Petroleum and natural gas industries — Pipeline transportation systems

Industries du pétrole et du gaz naturel — Systèmes de transport par conduites
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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13623 was prepared by Technical Committee ISO/TC 67, Materials, equipment and offshore structures for petroleum and natural gas industries, Subcommittee SC 2, Pipeline transportation systems.

Annexes A and B form a normative part of this International Standard. Annexes C, D, E and F are for information only.
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 International Standard is not a design manual; rather, it is intended to be used in conjunction with sound engineering practice and judgement. 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.
Petroleum and natural gas industries — Pipeline transportation systems

1 Scope

This International 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 International Standard is illustrated in Figure 1.

This International 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 International 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.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

NOTE Non-International Standards may be replaced, by agreement, with other recognized and equivalent national or industry standards.


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


ISO 13847, Petroleum and natural gas industries — Pipeline transportation systems — Field and shop 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.


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

API\(^1\) Std 620:1996, Design and construction of large, welded, low-pressure storage tanks.

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


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

MSS\(^4\) SP-25:1998, Standard marking system for valves, fittings, flanges and unions.

MSS SP-44:1996, Steel pipeline flanges.

NFPA\(^5\) 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.
3 Terms and definitions

For the purposes of this International 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 International 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 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 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 International 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 International 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:

- requirements for identification of pipelines, components 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 which take precedence over the requirements in this International Standard shall be specified by the country in which the pipeline 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 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 International 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 International 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:

- 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.

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:

- 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;
- 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 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:

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

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

— bathymetry;
— winds;
— tides;
waves;
— currents;
— atmospheric conditions;
— hydrologic conditions (temperature, oxygen content, pH value, resistivity, biological activity, salinity);
— marine growth;
— 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:
— functional; or
— environmental; or
— construction; or
— 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).

EXEMPLES 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;

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

- sand dune movement;
- sand encroachment.
The following effects shall be considered when designing for ice loads:

- ice frozen on pipelines or supporting structures;
- bottom scouring of ice;
- drifting ice;
- impact forces due to thaw of the ice;
- forces due to expansion of the ice;
- higher hydrodynamic loads due to increased exposed area;
- 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:

— 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, due to fluid pressure only (hoop stress), shall be calculated from the following formula:

$$\sigma_{hp} = \left( p_{id} - p_{od} \right) \cdot \frac{D_o - t_{min}}{2 \cdot t_{min}}$$

where

- $\sigma_{hp}$ 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:

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

\[ \sigma_{eq} \] is the equivalent stress;

\[ \sigma_h \] is the circumferential stress;

\[ \sigma_l \] is the longitudinal stress;

\[ \tau \] 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:

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

#### 6.4.2.2 Yielding

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

\[ \sigma_{hp} \leq F_h \cdot \sigma_y \]

where

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

\[ \sigma_y \] is the specified minimum yield strength (SMYS) at the maximum design temperature.

**NOTE** \[ \sigma_y \] 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

<table>
<thead>
<tr>
<th>Location</th>
<th>$F_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>General route&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0,77</td>
</tr>
<tr>
<td>Crossings and parallel encroachments&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>— minor roads</td>
<td>0,77</td>
</tr>
<tr>
<td>— major roads, railways, canals, rivers, diked flood defences and lakes</td>
<td>0,67</td>
</tr>
<tr>
<td>Pig traps and multi-pipe slug catchers</td>
<td>0,67</td>
</tr>
<tr>
<td>Piping in stations and terminals</td>
<td>0,67</td>
</tr>
<tr>
<td>Special constructions such as fabricated assemblies and pipelines on bridges</td>
<td>0,67</td>
</tr>
</tbody>
</table>

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.

<sup>a</sup> 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).

<sup>b</sup> See 6.9 for the description of crossings and encroachments.

### Table 2 — Hoop stress design factors $F_h$ for offshore pipelines

<table>
<thead>
<tr>
<th>Location</th>
<th>$F_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>General route&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0,77</td>
</tr>
<tr>
<td>Shipping lanes, designated anchoring areas and harbour entrances</td>
<td>0,77</td>
</tr>
<tr>
<td>Landfalls</td>
<td>0,67</td>
</tr>
<tr>
<td>Pig traps and multi-pipe slug catchers</td>
<td>0,67</td>
</tr>
<tr>
<td>Risers and station piping</td>
<td>0,67</td>
</tr>
</tbody>
</table>

<sup>a</sup> 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:

$$\sigma_{eq} \leq F_{eq} \cdot \sigma_y$$

where

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

### Table 3 — Equivalent stress design factors $F_{eq}$

<table>
<thead>
<tr>
<th>Load combination</th>
<th>$F_{eq}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction and environmental</td>
<td>1,00</td>
</tr>
<tr>
<td>Functional and environmental</td>
<td>0,90</td>
</tr>
<tr>
<td>Functional, environmental and accidental</td>
<td>1,00</td>
</tr>
</tbody>
</table>
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:

- pipeline deformations from predictable non-cyclic displacement of supports, ground or seabed, such as fault movement along the pipeline or differential settlement;
- 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;
- 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:

- local buckling of the pipe due to external pressure, axial tension or compression, bending and torsion, or a combination of these loads;
- buckle propagation;
- 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:

- demonstrate that initiation of cracking will 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 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 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;
- 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

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:

- \( 1,25 \times \text{MAOP} \) for pipelines on land; and
- \( 1,25 \times (\text{MAOP} \text{ minus the external hydrostatic pressure}) \) for offshore pipelines.

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

- the ratio of \( \sigma_y \) at test temperature divided by the derated value for \( \sigma_y \) at the design temperature in case of a lower specified minimum yield strength \( \sigma_y \) at the design temperature than exists during testing; and
- the ratio of \( t_{\text{min}} \) plus corrosion allowance divided by \( t_{\text{min}} \) 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:

- \( 1,1 \times \text{MAOP} \) for pipelines on land; and
- \( 1,1 \times (\text{MAOP} \text{ minus the external hydrostatic pressure}) \) 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 International 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:

— the possible effects of pipeline damage on public safety and the environment;
— the possible effects of interference from other activities;
— 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

<table>
<thead>
<tr>
<th>Location</th>
<th>Cover depth m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas of limited or no human activity</td>
<td>0,8</td>
</tr>
<tr>
<td>Agricultural or horticultural activity&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0,8</td>
</tr>
<tr>
<td>Canals, rivers&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1,2</td>
</tr>
<tr>
<td>Roads and railways&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1,2</td>
</tr>
<tr>
<td>Residential, industrial, and commercial areas</td>
<td>1,2</td>
</tr>
<tr>
<td>Rocky ground&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0,5</td>
</tr>
</tbody>
</table>

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.

<sup>a</sup> Cover shall not be less than the depth of normal cultivation.

<sup>b</sup> To be measured from the lowest anticipated bed.

<sup>c</sup> To be measured from the bottom of the drain ditches.

<sup>d</sup> 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:

- any hindrance caused to other users of the area;
- soil stability and settlement;
- pipeline stability;
- cathodic protection;
- pipeline expansion;
- 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:

— operation and maintenance;
— control of emergencies;
— 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:

— provision and location of permanent pig traps or connections for temporary pig traps;
— access;
— lifting facilities;
— isolation requirements for pig launching and receiving;
— requirements for venting and draining (for precommissioning and during operation);
— pigging direction(s);
— permissible minimum bend radius;
— distance between bends and fittings;
— maximum permissible changes in diameter;
— tapering requirements at internal diameter changes;
— design of branch connections and compatibility of line pipe material;
— internal fittings;
— internal coatings;
— 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 International Standard. Where the strength of such components cannot be computed or determined in accordance with the requirements of this International 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 International 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.

Special components shall be capable of withstanding a pressure equal to the pressure during the strength-testing of the pipeline system. Components installed in existing pipeline systems shall be pressure-tested before installation in accordance with 6.7.

6.14.3 Extruded outlets

Extruded outlets shall be designed in accordance with a recognized engineering standard.
6.14.4 Pig traps

All anticipated pigging operations, including possible internal inspection, shall be considered when determining the dimensions of the pig trap.

Pig traps, both permanent and temporary, shall be designed with a hoop stress design factor in accordance with Tables 1 and 2, including such details as vent, drain and kicker branches, nozzle reinforcements, saddle supports. Closures shall comply with ASME Section VIII, Division 1.

Closures shall be designed such that they cannot be opened while the pig trap is pressurized. This may include an interlock arrangement with the main pipeline valves.

Pig traps shall be pressure-tested in accordance with 6.7.

6.14.5 Slug catchers

6.14.5.1 Vessel-type slug catchers

All vessel-type slug catchers, wherever they are located, shall be designed and fabricated in accordance with ASME Section VIII, Division 1.

6.14.5.2 Multi-pipe slug catchers

Multi-pipe slug catchers shall be designed with a hoop stress design factor in accordance with Tables 1 and 2.

6.14.6 Fabricated assemblies

The hoop stress design factors for fabricated assemblies shall apply to the entire assembly and shall extend, excluding transition ends of piping, bends or elbows, for a distance of the lesser of five pipe diameters or 3 m in each direction beyond the last component.

6.15 Attachment of supports or anchors

The pipeline and equipment shall be adequately supported, so as to prevent or to damp out excessive vibration, and shall be anchored sufficiently to prevent undue loads on connected equipment.

Branch connections for pipelines on land shall be supported by consolidated backfill or provided with adequate flexibility.

When openings are made in a consolidated backfill to connect new branches to an existing pipeline on land, a firm foundation shall be provided for both the header and the branch to prevent both vertical and lateral movements.

Braces and damping devices required to prevent vibration of piping shall be attached to the carrier pipe by full encirclement members.

All attachments to the pipeline shall be designed to minimize the additional stresses in the pipeline. Proportioning and welding strength requirements of attachments shall conform to standard structural practice.

Structural supports, braces or anchors shall not be welded directly to pipelines designed to operate at a hoop stress of 50 % or more of SMYS. Instead, such devices shall be supported by a full encirclement member.

Where it is necessary to provide positive support, as at an anchor, the attachment should be welded to the encircling member and not to the pipe. The connection of the pipe to the encircling member shall be by continuous circumferential rather than intermittent welds.

Supports not welded to the pipeline should be designed to allow access for inspection of the pipeline underneath the supports.
Design of anchor blocks to prevent axial movement of a pipeline should take into account the pipeline expansion force and any pipe-to-soil friction preventing movement.

The design of the full encirclement member shall include the combined stress in the carrier pipe of the functional, environmental, construction and accidental loads. Attachment of the full encirclement member may be by clamping or continuous full encirclement welds.

The axial force, \( F \), to be resisted for fully restrained pipelines should be calculated as follows:

\[
F = A \left[ E \alpha (T_2 - T_1) - \nu \sigma_{hp} \right]
\]

where

- \( A \) is the cross-sectional area of pipewall;
- \( E \) is the modulus of elasticity;
- \( \alpha \) is the linear coefficient of thermal expansion;
- \( T_1 \) is the installation temperature;
- \( T_2 \) is the maximum or minimum metal temperature during operation;
- \( \sigma_{hp} \) is the hoop stress due to internal pressure, based on nominal wall thickness;
- \( \nu \) is the Poisson ratio.

Significant residual installation loads shall also be taken into account when determining axial pipeline forces.

### 6.16 Offshore risers

Offshore risers should be given careful design consideration because of their criticality to an offshore installation and its exposure to environmental loads and mechanical service connections. The following factors should be taken into consideration in their design:

- splash zone (loads and corrosion);
- reduced inspection capability during operation;
- induced movements;
- velocity amplification due to riser spacing;
- possibility of platform settlement;
- protection of risers by locating them within the supporting structure.

### 7 Design of stations and terminals

#### 7.1 Selection of location

In selecting the locations for stations and terminals on land, consideration shall be given to:

- topography;
- ground conditions;
Stations and terminals should be located such that the facilities constructed on the site can be protected from fires on adjacent properties which are not under the control of the pipeline operating company.

The location of pipeline facilities within installations, both on land and offshore, should be determined as part of an overall layout review of the installation, taking into account the results of safety evaluations. Possible consequences on personnel accommodation and evacuation in the case of explosion or fire should be minimized.

7.2 Layout

Open space shall be provided around stations and terminals for the free movement of fire-fighting equipment. Sufficient access and clearance shall be provided at stations and terminals for movement of fire-fighting and other emergency equipment.

Layouts of stations and terminals shall be based on minimizing the spread and consequences of fire.

Areas within stations and terminals with possible explosive gas mixtures shall be classified in accordance with IEC 60079-10 and the requirements for plant and equipment defined accordingly.

Spacing of tankage shall be in accordance with NFPA 30.

Piping shall be routed such that trip or overhead hazards to personnel are avoided, and access to piping and equipment for inspection and maintenance is not hindered. Requirements for access for replacement of equipment shall also be considered when routing primary piping.

Vent and drain lines to atmosphere shall be extended to a location where fluids may be discharged safely. Particular attention shall be paid to safety in locating vent and drain lines near living quarters on offshore installations.

7.3 Security

Access to stations and terminals shall be controlled. They should be fenced, with gates locked or attended.

Permanent notices shall be located at the perimeter indicating the reference details of the station or terminal and a telephone number at which the pipeline operating company may be contacted.

Security requirements for pipeline facilities within a station, terminal or installation shall be established in conjunction with the requirements for the station, terminal or installation.

7.4 Safety

Signs shall be placed to identify hazardous, classified and high-voltage areas. Access to such areas shall be controlled.

Fences shall not hinder the escape of personnel to a safe location. Escape gates shall open outward and be capable of being opened from the inside without a key when the enclosure is occupied.
Adequate exits and unobstructed passage to a safe location shall be provided for each operating floor of main pump and compressor buildings, basements, and any elevated walkway or platform. Exits shall provide a convenient possibility of escape.

Appropriate fire and gas detection and fire-fighting facilities shall be provided. For stations and terminals on land, the requirements for such facilities shall be established in consultation with the local fire authorities.

Tanks, dikes and firewalls shall meet the requirements of NFPA 30.

Ventilation shall be provided to prevent the exposure of personnel to hazardous concentrations of flammable or noxious liquids, vapours or gases in enclosed areas, sumps and pits during normal and abnormal conditions such as a blown gasket or packing gland. Equipment for the detection of hazardous concentrations of fluids shall be provided.

Hot and cold piping which may cause injury to personnel shall be suitably insulated or protected.

7.5 Environment

The disposal of effluent and discharges shall comply with national and local environmental requirements.

7.6 Buildings

Pump and compressor buildings, which house equipment or piping in sizes larger than 60 mm outside diameter, or equipment for conveying, except for domestic purposes, category D and E fluids, shall be constructed of fire-resistant, non-combustible or limited combustibility materials defined in NFPA 220.

7.7 Equipment

Pumps and compressors, prime movers, their auxiliaries, accessories, control and support systems, shall be suitable for the services specified in the system definition in accordance with 5.1. Pumps, compressors and their prime movers shall be designed for a range of operating conditions within the constraints of the pipeline system as limited by the controls identified in 5.4.

Prime movers, except electrical induction or synchronous motors, shall be provided with an automatic device which is designed to shut down the unit before the speed of the prime mover or of the driven unit exceeds the maximum safe speed specified by the manufacturer.

Plant and equipment shall meet the requirements of the area classification in accordance with 7.2.

7.8 Piping

7.8.1 Primary piping

Piping for conveying or storing fluids shall meet the strength requirements of 6.4.

NOTE 1 Tables 1 and 2 specify hoop stress design factors for piping.

Vibrations caused by vibrating equipment, fluid pulsations from reciprocating pumps or compressors and flow induced pulsations shall be considered during the piping design.

Piping shall be protected against damage from vacuum pressures and overpressures. Pressure control and overpressure protection shall comply with the requirements of 5.4.

NOTE 2 Piping may be subjected to overpressure or vacuum conditions as a result of surge following a sudden change in flow during valve closure or pump shutdown, excessive static pressure, fluid expansion, connection to high-pressure sources during a fault condition, or as a result of a vacuum created during shutdown or drain-down of the pipeline.
7.8.2 Secondary piping

7.8.2.1 Fuel gas piping

Fuel gas piping within a station shall be designed in accordance with ASME B31.3.

Fuel gas lines shall be provided with master shut-off valves located outside any building or residential quarters.

The fuel gas system shall be provided with pressure-limiting devices to prevent fuel pressures from exceeding the normal operating pressure of the system by more than 25%. The maximum fuel pressure shall not exceed the design pressure by more than 10%.

Provision shall be made to vent and purge fuel headers to prevent fuel gas from entering combustion chambers when work is in progress on the drivers or connected equipment.

7.8.2.2 Air piping

Air piping within a station shall be designed in accordance with ASME B31.3.

Air receivers or air storage bottles shall be constructed and equipped in accordance with ASME Section VIII, Division 1.

7.8.2.3 Lubricating oil and hydraulic oil piping

All lubricating oil and hydraulic oil piping within stations shall be designed and constructed in accordance with ASME B31.3.

7.8.2.4 Vent and drain lines

Vent and drain lines shall be sized to match the capacity of relief valves.

7.9 Emergency shutdown system

Each pump or compressor station shall be provided with an emergency shutdown system that is readily accessible, locally and/or remotely operated, and which will shut down all prime movers. Consideration should also be given to isolating the station from the pipeline and to relieving or venting the piping system when required.

Operation of the emergency shutdown system shall also permit the shutdown of any gas-fired equipment that could jeopardize the safety of the site provided it is not required for emergency purposes.

Uninterrupted power supply shall be provided for personnel protection and those functions that are necessary for protection of equipment.

7.10 Electrical

Electrical equipment and wiring installed in stations shall conform to the requirements of IEC 60079-14. Electrical installations which are to remain in operation during an emergency shall be based on the zone applicable during the emergency.

7.11 Storage and working tankage

Tanks for storage or handling of fluids shall be designed and constructed in accordance with the following standards:
— API 650 for fluids with a vapour pressure less than 0.035 bar(g);
— API 620 for fluids with a vapour pressure higher than 0.035 bar(g) but not more than 1 bar(g);
— this International Standard for pipe-type holders used for fluids with a vapour pressure of more than 1 bar(g);
— applicable standards for holders other than pipe-type holders for fluids with a vapour pressure of more than 1 bar(g).

Foundations shall be designed and constructed in accordance with plans and specifications which shall take into account local soil conditions, type of tank, usage and general location.

7.12 Heating and cooling stations
Temperature indication and controls should be provided where heating or cooling of the fluids is required for operation of the pipeline in accordance with 5.1.
For heating stations, trace heating may be required on pipework, pump bodies, drains and instrument lines to ensure satisfactory flow conditions following shutdown.

7.13 Metering and pressure control stations
Meters, strainers and filters shall be designed for the same internal pressure, and shall meet the pressure-test requirements of this International Standard.
Components shall be supported in such a manner as to prevent undue loading to the connecting piping system.
Design and installation shall provide for access and ease of maintenance and servicing while minimizing interference with the station operations. Consideration shall be given to backflow, vibration or pulsation of the flowing stream.
The retention size of any filtering medium shall be selected to protect the facilities against the intrusion of harmful foreign substances and to prevent electrostatic charge accumulation.

7.14 Monitoring and communication systems
The requirements for monitoring pressure, temperature, flowrate, physical characteristics of the fluid being conveyed, information on pumps, compressors, valve positions, meters and tank levels, together with alarm conditions such as power supply failure, high temperature of electric motor windings and rotating machinery bearings, excessive vibration levels, low suction pressures, high delivery pressures, seal leakage, abnormal temperatures, and the detection of fire and hazardous atmosphere shall be defined and included in the system design in accordance with clause 5.

Supervisory control and data acquisition (SCADA) systems may be used for controlling equipment.

Operating requirements of the pipeline system, as well as safety and environmental requirements, shall be the basis for determining the need for redundant monitoring and communication components, and back-up power supply.

8 Materials and coatings

8.1 General material requirements

8.1.1 Selection
Materials for use in the pipeline system shall:
— have the mechanical properties, such as strength and toughness, necessary to comply with the design requirements of 6.4;

— have the properties necessary to comply with the requirements for corrosion control of clause 9;

— be suitable for the intended fabrication and/or construction methods.

### 8.1.2 Materials for sour service

Specifications for materials in sour service shall include the requirement for performance testing to demonstrate resistance to sulfide stress-cracking and hydrogen-induced cracking, if the suitability of the materials for sour service is not stated in other standards.

**NOTE** Requirements to prevent hydrogen-induced cracking may include reduction and/or shape control of non-metallic inclusions.

### 8.1.3 Consistency of requirements

Requirements shall be specified consistently for all pressure-containing components in the pipeline system.

**EXAMPLES** Chemical composition to ensure weldability; toughness to prevent brittle fracture.

### 8.1.4 Chemical composition

Ferritic steel materials intended for welding and for which a product standard is not available should have a maximum carbon equivalent (CE) of:

— 0,45 for grades with a specified minimum yield strength not exceeding 360 MPa; and

— 0,48 for grades with a specified minimum yield strength above 360 MPa.

Ferritic steel materials intended for welding and for which a product standard is available shall have a CE not exceeding the above values or the values quoted in the product standard, whichever is the lowest.

The purchaser of materials may consider applications for which higher CEs will be acceptable or the acceptable maximum CE requires further limitation.

The CE shall be calculated as follows:

\[
CE = \%C + (\%Mn/6) + (\%Cr + \%Mo + \%V)/5 + (\%Cu + \%Ni)/15
\]

For pipelines designed for category A fluids, where the full chemical composition is not reported, an alternative CE formula may be used.

\[
CE = \%C + (\%Mn/6) + 0,04
\]

### 8.1.5 Brittle fracture toughness

Materials in pipeline systems shall be selected and applied in such a way that brittle fracture is prevented.

Materials used in pipelines transporting category C, D and E fluids, with a nominal diameter above DN 150 and of ferritic, ferritic/austenitic or martensitic stainless or carbon steel, shall meet the following minimum Charpy impact energy values for full-size Charpy V-notch test specimens:

— 27 J average/20 J individual for grades with a specified minimum yield strength not exceeding 360 MPa; and

— 40 J average/30 J individual for grades with a specified minimum yield strength above 360 MPa.
The requirements for preventing brittle fracture of materials in pipelines transporting category A and B fluids and of components with a nominal diameter not exceeding DN 150 in pipelines transporting category C, D and E fluids shall be determined based on the design conditions for the pipeline system.

NOTE Higher impact values can be required to arrest running ductile fractures (see 8.1.6).

Full-size Charpy V-notch tests shall be carried out in accordance with ISO 148. The alternative, tapered test pieces specified by ISO 3183 (all parts), may also be used. Reduced-size specimens may be tested and the minimum required impact energy values reduced in proportion to the thickness of the specimen when the thickness of the components to be tested does not permit a full-size Charpy V-notch test.

The test temperature shall not be higher than the minimum temperature the pipeline may experience, whilst under pressure. Lower test temperatures shall be considered for gas or gas/liquid lines, for offshore risers and for large-thickness components.

The requirements for preventing brittle fracture shall be met in parent metal and, for welded components, weld metal and heat-affected zones by the use of a welding procedure qualified to provide the specified brittle fracture resistance.

8.1.6 Shear fracture toughness

Parent metal of line pipe for pipelines conveying category C, D, and E fluids shall be capable of arresting running shear fractures. The phase behaviour of fluids during sudden decompression shall be determined and the required shear fracture arrest properties verified for all phases.

Line pipe for use in pipelines conveying category D fluids shall meet the Charpy energy values of Table 5.

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Minimum value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2.67 \times 10^{-4} \cdot \sigma_{\text{hp}}^{1.5} \cdot D_0^{0.5}$ with a minimum value of 40</td>
</tr>
<tr>
<td>L245 to L450</td>
<td>$3.21 \times 10^{-4} \cdot \sigma_{\text{hp}}^{1.5} \cdot D_0^{0.5}$</td>
</tr>
<tr>
<td>L485</td>
<td>$3.57 \times 10^{-5} \cdot \sigma_{\text{hp}}^{2} \cdot \left(\frac{D_0}{2}\right)^{1/3} \cdot t_{\text{nom}}^{1/3}$</td>
</tr>
<tr>
<td>L555</td>
<td></td>
</tr>
</tbody>
</table>

Values shall apply to all heat average values of full-size Charpy V-notch tests. Hoop stress $\sigma_{\text{hp}}$ in MPa, and diameter $D_0$ and nominal wall thickness $t_{\text{nom}}$ in mm.

Charpy V-notch tests shall be carried out, in accordance with the requirements of 8.1.5, at the minimum temperature the pipeline may experience during service under the effect of lowest air, seawater or ground temperature.

Mechanical crack arrestors consisting of sleeves or heavy-wall pipe may be applied where it is not practical to achieve the requirements of Table 5. The consequences of fracture propagation shall determine the locations and minimum spacing of arrestors along the pipeline.

8.1.7 Higher-temperature service

The mechanical properties at the maximum operating temperature of materials for operations above 50 °C should be documented unless specified in the referenced product standard or complementary justification.
8.1.8 Properties after forming and heat treatment

For materials subjected to heat treatment, hot or cold forming, or other processes which can affect the material properties, compliance with the specified requirements in the final condition shall be documented. Documentation shall be provided for parent metal and, in the case of welded components, for weld metal and heat-affected zones.

8.1.9 Production qualification programmes

Requirements for production qualification programmes and pre-production testing for material should be considered on the basis of available experience with previous fabrication of that material.

8.1.10 Marking

Materials and components shall be marked in accordance with the requirements of the applicable product standard or, if not specified, the requirements of MSS SP-25.

Marking by die stamping shall be done in a manner resulting in minimum stress concentrations and at locations where the marking will not be harmful.

8.1.11 Inspection documents

All materials shall be supplied with an inspection document in accordance with ISO 10474 which can be traced to the pipeline component. For materials for pressure-retaining components, an inspection certificate type 3.1.B in accordance with ISO 10474 shall be supplied as a minimum.

8.1.12 Specifications

All materials for line pipe, piping components and coatings shall be manufactured and used in accordance with the requirements of the relevant product standard and of this International Standard.

Requirements of this International Standard not included in the relevant product standard shall be specified and supplemented to the product standard.

Detailed specifications, which shall include the required properties, dimensional requirements and requirements for fabrication, testing, inspection, certification and documentation, shall be prepared for materials if a relevant product standard is not available.

8.1.13 Reuse of components

The reuse of components is permitted provided:

— the specification for the original fabrication is known and meets the requirements of this International Standard;
— inspection documentation complies with the requirements of 8.1.11;
— it is demonstrated by inspection, following cleaning, and repair where permitted by this International Standard, that they are sound and free from defects.

Line pipe for which the specification of the original fabrication is not known may be used as grade L245 only provided it is demonstrated by adequate inspection and testing that the line pipe meets the requirements of the appropriate part of ISO 3183. The use of such materials shall be limited to pipelines operating at stress levels below 30 % of the specified minimum yield strength.

NOTE The operator of a pipeline system can clarify in project specifications his acceptance of the reuse of materials.
8.1.14 Records

Specifications with agreed deviations, design dossier such as calculations and drawings, test and inspection results, and certification shall be collected for retention during operations, in accordance with the requirements of 13.1.7.

8.2 Line pipe

8.2.1 Carbon steel pipe

Line pipe made of C-Mn steel shall conform to ISO 3183-1, ISO 3183-2 or ISO 3183-3. ISO 3183-2 or ISO 3183-3 line pipe shall be used for applications where fracture toughness is required in 8.1.5 and 8.1.6. ISO 3183-3 shall be used for applications in sour service.

8.2.2 Stainless steel and non-ferrous metallic pipe

Stainless steel and non-ferrous metallic line pipe may be welded or seamless pipe.

8.2.3 Carbon steel pipe with stainless steel or non-ferrous metallic layer

Carbon steel line pipe shall conform to ISO 3183-1, ISO 3183-2 or ISO 3183-3. ISO 3183-2 or ISO 3183-3 line pipe shall be used for applications where fracture toughness is required by 8.1.5 and 8.1.6.

The design and internal corrosion evaluation shall address whether the internal stainless steel or non-ferrous metallic layer should be metallurgically bonded (clad) or may be mechanically bonded (lined) to the outer carbon steel pipe. The minimum thickness of the internal layer should not be less than 3 mm in the pipe and at the weld.

The requirement of pipe-end tolerances closer than specified in the appropriate part of ISO 3183 for welding shall be reviewed and specified if deemed necessary.

8.3 Components

8.3.1 Flanged connections

Flanged connections shall meet the requirements of ISO 7005-1, or other recognised codes such as ASME B16.5 or MSS SP-44. Proprietary flange designs are permissible. They should conform to relevant sections of ASME Section VIII, Division 1.

Compliance with the design requirements of ASME B16.5 shall be demonstrated when deviating from the flange dimensions and drillings specified in ASME B16.5 or MSS SP-44.

Consideration shall be given to matching the flange bore with the bore of the adjoining pipe wall to facilitate alignment for welding.

Gaskets shall be made of materials which are not damaged by the fluid in the pipeline system and shall be capable of withstanding the pressures and temperatures to which they will be subjected in service. Gaskets for services with operating temperatures above 120 °C shall be of non-combustible materials.

Bolt material shall be in accordance with ASTM A193 B7 or equivalent. Nut material shall be in accordance with ASTM A194 2H or equivalent. Bolts or studbolts shall completely extend through the nuts.
8.3.2 Bends made from pipe

Bends may be made from pipe by hot, cold or induction bending. The requirements for such bends are:

- pipe shall be of fully killed steels;
- the ovality of the bend body shall not exceed 2.5 % of the nominal outside diameter;
- bend end tolerances shall meet the pipe end tolerances of the matching pipe;
- wrinkling shall not be permitted;
- all areas of the bend shall comply with the requirements for specified minimum wall thickness of the adjacent piping;
- bends shall comply with the mechanical properties specified for the pipe in 8.2.

Testing and inspection of bends shall be done in the delivery condition.

Mitred bends shall not be used.

8.3.3 Fittings

Fittings shall be made from fully killed steel and made using recognized practices to provide the intended heat treat response and notch toughness properties.

Steel should comply with the requirements specified in ASTM A182, ASTM A350, MSS SP-75, ASME B16.9 or equivalent standards.

8.3.4 Valves

Ball, check, gate and plug valves shall meet the requirements of ISO 14313. Valves for subsea application shall meet the requirements of ISO 14723.

8.3.5 Prefabricated isolating couplings

Prefabricated isolating couplings shall be pressure-tested to 1.5 times MAOP and tested electrically to confirm the electrical discontinuity, prior to installation in the pipeline.

8.3.6 Other components

The design of components for which there is no product standard shall meet the requirements of ASME Section VIII, Division 1.

8.4 Coatings

8.4.1 General

All external and internal coatings shall comply with a recognized standard or specification, covering the following requirements:

- type of coating and reinforcement, where relevant;
- thickness of individual layers and total thickness;
- composition and/or base material;
— mechanical properties;
— temperature limitations;
— surface preparation requirements;
— adhesion requirements;
— requirements for materials, application and curing, including possible requirements for health, safety and environmental aspects;
— requirements for qualification testing of coating system and personnel where relevant;
— requirements for testing and inspection;
— repair procedures where relevant.

8.4.2 External coatings

8.4.2.1 Concrete weight coatings

Concrete weight coating shall comply with a specification which, in addition to the requirements of 8.4.1, covers the following requirements:

— composition of the concrete;
— required mechanical properties and test requirements;
— thickness and mass, including tolerances;
— reinforcement;
— adhesion to the pipe;
— requirements for application and curing;
— sacrificial anode installation;
— water absorption.

8.4.2.2 Coating for corrosion prevention and thermal insulation

Coating should comply with the requirements of 9.4 and 9.5.

8.4.3 Internal coatings/linings

Internal coating should in general comply with the requirements of 9.3.5 if applied to mitigate internal corrosion.

Anti-friction coatings should as a minimum comply with API RP 5L2 and have a minimum thickness of 40 μm. The coating may consist of an epoxy base and a curing agent based on epoxy aliphatic/cycloaliphatic amine or polyamide.
9 Corrosion management

9.1 General

Internal and external corrosion of pipeline systems shall be managed to prevent unacceptable risk of pipeline failure or loss of operability from corrosion within the specified design life. The corrosion management should include:

- identification and evaluation of the potential sources of corrosion;
- selection of the pipeline materials;
- identification of the necessary corrosion mitigation;
- definition of the requirements for corrosion monitoring and inspection;
- review of the findings from corrosion monitoring and inspection;
- periodic modification of the requirements of corrosion management, as dictated by experience and changes in the design conditions and environment of the pipeline.

Internal and external corrosivity evaluations shall be carried out to document that, for the selected material(s), corrosion can be controlled within the design intent over the design life of the pipeline.

The evaluations should be based on relevant operating and maintenance experience and/or the results of laboratory testing.

Any corrosion allowance should take into account the type and rate of corrosion predicted for the design life of the pipeline.

Possible internal and external corrosion of pipeline materials during transport, storage, construction, testing, preservation, commissioning and operational upset conditions shall be included in the evaluations.

9.2 Internal corrosivity evaluation

Possible loss or degradation of the pipeline materials shall be determined for all design conditions (5.1).

The possible formation of free liquid water shall be evaluated for the fluid velocities, pressures and temperatures anticipated during operations.

Components of the fluid(s) which may cause or affect internal corrosion shall be identified, and their potential for corrosion determined for the predicted ranges of concentrations, pressures and temperatures.

EXAMPLES Components which may cause or affect internal corrosion of pipelines transporting natural gases, crude oils or other produced fluids include carbon dioxide, hydrogen sulfide, elemental sulfur, mercury, oxygen, water, dissolved salts (chlorides, bicarbonates, carboxylates, etc.), solid deposits (in relation to line cleanliness), bacterial contamination, chemical additives injected during upstream activities, contamination from upstream process upsets.

The types of potential corrosion to be addressed shall include:

- general material loss and degradation;
- localized corrosion, such as pitting under deposits and mesa- or crevice-type attack;
- microbiologically induced corrosion;
- stress cracking;
— hydrogen-induced cracking or stepwise cracking;
— stress-oriented hydrogen-induced cracking;
— erosion and erosion-corrosion;
— corrosion fatigue;
— bimetallic/galvanic couples including preferential weld corrosion.

9.3 Internal corrosion mitigation

9.3.1 Methods

Methods for the mitigation of internal corrosion may include:

— a modification of design/operating conditions;
— the use of corrosion-resistant materials;
— the use of chemical additives;
— the application of internal coatings or linings;
— the use of regular mechanical cleaning;
— the elimination of bimetallic couples.

The compatibility of the selected mitigation with downstream operations should be considered.

9.3.2 Revision of design conditions

The fluid processing facilities upstream of the pipeline, and the procedures for operating the pipeline, may be reviewed to identify opportunities for the removal of corrosive components or conditions identified during the corrosivity evaluation.

9.3.3 Corrosion-resistant materials

The selection of a corrosion-resistant material shall take into account the results of the internal (9.2) and external (9.4) corrosivity evaluations.

9.3.4 Chemical additives

Factors to be considered during the selection of chemical additives should include:

— effectiveness at water-wetted areas over the full pipeline circumference and length;
— velocity variation of pipeline fluids;
— partitioning behaviour in multiphase systems;
— influence of sediments and scales;
— compatibility with other additives;
— compatibility with the pipeline component materials, in particular non-metallic materials in pipeline accessories;
9.3.5 Internal coatings or linings

Coatings or linings may be applied to reduce internal corrosion provided that it is demonstrated that incomplete protection, at areas such as holidays and other defects, does not lead to unacceptable corrosion.

Factors to be considered during coating or lining selection should include:

- internal coating of field joints;
- application methods;
- availability of repair methods;
- operating conditions;
- long-term effects of the fluid(s) on the coating/lining;
- resistance to pressure change;
- influence of temperature gradients over the coating;
- compatibility with pigging operations.

9.3.6 Cleaning

Requirements for the periodic internal mechanical cleaning of a pipeline should be determined. Factors to be considered should include:

- the removal of accumulated solids and/or pockets of corrosive liquid to assist in the reduction of corrosion in these areas;
- enhancement of the effectiveness of chemical additives.

In choosing a mechanical cleaning device, consideration should be given to:

- the possible consequences of removing protective layers of corrosion products or chemical additives, or damage to internal coatings or linings, by mechanical cleaning;
- the possible adverse effects of contacts between pipeline materials, such as stainless steels, and the materials of mechanical cleaning devices.

9.4 External corrosion evaluation

The possibility of external corrosion occurring shall be determined on the basis of pipeline operating temperatures (see 5.1) and the external conditions along the pipeline (see 6.2).

Table 6 lists typical environments which shall be considered when evaluating the possibility of external corrosion.
Table 6 — Environments to be considered for external corrosion

<table>
<thead>
<tr>
<th>Offshore pipelines</th>
<th>Pipelines on land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere (marine)</td>
<td>Atmosphere (marine/industrial/rural)</td>
</tr>
<tr>
<td>Air/water interface (splash zone)</td>
<td>Sea water (tidal zone/shore approach)</td>
</tr>
<tr>
<td>Sea water</td>
<td>Fresh or brackish water</td>
</tr>
<tr>
<td>Seabed or buried in seabed</td>
<td>Marshes and swamps</td>
</tr>
<tr>
<td>Inside bundles or sleeves</td>
<td>River crossings</td>
</tr>
<tr>
<td>Rock dump/concrete mattresses</td>
<td>Dry or wet soil</td>
</tr>
<tr>
<td>Inside J-tubes/caissons</td>
<td>Inside tunnels, sleeves or caissons</td>
</tr>
</tbody>
</table>

Environmental parameters which should be considered include:

— ambient temperatures;

— resistivity, salinity and oxygen content of the environment;

— bacterial activity;

— water current;

— degree of burial;

— potential in-growth of tree roots;

— potential soil pollution by hydrocarbons and other pollutants.

The evaluation of corrosion measures should take into account the probable long-term corrosivity of the environment rather than be solely confined to the as-installed corrosivity. For a pipeline on land, due consideration should be given to any known planned changes in the use of the land traversed by the pipeline route which may alter the environmental conditions and thus soil corrosivity, e.g. irrigation of land previously arid or of low corrosivity.

The possible effect of the pH of the environment and possible sources of stray and alternating currents shall be evaluated for pipelines on land.

The types of external corrosion damage to be considered shall include:

— general metal loss and degradation;

— localized corrosion, e.g. pitting under deposit or crevice attack;

— microbiologically induced corrosion;

— stress-corrosion cracking, e.g. carbonate/bicarbonate attack.

9.5 External corrosion mitigation

9.5.1 Protection requirements

All metallic pipelines should be provided with an external coating and, for buried or submerged sections, cathodic protection. The use of corrosion allowance and a durable coating or the use of a corrosion-resistant alloy cladding should also be considered for areas with a high probability of severe corrosion.
EXAMPLE The splash zone is an area with a high probability of severe external corrosion of risers in offshore pipelines.

9.5.2 External coatings

The effectiveness in providing the required protection and the possible hazards during application and service shall be considered when selecting external coatings.

Parameters to be considered when evaluating the effectiveness of external coatings shall include:

— electrical resistivity of the coating;
— moisture permeation and its relation to temperature;
— required adhesion between the coating and the pipeline base material;
— required resistance to shear forces between the coating and additional coating, insulation or environment;
— susceptibility to cathodic disbondment;
— resistance to ageing, brittleness and cracking;
— requirements for coating repair;
— possible detrimental effects on the pipe material;
— possible thermal cycling;
— resistance to damage during handling, shipping, storage, installation and service.

External coatings of line pipe should be factory-applied, except for field joints and other special points which shall be coated on site.

Field joints should be protected with a coating system which is compatible with the line-pipe coating. The coating should meet or exceed the line-pipe coating specification and allow satisfactory application under the predicted field conditions. The protection of thermally insulated pipelines may require an external coating between the pipeline and the insulation.

Pipelines in J-tubes should be externally coated. Possible coating damage during installation inside J-tubes should be considered when selecting a coating.

9.5.3 Cathodic protection

9.5.3.1 Cathodic protection potentials

Cathodic protection potentials shall be maintained within the limits given in Table 7 throughout the design life of the pipeline.
Table 7 — Cathodic protection potentials for non-alloyed and low-alloyed pipelines

<table>
<thead>
<tr>
<th>Reference electrode</th>
<th>Cu/CuSO₄</th>
<th>Ag/AgCl/Seawater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and low-resistivity soil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistivity &lt;100 Ω·m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobic $T &lt; 40 , ^\circ C$</td>
<td>$-0,850 , V$</td>
<td>$-0,800 , V$</td>
</tr>
<tr>
<td>Aerobic $T &gt; 60 , ^\circ C$</td>
<td>$-0,950 , V$</td>
<td>$-0,900 , V$</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>$-0,950 , V$</td>
<td>$-0,900 , V$</td>
</tr>
<tr>
<td>High-resistivity aerated sandy soil regions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistivity 100 Ω·m to 1000 Ω·m</td>
<td>$-0,750 , V$</td>
<td>$-0,700 , V$</td>
</tr>
<tr>
<td>Resistivity &gt; 1000 Ω·m</td>
<td>$-0,650 , V$</td>
<td>$-0,600 , V$</td>
</tr>
</tbody>
</table>

**NOTE 1** Potentials in this Table and in NOTE 4 apply to line pipe materials with actual yield strengths of 605 MPa or less.

**NOTE 2** The possibility for hydrogen embrittlement should be evaluated for steels with actual yield strengths above 605 MPa.

**NOTE 3** For all steels the hardness of longitudinal and girth welds and their implications for hydrogen embrittlement under cathodic protection should be considered.

**NOTE 4** The protection potential at the metal-medium interface should not be more negative than $-1,150 \, V$ in case of Cu/CuSO₄ reference electrodes, and $-1,100 \, V$ in case of Ag/AgCl reference electrodes. More negative values are acceptable provided it is demonstrated that hydrogen embrittlement damage cannot occur.

**NOTE 5** The required protection potentials for stainless steels vary. However, the protection potentials shown above can be used. For duplex stainless steels used for pipelines, extreme care should be taken to avoid voltage overprotection which could lead to hydrogen-induced failures.

**NOTE 6** If the protection levels for low-resistivity soils cannot be met, then these values may be used subject to proof of the high-resistance conditions.

**NOTE 7** Alternative protection criteria may be applied provided it is demonstrated that the same level of protection against external corrosion is provided.

**NOTE 8** The values used should be more negative than those shown within the constraints of the NOTES 1 to 7.

The protection potential criteria shown in Table 7 apply to the metal-medium interface. In the absence of interference currents this potential corresponds to the instantaneous "off" potential.

9.5.3.2 Design

The current density shall be appropriate for the pipeline temperature, the selected coating, the environment to which the pipeline is exposed and other external conditions which can effect current demand. Coating degradation, coating damage during construction and from third-party activities, and metal exposure over the design life should be predicted and taken into account when determining the design current densities.

9.5.3.2.1 Sacrificial anodes

The design of sacrificial anode protection systems shall be documented and include reference to:

- pipeline design life (see 5.1);
- design criteria and environmental conditions;
- applicable standards;
- requirements for electrical isolation;
9.5.3.2 Impressed current

The design of impressed-current protection systems shall strive for a uniform current distribution along the pipeline and shall define the permanent locations for the measurement of the protection potentials (see 9.5.3.3).

Design documentation shall at least include reference to:

- pipeline design life (see 5.1);
- design criteria and environmental conditions;
- requirements for electrical isolation;
- calculations of the pipeline area to be protected;
- anode ground bed design, its current capacity and resistance and the proposed cable installation and protection methods;
- measures required to mitigate the effects of possible a.c. and/or d.c. electrical interference;
- protection requirements prior to the commissioning of the impressed current system;
- applicable standards.

9.5.3.2.3 Connections

Cathodic protection anodes and cables should be joined to the pipeline by connections with a metallurgical bond.

The design of the connections should consider:

- the requirements for adequate electrical conductivity;
- the requirements for adequate mechanical strength and protection against potential damage during construction;
- the metallurgical effects of heating the line pipe during bonding.

The use of double plates should be considered when connecting anodes and cables to stainless steel pipelines. Possible interference by extraneous d.c. current sources in the vicinity of a pipeline and the possible effect of the protection of a new pipeline on existing protection systems shall be evaluated.

The shielding by thermal insulation and possible adverse effects of stray currents from other sources should be evaluated when considering cathodic protection systems for insulated pipelines.

9.5.3.3 Specific requirements for pipelines on land

Cathodic protection should normally be provided by impressed current.
NOTE 1 Sacrificial anode protection systems are normally only practical for pipelines with a high-quality coating in low-resistivity environments. The suitability of backfill material at anode locations should be reviewed.

Protected pipelines should, where practical, be electrically isolated from other structures, such as compressor stations and terminals, by suitable in-line isolation components.

Isolating joints should be provided with protective devices if damage from lightning or high-voltage earth currents is possible.

Low-resistance grounding to other buried metallic structures shall be avoided.

NOTE 2 It is recommended that the pipeline be isolated from structures, such as wall entries and restraints made of reinforced concrete, from the earthing conductors of electrically operated equipment and from bridges.

The possibility for corrosion on the unprotected sides of isolating couplings shall be considered when low-resistance electrolytes exist internally or externally.

Electrical continuity shall be provided across components, other than couplings/flanges, which would otherwise increase the longitudinal resistance of the pipeline.

The corrosion protection requirements of pipeline sections within sleeve or casing pipe shall be identified and applied.

Spark gaps shall be installed between protected pipelines and lightning protection systems.

If personnel safety is at risk or if an a.c. corrosion risk exists, unacceptably high a.c. voltages on a pipeline shall be prevented by providing suitable earthing devices between the pipeline and earthing systems without impacting on the cathodic protection.

Test points for the routine monitoring and testing of the cathodic protection should be installed at the following locations:

- crossings with d.c. traction systems;
- road, rail and river crossings and large embankments;
- sections installed in sleeve pipes or casings;
- isolating couplings;
- where pipelines run parallel to high-voltage cables;
- sheet piles;
- crossings with other major metallic structures with, or without, cathodic protection.

Additional test points, regularly spaced along the pipeline, should be considered to enable cathodic protection measurements to be taken for the entire pipeline route.

NOTE 3 The required test spacing depends on soil conditions, terrain and location.

9.5.3.4 Specific requirements for offshore pipelines

Cathodic protection should be by sacrificial anodes.

NOTE Experience has indicated that sacrificial anodes provide effective protection with minimum requirements for maintenance.
Electrical isolation is not typically provided between an offshore pipeline and its metallic support structure. However, electrical isolation may be provided between an offshore pipeline and connected metallic structures or other pipelines to allow the separate design and testing of the corrosion protection systems.

The cathodic protection of individual pipelines and structures shall be compatible if isolation is not provided.

Cathodic protection measurement points and techniques for offshore pipelines shall be selected to provide representative measurements of the cathodic protection levels.

Design of sacrificial anodes should be consistent with the pipeline construction method and the requirements associated with lay-barge tensioning equipment. Anode locations associated with pipeline crossings require special attention.

9.5.3.5 Cathodic protection system commissioning

Cathodic protection systems based on impressed current should normally be commissioned as soon as possible following pipeline installation. The requirement for temporary protection shall be determined in case of delays.

For all cathodic protection systems, the appropriate items from the list below shall be executed early in a system’s life:

— visual inspection of anodes and pipeline coatings during installation;
— testing of power supplies;
— completion of an initial cathodic protection survey to include:
  1) testing for detrimental stray or interference currents,
  2) measurement of current demand,
  3) testing of isolating couplings,
  4) measurement of the cathodic protection potentials along the length of the pipeline;
— corrective measures if the specified protection is not achieved;
— provision of commissioning records.

9.6 Monitoring programmes and methods

9.6.1 Requirement for monitoring

The requirements for corrosion monitoring programmes shall be established on the basis of the predicted corrosion mechanisms and corrosion rates (see 9.2 and 9.4), the selected corrosion mitigation methods (see 9.3 and 9.5) and safety and environmental factors.

The use of internal inspection tools should be considered if monitoring of internal or external corrosion or other defects is required over the full length of the pipeline. Approximate rates or trends of corrosion degradation may be determined by analysis of results of consecutive metal loss inspections.

NOTE An inspection of the pipeline soon after commissioning should be considered to provide a baseline for the interpretation of future surveys.
9.6.2 Monitoring internal corrosion

9.6.2.1 Selection of techniques

The selection of techniques for the monitoring of internal corrosion shall consider:

— anticipated type of corrosion;
— potential for water separation, erosion, etc. (flow characteristics);
— anticipated corrosion rate (see 9.2);
— required accuracy;
— available internal and external access;
— hindrance of passage of pigs or inspection vehicles by internal obstructions.

NOTE Possible techniques include the installation of devices such as coupons, to give an indication of the corrosion in the pipeline, or periodic analyses of the fluid to monitor its corrosivity.

9.6.2.2 Location of test points for local corrosion monitoring

Test points for corrosion monitoring should be located along the pipeline or associated facilities, where representative indications of corrosion in the pipeline are most likely to be obtained.

9.6.3 Monitoring external pipeline condition

Accessible pipeline sections should be visually surveyed periodically to assess the conditions of the pipeline and, where applied, its coating. Buried or submerged pipelines shall also be inspected when exposed.

Close visual examination of the coating shall be carried out periodically at locations with a high probability of severe corrosion.

NOTE Periodic close internal protection surveys of the pipeline coating can be considered for this purpose where the area of possibly severe attack cannot readily be visually examined.

The requirements for periodic surveys of the coating of pipelines on land shall be determined taking into account the selected coating and predicted degradation, the soil type, the observed cathodic protection potentials and current demands, and known metal loss.

9.6.4 Monitoring cathodic protection

Periodic surveys shall be carried out to monitor the cathodic protection using, as a minimum, the test points defined in 9.5.3.3 and 9.5.3.4.

The frequency of these surveys should be based on:

— the type of protection;
— the uniformity of soil properties along the pipeline;
— the coating quality;
— safety and environmental concerns;
— possible interference from electrical sources.
The possible hindrance from alternating a.c. or direct current d.c. interference during the surveys and the interpretation of the results shall be considered during the selection of the survey method.

"Over the line" cathodic protection surveys can be performed to provide more detailed information concerning the corrosion protection of the pipeline. Such surveys are recommended when abnormal coating damage, severely corrosive conditions and/or stray current interference are suspected.

9.7 Evaluation of monitoring and inspection results
All findings of the monitoring and inspection activities shall be analysed to:

— review the adequacy of the corrosion management;
— identify possible improvements;
— indicate a requirement for further detailed assessment of the pipeline condition;
— indicate the need to modify the corrosion management requirements.

9.8 Corrosion management documentation
Documentation shall be prepared which describes the following in accordance with the requirements for corrosion management given above (see 9.1 to 9.6):

— the assessment of the corrosion threats and associated potentials for failure;
— the choice of materials and corrosion mitigation methods;
— the selection of inspection and corrosion monitoring techniques and inspection frequencies;
— any specific decommissioning and abandonment requirements associated with the selected corrosion management approach.

10 Construction

10.1 General

10.1.1 Construction plan
A construction plan shall be prepared before commencement of construction to assist in the control of the work. This plan shall be commensurate with the complexity and the hazards of the work and should contain as a minimum:

— a description of the construction;
— a health, safety and environment plan;
— a quality plan.

The description of the construction should include methods, personnel and equipment required for the construction and working procedures.

NOTE Special construction, such as tunnels, landfalls for offshore pipelines, pipeline bridges and horizontal directional drilling, may require supplemental pipeline installation procedures.
The health, safety and environment plan should describe requirements and measures for the protection of the health and safety of the public, personnel involved in the construction and the environment. It should contain the requirements of the relevant legislation and applicable standards, identification of hazards and measures required for their control, and emergency procedures.

10.1.2 Construction near other facilities

All facilities which may be affected by construction of the pipeline system shall be identified prior to beginning the work.

Temporary provisions and safety measures necessary to protect the identified facilities during construction should be established. Owners and/or operators of the facilities should be consulted when defining these temporary provisions and safety measures, and shall be given timely notification of the commencement of construction.

EXAMPLES Other facilities may include existing roads and railways, watercourses, footpaths, pipelines, cables and buildings.

10.1.3 Plant, equipment and marine vessels

All major plant, equipment and marine vessels used for construction shall be inspected before and during construction to determine their suitability for the intended work in accordance with good engineering practice.

10.1.4 Transport and handling of materials

Handling, storing, transport and installation of pipeline materials shall be performed in a manner that prevents or minimizes damage to pipes, fittings, components and coating. Transport and handling procedures may be required. These procedures should identify the equipment to be used and the stacking requirements.

NOTE API RP 5LW and API RP 5L1 provide guidance for the transport of line pipe.

Materials shall be inspected for damage and defects which do not conform to the specifications. These materials shall not be installed unless the damage and/or defect has been removed or corrected.

10.2 Preparation of the route on land

10.2.1 Site inspections

Site inspections of existing conditions along the working width of the pipeline route shall be undertaken after access to the route has been granted and before commencement of construction. Reports of these inspections shall state the condition of the items potentially affected by construction and record the mutual approval of all parties concerned.

10.2.2 Survey and marking

The pipeline route, working width, buried structures and overhead structures shall be surveyed and marked prior to construction. Marking shall be maintained in good condition during the construction period.

10.2.3 Preparation of the working width

Appropriate fencing shall be provided along the working width where required for public safety and to prevent livestock from encroaching on the working width. Constraints or precautions to be observed within the working width shall be defined in the construction specifications.

EXAMPLES Such constraints or precautions include preservation of specific trees, disposition of trees and stumps, separation of topsoil, drainage, and scour and erosion prevention.
10.2.4 Blasting

Blasting shall be in accordance with relevant legislation and environmental constraints and shall be performed by competent and qualified personnel.

10.3 Preparation of the route offshore

10.3.1 Surveys

In addition to the survey requirements of 6.2.3, a pre-construction seabed survey should be performed along the proposed pipeline route to identify potential hazards for the pipeline or construction operations.

10.3.2 Seabed preparation

Seabed survey data shall be analysed and seabed preparation undertaken if necessary to meet the strength criteria in 6.4.2.

10.4 Welding and joining

10.4.1 Welding standard

Welding of pipeline systems shall be carried out in accordance with ISO 13847.

10.4.2 Weld examination

Examination of welds in pipeline systems shall be performed in accordance with ISO 13847 and, except as allowed for tie-in welds in 11.5, the weld examination shall be carried out before pressure-testing.

The extent of the non-destructive examination for girth welds shall be as follows:

a) All welds shall be visually examined.

b) A minimum of 10% of the welds completed each day shall be randomly selected by the owner or owner’s designated representative for examination by radiography or ultrasonics. The 10% level should be used for pipelines in remote areas, pipelines operating at 20% or less of SMYS, or pipelines transporting fluids which are low hazards to the environment or personnel in the event of a leak. The percentage of weld examination for other fluids and locations shall be selected appropriate to the local conditions. The examination shall be increased to 100% of the welds if lack of weld quality is indicated, but may subsequently be reduced progressively to the prescribed minimum percentage if a consistent weld quality is demonstrated.

c) 100% of the welds shall be examined by radiography or ultrasonics in the following circumstances:

- pipelines designed to transport category C fluids at hoop stresses above 77% of SMYS;
- pipelines designed to transport category D fluids at hoop stresses at or above 50% of SMYS;
- pipelines designed to transport category E fluids;
- pipelines not pressure-tested with water;
- within populated areas such as residential areas, shopping centres, and designated commercial and industrial areas;
- in environmentally sensitive areas;
- river, lake, and stream crossings, including overhead crossings or crossings on bridges;
- railway or public highway rights-of-way, including tunnels, bridges, and overhead crossings;
Radiography or ultrasonic examination shall cover the weld over its full circumference. The examination shall be appropriate to the joint configuration, wall thickness and pipe diameter.

Welds shall meet the acceptance criteria specified in the applicable welding standard. Welds not meeting these criteria shall either be removed or, if permitted, repaired and reinspected.

All other welds shall be fully examined in accordance with ISO 13847.

10.4.3 Joining other than welding

Joining by other techniques shall be performed in accordance with approved procedures.

10.5 Coating

10.5.1 Field coating

Field-applied coatings shall satisfy the requirements of 8.4.

The preparation of the pipe surface and the application of the field joint coating shall be performed in accordance with a qualified procedure (see 8.4.1) that meets the requirements of the coating manufacturer's recommendations. Coating shall be applied by competent operators who have received adequate instruction.

10.5.2 Coating inspection

Coatings shall be visually inspected at the time of pipe installation to ensure compliance with the specified standard and application procedure.

Immediately before the pipe is lowered into the trench, or before the pipe leaves the installation vessel, the entire coating surface shall be inspected, where accessible, using a holiday detector set to the correct voltage applicable to the coating. Defects shall be marked and repaired before the pipe is placed in its final position. Where coating damage or disbondment has occurred, the coating shall be removed, replaced and retested.

Coating on tie-ins, special assemblies and pipe sections for crossings shall be inspected with a holiday detector prior to installation.

10.6 Installation of pipelines on land

10.6.1 Pipe stringing

Stringing shall be performed in accordance with written procedures which define access limitations and provisions for minimizing interference with local and public land use and include provisions for access across the working width.

10.6.2 Field pipe bends

Pipes may be bent cold in the field to fit pipeline alignment and topographical conditions. Field bends shall be made on bending machines which provide sufficient support to the pipe cross-section to prevent buckling or wrinkling of the pipe wall and to maintain coating integrity.

The minimum bending radii should not be less than:

— 20 \(D\) for pipe OD of less than 200 mm;
Field bends may be made to a shorter radius than shown above provided that, after bending, the ovality is not greater and the wall thickness is not less than permitted by the design, and the material properties meet the toughness requirements specified for the line pipe.

Bends shall be free from buckling, cracks or other evidence of mechanical damage.

When bending pipe with diameters above 300 mm and with a diameter-to-wall-thickness ratio of less than 70:1, consideration should be given to the use of an internal mandrel.

A test bend should be made to verify that the requirements of this subclause will be met.

Bends should not be made from pipe lengths containing girth welds which are within 1 m of the bend. Longitudinal weld seams should be placed near the neutral axis of field bends.

### 10.6.3 Excavation

Trench depth shall be sufficient to provide the cover specified in accordance with 6.8.2.1.

Trench side slopes shall be analysed to determine whether shoring or sloping is required to provide safe working conditions. Erosion mitigation measures should be established to prevent trench instability and damage to the environment.

The trench bottom shall be flat and free from sharp edges or objects which may damage the pipe or its coating. If this is not possible, the pipe shall be protected by installing bedding material or mechanical protection. Any bedding material or mechanical protection shall not act as a shield to the passage of cathodic protection current to the pipe surface.

When work is performed in the trench, it shall be widened and deepened to allow safe working conditions. Precautions shall be taken prior to personnel entering the trench to ensure that safe non-flammable atmospheres are present. When trenching occurs adjacent to existing underground structures, precautions shall be taken to avoid damage to such structures. A minimum separation of 0.3 m shall be provided between the outside of any buried pipe and the extremity of any other underground structure, unless special provisions are made to protect the pipeline and the underground structure.

### 10.6.4 Lowering pipe

Prior to lowering, the trench bottom shall be clean and free of objects likely to cause coating damage and shall be graded to provide uniform support to the pipeline.

Equipment or methods used for lowering into the trench shall not damage the pipe or its coating. Lifting and lowering procedures shall not cause the strength criteria specified in 6.4.2 to be exceeded.

### 10.6.5 Backfill

To avoid coating damage, backfill should be carried out as soon as possible after lowering.

Flooded trenches should be pumped dry or drained prior to backfilling. When this is not possible and a flooded trench must be backfilled, care shall be exercised to ensure that liquefied backfill does not displace the pipe.

Backfill materials or protective measures shall be selected to prevent damage to the pipe or its coating.

Field drains, ditches and other drainage systems interrupted during the work should be reinstated.
Backfill materials and installation methods under roads, footpaths, shoulders, banks and similar areas shall be selected to ensure the stability and integrity of these facilities. When terrain, soil and water conditions are present which may cause erosion, consideration shall be given to the installation of barriers to prevent land slippage or washout.

10.6.6 Tie-in

Tie-in procedures shall include provisions for controlling the pipe stress to the allowable strength criteria in 6.4.2. Procedures shall include consideration of the pipeline configuration, planned movement after tie-in, and temperature differences between tie-in and future operations.

10.6.7 Reinstatement

Reinstatement of the working width and other areas affected by construction shall be carried out in accordance with procedures which meet the requirements of relevant legislation and agreements with landowners and occupants.

10.6.8 Crossings

All crossings shall be carried out in a manner which meets the requirements of 6.2.1 and 10.1.2.

Where watercourses are crossed by the open-cut method, consideration shall be given to the composition of the bottom, variation in banks, velocity of water, scouring, and special seasonal problems. Work shall be executed in such a way that flooding of adjacent land does not occur.

Precautions shall be taken during installation to avoid impact, distortion of the pipeline, or other conditions which may cause pipe stress or strain to exceed the levels established in the design.

Installation procedures for horizontal directionally drilled crossings shall address the requirements unique to such crossings, for example:

— containment and disposal of drilling fluid;

— selection of abrasion-resistant corrosion coating;

— instrumentation for monitoring drilling profile, alignment and pulling forces.

10.6.9 Markings

Pipeline location markers shall be placed as specified in 6.8.1.

10.7 Offshore installation

10.7.1 Marine operations

10.7.1.1 Anchors and station-keeping

The station-keeping system should have adequate redundancy or back-up systems to ensure that other marine vessels or installations are not endangered by its partial failure.

Construction vessels using anchors to maintain position should do so in accordance with a predetermined anchor pattern. The anchor pattern should be shown on a bathymetric chart to a suitable scale, containing the following information as appropriate:

— position of each anchor and each cable touchdown point;

— location of existing pipelines and installations;
vertical clearance between anchor cables and pipelines;
proposed pipeline route and lay corridor;
temporary works present during the construction period;
anchor patterns of other vessels in the vicinity;
construction vessel position;
prohibited anchoring zones;
wrecks and other potential obstructions.

To prevent damage to existing facilities, minimum clearances shall be established between anchor and anchor cables and fixed structures, subsea installations or other pipelines.

All anchors transported over subsea installations or pipelines should be secured on the deck of the anchor-handling vessel. Construction-vessel anchor winches should be equipped with a cable length and load indicator.

**10.7.1.2 Contingency procedures**

Prior to beginning the work, contingency procedures shall be prepared. These should include:

a) worksite abandonment;
b) pipe buckles (wet and dry);
c) loss of coating;
d) abandonment and recovery of the pipeline.

**10.7.1.3 Notifications**

Prior to construction of offshore pipelines, notification shall be given to operators of existing pipelines and cables which will be crossed during pipeline construction or pipeline tow. Notification shall also be given to the appropriate entities such as coastguard, fishermen and other users of the sea.

**10.7.2 Survey and positioning systems**

Horizontal surface positioning, either satellite- or land-based, should form the basis for locating construction vessels, pipeline position and points of reference for local positioning systems. The positioning system shall have sufficient accuracy to allow placement of the pipeline within the tolerances specified in the design documents. Operations in congested areas and work requiring precise location may require a positioning system of greater accuracy than that required for pipeline placement.

The survey system used offshore shall be correlated with the onshore survey system when the pipeline system includes a shoreline crossing.

**10.7.3 Pipe laying**

Pipe should be specified and ordered in lengths to suit the spacing of laybarge work stations such that variations in length do not disrupt operations.

The pipe-laying and tensioning systems shall be capable of laying the pipeline without exceeding the strength criteria in 6.4.2 and shall be designed to prevent damage to the coating and anodes.
The critical support points of the pipeline on the stinger should be monitored by video.

Buckle detectors should be used during pipe laying to detect reductions in diameter of the pipe. Detectors shall be capable of determining diameter changes of 5% or greater.

Instrumentation should be provided to monitor and record the parameters required to demonstrate that the allowable strength criteria in 6.4.2 are not exceeded.

Pipelines installed by towing into position, either on the bottom, off-bottom or on the surface, may require a monitoring and/or guard vessel to prevent interference with the towed pipeline by other vessels.

Construction plans for the J-lay and reel barge methods shall address the unique stress levels and tensioning requirements associated with such methods.

10.7.4 Landfalls

Landfalls by bottom pull, directional drilling or other methods shall not cause the pipeline design stresses or strains to exceed the strength criteria in 6.4.2 or damage to coating and anodes.

10.7.5 Trenching

Trenching depth and profile should be selected to ensure that the pipeline stresses during trenching operations do not exceed the strength criteria in 6.4.2. Loads imposed on the pipeline during trenching should be monitored. Consideration shall be given to the extra loads imposed if the pipeline is flooded. Monitoring for boulders, debris and excessive spanning should be carried out. Trenching methods and equipment shall be selected to prevent damage to the pipe, coating and anodes and should be suitable for the soil conditions.

Post-lay and simultaneous-lay trenching equipment shall be provided with instrumentation which monitors and records the parameters required to demonstrate that the strength criteria are not exceeded.

EXAMPLES Acceptable trenching methods include jetting, ploughing, mechanical cutting for rock or hard soils and dredging.

10.7.6 Backfilling

Backfill material shall be placed in a controlled manner to prevent pipe and pipe-coating damage and to ensure the specified grading, cover and profile requirements are met. Backfill profiles shall be selected to minimize interference with fishing and other third-party activities.

10.7.7 Crossings of other pipelines and cables

The location, position and condition of a pipeline or cable to be crossed shall be determined before construction of the crossing.

If preset supports are specified, the position of the existing pipeline or cable and the crossing point shall be accurately established prior to installing supports. The installation of supports should produce a smooth crossing profile which minimizes the risk of damage to either structure from external forces such as from anchors and fishing equipment.

Horizontal-surface positioning systems shall be supplemented by an on-bottom positioning system. Because of the close tolerances required, the crossing installation should be monitored to confirm that the structures are in their correct position.

10.7.8 Spans

The pipeline shall be surveyed for the presence of spans, and span rectification shall be performed where required to satisfy the strength criteria limitations of 6.4.2. The potential for scour and the stability of supports or imported material shall be established.
10.7.9 Tie-ins

Construction procedures for tie-ins shall include provisions for controlling the pipe stress to the allowable strength criteria in 6.4.2.

10.8 Cleaning and gauging

Following construction, the pipeline sections should be cleaned by the passage of cleaning pigs or similar devices to remove dirt, construction debris and other matter.

Gauging pigs or devices which check for ovality and internal obstructions should be passed through each section before testing. The gauging plate diameter shall be no less than 95% of the smallest nominal internal pipe diameter of the pipeline, except that in no case should the clearance between the gauging plate and the pipe wall be less than 7 mm.

10.9 As-built surveys

Upon completion of construction, an as-built survey shall be performed to record the accurate location of the pipeline, crossings, adjacent features, spans and associated appurtenances.

10.10 Construction records

Permanent records in reproducible and retrievable form which identify the location and description of the pipeline system shall be compiled upon completion of the work and shall include the following:

- as-built surveys;
- welding documentation;
- as-built drawings and technical specifications; and
- construction procedures.

11 Testing

11.1 General

Pressure-testing shall be in accordance with 6.7.

The number of test sections should be minimized. Selection of test sections shall take into account:

- safety of personnel and the public, and the protection of the environment and other facilities;
- construction sequence;
- terrain and access;
- availability and disposal of test water.

If the test medium is subject to thermal expansion during the test, provisions shall be made for relieving excess pressure.

Equipment which should not be subjected to the test pressures shall be isolated from the pipeline during testing.
Valves should not be used as end closures during pressure-testing, unless rated for the differential pressure across the valve during testing. All devices used as end closures shall have sufficient strength to withstand the test pressure.

Temporary testing manifolds, temporary pig traps and other testing components connected to the test section shall be designed and fabricated to withstand the internal design pressure of the pipeline.

Individual components and fabricated items such as scraper traps, manifolds, metering skids, block valve assemblies, pipe for crossings (stream, road or railway), risers and tie-in assemblies may be pretested in accordance with the provisions of this International Standard. Pretested assemblies shall be tested to at least the test pressure that is required if they were tested as a part of the pipeline system.

11.2 Safety

Work on, or near, a pipeline under test shall not be permitted for the period from the start of the increase in pressure to the reduction in pressure at the end of the test, except where necessary for the testing.

Warning signs shall be placed and the pipeline route patrolled as appropriate to prevent access to the pipeline during the test.

In the case of pneumatic testing, the hazards from energy stored in the pipeline shall be taken into account when designing the safety requirements.

The safety of the public, construction personnel, adjacent facilities and the protection of the environment shall be ensured when depressurizing the test medium. If air or gas is used as a test medium, it shall be relieved by reducing pressure in a controlled manner.

11.3 Procedures

11.3.1 Written procedures

Written procedures for strength and leak tests shall be prepared prior to the beginning of testing and shall include the requirements of 6.7 and the following:

— profile and length of each test section with the test pressure specified for each end of pipe section being tested;

   NOTE The profile should indicate the pipe grade and wall thickness.

— safety provisions;

— requirements for continuous monitoring (see 11.6 and 11.7);

— source and composition of test water and its disposal;

— equipment requirements;

— pressures and durations;

— evaluation of test results;

— leak-finding.

11.3.2 Communications

Communications should be provided between all points manned during the test.
11.3.3 Water quality

Water for testing and flushing should be clean and free from any suspended or dissolved substance which could be harmful to the pipe material or internal coating (where applied) or which could form deposits within the pipeline. Water samples should be analysed and suitable precautions taken to remove or inhibit any harmful substances. Consideration shall be given to the control of internal corrosion in accordance with 9.6.2.

11.3.4 Inhibitors and additives

If hydrostatic test water analysis or procedures indicate that inhibitors and additives, such as corrosion inhibitors, oxygen scavengers, biocide and dyes, are necessary, then consideration shall be given to their interaction and the effect on the environment during test water disposal. Consideration shall also be given to the effect of any such additives on the materials throughout the pipeline system.

11.3.5 Filling rate

Filling shall be performed at a controlled rate. Pigs or spheres may be used to provide a positive air-to-water interface and to minimize air entrainment. All locations in which air could be trapped, such as valve bodies and bypass piping, should be vented during the filling and sealed prior to beginning the hydrostatic test.

When the pipeline traverses steep terrain, provisions should be taken to prevent the pigs or spheres from running ahead of the linefill and creating a safety concern at the end of the fill section. Consideration should be given to the use of a pig tracking system and to the use of backpressure to control the pig speed.

11.3.6 Air content

Where the air content could affect the accuracy of the hydrostatic test, the air content shall be determined and accounted for during the evaluation of the test results.

NOTE The assessment of air content can be carried out by constructing a plot of pressure against volume during the initial filling and pressurization until a definite linear relationship is apparent.

11.3.7 Temperature stabilization

Prior to beginning the hydrostatic pressure test, time should be allowed after filling for the temperature of the water in the pipeline to stabilise with the ambient temperature.

11.3.8 Temperature effects and correlations

Correlations which show the effect of temperature changes on the test pressures shall be developed to assess the possible differences between the initial and final test pressures and temperatures.

11.3.9 Leak-finding

Leak detection and location procedures shall be developed as part of the hydrostatic test procedure.

11.4 Acceptance criteria

The pressure test shall meet the requirements of 6.7.

11.5 Tie-ins following testing

Tie-in welds not to be subjected to a strength test after tie-in shall be examined in accordance with 10.4.2 c) or other accepted examination method if radiography or UT are not possible.
Non-welded tie-in connections not pressure-tested after construction should be leak-tested at commencement of operation at the maximum available pressure but not exceeding MAOP.

11.6 Testing equipment

Hydrostatic testing equipment should include the following:

- deadweight tester or other device with equivalent accuracy;
- pressure gauges;
- volume-measuring equipment;
- temperature-measuring equipment; and
- pressure- and temperature-recording equipment.

Current certificates of calibration which identify the instrument with the calibration certification shall be provided.

11.7 Test documentation and records

Test records shall be retained for the life of the pipeline system and shall include the following:

- test procedure;
- pressure and volume change at half-hour intervals over the test period;
- seawater, underground and air temperature, where appropriate and weather conditions at hourly intervals;
- pressure-recording charts;
- test instrument calibration data;
- name of the pipeline system operator;
- name of the person responsible for making the test;
- name of the test company, if used;
- date and time of the test;
- minimum and maximum test pressures at the test site;
- test medium;
- test duration;
- test acceptance signature;
- description of the facility tested and the test apparatus;
- an explanation and disposition of any pressure discontinuities, including test failures, that appear on the pressure-recording charts;
- where elevation differences in the section under test exceed 30 m, a profile of the pipeline showing elevations and test sites over the entire length of the test section.
11.8 Disposal of test fluids

Test fluids shall be disposed of in such a manner as to minimize damage to the public and the environment.

11.9 Protection of pipeline following test

Test fluids shall not be left in the pipeline following testing, unless provisions identified in accordance with 9.2 have been incorporated.

If water is used as a test medium in cold regions, provisions shall be made to prevent freezing of the test water.

12 Precommissioning and commissioning

12.1 General

Written procedures shall be established for precommissioning and commissioning. Procedures shall consider the characteristics of the fluids, the need to isolate the pipeline from other connected facilities and the transfer of the constructed pipeline to those responsible for its operation.

Precommissioning and commissioning procedures, devices and fluids shall be selected to ensure that nothing is introduced into the pipeline system that will be incompatible with the fluids, or with the materials in the pipeline components.

12.2 Cleaning procedures

Consideration shall be given to the need for cleaning the pipe and its components beyond that required in 10.8. Additional cleaning may be required to remove the following:

- particles, including residue from testing and millscale;
- metallic particles which may affect intelligent pig result interpretation;
- chemical residue from test water inhibitor;
- organisms resulting from test water;
- construction devices such as isolation spheres used for tie-ins.

Pipeline cleaning procedures shall consider the following:

- protection of pipeline components from damage by cleaning fluids or devices;
- removal of particles which may contaminate the fluid; and
- removal of metallic particles which may affect intelligent pigging devices.

12.3 Drying procedures

Drying methods should be selected on the basis of the need for dryness to meet the quality specifications of the transported fluids.

Dryness criteria shall be established as a water dew-point temperature. Drying procedures shall consider the following:

- compatibility with the transported fluid quality specifications;
— the effect of drying fluids and devices on valve seal materials, pipeline internal coating and other components;
— the corrosion potential caused by a combination of free water and the drying fluids, especially for H₂S and CO₂ corrosion potential;
— removal of water and drying fluids from valve cavities, branch piping and other cavities in the system where such fluids may be retained;
— the effect of hydrate formation during commissioning.

EXAMPLES Drying methods include swabbing with drying fluids or gels, air or nitrogen purging, vacuum drying or using the transported fluid itself.

12.4 Functional testing of equipment and systems

As a part of commissioning, all pipeline monitoring and control equipment and systems shall be fully function-tested, especially safety systems such as pig-trap interlocks, pressure- and flow-monitoring systems, and emergency pipeline-shutdown systems. Consideration should also be given to performing a final test of pipeline valves prior to the introduction of the transported fluid to ensure that they operate correctly.

12.5 Documentation and records

Precommissioning and commissioning records which shall be retained should include:
— cleaning and drying procedures;
— cleaning and drying results;
— function-testing records of pipeline monitoring and control equipment systems.

12.6 Start-up procedures and introduction of transported fluid

Written start-up procedures shall be prepared before introducing the transported fluid into the system and shall require the following:
— the system should be mechanically complete and operational;
— all functional tests should be performed and accepted;
— all necessary safety systems shall be operational;
— operating procedures shall be available;
— a communication system shall be established;
— formal transfer of the completed pipeline system to those responsible for its operation.

During pipeline filling with the fluid, the rate of fill shall be controlled and the fluid pressure shall not be allowed to exceed permitted limits.

NOTE Filling rates may be critical for certain fluids to prevent detonation, layering of gases, unstable dusty atmospheres, etc.

For pipelines carrying liquids, backpressure should be established to prevent hydraulic lock during filling.

Leak checks should be carried out periodically during the filling process.
13 Operation, maintenance and abandonment

13.1 Management

13.1.1 Objectives and basic requirements

A management system shall be established and implemented with the objectives of:

- ensuring safe operation of the pipeline system;
- ensuring compliance with the design;
- managing corrosion;
- ensuring safe and effective execution of maintenance, modifications and abandonment;
- dealing effectively with incidents and modifications.

The management system shall include the following:

- identification of personnel responsible for the management of the operation and maintenance of the pipeline, and for key activities;
- an appropriate organization;
- a written plan covering operating and maintenance procedures;
- a written emergency response plan, covering failure of pipeline systems and other incidents;
- a written permit-to-work system;
- a written plan for the control of change of design conditions.

In addition, the management system shall specify the requirements for training, liaison with third parties and retention of records.

The operation, maintenance, modifications and abandonment of the pipeline system shall be carried out in accordance with the plans.

The management systems shall be reviewed from time to time as experience dictates, and as changes in the operating conditions and in the pipeline environment require.

13.1.2 Operating and maintenance plan

The operating and maintenance plan shall include:

- procedures for normal operations and maintenance;
- requirements for personnel communications;
- a plan for the issue of procedures to cover non-routine operations and maintenance.

Operating and maintenance procedures shall define:

- individual and functional responsibilities and tasks;
- necessary safety precautions;
— interfaces with other pipeline systems and installations;
— relevant information and references to applicable rules and guidelines.

Procedures for dealing with interfaces with other pipeline systems and installations should be developed in consultation with their operators.

NOTE Annex E provides guidance on the possible content of the operating and maintenance procedures.

13.1.3 Incident and emergency response plan

The incident and emergency response plan shall define the requirements for personnel and equipment for responding to incidents and emergencies, and for training.

The effectiveness of the plan shall be tested periodically through desk and field simulations of incidents and emergencies. Simulations may be carried out in cooperation with operators of other pipelines or facilities, organizations and individuals who are directly affected by an incident or emergency, or who contribute to the response.

Causes of pipeline incidents and emergencies should be identified and analysed, and actions necessary to minimize recurrence implemented.

NOTE Annex E provides guidance on the content of the emergency procedures.

13.1.4 Permit-to-work system

The permit-to-work system shall define the activities to which it applies, the personnel authorized to issue a permit-to-work, and the personnel responsible for specifying the necessary safety measures.

The permit-to-work system should specify requirements for:
— training and instruction in the issue and use of permits;
— reviewing the effectiveness of the permit-to-work system;
— informing personnel controlling the pipeline system of the work activity and all related safety requirements;
— display of permits;
— control of pipeline operation in the event of suspension of the work;
— handover between shifts.

The permit-to-work should:
— define the scope, nature, location and timing of the work;
— indicate the hazards and define necessary safety measures;
— reference other relevant work permits;
— state the requirements for returning the pipeline system to service;
— state the authorization for execution of the work.

13.1.5 Training

Training of personnel should include, where relevant:
— familiarization with the pipeline system, equipment, potential hazards associated with the pipeline fluid, and procedures for operations and maintenance;
— the use of permits-to-work;
— the use of protective equipment and fire-fighting equipment;
— provision of first aid;
— response to incidents and emergencies.

13.1.6 Liaison

Contacts should be established and maintained with appropriate organizations and individuals, such as:
— fire, police, coast guard and other emergency services;
— regulatory and statutory authorities;
— operators of public utilities;
— operators of other pipelines which connect to, cross, or run in close proximity to the pipeline;
— members of the public living in close proximity to the pipeline;
— owners and occupiers of land crossed by the pipeline;
— third parties involved in any activity which could affect, or be affected by the pipeline.

Pipeline route maps should be deposited with statutory authorities or "one-call" organizations, as appropriate.

NOTE A "one-call" organization collects information on underground facilities and, following notification of construction in the area, advises the presence of these facilities. Local legislation can stipulate the requirement for soliciting information on the presence of underground utilities before commencement of work.

13.1.7 Records

Records of operating and maintenance activities shall be prepared and retained to:
— demonstrate that the pipeline system is operated and maintained in accordance with the operating and maintenance plans;
— provide the information necessary for reviewing the effectiveness of the operations and maintenance plans;
— provide the information necessary for assessing the integrity of the pipeline system.

NOTE Annex F provides guidance on the retention of records.

13.2 Operations

13.2.1 Fluid parameter monitoring

Procedures for the operation of the pipeline system should define the envelope of operating conditions permitted by the design, and the operating requirements and constraints for the control of corrosion. Fluid parameters should be monitored to establish that the pipeline system is operated accordingly.

Procedures for the operation of multi-product pipeline systems should include requirements for the detection, separation and prediction of arrival of batches.
Procedures for the operation of multi-phase pipeline systems should include requirements for control of liquid hold-up in the pipeline and free volume in the slug catcher.

Deviations from the operating plan shall be investigated and reported, and measures to minimize recurrence implemented.

13.2.2 Stations and terminals

Procedures for the operation of stations and terminals should include requirements for start-up and shutdown of equipment, and for the periodic testing of equipment, control, alarm and protection devices.

13.2.3 Pigging

Procedures for pigging operations should include requirements for:

- confirming that the pipeline is free of restraints or obstructions for the passage of pigs;
- control of pig travelling speed;
- safe isolation of pig traps;
- contingencies in the event of a stuck pig.

13.2.4 Decommissioning

Consideration should be given to decommission pipelines planned to be out of service for an extended period. The removal of fluids shall be in accordance with 13.3.7.

Decommissioned pipelines, except when abandoned, shall be maintained and cathodically protected.

13.2.5 Recommissioning

The condition of a decommissioned pipeline system shall be established and its integrity confirmed before recommissioning.

Pipeline filling shall meet the requirements of 12.6.

13.3 Maintenance

13.3.1 Maintenance programme

Maintenance programmes shall be prepared and executed to monitor the condition of the pipeline and to provide the information necessary to assess its integrity. Factors which shall be considered when defining the requirements for condition monitoring include:

- pipeline system design;
- as-built condition;
- results of earlier inspections;
- predicted deterioration in the condition of the pipeline;
- adverse site conditions;
- inspection time intervals;
- requirements of relevant legislation and statutory authorities.
EXAMPLES Possible deteriorations in pipeline condition include general and pitting corrosion, changes in the pipewall geometry (such as ovality, wrinkles, dents, gouges), cracking (such as stress corrosion and fatigue cracking), changes in the pipeline position, support or cover, and loss of weight coating.

Unfavourable results, such as defects, damage and equipment malfunctioning, shall be assessed and corrective action taken where necessary to maintain the intended integrity.

The maintenance programmes shall cover the complete pipeline system, including fire-fighting and other safety equipment, access roads, buildings, security provisions such as fences, barriers and gates, means of identifying the pipeline, its components and the fluids it carries, and notices. Particular attention should be paid to pipeline protection and safety equipment.

13.3.2 Route inspection

13.3.2.1 General

The pipeline route, including the right-of-way for pipelines on land, shall be periodically patrolled/surveyed to detect factors which may affect the safety and the operation of the pipeline system. The results of surveys shall be recorded and monitored.

13.3.2.2 Pipelines on land

The right-of-way should be maintained to provide the necessary access to the pipeline and associated facilities. Pipeline markers shall be maintained to ensure that the route of the pipeline is clearly indicated. If necessary, additional markers should be installed in areas where new developments take place.

Surveys should identify:

— encroachments;
— mechanical damage to above-ground and exposed pipeline sections and leakages;
— third-party activities;
— change of land use;
— fire;
— mineral extraction/mining operations;
— ground movement;
— soil erosion;
— the condition of water crossings, such as sufficiency of cover, accumulation of debris, flood or storm damage.

The requirements for the route inspection of offshore pipelines in 13.3.2.3 shall also apply to sections of pipelines on land crossing large rivers and estuaries.

13.3.2.3 Offshore pipelines

Surveys of the pipeline and adjacent seabed should identify:

— mechanical damage to the pipeline, including leakage;
— evidence of pipeline movement;
— extent of marine growth;
— condition of the adjacent seabed, including the presence of foreign objects;
— extent of any free spans;
— extent of any loss of cover along the buried or protected sections;
— extent of any loss of weight coating;
— extent of bank erosion or deposition of material;
— security of pipeline attachments, including anodes and clamps on piggy-back pipelines.

13.3.3 Pipeline mechanical condition

13.3.3.1 Corrosion control

The maintenance programmes shall include the requirements for corrosion monitoring established for corrosion management in accordance with clause 9.

The quality and performance of corrosion inhibitors should be verified periodically to ensure that they remain effective.

13.3.3.2 Adverse ground conditions and vibration

Surveillance in areas with adverse ground conditions, as identified in accordance with 6.10, shall be implemented.

Procedures shall be established to cover the protection of all pipelines and associated facilities in the vicinity of blasting or any other activity resulting in ground vibrations which could affect the integrity of the pipeline. Such procedures should state the maximum allowable effect on the pipeline.

13.3.4 Leak detection and surveys

The performance of the leak detection system should be reviewed and tested periodically to confirm compliance with the requirements of 5.5. Records should be kept of alarms and leaks to assist the performance review. Where appropriate, leakage surveys should be carried out. The type of survey selected shall be effective for determining if potentially hazardous leakage exists.

13.3.5 Pipeline facilities, equipment and components

13.3.5.1 Above-ground pipework and overhead crossings

Above-ground pipework and pipe supports should be inspected for corrosion, mechanical integrity, stability and concrete degradation.

Barriers designed to restrict access to above-ground pipe should be maintained.

13.3.5.2 Valves

Valves should be inspected periodically, moved and/or tested for proper operation. Where it is required to fully operate a pipeline valve, due account should be taken of the permissible pressure drop across the valve.

Remotely operable valves and actuators should be tested remotely to ensure the correct functioning of the whole system.

Pressure vessels associated with valve actuators shall be inspected and tested periodically.
13.3.5.3 Protection devices

Protection devices, including actuators, associated instrumentation and control systems, shall be inspected and tested periodically. The inspection and testing shall cover:

- condition;
- verification of proper installation and protection;
- correct setting and activation;
- inspection for leakages.

EXAMPLES Protection devices include pressure control and overpressure protection, emergency shutdown isolations, quick-connect/disconnect connectors, storage tank level controls, etc.

Emergency shutdown valves, including actuators and associated control systems, should be inspected and tested periodically to demonstrate that the whole system will function correctly and that valve-seal leakage rates are acceptable.

Particular attention shall be paid to storage tank level controls and to relief valves on pressure storage vessels.

13.3.5.4 Pig traps and filters

Pig traps and filters with “quick-release” closures, together with associated equipment, shall be maintained, with special attention given to the locking closure mechanism which shall be periodically tested.

Temporary or transportable pig traps should be inspected before use for signs of mechanical damage caused during transit or installation.

13.3.5.5 Instrumentation

Instrumentation, telemetry systems and the data acquisition, display and storage systems, essential for the safe operation of the pipeline system shall be examined, tested, maintained and calibrated.

Maintenance procedures should cover the control of temporary disarming or overriding of instrumentation, for maintenance or other purposes.

13.3.5.6 Pipeline risers

Pipeline risers on offshore installations shall be inspected periodically with particular attention paid to sections in the “splash zone”. These inspections should cover:

- the condition of the riser pipe, including any loss of wall thickness, particularly under riser clamps and guides;
- the condition of impact protection, fire protection, protective coatings, cladding and fitted anodes;
- the condition of riser flanges or couplings;
- the condition of attachment or clamping arrangements, and associated supporting structure;
- changes in position of the riser;
- the extent of marine growth;
- the corrosion protection in enclosed J-tubes or caissons.
13.3.5.7 Pipeline sleeves or casings

The inspection of pipeline sections in sleeves or casings shall cover:

- the condition of pipeline and sleeve or casing;
- the electrical isolation between the pipeline and sleeve or casing;
- leakage into, or from, pressurized sleeve or casing systems.

13.3.5.8 Storage vessels and tanks

Storage vessels and tanks, atmospheric and pressurized, shall be inspected to cover:

- the stability of foundations;
- the condition of tank bottom, shell, stairs, roof and seals;
- venting and safety valve equipment;
- the condition of firewalls and tank bunds/dikes;
- condition and blockage of drain lines.

13.3.5.9 Pipelines in arctic conditions

Inspection of pipelines in arctic conditions shall include:

- requirements for surveillance defined in accordance with 6.10;
- inspections and surveillance during and after spring ice break-up to monitor frost heave and erosion from floods;
- periodic inspection and surveillance of pipework exposed to wind-induced vibration, with particular attention to circumferential welds and threaded joints.

Procedures shall address requirements for snow removal from structures that are exposed to heavy snowfall.

13.3.6 Pipeline defects and damage

13.3.6.1 Initial actions

When a defect or damage is reported, the pipeline pressure shall be maintained at or below the pressure at the time the defect or damage was first reported.

A preliminary assessment shall be carried out by a competent person and, if any unsafe condition is found, appropriate action shall be taken immediately.

13.3.6.2 Examination, inspection and assessment of defects

Care shall be exercised during preparation and examination of damaged and pressurized pipelines because of the possibility of sudden failure. Consideration should be given to reducing the pipeline operating pressure to ambient conditions, e.g. when divers are to conduct an examination of an underwater pipeline, or to a stress level which will not lead to pipeline rupture.

Procedures shall be established for assessment of pipeline defects and damages.
Defects and damage permitted under the original fabrication and construction specifications may remain in the pipeline without further action.

For other defects, further assessment should be made to determine their acceptability or the requirement for pressure-derating, repair or other corrective action. These assessments may include the review of:

- inspection and measurement data, including orientation of the defect and proximity to other features such as welds or heat-affected zones;
- details of the original design and fabrication specifications;
- actual pipe-material mechanical and chemical properties;
- possible modes of failure;
- possible growth of the defect;
- operating and environmental parameters, including effect on pigging operations;
- consequences of failure;
- monitoring of the defect where possible.

### 13.3.7 Pipeline repairs and modifications

#### 13.3.7.1 General

Repair procedures shall cover the selection of repair techniques and the execution of repairs. Repairs shall reinstate the intended integrity of the pipeline at the location of the defect or damage.

**NOTE** Pipeline defects and damage may be grouped under a number of headings, including: pipewall defects (such as cracks including cracking caused by stress corrosion and fatigue, gouges, dents, corrosion, weld defects, laminations); pipe coating defects (such as loss of wrap or concrete coating); loss of support (such as spanning of pipelines); and pipe movement (such as upheaval buckling, frost heave and landslip which may also result in buckling, denting or cracking).

**EXAMPLES** Possible isolation techniques include removable spools, spectacle blinds, valves, pipe freezing or freeze blocking, line plugging, high friction pigs, inert fluid slugs.

#### 13.3.7.2 Pipeline isolation

The selection of an isolation method should take into account:

- hazards associated with the fluid;
- required availability of the pipeline system;
- the duration of the work activity;
- the need for “redundancy” in the isolation system;
- possible effect on pipeline materials;
- isolation of interconnected vents, drains, instrumentation piping and “dead legs”.

**EXAMPLES** Possible isolation techniques include removable spools, spectacle blinds, valves, pipe freezing or freeze blocking, line plugging, high friction pigs, inert fluid slugs.

#### 13.3.7.3 Venting and flaring

Hazards and constraints which should be considered when planning to vent or flare are:

- asphyxiating effects of vented gases;
— ignition of gases by stray currents, static electricity or other potential ignition sources;
— noise level limits;
— hazard to aircraft movements, particularly helicopters in the vicinity of offshore installations and terminals;
— hydrate formation;
— valve freezing;
— embrittlement effects on steel pipework.

13.3.7.4 Draining

Liquids may be pumped, or pigged, out of a pipeline using water or an inert gas. Hazards and constraints which should be considered when planning to drain include:

— asphyxiating effects of inert gases;
— protection of reception facilities from overpressurization;
— drainage of valve cavities, “dead legs”, etc.;
— disposal of pipeline fluids and contaminated water;
— buoyancy effects if gas is used to displace liquids;
— compression effects leading to ignition of fluid vapour;
— combustibility of fluids at increased pressures;
— accidental launch of stuck pigs by stored energy when driven by inert gas.

13.3.7.5 Purging

Hazards and constraints which should be considered when preparing for purging include:

— asphyxiating effects of purge gases;
— minimizing the volume of flammable or toxic fluids released to the environment;
— combustion, product contamination or corrosive conditions when reintroducing fluids.

13.3.7.6 Cold cutting or drilling

Procedures for cold cutting and drilling shall specify the requirements for preventing the accidental release or ignition of the fluid, and other unsafe conditions.

Where appropriate, the section of pipeline to be worked on shall be isolated, depressurized by venting, flaring or draining and purged.

A temporary electrical continuity bond should be fitted across any intended break in an electrically conductive pipeline before making such breaks.

13.3.7.7 Hot work

The following should be considered prior to carrying out hot work on pipelines in service:
— possible physical and chemical reactions, including combustion of the pipeline fluids or their residues;
— the type, properties and condition of the pipe material, and the wall thickness at the location of the hot work;
— possible corrosion of pipe and welds.

Welding procedures shall be approved and the validity of the welder qualification checked before commencement of welding.

The pressure, temperature and flowrate of the fluid through the pipeline should be monitored and maintained within the limits specified in the approved welding procedure.

All welds shall be adequately inspected during and after welding.

Consideration should be given to leak testing of welds of sleeves, saddles, reinforcing pads or any associated fitting before introducing fluids.

13.4 Changes to the design condition

13.4.1 Change control

The change control plan shall define the requirements for following documented procedures to handle changes in the design condition.

It shall be demonstrated that the revised pipeline system meets the requirements of this International Standard before implementing changes to the design condition, such as an increase in MAOP or change of fluid. The documentation required by this International Standard shall be updated to reflect the revised design condition.

13.4.2 Operating pressure

An increase in MAOP may require additional hydrostatic testing, inspection, additional cathodic protection surveys and other measures to comply with this International Standard. When increasing operating pressures, pressures should be raised in a controlled manner to allow sufficient time for monitoring the pipeline system.

Where pipelines are permanently derated from pressures which cannot subsequently be reapplied to the pipeline, stringent data and supporting calculations shall be maintained to record the changes.

13.4.3 Service conversion

Prior to a change in service, including change of fluid, it shall be demonstrated that the design and integrity of the pipeline is appropriate for the proposed new duty. A detailed review of as-built, operational and maintenance data of the pipeline shall be made before implementing a change in service. Data to be reviewed should include:

— original pipeline design, construction, inspection and testing. Particular attention should be paid to the welding procedures used, other jointing methods, internal and external coatings and pipe, valve and other materials;
— all available operating and maintenance records, including corrosion-control practice, inspections, modifications, pipeline incidents and repairs.

13.4.4 New crossings and developments

Compliance with the strength requirements in 6.4 shall be demonstrated when crossing the pipeline with a new road, railway or other pipeline. The effect of a new crossing on the existing cathodic protection system shall be investigated.

The possible effects of new developments in the vicinity of the pipeline shall be evaluated.
13.4.5 Moving in-service pipelines

The following analyses and preparation should be carried when planning the movement of pipelines in service:

— analysis of loads on the pipeline to demonstrate that the pipeline can be moved without overstressing;
— confirmation of the assumed pipeline data and its condition;
— preparation of procedures which should define the pipeline operating condition during movement, contingencies and safety measures for the protection of personnel, the public and the environment.

13.4.6 Testing of modified pipelines

All prefabricated pipeline assemblies, including spool pieces, should be pressure-tested in accordance with 6.7, or before installation in the pipeline.

Mechanical joints in pressure-containing parts of the pipeline which have been disconnected or disturbed shall, as a minimum, be leak-tested. Joints shall not show sign of leakage during the test.

The medium for the in situ pressure-testing should, in order of preference to minimize risks, be:

a) water;
b) the normal pipeline fluid (if liquid);
c) an inert gas such as nitrogen (with a tracer element, if possible);
d) the normal pipeline fluid (if gas).

Modifications involving the use of welded tie-ins shall be inspected in accordance with 11.5 if not pressure-tested. Small-diameter pipework and secondary piping (see 7.8.2) should be tested to ensure the integrity of all joints and connections after any work activity where pipework has been disturbed.

13.5 Abandonment

Pipeline systems planned to be abandoned shall be decommissioned in accordance with 13.2.4 and disconnected from other parts of the pipeline system remaining in service.

Abandoned pipeline sections shall be left in a safe condition.
Annex A
(normative)

Safety evaluation of pipelines

A.1 Introduction

This annex provides guidelines for the planning, execution and documentation of safety evaluations of pipelines required in 6.2.1.2.

This annex refers mainly to the evaluation of the effect of loss of fluids on public safety. The principles in this annex can, however, also be used for other safety evaluations.

A.2 General requirements

Safety evaluations should be performed according to a defined sequence of steps; Figure A.1 shows a sequence of steps which may be followed.

Safety evaluations should demonstrate that the pipeline is designed, constructed and operated in accordance with the safety requirements of this International Standard.

The level of detail of the evaluation and the techniques to be applied shall be appropriate to the objectives of the evaluation.

Further safety evaluations should be carried out during the operational life of the pipeline in case of relevant changes to the definition of the pipeline and the pipeline environment or other circumstances which may render the conclusions of the evaluation invalid.

Safety evaluations should be performed by personnel having the necessary specialist technical and safety expertise.

A.3 Scope definition

The scope of the evaluation should be defined and formulated to provide the basis for the safety evaluation plan. The scope should include as a minimum:

— reason(s) for performing the evaluation and case-specific objective(s);
— definition of the pipeline to be evaluated;
— definition of the environment, e.g. human habitation and activities near the pipeline;
— identification of measures which may be practical and effective in removing or mitigating adverse effects on public safety;
— description of assumptions and constraints governing the evaluation;
— identification of the required output.
A.4 Hazard identification and initial evaluation

The hazard scenarios with the potential to result in a loss of fluid should be identified, together with their root causes. These may include:

- design, construction or operator error;
- material or component failure;
- degradation due to corrosion or erosion, leading to loss of wall thickness;
- third-party activity;
- natural hazards.
Methods applied for identifying hazards may include review of checklists and historical incident data, brainstorming, and hazard and operability studies.

An initial evaluation of the significance of the identified hazards should be carried out based on the likelihood of their occurrence and estimation of possible consequences.

This step of the evaluation should result in one of the following courses of action for each of the identified hazards:

- curtailment of the evaluation because the likelihood of occurrences or consequences of the hazard is insignificant;
- recommended measure(s) to eliminate or reduce the hazard to a tolerable level;
- estimation of risk.

A.5 Hazard estimation

A.5.1 General

Hazard estimation should produce a measure of the level of effect on public safety from a particular hazard. Estimates may be expressed quantitatively or qualitatively and determined in frequency of occurrence, consequence, risk or a combination as appropriate for accomplishing the objectives of the safety analysis.

There should be a clear explanation of all the terms employed when expressing exposure. Estimated exposure should not be attributed to a level of precision inconsistent with the accuracy of the information and analytical methods employed.

The effect on public safety from the hazards identified as relevant in the hazard identification stage should be examined and the benefits of the identified mitigating measures in reducing this effect determined.

A.5.2 Frequency analysis

The likelihood of loss of fluid for each of the hazards identified should be estimated by such approaches as:

- use of relevant historical data;
- synthesis of event frequencies using techniques such as failure mode and effect analysis;
- judgement.

A.5.3 Consequence analysis

Estimating the likely impact of the loss of fluid should take into account:

- nature of fluid, e.g. flammable, toxic, reactive, etc.;
- pipeline design;
- buried- or above-ground topography;
- environmental conditions;
- size of hole or rupture;
- mitigating measures to restrict loss of containment, such as leak detection and use of isolation valves;
mode of escape of fluids;

— dispersion of fluid and probability of ignition;

— possible accident scenarios following a fluid loss, which may include:
  1) pressure waves following fluid release,
  2) combustion/explosion following ignition,
  3) toxic effects or asphyxiations;

— level of exposure and estimated effect.

A.5.4 Risk calculation

Risk is the exposure determined from the frequencies of occurrence and consequences of the hazards identified.

Risk should be determined in the most suitable terms for either individuals or populations and may be expressed qualitatively or quantitatively as appropriate. The completeness and accuracy of the calculated risk should be stated and effects of uncertainties or assumptions tested.

A.6 Review of results

The results of the hazard identification, initial evaluation and risk estimation shall be compared with the safety requirements to demonstrate compliance.

A.7 Documentation

The documentation on pipeline safety evaluations should include as a minimum:

— table of contents;

— summary;

— objectives and scope;

— safety requirements;

— limitations, assumptions and justification of hypotheses;

— description of system;

— analysis methodology;

— hazard identification results;

— model description with assumptions and validation;

— data and their sources;

— effect on public safety;

— sensitivity and uncertainties;
— discussion of results;
— conclusions;
— references.
Annex B
(normative)

Supplementary requirements for public safety of pipelines for category D and E fluids on land

B.1 Objective

This annex provides specific supplementary requirements for maximum hoop stresses and pressure testing for category D and E fluid pipelines on land. This annex is applicable to pipelines at locations where specific requirements for protection of public safety are not available.

B.2 Location classification

Pipeline locations shall be classified in relation to population density and concentration of people in accordance with Table B.1.

A significant factor contributing to the failure of pipelines is line damage caused by third-party activities along the line. Determining location classes based on human activity provides a method of assessing the degree of exposure of the line to damage and consequent effect on public safety.

Table B.1 — Location classes

<table>
<thead>
<tr>
<th>Location class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Locations subject to infrequent human activity with no permanent human habitation. Location Class 1 is intended to reflect inaccessible areas such as deserts and tundra regions.</td>
</tr>
<tr>
<td>2</td>
<td>Locations with a population density of less than 50 persons per square kilometre. Location Class 2 is intended to reflect such areas as wasteland, grazing land, farmland and other sparsely populated areas.</td>
</tr>
<tr>
<td>3</td>
<td>Locations with a population density of 50 persons or more but less than 250 persons per square kilometre, with multiple dwelling units, with hotels or office buildings where no more than 50 persons may gather regularly and with occasional industrial buildings. Location Class 3 is intended to reflect areas where the population density is intermediate between Location Class 2 and Location Class 4, such as fringe areas around cities and towns, and ranches and country estates.</td>
</tr>
<tr>
<td>4</td>
<td>Locations with a population density of 250 persons or more per square kilometre, except where a Location Class 5 prevails. A Location Class 4 is intended to reflect areas such as suburban housing developments, residential areas, industrial areas and other populated areas not meeting Location Class 5.</td>
</tr>
<tr>
<td>5</td>
<td>Location with areas where multistorey buildings (four or more floors above ground level) are prevalent and where traffic is heavy or dense and where there may be numerous other utilities underground.</td>
</tr>
</tbody>
</table>
B.3 Population density

Population density, expressed as the number of persons per square kilometre, shall be determined by laying out zones along the pipeline route, with the pipeline centreline of this zone having a width of:

— 400 m for pipelines conveying category D fluids; and

— to be determined for category E fluid pipelines, taking into account the possible extent of consequence of fluid release on the public, but not less than 400 m.

NOTE Other values may be used for the zone width, provided representative values are obtained for the population density and half the width of the zone is not less than the effect distance of a fluid release.

This zone shall then be divided in random sections of 1.5 km in length such that individual lengths include the maximum number of buildings intended for human occupancy. For this purpose, each separate dwelling unit in a multiple-dwelling-unit building shall be counted as a separate building intended for human occupancy.

The length of random sections may be reduced where it is justified that physical barriers or other factors exist which will limit the extension of the more densely populated area to a total distance of less than 1.5 km.

Measurement of population density shall be based on a direct count of the number of inhabitants or a survey of normally occupied dwellings, and should include premises where people congregate for significant periods of time, such as schools, public halls, hospitals and industrial areas.

The location and number of dwellings and premises shall be determined from available large-scale plans and/or aerial photographic surveys and, if necessary, field surveys. The occupancy of dwellings may be determined from census statistics where these are available.

The possible increase in population density and level of human activity from planned future developments shall be determined and accounted for when determining population density.

B.4 Concentration of people

Additional consideration shall be given to the possible consequences of a failure near a concentration of people such as found in a church, school, multiple-dwelling unit, hospital, or recreational area of an organised character in Location Classes 2 and 3.

Unless the facility is used infrequently, the supplementary requirements of Location Class 4 shall also apply to pipelines in Location Classes 2 and 3 when near places of public assembly or concentrations of people such as churches, schools, multiple-dwelling-unit buildings, hospitals or recreational areas of an organized nature.

NOTE Concentrations of people referred to above are intended to apply to groups of 20 or more people in an outside area as well as in a building.

B.5 Maximum hoop stress

The hoop stress design factors of Table 1 shall be replaced by the factors in Table B.2 for determining maximum permissible hoop stresses in accordance with 6.4.2.2.
Table B.2 — Hoop stress design factors $F_h$

<table>
<thead>
<tr>
<th>Fluid category</th>
<th>D</th>
<th>E</th>
<th>D and E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location class</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>General route</td>
<td>0,83</td>
<td>0,77</td>
<td>0,77</td>
</tr>
<tr>
<td>Crossings and parallel encroachments&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— minor roads</td>
<td>0,77</td>
<td>0,77</td>
<td>0,77</td>
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<tr>
<td>— major roads, railways, canals, rivers, diked flood defenses, and lakes</td>
<td>0,67</td>
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<tr>
<td>Pig traps and multipipe slug catchers</td>
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<tr>
<td>Piping in stations and terminals</td>
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<td>0,67</td>
<td>0,67</td>
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<tr>
<td>Special constructions, such as fabricated assemblies and pipelines on bridges</td>
<td>0,67</td>
<td>0,67</td>
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</tbody>
</table>

<sup>a</sup> See 6.9 for the description of crossings and encroachments.

B.6 Pressure test requirements

The minimum pressure in the pipeline during strength testing shall be increased from 1,25 to 1,40 times MAOP for pipelines in Location Classes 4 and 5.
Annex C  
(informative)

Pipeline route selection process

C.1 Limits

The geographic limits within which pipeline route selection is to take place should be defined by identification of the starting point of the pipeline, the end point of the pipeline and any intermediate fixed points. These points should be marked on suitably scaled plans covering the area, for further consideration during the routing procedure.

C.2 Constraints

Existing and planned constraints to route selection (see 6.2.1) occurring within the area of interest should be identified to assist the selection of route options. The constraints identified should be plotted on suitably scaled maps, considering the complexity of terrain and information gathered. Potential corridors of interest should then be selected for route development.

C.3 Preferred corridors of interest

A preferred route corridor should be selected, taking into account all the technical, environmental and safety-related factors that may be significant during installation and operation of the pipeline system. It should be noted that the shortest corridor may not be the most suitable.

C.4 Detailed routing

The adoption of a provisional route within the selected route corridor should be preceded by a desk study, consultation and visual appraisal making use of all information available within the public domain.

Prior to the selection of the final route, land and environmental surveys should be made; these should cover sufficient width and depth around the provisional route and have sufficient accuracy to identify all features that could adversely influence installation and operation of the pipeline. This should be accompanied by further detailed consultation with all affected third parties and route-walking where appropriate.

Third-party activities along the pipeline route and related safety aspects should be investigated.

A complete set of data relevant to design, construction and the safe and reliable operation of the pipeline should be compiled from records, maps and physical surveys. The selected route should be recorded on alignment sheets of an appropriate scale. The coordinates of all significant points, such as target points, crossing points, bend starting- and end-points, should be indicated. Contour lines should be recorded at intervals sufficient for design purposes, particularly with regard to the installation and operational phases, and consideration should be given to the need for a vertical profile of the route.
Annex D  
(informative)

Examples of factors for routing considerations

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Pipelines on land</th>
<th>Offshore pipelines</th>
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</thead>
<tbody>
<tr>
<td>Safety</td>
<td>See annex A</td>
<td>See annex A</td>
</tr>
<tr>
<td>Environment</td>
<td>Environmentally sensitive areas:</td>
<td>Environmentally sensitive areas:</td>
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<td></td>
<td>— areas of outstanding beauty</td>
<td>— areas of special scientific interest</td>
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<td></td>
<td>— areas of archaeological importance</td>
<td>— areas of natural conservation importance</td>
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<td></td>
<td>— areas of designated landscape</td>
<td>— areas of marine archaeological importance</td>
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<td></td>
<td>— areas of conservation interest</td>
<td>— marine parks</td>
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<td></td>
<td>— natural resources such as water catchment areas, reservoirs and forestry</td>
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<td></td>
<td>— aquifers and potable water supplies</td>
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<tr>
<td>Facilities</td>
<td>Pipelines</td>
<td>Pipelines</td>
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<td>Underground and above-ground services</td>
<td>Cables</td>
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<td>Tunnels</td>
<td>Subsea structures and wellheads</td>
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<tr>
<td>Third-party activities</td>
<td>Land use</td>
<td>Coastal protection works</td>
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<td>Mineral workings</td>
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<td>Mining</td>
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<td>Military zones</td>
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<td>Shipping lanes</td>
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<td>Anchoring</td>
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<td>Recreation</td>
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<td>Fishing</td>
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<td>Exploration and production</td>
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<td>Dredging and dumping</td>
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<td>Military exercises</td>
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<td>Offloading at platforms</td>
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<td>Boat landing</td>
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<td>Consideration</td>
<td>Pipelines on land</td>
<td>Offshore pipelines</td>
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<td>Geotechnical conditions:</td>
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<td>— uneven topography, outcrops and depressions</td>
<td>— uneven topography, outcrops and depressions</td>
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<td></td>
<td>— instability like faults and fissuring</td>
<td>— earthquake zones</td>
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<td></td>
<td>— soft and waterlogged ground</td>
<td>— high-slope gradients</td>
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<td>— soil corrosivity</td>
<td>— seabed instability</td>
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<td>— rock and hard ground</td>
<td>— soft sediment and sediment transport</td>
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<td></td>
<td>— flood plains</td>
<td>— presence of near-surface gas</td>
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<td></td>
<td>— earthquake areas</td>
<td>— coastal erosion</td>
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<td>— muskeg and permafrost areas</td>
<td>— beach movement</td>
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<td>— areas of land slippage, subsidence and differential settlement</td>
<td>— high near-bottom currents</td>
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<td>— infill land and waste disposal sites including those contaminated by disease</td>
<td>Hydrographic conditions</td>
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<td>or radioactivity</td>
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<td></td>
<td>Hydrographic conditions</td>
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</table>

| **Construction and operation** | Access                                                                           | Maximum approachable water depth                                                  |
|                               | Working width                                                                    | Minimum feasible laying radius                                                    |
|                               | Utilities                                                                        | Station-keeping vessels                                                           |
|                               | Availability and disposal of test water                                         | Platforms and subsea wellhead approach                                             |
|                               | Crossings                                                                        | Tie-ins                                                                           |
|                               | Logistics                                                                        | Shore approach and landfall installation technique                                 |
|                               |                                                                                 | Crossings                                                                         |
|                               |                                                                                 | Logistics                                                                         |
Annex E  
(informative)

Scope of procedures for operation, maintenance and emergencies

E.1 Operating procedures

Operating procedures may include details of the following:

— the organization showing the responsible persons;
— the pipeline system, including pumping stations, terminals, tank farms, platforms and other installations;
— the fluids that may be transported;
— the pipeline system operating conditions including limitations and permitted deviations from such limitations;
— the control functions and communications;
— the pipeline monitoring system and the means by which leaks may be detected;
— marine operations procedures (where applicable);
— scheduling and dispatching procedures;
— pigging procedures and their purpose;
— references to related documentation, e.g. permits-to-work, manufacturer's literature, drawings, maps, etc.;
— coordination with third parties;
— drawings showing demarcation of the pipeline system and limits of ownership and operatorship within the whole pipeline system;
— venting and flaring procedures;
— requirements of relevant legislation or statutory authorities.

E.2 Maintenance procedures

Maintenance procedures may include details of the following:

— the organization, showing the responsible persons;
— the pipeline system, including pumping stations, terminals, tank farms, platforms and other installations;
— schedules, inspection and maintenance specifications and instructions for each element of the pipeline system;
— references to related manuals and documentation, e.g. manufacturer's literature and permit-to-work systems;
— relevant drawings and route maps;
— stores and spares organization;
— specific procedures may be required for certain repairs or modifications.
E.3 Emergency procedures

Emergency procedures may include details of the following:

— duties of all personnel to be involved in the event of an incident or emergency — reference should be made to the organization chart;

— the pipeline system, including pumping stations, terminals, tank farms, platforms and other installations;

— the pipeline fluids (including details of any hazards associated with the release of the fluids) and normal operating conditions;

— the location and details of communications with control centres;

— the company and/or contract personnel, third parties and statutory bodies who have to be notified in the event of an incident or emergency;

— location of emergency equipment and specialist services;

— arrangements for the evacuation of personnel or third parties, particular attention being given to divers who may be undergoing decompression and are, therefore, confined to a chamber;

— arrangements to make safe the pipeline system in the event of an emergency and for limiting the effects of any loss of containment or to reduce the risk of loss of containment;

— for pipeline systems that link installations, procedures for shutting down the pipeline in the event of an emergency at another installation;

— venting and flaring procedures.
Annex F
(informative)

Records and documentation

Records and documentation should include:

a) design and construction details:
   — design basis and calculations;
   — material specifications and certification;
   — inspection and test certification and reports;
   — documents relating to authorizations and permits to operate;
   — land ownership details;
   — surveys and route documentation, including location of other services;
   — as-built route alignment maps, special crossing details, detailed pipework and instrumentation diagrams;
   — pipeline operating parameters, such as pressure and temperature.

b) operational records:
   — operations and maintenance details;
   — inspection survey reports, including for example, acoustic/video records and cathodic protection surveys;
   — incident records;
   — repairs and modifications;
   — service conversions;
   — personnel training and qualification records.

c) Records of abandoned pipelines
   — details of abandoned pipelines on land including route maps, the size of the pipeline, depth of burial and its location relative to surface features;
   — details of abandoned offshore pipelines, including navigation charts showing the route of the pipeline.
Bibliography


6) To be published.