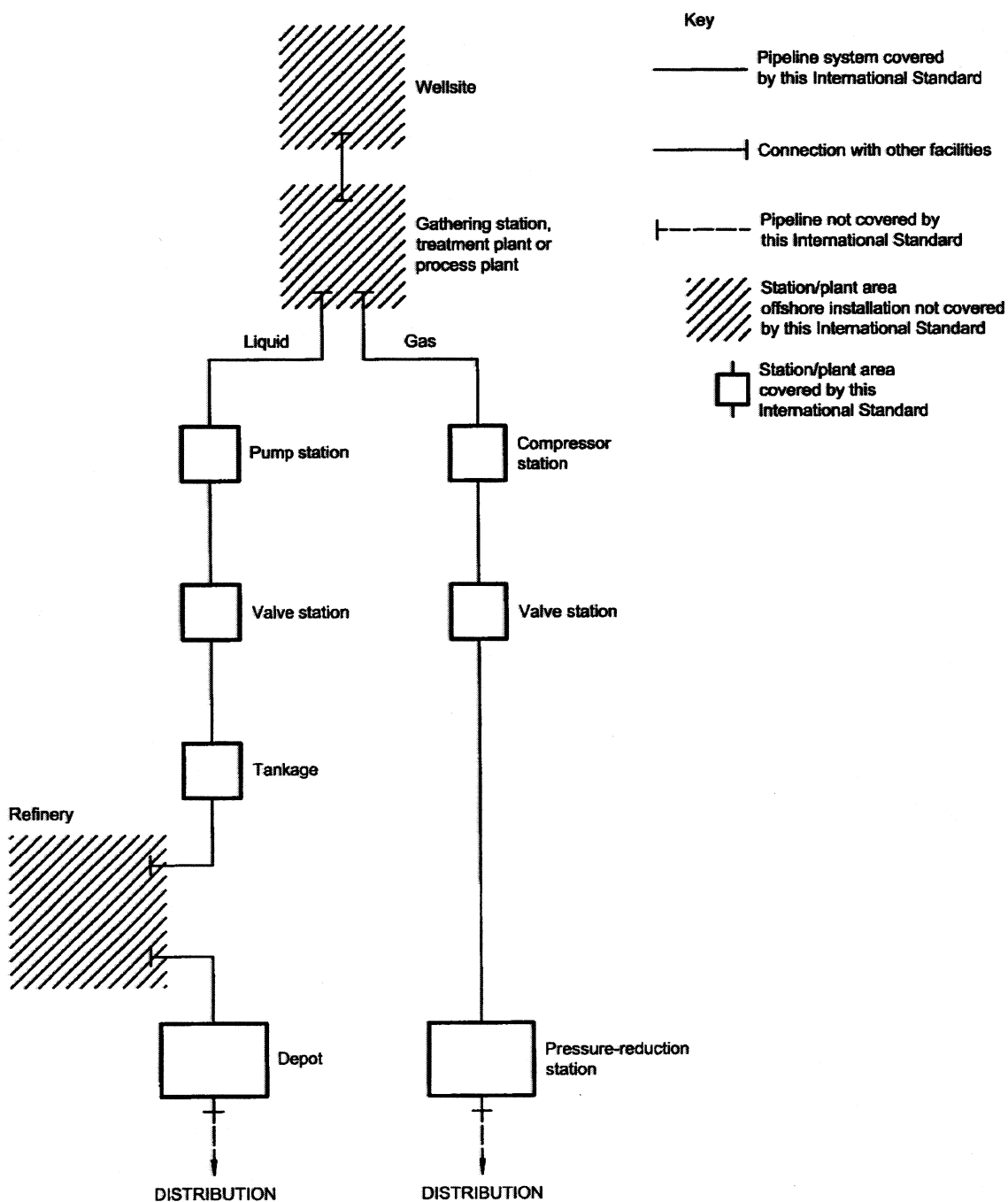
1) American Petroleum Institute, 1220 L Street, Northwest Washington, DC 20005-4070, USA.

2) American Society of Mechanical Engineers, 345 East 47th Street, NY 10017-2392, USA.

3) American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, PA 19428-2959, USA.

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

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



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 European Standard

3 Terms and definitions

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

3.1**commissioning**

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

3.2**fabricated assembly**

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

3.3**fluid**

medium to be transported through the pipeline system

3.4**hot tapping**

tapping, by mechanical cutting, of a pipeline in service

3.5**in-service pipeline**

pipeline that has been commissioned for the transportation of fluid

3.6**internal design pressure**

maximum internal pressure at which the pipeline or section thereof is designed in compliance with this European Standard

3.7**lay corridor**

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

3.8**location class**

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

3.9**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.

3.10**maximum allowable operating pressure****MAOP**

maximum pressure at which a pipeline system, or parts thereof, is allowed to be operated

3.11**offshore pipeline**

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

3.12**pipeline**

those facilities through which fluids are conveyed, including pipe, pig traps, components and appurtenances, up to and including the isolating valves

3.13**pipeline design life**

period of time selected for the purpose of verifying that a replaceable or permanent component is suitable for the anticipated period of service

3.14

pipeline on land

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

3.15

pipeline system

pipeline with compressor or pump stations, pressure control stations, flow control stations, metering, tankage, 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

3.16

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

3.17

riser

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

3.18

specified minimum yield strength

SMYS

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

4 General

4.1 Health, safety and the environment

The objective of this European 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 are 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 European Standard.

NOTE ISO 9000-1 gives guidance on the selection and use of quality 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 European Standard. Annex F may be used for guidance or 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 to be transported shall be placed in one of the following five categories according to the hazard potential in respect of public safety:

Category A	Typically non-flammable water-based fluids.
Category B	Flammable and/or toxic fluids which 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 which 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 which 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 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 6.3.2.1 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 may include:

- ¾ requirements for identification of pipelines, components and fluids transported;
- ¾ principles for system control, including consideration of manning levels and instrumentation;
- ¾ location and hierarchy of control centres;
- ¾ voice and data communications;
- ¾ corrosion management;
- ¾ condition monitoring;
- ¾ leak detection;
- ¾ pigging philosophy;
- ¾ access, sectionalizing and isolation for operation, maintenance and replacement;
- ¾ interfaces with upstream and downstream facilities;
- ¾ emergency shut-in;
- ¾ depressurization with venting and/or drainage;
- ¾ shutdowns and restart;
- ¾ requirements identified from the hydraulic analysis.

5.6 Public safety and protection of the environment

National requirements which take precedence over the requirements in this European Standard shall be specified by the country in which the pipeline is located. The requirements in this European 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 Pipeline design

6.1 Design principles

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

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 relevant 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 requirement in 6.4.2.2 for the maximum permissible hoop stress due to fluid pressure.

NOTE 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.

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 European Standard.

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

Factors which shall be considered during route selection include:

- ¾ safety of the public, and personnel working on or near the pipeline;
- ¾ protection of the environment;
- ¾ other property and facilities;
- ¾ third-party activities;
- ¾ geotechnical, corrosivity and hydrographical conditions;
- ¾ requirements for construction, operation and maintenance;
- ¾ national and/or local requirements;
- ¾ future exploration.

NOTE Annex C provides guidance on the planning of a route selection. Annex D provides examples of factors which 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:

- ¾ pipelines conveying category D fluids in locations where multi-storey buildings are prevalent, where traffic is heavy or dense, and where there may be numerous other utilities underground;

¾ pipelines conveying category E fluids.

6.2.1.3 Environment

An assessment of environmental impact shall consider as a minimum:

- ¾ temporary works during construction, repair and modification;
- ¾ the long-term presence of the pipeline;
- ¾ potential loss of fluids.

6.2.1.4 Other facilities

Facilities along the pipeline route which may 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 may 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, which could 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:

- ¾ geological features and natural hazards;
- ¾ pipelines, cables and wellheads;
- ¾ obstructions such as wrecks, mines and debris;
- ¾ geotechnical properties.

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

- ¾ bathymetry;
- ¾ winds;
- ¾ tides;
- ¾ waves;
- ¾ currents;
- ¾ atmospheric conditions;
- ¾ hydrologic conditions (temperature, oxygen content, pH value, resistivity, biological activity, salinity);
- ¾ marine growth;
- ¾ soil accretion and erosion.

6.3 Loads

6.3.1 General

Loads, which may cause or contribute to pipeline failure or loss of serviceability of the pipeline system, shall be identified and accounted for in the design.

For the strength design, loads shall be classified as:

- ¾ functional; or
- ¾ environmental; or
- ¾ construction; or
- ¾ accidental.

6.3.2 Functional loads

6.3.2.1 Classification

Loads arising from the intended use of the pipeline system 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 Internal design pressure

The internal 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 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 in fluid temperatures during normal operations and anticipated blowdown conditions shall be considered when determining temperature-induced loads.

6.3.3 Environmental loads

6.3.3.1 Classification

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

EXAMPLES 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 of the pipeline system 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 Earthquakes

The following effects shall be considered when designing for earthquakes:

- ¾ direction, magnitude and acceleration of fault displacements;
- ¾ flexibility of pipeline to accommodate displacements for the design case;
- ¾ mechanical properties of the carrier pipe under pipeline operating pressure (conditions);
- ¾ design for mitigation of pipeline stresses during displacement caused by soil properties for buried crossings and inertial effects for above-ground fault crossings;
- ¾ induced effects (liquefaction, landslides);
- ¾ mitigation of exposure to surrounding area by pipeline fluids.

6.3.3.4 Soil and ice loads

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

- ¾ sand dune movement;
- ¾ sand encroachment.

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

- ¾ ice frozen on pipelines or supporting structures;
- ¾ bottom scouring of ice;
- ¾ drifting ice;
- ¾ impact forces due to thaw of the ice;
- ¾ forces due to expansion of the ice;
- ¾ higher hydrodynamic loads due to increased exposed area;
- ¾ 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 the installation and pressure testing of the pipeline system 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 which may need to be considered 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.

EXAMPLES Loads arising from fire, explosion, sudden decompression, falling objects, transient conditions during landslides, third-party equipment (such as excavators or ship's 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 which can be predicted to occur simultaneously shall be considered.

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

$\frac{3}{4}$ design environmental loads plus appropriate reduced functional loads ;

$\frac{3}{4}$ 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, due to fluid pressure only (hoop stress), shall be calculated from the following formula:

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

where

p_{hp} is the circumferential stress due to fluid pressure;

p_{id} is the internal 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 has been 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 shall be calculated using the von Mises equation as follows:

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

where

σ_{eq} is the equivalent stress;

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:

¾ excessive yielding;

¾ buckling;

¾ fatigue;

¾ excessive ovality.

6.4.2.2 Yielding

The maximum hoop stress due to fluid pressure shall not exceed:

$$\sigma_{hp} = F_h \times \sigma_y$$

where

F_h is the hoop stress design factor, obtained from Table 1 for pipelines on land and Table 2 for offshore pipelines;

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

NOTE σ_y should be documented for design temperatures above 50 °C in accordance with 8.1.7.

Table 1 — Hoop stress design factors F_h for pipelines on land

Location	F_h
General route ^a	0,77
Crossings and parallel encroachments ^b	
— 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
Piping in stations and terminals	0,67
Special constructions such as fabricated assemblies and pipelines on bridges	0,67
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.	
^a 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).	
^b See 6.9 for the description of crossings and encroachments.	

Table 2 — 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 station 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 shall not exceed:

$$F_{eq} \times \sigma_y$$

where

F_{eq} is the equivalent stress design factor, obtained from Table 3.

Table 3 — 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:

- ¾ the configuration of the pipeline is controlled by imposed deformations or displacements; or
- ¾ 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:

- ¾ pipeline deformations from predictable non-cyclic displacement of supports, ground or seabed, such as fault movement along the pipeline or differential settlement;
- ¾ non-cyclic deformations where the pipeline will be supported before exceeding the permissible strain, such as in case of a pipeline offshore which is not continuously supported but with sagging limited by the seabed;
- ¾ 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 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:

- ¾ local buckling of the pipe due to external pressure, axial tension or compression, bending and torsion, or a combination of these loads;
- ¾ buckle propagation;
- ¾ restrained pipe buckling due to axial compressive forces induced by high operating temperatures and pressures.

NOTE Restrained pipe buckling can take the form of horizontal snaking 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 may be subject to fatigue from cyclic loads in order to:

- ¾ demonstrate that initiation of cracking will not occur; or
- ¾ 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 may 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, that could cause buckling or interference with pigging operations, should be avoided.

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 European Standard.

Factors which should be considered in the stability design include:

- ¾ hydrodynamic and wind loads ;
- ¾ axial compressive forces at pipeline bends and lateral forces at branch connections;
- ¾ lateral deflection due to axial compression loads in the pipelines;
- ¾ exposure due to general erosion or local scour;
- ¾ geotechnical conditions including soil instability due to, for example, seismic activity, slope failures, frost heave, thaw settlement and groundwater level;
- ¾ construction method;
- ¾ 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:

- ¾ support conditions;
- ¾ interaction with adjacent spans;
- ¾ possible vibrations induced by wind, current and waves;
- ¾ axial force in the pipeline;
- ¾ soil accretion and erosion;
- ¾ possible effects from third-party activities;

¾ soil properties.

6.7 Pressure test requirements

6.7.1 General

Pipeline systems 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 when low ambient temperatures prevent testing with water, when sufficient water of adequate quality cannot be made available, when disposal of water is not possible, when testing is not expedient or when 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 may not be expedient.

6.7.3 Pressure levels and test durations

The pipeline system 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 :

¾ 1,25 MAOP for pipelines on land; and

¾ 1,25 (MAOP minus the external hydrostatic pressure) for offshore pipelines.

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

¾ the ratio of σ_y at test temperature divided by the derated value for σ_y at the design temperature in case of a lower specified minimum yield strength σ_y at the design temperature than exists during testing; and

¾ the ratio of $t_{\min}$ 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 MAOP, provided the maximum incidental pressure cannot exceed 1,05 times MAOP.

Following a successful strength test, the pipeline system shall be leak-tested for a minimum period of 8 h with a pressure at any point in the system of at least:

¾ 1,1 MAOP for pipelines on land; and

¾ 1,1 (MAOP minus the external hydrostatic pressure) for offshore pipelines.

The strength and leak test may be combined by testing for 8 h at the pressure specified above for strength testing. The requirement for a minimum duration of a leak test is not applicable to pipeline systems completely accessible for visual inspection, provided the complete pipeline is visually inspected for leaks following a hold-period of 2 h at the required leak-test pressure. The additional test requirements of clause B.6 shall apply for category D and E pipelines to which annex B applies.

6.7.4 Acceptance criteria

Pressure variations during strength testing shall be acceptable if they can be demonstrated to be caused by factors other than a leak.

Pressure increases or decreases during leak testing shall be acceptable provided they can be demonstrated through calculations to be caused by variations in ambient temperature or pressure, such as tidal variation for offshore pipelines.

Pipelines not meeting these requirements shall be repaired and retested in accordance with the requirements of this European Standard.

6.8 Other activities

6.8.1 Activities by others

The following factors shall be considered when determining the requirements for the protection of pipelines:

- ¾ the possible effects of pipeline damage on public safety and the environment;
- ¾ the possible effects of interference from other activities;
- ¾ national requirements for public safety and the protection of the environment.

EXAMPLES Activities to be considered for pipelines on land include other land users, traffic, cultivation, installation of drainage, construction of buildings and work on roads, railways, waterways and military exercises. Examples for offshore pipelines include the setting of jack-up vessels, the movement of anchors and anchor chains, snagging cables and umbilicals, dropping of objects near installations, moving vessels close to risers, seabed fishing activity during their installation and military exercises.

Protection requirements shall be established as part of the safety evaluation in 6.2.1.2 where required.

EXAMPLES Protection of pipelines on land includes cover, increased wall thickness, markers and marker tape, mechanical protection, controlling access to the pipeline route, or a combination of these measures. Trenching or burial, rock dumping, cover with mattresses or protective structures and riser protection are possible protective measures for offshore pipelines.

For pipelines on land, markers should be erected at road, rail, river and canal crossings and elsewhere, to enable other users of the area to identify the location of pipelines. The use of marker tape should be considered for buried pipelines on land.

6.8.2 Pipeline cover

6.8.2.1 Pipelines on land

Buried pipelines on land should be installed with a cover depth not less than shown in Table 4.

Table 4 — Minimum cover depth for pipelines on land

Location	Cover depth m
Areas of limited or no human activity	0,8
Agricultural or horticultural activity ^a	0,8
Canals, rivers ^b	1,2
Roads and railways ^c	1,2
Residential, industrial, and commercial areas	1,2
Rocky ground ^d	0,5
Cover depth shall be measured from the lowest possible ground surface level to the top of the pipe, including coatings and attachments.	
Special consideration for cover may be required in areas with frost heave.	
^a Cover shall not be less than the depth of normal cultivation. ^b To be measured from the lowest anticipated bed. ^c To be measured from the bottom of the drain ditches. ^d The top of pipe shall be at least 0,15 m below the surface of the rock.	

Pipelines may be installed with less cover depth than indicated in Table 4, provided a similar level of protection is provided by alternative methods.

The design of alternative protection methods should take into account:

- ¾ any hindrance caused to other users of the area;
- ¾ soil stability and settlement;
- ¾ pipeline stability;
- ¾ cathodic protection;
- ¾ pipeline expansion;
- ¾ access for maintenance.

6.8.2.2 Offshore pipelines

Offshore pipelines shall be trenched, buried or protected if external damage affecting the integrity is likely, and where necessary to prevent or reduce interference with other activities. Other users of the area shall be consulted when determining the requirements for reducing or preventing this interference.

Protective structures for use on offshore pipelines should present a smooth profile to minimize risks of snagging and damage from anchoring cables and fishing gear. They should also have sufficient clearance from the pipeline system to permit access where required, and to allow both pipeline expansion and settlement of the structure foundations. The design of the cathodic protection of the pipeline should be compatible with that of any connecting structure.

6.9 Crossings and encroachments

6.9.1 Consultations with authorities

The pipeline design loads, including frequency, construction methods and requirements for the protection of crossings, shall be established in consultation with the appropriate authorities.

6.9.2 Roads

Roads should be classified as major or minor for the application of the hoop stress design factor.

Motorways and trunk roads should be classified as major and all other public roads as minor. Private roads or tracks should be classified as minor even if used by heavy vehicles.

The hoop stress design factors in Table 1 and the cover depth requirements in Table 4 should, as a minimum, apply to the road right-of-way boundary or, if this boundary has not been defined, to 10 m from the edge of the hard surface of major roads and 5 m for minor roads.

Pipelines running parallel to a road should be routed outside the road right-of-way boundary where practicable.

6.9.3 Railways

The hoop stress design factors in Table 1 and the cover depth requirements in Table 4 should, as a minimum, apply to 5 m beyond the railway boundary or, if the boundary has not been defined, to 10 m from the rail.

Pipelines running parallel to the railway should be routed outside the railway right-of-way where practicable.

The vertical separation between the top of the pipe and the top of the rail should be a minimum of 1,4 m for open-cut crossings and 1,8 m for bored or tunnelled crossings.

6.9.4 Waterways and landfalls

Protection requirements for pipeline crossings of canals, shipping channels, rivers, lakes and landfalls should be designed in consultation with the water and waterways authorities.

Crossings of flood defences can require additional design measures for the prevention of flooding and limiting the possible consequences.

The potential for pipeline damage by ships' anchors, scour and tidal effects, differential soil settlement or subsidence, and any future works such as dredging, deepening and widening of the river or canal, shall be considered when defining the protection requirements.

6.9.5 Pipeline/cable crossings

Physical contact between a new pipeline and existing pipelines and cables shall be avoided. Mattresses or other means of permanent separation should be installed if necessary to prevent contact during the design life of the pipeline.

Crossings should occur at as close as practicable to 90°.

6.9.6 Pipe bridge crossings

Pipeline bridges may be considered when buried crossings are not practicable.

Pipe bridges shall be designed in accordance with structural design standards, with sufficient clearance to avoid possible damage from the movement of traffic, and with access for maintenance. Interference between the cathodic protection of the pipeline and the supporting bridge structure shall be considered.

Provision shall be made to restrict public access to pipe bridges.

6.9.7 Sleeved crossings

Sleeved crossings should be avoided where possible.

NOTE API RP 1102 provides guidance on the design of sleeved crossings.

6.10 Adverse ground and seabed conditions

Where necessary, protective measures, including requirements for surveillance, shall be established to minimize the occurrence of pipeline damage from adverse ground and seabed conditions.

EXAMPLES Adverse ground and seabed conditions include landslide, erosion, subsidence, differential settlement, areas subject to frost heave and thaw settlement, peat areas with a high groundwater table and swamps. Possible protective measures are increased pipe wall thickness, ground stabilization, erosion prevention, installation of anchors, provision of negative buoyancy, etc., as well as surveillance measures. Measurements of ground movement, pipeline displacement or change in pipeline stresses are possible surveillance methods.

Local authorities, local geological institutions and mining consultants should be consulted on general geological conditions, landslide and settlement areas, tunnelling and possible adverse ground conditions.

6.11 Section isolation valves

Section isolation valves should be installed at the beginning and end of a pipeline and where required for:

- ¾ operation and maintenance;
- ¾ control of emergencies;
- ¾ limiting potential spill volumes.

Account should be taken of topography, ease of access for operation and maintenance including requirements for pressure relief, security and proximity to occupied buildings when locating the valves.

The mode of operation of section isolation valves shall be established when determining their location.

6.12 Integrity monitoring

Requirements for pipeline integrity monitoring shall be established at the design stage.

NOTE Monitoring can include corrosion monitoring, inspection and leak detection.

6.13 Design for pigging

The requirements for pigging shall be identified and the pipeline designed accordingly. Pipelines should be designed to accommodate internal inspection tools.

The design for pigging should consider the following:

- ¾ provision and location of permanent pig traps or connections for temporary pig traps;
- ¾ access;
- ¾ lifting facilities;
- ¾ isolation requirements for pig launching and receiving;
- ¾ requirements for venting and draining (for precommissioning and during operation);
- ¾ pigging direction(s);
- ¾ permissible minimum bend radius;
- ¾ distance between bends and fittings;
- ¾ maximum permissible changes in diameter;
- ¾ tapering requirements at internal diameter changes;
- ¾ design of branch connections and compatibility of line pipe material;
- ¾ internal fittings;
- ¾ internal coatings;
- ¾ pig signallers.

The safety of access routes and adjacent facilities shall be considered when determining the orientation of pig traps.

6.14 Fabricated components

6.14.1 Welded branch connections

Welded branch connections on steel pipe shall be designed in accordance with the requirements of a recognised design standard. The hoop stress in the connection shall not exceed the hoop stress permitted in the adjacent pipe.

Mechanical fittings may be used for making hot taps on pipelines, provided they are designed to meet or exceed the design pressure of the pipeline.

6.14.2 Special components fabricated by welding

The design of special components shall be in accordance with sound engineering practice and this European Standard. Where the strength of such components cannot be computed or determined in accordance with the requirements of this European Standard, the maximum allowable operating pressure shall be established in accordance with the requirements of ASME Section VIII, Division 1.

Prefabricated items, other than commonly manufactured butt-welded fittings, which employ plate and longitudinal seams shall be designed, constructed and tested in accordance with this European Standard. Orange-peel bull plugs, orange-peel swages and fish tails shall not be used.

Flat closures shall be designed in accordance with ASME Section VIII, Division 1.

Welding shall be performed using procedures and operators qualified in accordance with ISO 13847.