PD 8010-1:2015

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Pipeline systems –

Part 1: Steel pipelines on land – Code of practice

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 164, an inside back cover and a back cover.

Foreword

Publishing information

This part of PD 8010 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 March 2015. It was prepared by Subcommittee PSE/17/2, *Pipeline transportation systems*, under the authority of Technical Committee PSE/17, *Materials and equipment for petroleum*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This part of PD 8010 supersedes PD 8010-1:2004, which is withdrawn.

Relationship with other publications

The PD 8010 series comprises:

- Part 1: *Steel pipelines on land – Code of practice*;
- Part 2: *Subsea pipelines – Code of practice*;
- Part 3: *Steel pipelines on land – Guide to the application of pipeline risk assessment to proposed developments in the vicinity of major accident hazard pipelines containing flammables – Supplement to PD 8010-1:2004*;
- Part 4: *Steel pipelines on land and subsea pipelines – Code of practice for integrity management*;
- Part 5: *Subsea pipelines – Guide to operational practice*.

This part of PD 8010 has been prepared to take into account the publication of BS EN 14161, which is based on ISO 13623. It provides a more comprehensive approach and covers a number of issues that are outside the scope of BS EN 14161.

This part of PD 8010 takes into account the publication of BS EN 1594 and IGEM/TD/1 Edition 5:2012.

BS EN 1594 and BS EN 12007 contain requirements for gas supply systems operating above and below 1.6 N/mm^2 (16 bar) respectively.

BS EN 13480-3 and BS ISO 15649, which incorporates ASME B31.3 by normative reference, give design stresses and guidelines for pipe materials required to operate outside the temperature range –25 °C to +120 °C, and for pipelines routed above ground on supports, racks and bridges. BS ISO 15649 also contains requirements for buried piping.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- general updating of the text to take into account new standards and legislation introduced since the 2004 edition;
- update of the guidance for pipelines carrying carbon dioxide;
- update of the guidance on HIPPS, strain based design, fracture and fatigue.

This part of PD 8010 is intended for use by designers, manufacturers, operators and owners of pipelines. Clause **4** deals with health, safety and assurance and is relevant to all users of this document. Clause **5** to Clause **9** are mainly of relevance to designers. Clause **10** and Clause **11** are mainly of relevance to constructors. Clause **12** might be of relevance to both constructors and operators. Clause **13** and Clause **14** are mainly of relevance to operators.

The guidance given in this part of PD 8010 on the design of pipelines for the transmission of dry natural gas is based on the philosophy and guidance contained in the Institution of Gas Engineers and Managers' recommendations for transmission and distribution practice (IGEM/TD series). The IGEM's guidance is applicable to first, second and third family gases as defined in BS EN 437 provided the impact on design, material, operations and maintenance is taken into account. The 2012 revision of IGEM/TD/1 gives requirements for the transmission of dry natural gas (predominantly methane), at a maximum allowable operating pressure (MAOP) not exceeding 10 N/mm^2 (100 bar) at temperatures between a range of –25 °C and +120 °C inclusive. The scope of IGEM/TD/1 may be extended beyond 10 N/mm^2 (100 bar), but specific areas will require further justification and documentation that embraces a safety evaluation.

For pipelines laid on land which cross inland waterways experiencing extreme hydraulic conditions, PD 8010-2 might provide better guidance.

The International System of Units (SI) (see BS EN ISO 80000-1) is followed in this part of PD 8010, except for units of pressure where the bar equivalent is provided for information.

NOTE 1 bar = 10^5 N/m^2 = 10^5 Pa. All references to pressure are gauge pressure, unless otherwise stated.

Hazard warnings

WARNING. This part of PD 8010 calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Use of this document

As a code of practice, this part of PD 8010 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this part of PD 8010 is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the drafting of this Published Document that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. "organization" rather than "organisation").

Contractual and legal considerations

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

Compliance with a Published Document cannot confer immunity from legal obligations.

Particular attention is drawn to the following specific regulations:

- Construction (Design and Management) Regulations 2007 [1];
- Deregulation (Pipe-lines) Order 1999 [2];
- Electricity and Pipe-lines Works (Assessment of Environmental Effects) Regulations 1990 and subsequent amendments [3];
- Environmental Protection Act 1990 [4];
- Factories Act 1961 [5];
- Factories Act (Northern Ireland) 1965 [6];
- Gas Act 1995 [7];
- Gas Safety (Management) Regulations 1996 [8];
- Health and Safety at Work, etc. Act 1974 [9];
- Health and Safety at Work (Northern Ireland) Order 1978 [10];
- Oil and Pipelines Act 1985 [11];
- Petroleum Act 1998 [12];
- Pipe-line Works (Environmental Impact Assessment) Regulations 2000 [13];
- Pipe-lines Act 1962 [14];
- Pipelines Safety Regulations 1996 [15];
- Pipelines Safety Regulations (Northern Ireland) 1997 [16];
- Pipelines Safety (Amendment) Regulations 2007 [17];
- Planning Act 2008 [18];
- Pressure Equipment Regulations 1999 [19];
- Pressure Systems Safety Regulations 2000 [20];
- Town and Country Planning Act 1990 [21] in respect of planning permission for local pipelines.

Attention is also drawn to guidance notes published by appropriate authorities. For planning applications, consent and environmental regulations, it might be necessary to refer to local/regional authorities, e.g. Northern Ireland, Scotland, Wales, etc.

1 Scope

This part of PD 8010 gives recommendations for and guidance on the design, selection, specification and use of materials, routeing, land acquisition, construction, installation, testing, operation, maintenance and abandonment of land pipeline systems constructed from steel. The principles of this part of PD 8010 apply to new pipelines and major modifications to existing pipelines. It is not intended to replace or duplicate hydraulic, mechanical or structural design manuals.

This part of PD 8010 is applicable to pipelines intended for the conveyance of oil, gas, carbon dioxide and other substances that are hazardous by nature of being explosive, flammable, toxic, reactive, or liable to cause harm to persons or to the environment. It covers pipelines operating at temperatures between a range of –25 °C and +120 °C inclusive.

The extent of pipeline systems covered by this part of PD 8010 is shown in Figure 1.

NOTE Annex A shows the full range of onshore oil and gas pipeline systems covered by this part of PD 8010.

This part of PD 8010 does not give recommendations for subsea pipelines, which are covered in PD 8010-2.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

ASME B16.5, *Pipe flanges and flanged fittings* [1)]

ASME B16.9, *Factory-made wrought steel buttwelding fittings*

ASME B16.11, *Forged fittings, socket-welding and threaded*

ASME B16.20, *Metallic gaskets for pipe flanges – Ring joint spiral wound and jacketed*

ASME B16.21, *Nonmetallic flat gaskets for pipes flanges*

ASME B16.47, *Large diameter steel flanges*

ASME B31.3, *Chemical plant and petroleum refinery piping – Process piping*

ASME B31.8, *Chemical plant and petroleum refinery piping – Gas transmission and distribution piping systems*

ASME BPVC-VIII-1, *Boiler and pressure vessels code – Section VIII, Division 1: Rules for construction of pressure vessels – Design and fabrication of pressure vessels*

ASTM A193/A193M 12b, *Standard specification for alloy-steel and stainless steel bolting for high temperature or high pressure service and other special purpose applications*

ASTM A194/A194M 13, *Specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both*

1) American Society of Mechanical Engineers (ASME) standards are available from BSI Customer Services, Tel: +44 (845 0860) 9001.

Figure 1 **Extent of pipeline systems that are covered by this part of PD 8010** *(1 of 2)*

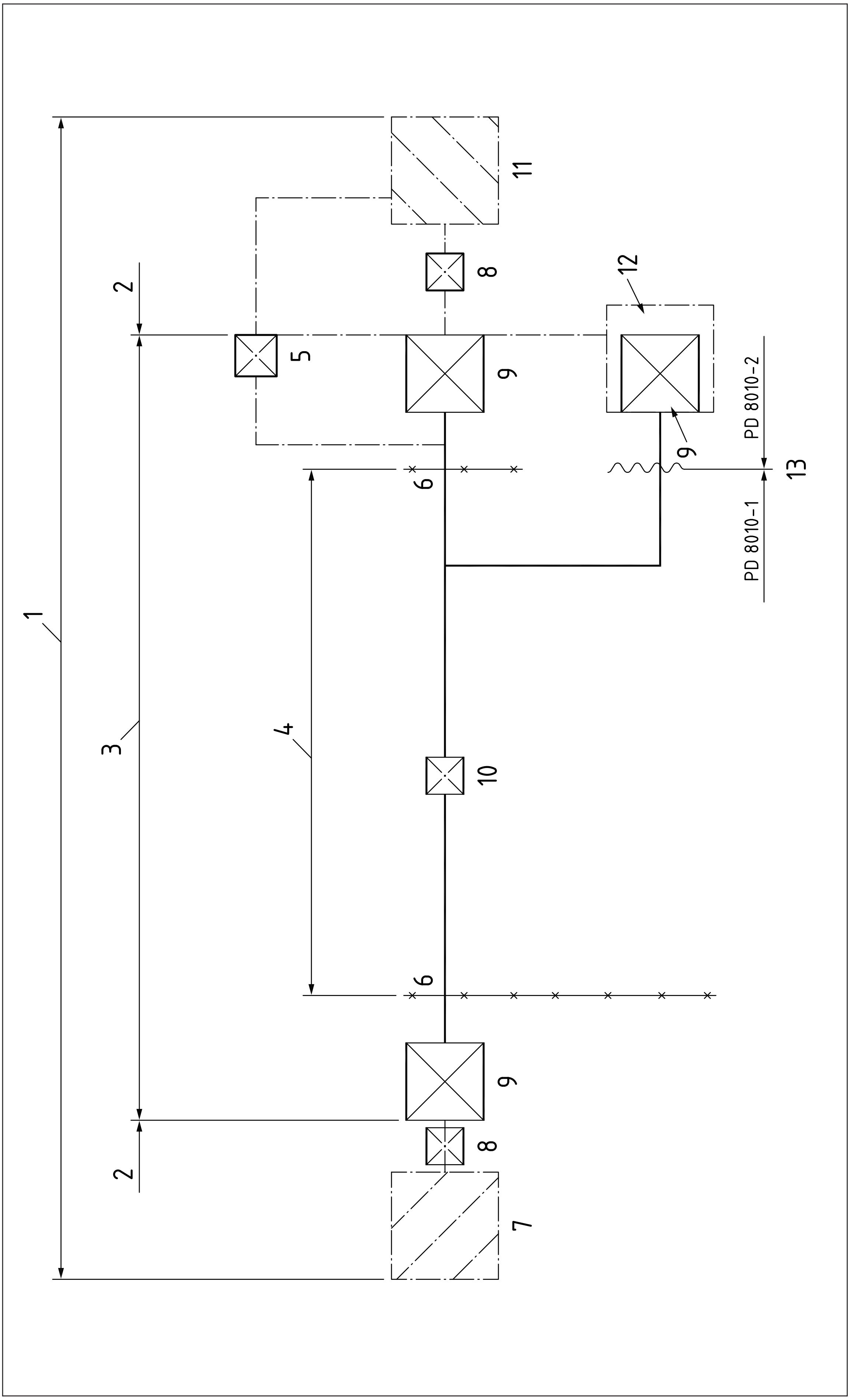

Figure 1 **Extent of pipeline systems that are covered by this part of PD 8010** *(2 of 2)*

Key

1	Pipeline system	8	Metering/integrity monitoring facility [E)]
2	Plant pressure system [A)]	9	Emergency shutdown device [F)]
3	Pipeline limit [B)]	10	In-line station [G)]
4	Third party land or business undertaking	11	Pressure letdown or storage facility [H)]
5	Relief device [C)]	12	Offshore platform (PD 8010-2)
6	Boundary fence	13	High water tide level [I)]
7	Pressure source [D)]		

NOTE The pipeline system covers all operational equipment needed to control and operate the pipeline.

A) Pressure system of wellhead or terminal. Such equipment is outside the scope of this part of PD 8010.

B) The mechanical limit of the pipeline, including emergency shutdown devices.

C) This can be for thermal relief or overpressure protection.

D) For example, a pump, compressor, wellhead or pressure reservoir.

E) This can be positioned either inside or outside the pipeline limit. It can comprise commercial metering devices and/or other facilities for monitoring the safe operation and integrity of the pipeline. For low-hazard fluids or pipelines in safe areas it can comprise a single meter at one end of the pipeline.

F) See **7.8** for position of emergency shutdown device.

G) Major isolation between plant and pipeline. For example a single block and bleed, and a pig launcher or receiver.

H) For example, a tank, vessel, letdown valve to low pressure distribution pipeline system or reservoir.

I) This indicates the cut-off point between PD 8010-1 (onshore pipelines) and PD 8010-2 (subsea pipelines).

ASTM A312, *Standard specification for seamless and welded austenitic stainless steel pipes* [2)]

ASTM A320/A320M 11a, *Specification for alloy/steel bolting materials for low-temperature service*

ASTM A790, *Standard specification for seamless and welded ferritic/austenitic stainless steel pipe*

ASTM B423, *Standard specification for nickel-iron-chromium-molybdenum-copper alloy (UNS N08825 AND N08221)* seamless pipe and tube*

ASTM B444, *Standard specification for nickel-chromium-molybdenum-columbium alloys (UNS N06625) and nickel-chromium-molybdenum-silicon alloy (UNS N06219) pipe and tube*

BS 3293, *Specification for carbon steel pipe flanges (over 24 inches nominal size) for the petroleum industry*

BS 3518-1, *Methods of fatigue testing – Part 1: Guide to general principles*

BS 3518-3, *Methods of fatigue testing – Part 3: Direct stress fatigue tests*

BS 3799, *Specification for steel pipe fittings, screwed and socket-welding for the petroleum industry*

BS 4515-1, *Specification for welding of steel pipelines on land and offshore – Part 1: Carbon and carbon manganese steel pipelines*

BS 4515-2, *Specification for welding of steel pipelines on land and offshore – Part 2: Duplex stainless steel pipelines*

BS 4882, *Specification for bolting for flanges and pressure containing purposes.*

BS 7448 (all parts), *Fracture mechanics toughness tests*

BS 7608, *Guide to fatigue design and assessment of steel products*

BS 7910, *Guide to methods for assessing the acceptability of flaws in metallic structures*

BS EN 10204, *Metallic products – Types of inspection* documents

BS EN 10224, *Non-alloy steel tubes and fittings for the conveyance of water and other aqueous liquids – Technical delivery conditions*

BS EN 13480-3, *Metallic industrial piping – Part 3: Design and calculation* [3)]

BS EN 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

BS EN 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

BS EN 62305 (all parts), *Protection against lightning*

BS EN ISO 148-1, *Metallic materials – Charpy pendulum impact test – Part 1: Test method*

BS EN ISO 3183:2012, *Petroleum and natural gas industries – Steel pipe for pipeline transportation systems* [4)]

BS EN ISO 9606-1, *Qualification testing of welders – Fusion welding*

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2) ASTM International (formerly American Society for Testing and Materials) standards are available from BSI Customer Services, Tel: +44 (845 086) 9001.

3) This part of PD 8010 also gives an informative reference to BS EN 13480-3:2012.

4) API 5L:2012 is the same as BS EN ISO 3183:2012, except that the API standard does not include Annex M.

BS EN ISO 15156 (all parts), *Petroleum and natural gas industries – Materials for use in H2S-containing environments in oil and gas production*

BS EN ISO 15607, *Specification and qualification of welding procedures for metallic materials – General rules*

BS EN ISO 15609 (all parts), *Specification and qualification of welding procedures for metallic materials – Welding procedure specification*

BS EN ISO 15610, *Specification and qualification of welding procedures for metallic materials – Qualification based on tested welding consumables*

BS EN ISO 15614 (all parts), *Specification and qualification of welding procedures for metallic materials – Welding procedure test*

BS EN ISO 15653, *Metallic materials – Method of test for the determination of quasistatic fracture toughness of welds*

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

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

BS ISO 1143, *Metallic materials – Rotating bar bending fatigue testing*

BS ISO 7005-1, *Pipe flanges – Part 1: Steel flanges for industrial and general service piping systems*

BS ISO 10474, *Steel and steel products – Inspection documents*

BS ISO 12107, *Metallic materials – Fatigue testing – Statistical planning and analysis of data*

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

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

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

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

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

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

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

PD 5500, *Specification for unfired fusion welded pressure vessels* [5)]

PD 8010-3:2009+A1:2013, *Pipeline systems – Part 3: Steel pipelines on land – Guide to the application of pipeline risk assessment to proposed developments in the vicinity of major accident hazard pipelines containing flammables – Supplement to PD 8010-1:2004*

[5)] This part of PD 8010 also gives an informative reference to PD 5500:2012+A3:2014.

Industry standards publications

API 5L:2012 (45th edition), *Specification for line pipe* [6)]

API 5LC, *Specification for CRA line pipe*

API 5LD, *Specification for CRA clad or lined steel pipe*

API 6A, *Wellhead and Christmas tree equipment*

API RP 5L2, *Internal coating of line pipe for non-corrosive gas transmission service*

IGEM/TD/1 Edition 5:2012, *Steel pipelines for high pressure gas transmission* [7)]

MSS SP 44, *Specification for steel pipelines flanges* [8)]

NACE MR0175, *Metals for sulfide stress cracking and stress corrosion cracking resistance in sour oilfield environments* [9)]

NFPA 30, *Flammable and combustible liquids code* [10)]

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this part of PD 8010, the following terms and definitions apply.

NOTE Additional definitions are given in BS EN 14161 and ISO 13623.

3.1.1 cathodic protection

system that reduces the rate of external corrosion of a steel pipeline, and the ferrous compounds of pipeline components, by regulating the electrical potential between a pipeline and its environment

3.1.2 commissioning

introduction of product into a pipeline to put the system into operation

3.1.3 component

any item that is part of a pipeline other than a straight pipe or field bend

NOTE A component can also be referred to as a fitting.

3.1.4 control zone

strip of land over which a pipeline operator has a right to control activities

3.1.5 decommissioning

activities required to take out of service any pipework, station, equipment or assemblies and to isolate them from the pipeline system

NOTE This does not necessarily include abandonment.

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6) American Petroleum Institute (API) standards are available from BSI Customer Services, Tel: +44 (845 086) 9001.

7) Institute of Gas Engineers and Managers (formerly Institution of Gas Engineers) (IGE) standards are available from the Institution of Gas Engineers and Managers, Charnwood Wing, Holywell Park, Ashby Road, Loughborough, Leicestershire LE11 3GR.

8) Manufacturers Standardization Society (MSS) standards are available from BSI Customer Services, Tel: +44 (846 086) 9001.

9) National Association of Corrosion Engineers (NACE) Standards are available from BSI Customer Services. Tel: +44 (846 086 9001.

10) National Fire Prevention Association (NFPA) Standards are available from BSI Customer Services. Tel: +44 (846 086) 9001.

3.1.6 design factor
factor applied to hoop stress when calculating the wall thickness or pressure

3.1.7 design life
time period for which a pipeline is to be used for its intended purpose with planned integrity management

3.1.8 design pressure
pressure on which design criteria are based

3.1.9 design temperature
maximum or minimum temperature which determines the selection of material for the duty proposed

NOTE This represents the most arduous condition expected.

3.1.10 easement
legally binding agreement granted by a landowner to the promoter of a pipeline, either in perpetuity or for a defined period, which sets out the rights and obligations of both parties (and their respective successors in title) in relation to the matter, but under which ownership of the land remains with the landowner

3.1.11 emergency
situation which could affect the safe operation of the pipeline system and/or the health, safety and environment of the surrounding area, requiring urgent action

3.1.12 gas
fluid that has a gaseous state at a temperature of 15 °C under normal atmospheric pressure

3.1.13 header drain
length of land drainage pipe, usually installed parallel to a pipeline, used to convey sub-surface water from existing land drainage systems that are severed by a pipeline

3.1.14 holiday
flaw in the coating or lining of a pipe

3.1.15 holiday detector
device for detecting flaws in the coating or lining of a pipe

3.1.16 incident
unexpected occurrence that could lead to an emergency situation

3.1.17 incidental pressure
level of pressure that occurs incidentally within a system, at which a safety device becomes operative

3.1.18 installation
equipment and facilities for the extraction, production, chemical treatment, measurement, control, storage or offtake of the transported fluid

3.1.19 installation temperature
temperature arising from ambient or installation conditions during laying or during construction

3.1.20 isolation joint
fitting having high electrical resistance, which can be inserted in a pipeline to electrically insulate one section of pipeline from another

3.1.21 intermediate station
pump, compressor, valve, pressure control, heating or metering station, etc. located along a pipeline route between the pipeline terminals

3.1.22 internal design pressure
maximum sustained pressure exerted by the pipeline contents which a pipeline is designed to withhold

3.1.23 lease
period of time during which ownership of land is temporarily transferred to the promoter

3.1.24 line pipe
standard length of pipe (**3.1.33**) as supplied for the construction of pipelines

3.1.25 lining
durable material applied to the internal surface of steel pipes and fittings to protect the metal from corrosion, erosion or chemical attack

3.1.26 maximum allowable operating pressure (MAOP)
maximum pressure at which a system can be operated continuously under normal conditions at any point along the pipeline and which is the sum of the static head pressure, the pressure required to overcome friction losses and any required backpressure

3.1.27 night cap
temporary closure at the end of a section of pipeline

3.1.28 operating pressure
pressure that occurs within a pipeline system under normal operating conditions

3.1.29 operating temperature
temperature that occurs within a pipeline system under normal operating conditions

3.1.30 operator
person or organization having control over the conveyance of fluid through a pipeline system at any time during all stages of its life cycle

NOTE Further information on the definition of "operator" is given in the Pipelines Safety Regulations 1996 [15], Regulation 2.

3.1.31 pig
device propelled through a pipeline by fluid pressure, for cleaning, swabbing, gauging, inspection or batch separation

3.1.32 pig trap
device allowing entry to a pipeline for the launching and receiving of pigs, inspection tools and other equipment to be run through a pipeline

3.1.33 pipe
hollow cylinder through which fluid can flow, as produced by the manufacturer prior to assembly into a pipeline

3.1.34 pipeline
continuous line of pipes of any length, without frequent branches, used for transporting fluids

NOTE 1 Pipelines do not include piping systems such as process plant piping within refineries, factories or treatment plants. However, the pipeline system covers the pipeline plus all operational equipment needed to control and operate the pipeline. Refer to Figure 1 for physical clarification of a pipeline system and a pipeline limit.

NOTE 2 A pipeline on land is a pipeline laid on or in land, including those sections laid under rivers, lakes and inland watercourses. A subsea pipeline is a pipeline laid under maritime waters and estuaries and the shore below the high water mark. Recommendations for subsea pipelines are given in PD 8010-2.

*NOTE 3 Information on establishing the interface between a pipeline and other connecting pipework systems is given in HSE publication L82 [22]. Various examples of the interfaces of pipelines with other piping systems are given in Clause **5** of this part of PD 8010 and while these are indicative, they give an illustration of the limits where the application of PD 8010 can be applied.*

3.1.35 pipeline spread
continuous length of sequential pipeline installation on which a contractor is currently working

3.1.36 pipeline system
full pressure envelope from the pressure source to the receiving vessel or pressure letdown station

NOTE Attention is also drawn to the definition given in the Pipelines Safety Regulations 1996 [15]. The extent of pipeline systems covered in this part of PD 8010 is illustrated in Figure 1.

3.1.37 pipework
assembly of pipes and fittings

3.1.38 pre-commissioning
activities, including cleaning, pigging, testing, de-watering, purging and drying as appropriate, carried out prior to commissioning

3.1.39 pressure
gauge pressure of the fluid inside a system, measured in static conditions

3.1.40 pressure safety system
system which, independent of the pressure regulating system, ensures that the outlet pressure of the regulator does not exceed the preset value

NOTE This can be a pressure relief valve or a system of pressure letdown by any means.

3.1.41 promoter
organization that seeks to install, operate and maintain a pipeline under statutory powers

3.1.42 pup
short make-up piece of pipe

3.1.43 re-commissioning
activities required to put a decommissioned pipeline, associated stations and equipment back into service

3.1.44 redundancy
incorporation of components in parallel in a control system, in which the system fails to operate only if all its components fail to operate

3.1.45 reliability
probability of a device or system performing in the manner desired for a specified period of time

3.1.46 right of way
corridor of land within which a pipeline operator has the right to conduct activities in accordance with an agreement with the landowner

3.1.47 spacer
non-stress distribution element provided to locate and support pipelines within the configuration of strapped or encased bundles

3.1.48 station
plant or facility for the operation of a pipeline system and/or the processing of fluid

3.1.49 statutory notice
notice issued under an Act of Parliament by a promoter to a landowner, occupier or relevant authority stating the statutory powers which the promoter will exercise in surveying, installing, operating and maintaining a pipeline

NOTE Such notice is sometimes required to be displayed for public comment.

3.1.50 strength test
specific procedure used to ascertain whether the pipeline, pipework and/or station meets the recommendations for mechanical strength

3.1.51 surge pressure
maximum pressure caused by:

a) rapid closure of valves during pipeline operation;

b) pump trips and re-start operations;

c) vacuum cavities in the pipeline;

d) reverse flow operations;

e) a combination of the above usually caused by mal-operation

NOTE Surge pressure is applied to liquid lines and multi-phased lines. Uninhibited surge pressure is the maximum of the combination of liquid surge pressure at maximum operation conditions and the pump shut-in head pressure.

3.1.52 test pressure
pressure to which a system is subjected to ascertain whether it can operate safely

3.1.53 tie-in weld
weld carried out between two sections of pipeline to join the sections together before or after a pressure test

NOTE A tie-in weld after pressure test is also known as a non-pressure-tested closure weld (golden weld).

3.1.54 voting system
system incorporating parallel components which operate only if a predetermined proportion of the components indicate that the system should operate

3.1.55 way leave
agreement granted by a landowner to a promoter, permitting the promoter to execute works on the terms specified

NOTE This is similar in nature to but less specific than an easement.

3.1.56 working width
strip of land used by a contractor for the purpose of installing a pipeline

NOTE The working width is usually wider than that covered by an easement, lease or way leave.

3.2 Symbols

For the purposes of this part of PD 8010, the following symbols apply.

A cross-sectional area of pipe wall, in square millimetres (mm^2)

a design factor

C_f flattening coefficient

C_p ovalization magnification factor accounting for pressure effects

D outside diameter of a pipe, as used in testing and buckling calculations, in metres (m)

D_i inside diameter of a pipe, in millimetres (mm)

D_{max} maximum (oval) outside diameter, in metres (m)

D_{min} minimum (oval) outside diameter, in metres (m)

D_o outside diameter of a pipe, in millimetres (mm)

E Young's modulus of elasticity, in newtons per square millimetre (N/mm^2)

E_b Young's modulus of elasticity, as used in buckling calculations, in newtons per square metre (N/m^2)

e weld joint factor

F axial force, in newtons (N)

F_s shear force applied to a pipeline, in newtons (N)

F_x compressive axial force, in newtons (N)

F_{xc} mean axial compression load or force, in newtons (N)

F_y yield load or force, in newtons (N)

f total ovalization of a pipe

f_o initial ovalization of a pipe cross-section

NOTE 1 The term "initial" refers to the deflection due to influences, including fabrication and bending loads, other than hydrostatic pressure.

H_c characteristic upheaval buckle imperfection height, in metres (m)

I moment of inertia, in metres to the power 4 (m^4)

i stress intensification factor (see BS EN 13480 or ASME B31.3)

k ratio D_o/D_i

L_c characteristic length associated with upheaval buckle imperfection, in metres (m)

M bending moment, in newton metres (N·m)

M_b bending moment applied to a pipeline, in newton metres (N·m)

M_c characteristic bending moment, in newton metres (N·m)

M_p full plastic moment capacity of pipeline cross-section, in newton metres (N·m)

n inner bend radius divided by pipe diameter for wall thinning formulae

P external overpressure (buckling), in newtons per square metre (N/m^2)

P_c characteristic external pressure (collapse), in newtons per square metre (N/m^2)

P_{cm} cracking carbon equivalent

P_e critical pressure for an elastic circular tube, in newtons per square metre (N/m^2)

P_{eff} effective axial force, in newtons (N)

P_i internal pressure, in newtons per square metre (N/m^2)

P_o external pressure, in newtons per square metre (N/m^2)

P_p buckle propagation pressure, in newtons per square metre (N/m^2)

P_y yield pressure, in newtons per square metre (N/m^2)

p internal design pressure (N/mm^2)

Q substance factor

S_L total longitudinal stress (combination of direct and bending stresses), in newtons per square millimetre (N/mm^2)

S_{L1} total restrained longitudinal tensile stress for a restrained section of a pipeline, in newtons per square millimetre (N/mm^2)

S_{L2} total unrestrained longitudinal tensile stress for unrestrained sections of a pipeline, in newtons per square millimetre (N/mm^2)

S_{ae} allowable equivalent stress, in newtons per square millimetre (N/mm^2)

S_{ah} allowable hoop stress, in newtons per square millimetre (N/mm^2)

S_e equivalent stress, in newtons per square millimetre (N/mm^2)

S_h actual hoop stress, in newtons per square millimetre (N/mm^2)

S_{hl} hoop stress using nominal pipe wall thickness, in newtons per square millimetre (N/mm^2)

S_y SMYS of pipe, in newtons per square millimetre (N/mm^2)

NOTE 2 See BS EN ISO 3183:2012 and API 5L:2012 (SI equivalent).

T torque applied to the pipeline, in newton metres (N·m)

T_f temperature factor change during a test

NOTE 3 This is obtained from Figure 5.

T_1 installation temperature, in degrees Celsius (°C)

T_2 maximum or minimum metal temperature, in degrees Celsius (°C)

t actual pipeline wall thickness, in metres (m)

NOTE 4 The nominal wall in metres may be substituted if the actual thickness is not known.

t_{min} minimum design thickness, in millimetres (mm)

NOTE 5 This excludes corrosion allowance and mill tolerance.

t_{nom} nominal pipe wall thickness, in millimetres (mm)

t_{thin} wall thinning, as a percentage (%)

V volume of a test section, in cubic metres (m^3)

Y minimum distance between a pipeline and an occupied building, in metres (m)

Z pipe section modulus, in cubic millimetres (mm^3)

α linear coefficient of thermal expansion, per degree Celsius ($°C^{-1}$)

α_{fab} fabrication factor

α_{τ} torsion coefficient

γ factor used in the calculation of load combinations

Δ_V incremental volume of water added during a test, in cubic metres (m^3)

Δ_P incremental pressure change during a test, in newtons per square millimetre per degree Celsius ($N/mm^2/°C$)

ε_b maximum bending strain

ε_{bc} characteristic bending strain

ε_p equivalent uniaxial plastic strain

ε_{pH} hoop plastic strain

ε_{pL} longitudinal plastic strain

ε_{pr} radial plastic strain

Φ_L imperfection coefficient

Φ_W download coefficient

ν Poisson's ratio

σ_{hb} hoop stress used in buckling analysis, in newtons per square metre (N/m^2)

σ_{hcr} critical compressive hoop stress when pressure is acting alone, in newtons per square metre (N/m^2)

σ_{hE} critical compressive hoop stress for completely elastic buckling, in newtons per square metre (N/m^2)

σ_y SMYS of pipe, as used in buckling calculations, in newtons per square metre (N/m^2)

τ shear stress, in newtons per square millimetre (N/mm^2)

τ_C characteristic torsional shear stress, in newtons per square metre (N/m^2)

τ_y yield shear stress, in newtons per square metre (N/m^2)

ω submerged weight of pipe plus over-burden, in newtons (N)

3.3 Abbreviations

For the purposes of this part of PD 8010, the following abbreviations apply.

AGI	above-ground installation
ALARP	as low as reasonably practicable
AUT	automated ultrasonic testing
CE	carbon equivalent
CIPS	close interval potential survey
cpm	chance per million per annum of an individual receiving a dangerous dose (equivalent to 1% lethality) or worse from a flammable, toxic or asphyxiate gas release from a pipeline leak, rupture or pipeline component failure
CRA	corrosion-resistant alloy
CTOD	crack tip opening displacement
DP	dye penetrant
DWT	deadweight tester
DWTT	drop weight tear testing
ECA	engineering critical assessment
EIA	environmental impact assessment
ES	environmental statement
GIS	geographical information system
HAZ	heat-affected zone
HFW	high frequency welding
LPG	liquefied petroleum gas
MAHP	major accident hazard pipeline
MAOP	maximum allowable operating pressure
MPI	magnetic particle inspection
NDT	non-destructive testing
NGL	natural gas liquid
SAW	submerged arc welding
SMYS	specified minimum yield strength
SRA	structural reliability analysis
SSSI	site of special scientific interest
TPO	tree preservation order
UT	ultrasonic testing
UTS	ultimate tensile strength

4 Health, safety and assurance

4.1 Health, safety and the environment

The recommendations included in this part of PD 8010 are based upon considerations of safety extending throughout the lifetime of a pipeline system.

Experienced and competent engineering judgement should be employed to assess the individual requirements of each pipeline project undertaken.

The design, chosen materials, route, environmental impact and hazard/risk analysis should all be fully assessed and the most appropriate measures selected to ensure as far as possible that the pipeline system will be fit for service throughout its lifetime.

To increase the overall safety of the installation, as many of the following additional measures as are deemed appropriate should be taken against third-party interference:

- modification of the design factor by increasing the wall thickness or using high-strength pipe steels (including selection of appropriate toughness properties for fracture-arrest capability);
- route of the pipeline at an appropriate distance from buildings. The distance should be fixed by the particular hazards (see **5.5.3**);
- increase in depth for the pipeline greater than that of normal agricultural/horticultural activities expected in the area;
- route of the pipeline clearly identified by a locating system such as additional route markers;
- increase in frequency of surveillance, inspection and control;
- regular communication with landowners, occupiers, local authorities and the emergency services along the pipeline route;
- additional forms of mechanical protection. Designers should carefully select the forms of additional protection to minimize any adverse effects on the efficiency of the cathodic protection.

NOTE 1 The probability of third-party interference to the pipeline decreases if a depth greater than the minimum recommended in this part of PD 8010 is adopted.

NOTE 2 Ensuring an adequate frequency of surveillance can further increase pipeline safety.

NOTE 3 Attention is drawn to the Pipe-lines Act 1962 [14] in respect of application for a Pipeline Construction Authorization for pipelines greater than 10 miles (16.093 km) long. Attention is drawn to the Town and Country Planning Act 1990 [21] in respect of planning permission for local pipelines.

NOTE 4 Attention is drawn to the Pipelines Safety Regulations 1996 [15] and the Pressure Systems Safety Regulations 2000 [20] in respect of inspection and operation safety regimes.

4.2 Competence assurance

The design, construction, testing, operation, maintenance and abandonment of the pipeline system should be carried out by suitably qualified and competent persons, under the supervision of an experienced chartered engineer or equivalent.

NOTE The best manufacturing and construction methods cannot compensate for inadequate design.

Procedures should be established and maintained to control and verify the design, construction and testing of the pipeline, to ensure that the pipeline specification is met, and to minimize error during this process.

4.3 Quality assurance

4.3.1 General

Quality assurance procedures should be applied throughout the feasibility, investigation, design, procurement, construction, testing, operation, maintenance and modification of a pipeline system to ensure compliance with all the relevant standards.

An efficient document control system is essential. A quality plan should be developed appropriate to the duty and nature of the substance to be carried. For pipelines conveying category A, category B or category C substances, some of the quality recommendations given in Annex B may be omitted as appropriate for the nature of the hazard and the pressure of the system, provided that it can be demonstrated that the integrity of the pipeline and quality system can be maintained. For pipelines conveying category D or category E substances, all of the recommendations given in Annex B should be followed.

***Assessed capability**. Users of this Published Document are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 and BS EN ISO 14001 series by an accredited third-party certification body.*

4.3.2 Inspection

The level of inspection should be such as to meet the requirements of the quality plan (see Annex B and **C.6**). Inspection activities should be certified by appropriately qualified personnel.

4.3.3 Records and document control

All documents, specifications, drawings, certificates and change orders relating in any way to project quality should be retained, cross-referenced and filed in accordance with the quality plan

Annex C gives details of the documents that should normally be included in the quality system. For pipelines conveying category A, category B or category C substances, some of these documents may be omitted due to the low risk nature of the hazard and the low pressure of the system, provided that it can be demonstrated that the integrity of the pipeline and its essential documentation can be maintained.

NOTE The control of pipeline records and operations can be improved by the use of electronic systems, such as pipeline databases and geographical information system (GIS).

All design, procurement, construction, testing, inspection and survey documentation should be retained for the life of the pipeline.

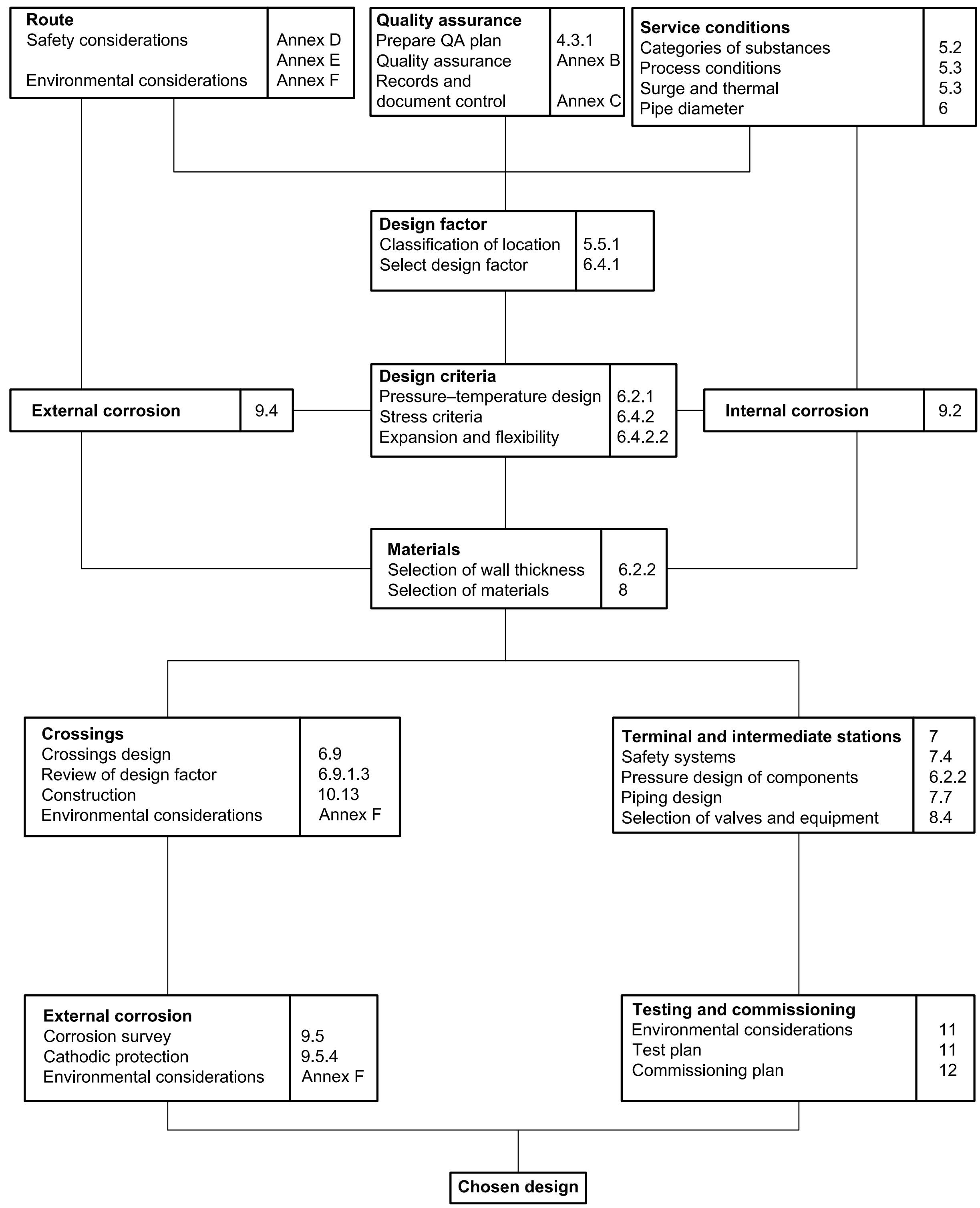
4.4 Design, construction and commissioning assurance

A design assurance system should be established, such as the one shown in Figure 2, which should include all aspects of the design process. As a minimum it should include all of the issues addressed in Clause **5** to Clause **9**. It should also address practicalities and limitations associated with construction (Clause **10** and Clause **11**), and requirements for pre-commissioning and commissioning (Clause **12**), operation (Clause **13**), and abandonment (Clause **14**).

The construction through to commissioning process should reflect the design and should take into account, validate and record any changes or deviations from the original design (see also **4.6.6**).

NOTE The pipeline design flowchart shown in Figure 2 has been developed to give general guidance on the design process. This flowchart may be used as a guide through the design process. It does not attempt to show all the various pathways required to arrive at the chosen design.

Figure 2 **Example of a pipeline design flowchart**



NOTE The numbers shown in the flowchart boxes refer to the subclause numbering of this part of PD 8010.

4.5 Operation and abandonment assurance

The operation and abandonment process should take into account the design, any changes made during or subsequent to construction, and the condition of the system (see Clause **13** and Clause **14** for more detailed recommendations).

4.6 Plans and drawings

4.6.1 Preliminary routeing plans

For preliminary routeing plans, maps of either 1:25 000 or 1:50 000 scale should be used, according to the complexity of the terrain.

4.6.2 Field reconnaissance plans

For field reconnaissance plans, Ordnance Survey maps of either 1:10 000 or 1:25 000 scale should be used.

NOTE 1 The use of 1:10 000 maps can obviate duplication, since this is the smallest scale acceptable for applications under the Pipe-lines Act 1962 [14].

NOTE 2 For local and cross-country pipelines, aerial photographs with a resolution of 250 mm or better, overlaid with Ordnance Survey coordinates at scales of 1:10 000 and less, are acceptable provided they are located by a known Ordnance Survey coordinate.

NOTE 3 Ordnance Survey Maps and Sheets may not be reproduced or copied without the permission of the Director-General of Ordnance Survey [11)].

4.6.3 Final field survey plans

For final field survey plans, Ordnance Survey sheets of 1:2 500 scale with field numbers should be used.

4.6.4 Strip plans

Strip plans (also commonly referred to as alignment sheets) should be prepared from Ordnance Survey sheets or aerial imagery of 1:2 500 scale. In built-up areas, plans of 1:1 250 scale should be used if necessary. Any alteration to land drainage works should be detailed on these plans. Any vertical section or profile along the pipeline route should be shown to a scale appropriate to the variations in ground elevation. Crossings should be detailed on separate drawings that should be cross-referenced to the appropriate strip plan; the scale should be between 1:250 and 1:25 depending on the complexity of the work.

4.6.5 Plans for landowner agreements

Plans for landowner agreements should normally be based on the Ordnance Survey sheets, preferably the 1:2 500 scale. Exceptions to this are when the area of land is very small or complex, when a larger scale should be used, and when the area of land is very large and uniform, when a smaller scale should be used.

4.6.6 As-built plans

If during construction of the pipeline there are any changes or deviations from any issued plans following discussions with third parties or changes in design, as-built plans (to the same scale as the original plans) should be issued to all the original recipients on completion of the work.

*NOTE If found more convenient, the strip plans detailed in **4.6.4** may be used for this purpose.*

[11)] Ordnance Survey, Romsey Road, Southhampton, S016 4GU. Tel: +44 (0) 8456 050505. Fax: +44 (0)23 8079 2615.

5 Design – System and safety

*COMMENTARY ON CLAUSE **5***

This clause addresses the safety of the entire pipeline system, including pipeline process engineering.

The extent of a pipeline system covered by this part of PD 8010 is shown in Figure 1.

An example of a design flowchart is given in Figure 2.

5.1 System definition

The extent of the pipeline system, its functional requirements and applicable legislation, including proposals for future abandonment, should be defined and documented.

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

The definition of functional requirements should include the intended design life and design conditions. The design conditions should include foreseeable normal operating conditions, upset and operational extremes, including shut-in operating conditions. It should also include possible ranges in flow rates, pressures, temperatures, fluid compositions and fluid qualities.

5.2 Categorization of substances

5.2.1 General

The substances to be transported should be categorized, with respect to hazard potential in respect of public safety, into one of the five categories given in Table 1.

NOTE 1 Attention is drawn to the Pipelines Safety Regulations 1996 [15] for the definition and classification of dangerous fluids (hazardous substances).

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

NOTE 2 Guidance is given in a number of publications including HSE publication L82 [22] and ICE publication Nomenclature for hazard and risk assessment *[23].*

NOTE 3 Additional guidance on CO_2 pipelines is given in DNV-RP-J202.

5.2.2 Hazard potential

*COMMENTARY ON **5.2.2***

In the event of a rupture of a pipeline conveying a gas, the blast effect owing to stored energy is an important factor in the hazard potential of the substance. The rupture of a pipeline conveying a liquid has a much lower blast effect owing to the relatively incompressible nature of liquids. Gases conveyed as liquids have an intermediate effect. The characteristics of some hazardous substances commonly conveyed in pipelines are described in Annex D, to assist the designer in determining the category into which hazardous substances are to be placed.

See also Annex E, which gives recommendations for safety evaluation.

The designer should determine the category into which hazardous substances are to be placed.

Table 1 **Categorization of substances according to hazard potential**

Category	Description	Typical examples
A	Typically non-flammable water-based fluids	Water, brine, dilute effluents
B	Flammable and/or toxic fluids that are liquids at ambient temperature and at atmospheric pressure conditions	Oil and petroleum products Methanol
C	Non-flammable fluids that are non-toxic gases at ambient temperature and atmospheric pressure conditions	Nitrogen, oxygen, argon and air
D	Non-toxic, single-phase natural gas	—
E	Flammable and/or toxic fluids that are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases and/or liquids Mixtures of petroleum or chemical substances, having a Reid vapour pressure greater than 31 kPa absolute	Hydrogen, carbon dioxide, natural gas (not otherwise covered in category D), ethane, ethylene, liquefied petroleum gas (e.g. propane and butane), natural gas liquids, ammonia and chlorine Spiked or live crude oil

5.3 Pipeline process design

5.3.1 General

All pipelines should have a pipelines process data sheet or document including:

a) means of pressure;

b) fluid characteristics;

c) process;

d) pipeline size;

e) fluid volume;

f) fluid transfer rates;

g) modes of pipeline operation;

h) process operating conditions;

i) hydraulic route analysis;

j) maximum operating and surge pressure;

k) direction of flow;

l) maximum shut-in head;

m) surge pressure and surge control;

n) proposed relief systems;

o) thermal relief control;

p) fracture control.

5.3.2 Hydraulic analysis

The hydraulics of the pipeline system should be analysed to demonstrate that the system can operate safely at the design conditions identified in **5.3.1**, and to identify and determine the constraints and requirements for its operation. The analysis should cover steady state and transient operating conditions.

NOTE Examples of constraints and operational requirements are:

- *allowances for pressure surges;*

- *prevention of blockages, e.g. 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.*

5.3.3 Pressure control and overpressure protection

If the operating pressure could exceed the MAOP anywhere in the pipeline system, provisions such as pressure safety systems, control valves or automatic shutdown of pressurizing equipment should be installed. Such provisions or procedures should prevent the operating pressure exceeding MAOP under normal steady-state conditions.

Overpressure protection, such as relief or source isolation valves, should be provided if necessary to prevent incidental pressures exceeding the limits recommended in **6.2.1.5** anywhere in the pipeline system.

5.3.4 Operation and maintenance

The requirements for operation and maintenance of the pipeline system should be established and documented. For operation and maintenance plans, the specific recommendations given in Clause **13** should be followed.

5.3.5 Heated pipeline systems

Temperature indication and controls should be provided where heating or cooling of the fluids is required for operation of the pipeline system.

NOTE For heating stations, trace heating can be required on pipework, pump bodies, drains and instrument lines to ensure satisfactory flow conditions following shutdown.

Account should be taken of the safety, technical reliability, electrical efficiency, repair difficulty and system track record of the proposed system. The impact on the surrounding ground water, coatings and cathodic protection systems should be assessed.

5.4 Public safety and protection of the environment

*COMMENTARY ON **5.4***

The recommendations given in this subclause are expected to be adequate for public safety and environmental protection under conditions usually encountered in pipelines, including those in offshore and nearshore areas. However, these recommendations do not replace the need for appropriate experience and competent engineering judgement.

Materials and practices not specifically recommended in this part of PD 8010 may be used providing they can be shown to achieve comparable safety standards.

5.4.1 General

The design and location of a pipeline should take account of the hazard potential of the substance to be conveyed (see **5.2.1**), the proximity of the pipeline to normally occupied buildings, the density of population in areas through which the pipeline passes, whether the pipeline is located within a corridor of hazardous pipelines and the likely causes of failure.

Potential causes of pipeline damage which can lead to subsequent failure include the activities of third parties carrying out agricultural or construction works along the route of the pipeline, such as those associated with deep working of the land, drainage, installation and maintenance of underground services and general road works.

The provision of suitable and safe access for in-service inspection should be included at the design stage.

*NOTE The safety and reliability of a pipeline system can be improved by the application of quality assurance procedures in design (see Clause **4**).*

5.4.2 Safety evaluation

Where a safety evaluation is required, it should be carried out in accordance with Annex E.

NOTE Attention is drawn to the Pipelines Safety Regulations 1996 [15] in respect of the requirement to carry out a safety evaluation for major accident hazard pipelines (MAHPs).

5.5 Location of pipeline systems

5.5.1 Classification

The location of pipelines conveying category C, category D or category E substances should be classified in relation to population density along the route of the pipeline, to determine the operating stress levels and proximity distances from normally occupied buildings. Location should be classified in accordance with Table 2.

*NOTE The location of pipelines conveying category A or category B substances need not be classified in relation to population density, but pipelines conveying category B substances can require extra protection or be subjected to a safety evaluation (see **5.4.2** and Annex E).*

Table 2 **Classification of location in relation to population density**

Location class	Description
1	Areas with a population density less than 2.5 persons per hectare
2	Areas with a population density greater than or equal to 2.5 persons per hectare and which might be extensively developed with residential properties, schools and shops, etc.
3	Central areas of towns and cities with a high population and building density, multi-storey buildings, dense traffic and numerous underground services

*NOTE The measurement of population density is described in **5.5.2**.*

Any relevant additional factors should be taken into account when classifying pipeline location, such as possible future developments, topographical features in the area through which the pipeline passes, and watercourses crossed or adjacent to the pipeline leading to areas of higher population density. In these and other comparable cases, a more stringent classification of location should be used when necessary, especially where the effects of a pipeline failure could be experienced by population centres outside the immediate vicinity of the pipeline.

5.5.2 Population density

The population density should be expressed in terms of number of persons per hectare. Measurement of population density should be based on a survey of normally occupied buildings, including houses, schools, hospitals, public halls, and industrial units. The population should be estimated following consultation with local authorities to assess the population level in the area concerned.

For pipelines conveying category C, category D or category E substances, the population density should be calculated as the total of the average number of persons normally occupying buildings lying within the 0.3 cpm individual risk contours for the pipeline.

Individual risk contours used for the purposes of calculating the population density and the minimum distance between a pipeline and occupied buildings should be calculated using a casualty criterion corresponding to a dangerous dose or worse (equivalent to 1% lethality), in order to be consistent with land use planning zones, as detailed in PD 8010-3:2009+A1, Annex A.

NOTE A casualty criterion corresponding to a significant likelihood of death (50% lethality) is commonly used in risk assessments; see Annex E and PD 8010-3:2009+A1.

Where individual risk levels are not available, the population density for pipelines conveying category C substances should be calculated as the total of the average number of persons normally occupying buildings within a strip centred on the pipeline of width three times the minimum distance given in **5.5.3.2** for any 1.6 km length of pipeline. For pipelines conveying category D or category E substances, the population density should be calculated as the total of the average number of persons normally occupying buildings within a strip centred on the pipeline of width eight times the minimum distance given in **5.5.3.2** for any 1.6 km length of pipeline.

It is recommended that the boundary between location class 1 and class 2 in relation to population density is determined in a manner equivalent to that used in IGEM/TD/1 Edition 5:2012 to determine the boundary between Type R and Type S areas. On this basis, the point at which the required degree of protection changes adjacent to the boundary between location class 1 and class 2 areas should be determined as the point at which the population density exceeds the class 1 limit. In order to determine the boundary position, the population should be calculated within circles of diameter equivalent to twice the 0.3 cpm risk contour distance from the pipeline or eight times the distance calculated in accordance with **5.5.3.2**. By using such circles in sequence outwards from the high density area, the circle within which the population density first falls below/above 2.5 persons per hectare should be determined. The centre of this circle should then be taken as the class 1/class 2 boundary.

Occasionally the method of population density assessment can lead to an anomaly in location class such as might occur, for example, in a ribbon development area. In such cases, a more stringent classification than would be indicated by population density alone should be used where necessary. Societal risk should be taken into account in these instances.

When routeing pipelines conveying toxic substances, a more stringent classification should be given where populated areas with the characteristics of location classes 2 or 3 are outside, but close to the edge of, the strip used to define the population density. Societal risk should be taken into account in these instances.

A strip centred on the pipeline of width sixteen times the minimum distance given in **5.5.3.2** should be used when identifying populated areas that might be of concern.

5.5.3 Proximity to occupied buildings

5.5.3.1 Pipelines conveying category A or category B substances

The minimum distance between a pipeline conveying category A or category B substances and occupied buildings should be determined by the designer, who should take into account both access requirements during construction, and access requirements for maintenance and emergency services during operation.

5.5.3.2 Pipelines conveying category C, category D or category E substances

For pipelines conveying category C, category D or category E substances, the initial route and population density assessment should be established by the designer at the feasibility study stage.

a) Where individual risk contours have been calculated for the pipelines, these should be used. The distance for routeing purposes between a pipeline and occupied buildings should be no less than the distance to the 10 cpm risk contour.

NOTE 1 Land use planning controls exercised by local planning authorities can require this distance to increase, with the consequent reappraisal of pipe wall thickness or mitigating measures. See also ***E.10****.*

b) Where individual risk contours are not available, the initial route and population density assessment should take account of the proximity to occupied buildings.

c) For pipelines having a design factor not exceeding 0.72, the minimum distance for routeing purposes between the pipeline and occupied buildings, Y, should be determined using equation (1).

$$Y = Q\left(\frac{{D_o}^2}{32000} + \frac{D_o}{160} + 11\right)\left(\frac{p}{3.2} + 1.4\right) \tag{1}$$

The substance factor Q should be determined in accordance with Table 3.

NOTE 2 The substance factors give cautious estimates of the minimum distance for routeing purposes. A more rigorous analysis using a risk-based approach gives smaller distances.

Table 3 **Substance factors**

Substance	**Substance factor, *Q***
Ammonia	2.5
Carbon dioxide	2.0 for dense phase and 1.0 for gas phase [A)]
Ethylene	0.8
Hydrogen	0.45
Liquid petroleum gas	1.0
Natural gas liquids	1.25
Category C	0.3

A) The substance factor for carbon dioxide is informative. The selected value should be supported by reference to joint industry or project specific research and guidance on the routeing of pipelines conveying carbon dioxide.

The proximity distances for pipelines conveying category C substances at pressures less than 3.5 N/mm² (35 bar) should be the same as those for the substance calculated at 3.5 N/mm² (35 bar).

Substances not specifically listed by name in Table 3 should be given the substance factor most closely similar in hazard potential to those quoted.

For pipelines conveying category C substances and having a design factor not exceeding 0.3, the initial route may be established by allowing a minimum distance of 3 m between the pipeline and occupied buildings. For pipelines conveying category D substances and having a design factor not exceeding 0.3 and a wall thickness greater than or equal to 11.91 mm, the initial route may be established by allowing a minimum distance of 3 m between the pipeline and occupied buildings.

For pipelines conveying category E substances and having a design factor not exceeding 0.3 and a wall thickness greater than or equal to 11.91 mm, the initial route may be established by allowing a minimum distance of 5.5Q m between the pipeline and occupied buildings.

A more rigorous analysis using a risk-based approach should be used for the final design limits. For pipelines conveying category D or category E substances, societal risk should be taken into account.

NOTE 3 Guidance is given in PD 8010-3:2009+A1.

NOTE 4 A societal risk calculation is not normally required for pipelines conveying category D substances if the area types and proximity distances in IGEM/TD/1 Edition 5:2012 are followed.

Societal risk calculations should be carried out for pipelines conveying toxic category E substances (e.g. ammonia or carbon dioxide).

5.6 Route selection

Safety, environmental, technical and economic considerations should be the primary factors governing the choice of pipeline routes. The shortest route might not be the most suitable, and physical obstacles, environmental and other factors should be taken into account.

Route selection should further take into account the design, construction, operation, maintenance and abandonment of the pipeline. To minimize the possibility of future corrective work and limitations, anticipated urban and industrial developments should be taken into account.

For pipeline route selection, the specific recommendations given in Annex F should be followed.

6 Design – Mechanical integrity

*COMMENTARY ON CLAUSE **6***

*This clause deals with the mechanical integrity of a pipeline. Recommendations for pipeline system and safety design are given in Clause **5**.*

6.1 General

The methods used in designing pipelines should 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.

6.2 Design criteria

*COMMENTARY ON **6.2***

The design criteria or design basis of a pipeline are determined by how hazardous the fluid to be conveyed is and how difficult the route is. The more hazardous the fluid, the higher the design quality and the more detailed the design.

6.2.1 Process conditions (pressure–temperature ratings)

6.2.1.1 Pipe and components having specific pressure–temperature ratings

The pressure–temperature ratings for pipe and components should be consistent with the appropriate component standard(s) selected for the project.

6.2.1.2 Components not having specific pressure–temperature ratings

If components not having specific pressure–temperature ratings are to be used, the pressure design should be based on sound engineering analysis supported by proof tests, experimental stress analysis and/or engineering calculations as appropriate.

6.2.1.3 Normal operating conditions

For normal operation the MAOP should not exceed the internal design pressure and pressure ratings for the components used. It should exclude surge pressure, thermal relief pressure and other variations that can occasionally occur above the design pressure.

NOTE The MAOP may be reviewed and revised during the lifetime of the pipeline according to the pressure source, overall pipeline system integrity and condition of the pressure envelope.

6.2.1.4 Allowance for variations from normal operation

NOTE Surge pressures that occur in liquid pipelines can be produced by sudden changes in flow, for example, following valve closure, pump shutdown, pump start-up or blockage of the moving stream.

Surge pressure calculations should be carried out to assess the maximum positive and negative surge pressures in the system. Account should be taken of surge pressures produced within the pipeline affecting systems that are outside the scope of this part of PD 8010, such as upstream of pumping stations or downstream of pipeline terminals.

6.2.1.5 Overpressure protection

Controls and protective equipment should be provided to ensure that the incidental pressure which is the sum of the operational pressure, the surge pressure, thermal relief pressure or other variations from normal operations does not exceed the internal design pressure at any point in the pipeline system by more than 10%.

NOTE The safe operating limit defined in the Pipelines Safety Regulations 1996 [15] is equal to or greater than the incidental pressure.

6.2.1.6 Different pressure conditions

When two pipeline systems operating at different pressure conditions are connected, the valves or components separating the two pipeline systems should be designed for the more severe design conditions.

6.2.2 Pressure design of pipeline and pipeline components

6.2.2.1 Straight pipe under internal pressure

The nominal thickness of steel pipe, minus the specified manufacturing tolerance on wall thickness and the designated corrosion allowance where applicable, should be not less than the design thickness used in the calculation of hoop stress (see **6.4.2.1**). A nominal pipe wall thickness should be selected to ensure structural integrity in construction handling and welding.

*NOTE For treatment of corrosion allowance, see **6.8.1**.*

6.2.2.2 Straight pipe under external loading

Pipe wall thickness should be sufficient to prevent collapse under conditions during construction or operation when the external pressure exceeds the internal pressure, taking into account pipe mechanical properties, bending stresses, dimensional tolerance and external loads (see BS EN 13480-3 or ASME B31.3).

For pipelines assuming a natural curvature that incurs a permanent elastic bending stress, the minimum bending radius should be determined at the design stage through stress analysis.

6.2.2.3 Bends

Changes in direction may be made by bending pipe or installing factory-made bends or elbows. All bends should be free from buckling, cracks or other evidence of mechanical damage. The nominal internal diameter of a bend should not be reduced in ovality by more than 2.5% at any point around the bend. Sufficient tangent lengths should be left at each end of a bend to ensure good alignment and to facilitate welding. Pipes bent cold should not contain a girth weld within the bent section.

The wall thickness of finished bends should take into account wall thinning at the outer radius and the torus effect, and therefore should be greater than the design thickness shown in **6.2.2.1**. An indication of wall thinning as a percentage can be calculated using equation (2).

$$t_{\text{thin}} = \frac{50}{n+1} \tag{2}$$

This formula does not take into account other factors that depend on the bending process, and the bend manufacturer should be consulted where wall thinning is critical.

*NOTE 1 See **8.3.5** for materials aspects of bending and **10.12.5** for field bending during construction.*

Mitred, wrinkled or gusseted bends should not be used in pipelines, with the exception of pipelines conveying category A substances at low pressure (see Note 2). Account should be taken of the use of cleaning, scraper and internal inspection devices (pigs) when specifying the radius of bends intended for installation in pipelines.

NOTE 2 For existing pipelines with mitred, wrinkled or gusseted bends, a fitness-for-purpose assessment is needed for revalidation to ensure structural integrity.

Factory-made bends and factory-made wrought steel elbows may be used provided that they are in accordance with **8.3.5** and the present subclause.

NOTE 3 Additional forces might need to be taken into account.

6.3 Loads

6.3.1 General

The design should account for loads that can cause or contribute to pipeline failure or loss of serviceability. The design should be for the most severe coincident conditions of pressure, temperature and loading which could occur during normal operation or testing.

The loads described in Annex G should be taken into account, and the recommendations in Annex G should be followed for each type of load.

6.3.2 Internal design pressure

The internal design pressure used in design calculations should be not less than the MAOP at that point.

NOTE 1 The MAOP is the sum of the operating pressure, static head pressure, the pressure required to overcome friction losses and any necessary backpressure. The net internal design pressure used in design calculations may be modified by taking into account the difference in pressure between the inside and outside of any pipeline component.

NOTE 2 The pressure definitions are illustrated in Figure 3.

6.4 Strength

6.4.1 Design factors

6.4.1.1 General

*NOTE 1 See **5.2** for fluid categorization and **5.5.1** for location classifications.*

NOTE 2 BS EN 14161 allows a design factor of up to 0.77 to be used (up to 0.83 for environments such as desert and tundra).

The design factors in **6.4.1.2**, **6.4.1.3** and **6.4.1.4** should be used.

6.4.1.2 Category B substances

For pipelines designed to convey category B substances, the design factor, *a*, should under normal circumstances not exceed 0.72 in any location (see **6.4.1.3**). In areas of high population density extensively developed with residential properties, schools, shops, public buildings and industrial areas, extra protection to the pipeline should be provided where necessary, as described in **E.9**.

6.4.1.3 Category C, category D and category E substances

For pipelines designed to convey category C, category D or category E substances, the design factor, *a*, should under normal circumstances not exceed 0.72 in class 1 locations. In class 2 locations, the design factor should normally not exceed 0.30, but this may be raised to a maximum of 0.72 provided that it can be justified to a statutory authority by a risk analysis carried out as part of a safety evaluation for the pipeline.

For pipelines designed to convey category C substances that are to be pneumatically tested, the design factor should not exceed 0.30, unless this can be justified through a fracture mechanics analysis.

Pipelines designed to convey category D or category E substances in class 2 locations should either have a nominal wall thickness of at least 9.52 mm or be provided with impact protection in accordance with **6.9.7** (see also **E.9**) to reduce the likelihood of penetration from mechanical interference.

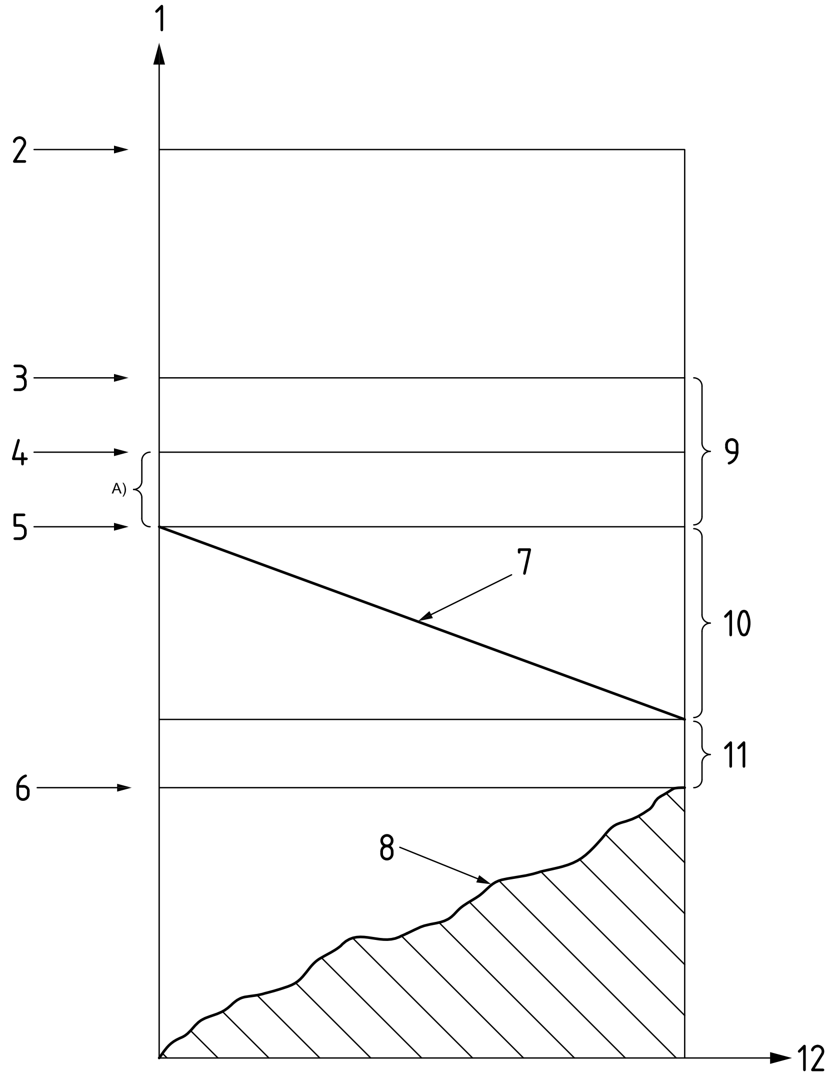
Routeing of pipelines conveying category C (hazardous), category D or category E substances through class 3 locations should be avoided.

6.4.1.4 Design factors above 0.72

NOTE 1 The UK regulatory authorities recommend that design factors be no higher than 0.72. A full risk assessment (see Annex E) is recommended if design factors above 0.72 are used, and might be subject to regulatory review.

Any increase in design factor above 0.72 should be applied to pipelines in class 1 areas or minor incursions into class 2 areas only.

Figure 3 **Design and test pressure**



Key

1 Pressure
2 Test pressure
3 1.10 × internal design pressure
4 Net internal design pressure [A)]
5 Maximum allowable operating pressure [A)]
6 Static head pressure
7 Hydraulic gradient
8 Ground profile
9 Surge pressure, thermal and other variations
10 Pressure recommended to overcome friction losses
11 Recommended backpressure
12 Distance along pipe

[A)] The MAOP may vary between these limits dependent upon the test pressure.

If design factors above 0.72 are to be adopted, it should be demonstrated to the regulatory authorities that the increase in failure probability and risk due to the ultimate limit states is not significant when compared to operation at the design factors recommended in **6.4.1.2** and **6.4.1.3**. Such demonstration should be provided through the use of risk-based techniques and structural reliability analysis or other relevant advanced analysis methods.

All relevant ultimate limit states should be taken into account and the limit state principles and requirements should be applied consistently and comprehensively throughout the design.

The design should also take account of the relevant serviceability limit states.

NOTE 2 Further information on these methods and their application to category D substances and the justification and use of higher design factors is given in IGEM/TD/1 Edition 5:2012. Information is also given in BS EN ISO 16708.

All relevant sources of uncertainty in loads (including fatigue) and load resistance should be taken into account, and statistical data should be obtained for characterization of these uncertainties.

NOTE 3 BS EN 1594 provides some general guidance on the application of structural reliability-based limit state design principles.

NOTE 4 Ultimate limit states are normally associated with loss of structural integrity (product containment), e.g. rupture, fracture, or collapse, whereas exceeding serviceability limit states prevents the pipeline from operating as intended.

6.4.2 Calculation of stresses

6.4.2.1 Hoop stress

The hoop stress, S_h, developed in the pipe wall at the internal design pressure should not exceed the allowable hoop stress, S_{ah}, given in **6.4.3.1**. The hoop stress should be calculated using equation (3) for thin pipe walls and equation (4) for thick pipe walls (the thick wall equation should be used when the D_o/t_{min} ratio is less than or equal to 20). This gives the maximum hoop stress encountered at the outside face of the pipe wall.

Thin wall:

$$S_h = \frac{pD_o}{2t_{min}} \tag{3}$$

Thick wall:

$$S_h = \frac{p\left(D_o^2 + D_i^2\right)}{\left(D_o^2 - D_i^2\right)} \tag{4}$$

where D_i is given by ($D_o - 2t_{min}$).

NOTE Equation (4) gives a more accurate calculation of hoop stress and always gives the lowest value of maximum stress. When the D_o/t_{min} ratio is greater than 20, the difference between the stresses calculated from the two formulae is less than 5%.

6.4.2.2 Expansion and flexibility

Pipelines and piping should be designed with sufficient flexibility to prevent expansion or contraction causing excessive forces or stresses in pipe material, joints, equipment, anchors or supports.

Expansion calculations should be carried out for buried and above-ground pipelines where flexibility is in doubt, and where significant temperature changes are expected such as those which occur in heated oil or refrigerated pipelines. Thermal and pressure expansion or contraction of buried pipelines can cause movement at termination points, changes in direction or changes in size. The necessary flexibility should be provided if such movements are unrestrained. Account should be taken of buckling forces that can be imposed on pipelines laid where ground movement might occur (see **6.4.4**).

The effect of restraints, such as support friction, branch connections and lateral interferences, should be taken into account.

Calculations should take into account stress intensification factors found to be present in components such as bends and field joints (other than plain straight pipe). Account should be taken of any extra flexibility of such components.

NOTE In the absence of more directly applicable data, the flexibility factors and stress intensification factors given in BS EN 13480-3 or ASME B31.3 may be used.

Above-ground pipelines and piping can be restrained by anchors so that the longitudinal movement owing to thermal and pressure changes is absorbed by direct axial compression or tension of the pipe. In such cases expansion calculations should be carried out taking into account all the forces acting on the pipeline. Account should be taken of elastic instability due to longitudinal compressive forces.

Where movement is restrained, flexibility should be provided by means of loops, offsets or special fittings. The total operating temperature range should be taken as the difference between the maximum and minimum metal temperatures for the operating cycle under consideration and should be used in calculating stresses in loops, bends and offsets.

The temperature range used in the calculation of reactions on anchors and equipment should be taken as the difference between the maximum or minimum metal temperatures and the installation temperature, whichever gives the greater reaction.

Where there is a likelihood of repeated stress changes (including thermal stress) giving rise to fatigue conditions, the stress range and allowable number of cycles should be calculated in accordance with **6.4.6**.

Nominal pipe wall thickness (including any corrosion allowance) and nominal outside diameter should be used for expansion and flexibility calculations.

6.4.2.3 Longitudinal stress

The total longitudinal stress should be the sum of the longitudinal stress arising from pressure, bending, temperature, mass, other sustained loadings and occasional loadings (see Annex G).

NOTE A pipeline is deemed to be totally restrained when axial movement and bending resulting from temperature or pressure change is totally prevented.

For totally restrained sections of a pipeline, the longitudinal tensile stress, S_{L1}, resulting from the combined effects of temperature and pressure change alone should be calculated using equation (5) for thin wall or equation (6) for thick wall.

Thin wall:

$$S_{L1} = vS_{hl} - E\alpha(T_2 - T_1) \tag{5}$$

Thick wall:

$$S_{L1} = v(S_{hl} - p) - E\alpha(T_2 - T_1) \tag{6}$$

where S_{hl} is calculated using equation (3) or (4) as appropriate, but using the nominal pipe wall thickness, t_{nom}, instead of t_{min}.

For unrestrained sections of a pipeline, the longitudinal tensile stress, S_{L2}, resulting from the combined effects of temperature and pressure change alone should be calculated using equation (7) for thin wall or equation (8) for thick wall.

Thin wall:

$$S_{L2} = \frac{S_{hl}}{\kappa^2 + 1} + \frac{1000 M_b i}{Z} \qquad (7)$$

where $k = 1$.

Thick wall:

$$S_{L2} = \frac{S_{hl}}{\kappa^2 + 1} + \frac{1000 M_b i}{Z} \qquad (8)$$

where $k = D_o/D_i$.

6.4.2.4 Shear stress

The shear stress, τ, should be calculated from the torque and shear force applied to the pipeline using equation (9).

$$\tau = \frac{1000T}{2Z} + \frac{2F_s}{A} \qquad (9)$$

6.4.2.5 Equivalent stress

The equivalent stress, S_e, should not exceed the allowable equivalent stress, S_{ae}, given in **6.4.3.2**. The equivalent stress should be calculated using equation (10).

$$S_e = \left(S_{hl}^2 + S_L^2 - S_{hl} S_L + 3\tau^2\right)^{0.5} \qquad (10)$$

where S_{hl} is calculated using equation (3) or (4) as appropriate, but using the nominal pipe wall thickness, t_{nom}, instead of t_{min}.

NOTE Equation (10) gives the von Mises equivalent stress criterion. This has been derived from the full equation by assuming that the third principal stress is negligible.

6.4.3 Limits of calculated stress

6.4.3.1 Allowable hoop stress

The allowable hoop stress, S_{ah}, should be calculated using equation (11).

$$S_{ah} = a e S_y \qquad (11)$$

The weld joint factor, e, should be 1.0 for pipe conforming to BS EN ISO 3183:2012 and/or API 5L:2012 when supplied as seamless, longitudinally welded or spirally welded pipe. If the pipe history is unknown, the weld joint factor e should not exceed 0.60 for pipe of 0.114 m outside diameter or smaller, or 0.80 for pipe larger than 0.114 m outside diameter.

NOTE The effect of temperature de-rating on the SMYS of carbon steel is included in the design factors for temperatures up to 120 °C.

6.4.3.2 Allowable equivalent stress

The allowable equivalent stress, S_{ae}, should be calculated using equation (12).

$$S_{ae} = 0.9 S_y \qquad (12)$$

NOTE Further guidance is given in BS EN 13480, ASME B31.3 and ASME B31.8.

6.4.4 Strain-based design

The limit on equivalent stress recommended in **6.4.2.5** may be replaced by a limit on allowable strain, provided that all the following conditions are met.

a) The allowable hoop stress criterion (see **6.4.2.1** and **6.4.2.2**) is met.

b) Under the maximum operating temperature and pressure, the plastic component of the equivalent strain does not exceed 0.005 (0.5%).

c) The reference state for zero strain is the as-built state (after pressure test). The plastic component of the equivalent uniaxial tensile strain should be calculated using equation (13).

$$\varepsilon_{p} = \left\{ \frac{2}{3} \left(\varepsilon_{pL}{}^{2} + \varepsilon_{pH}{}^{2} + \varepsilon_{pr}{}^{2} \right) \right\}^{0.5} \qquad (13)$$

This analysis can be performed conservatively by assuming a linearly elastic – perfectly plastic stress/strain curve. Other, more realistic stress/strain curves may be used. However, it is essential that the assumed curve is validated as being conservative by material stress/strain curves from the manufactured pipe.

d) Any plastic deformation occurs only when the pipeline is first raised to its maximum operating pressure and temperature, but not during subsequent cycles of depressurization, reduction in temperature to the minimum operating temperature, or return to the maximum operating pressure and temperature.

This should be determined via analytical methods or an appropriate finite element analysis. The analysis should include an estimate of the operational cycles that the pipeline is likely to experience during the operational lifetime.

e) The D_o/t_{nom} ratio does not exceed 60.

f) Axial or angular misalignment at welds is maintained within defined tolerances.

g) A fracture analysis is carried out in accordance with **6.4.6**.

h) A fatigue analysis is carried in accordance with **6.4.7**.

i) The weld metal yield stress matches or overmatches the longitudinal yield stress of the pipe.

j) For welds where allowable defect sizes are based on an ECA, UT supplements radiographic testing, unless automated ultrasonic testing (AUT) is performed.

k) Additional limit states are analysed as follows:

   1) bending failure resulting from application of a moment in excess of the moment capacity of the pipe;

   2) ovalization – distortion of the pipe wall associated with bending to high strain levels (see **6.4.5.2** and Annex H);

   3) local buckling (see **6.4.5.1** and Annex H);

   4) global buckling – lateral or upheaval buckling due to overall axial compression (see **6.4.5.1** and Annex H).

Plastic deformation reduces pipeline flexural rigidity; this effect can reduce resistance to upheaval buckling and should be checked if upheaval buckling might occur. The effects of strain localization should be taken into account in the strain-based design.

NOTE Strain localization is associated with discontinuities in stiffness of the pipeline (bending or axial) and can therefore develop in the following locations:

- *changes in wall thickness;*
- *locally thinned regions, e.g. due to corrosion;*
- *field joints and coatings;*
- *welds, due to under matching of the strength of the weld.*

6.4.5 Buckling

6.4.5.1 General

NOTE 1 Buckling on above-ground pipelines is usually covered by a local stress analysis.

For onshore buried pipelines, the need for buckling analysis should be assessed.

Buckling due to overburden and/or external loads should be taken into account at areas of impact protection or increased overburden, areas where landscaping will cause increased overburden or where ground movement could occur, road, rail, river, and water crossings/parallel encroachments, and areas where the external loads are or could in the future be substantial.

The following buckling modes should be taken into account:

a) local buckling of the pipe due to external pressure, axial tension or compression, bending and torsion, or a combination of these loads (see **H.1**). For fabrication processes which introduce cold deformations giving different strength in tension and compression, a fabrication factor, α_{fab}, should be determined;

   *NOTE 2 Guidance on the selection of a suitable fabrication factor is given in DNV-OS-F101:2013, Section **5**.*

b) propagation buckling due to external pressure following the formation of local buckles or localized damage (see **H.2**);

c) restrained pipe buckling due to axial compressive forces induced by high operating temperatures and pressures. This can take the form of horizontal snaking for exposed pipelines or vertical upheaval of trenched or buried pipelines (see **H.3**).

NOTE 3 The formulae given in Annex H define one approach to analysis. Alternative approaches are available and may be used where justified.

NOTE 4 To supplement the above methodology, the approaches defined within DNV-OS-F101 and DNV-RP-F110 may be adopted.

In all buckling analyses, the nominal wall thickness should be used.

6.4.5.2 Ovality

Ovality, or out-of-roundness, of pipes or a section of pipeline that could cause buckling or interference with pigging operations should be avoided.

NOTE 1 In some situations, where loading is dominated by bending, buckling might not occur but unacceptable levels of ovalization can result.

*NOTE 2 Ovalization may be calculated in accordance with **H.4** in the absence of a more rigorous evaluation.*

6.4.5.3 Coatings

Any beneficial effect of weight coating or insulation coating on buckling should not be taken into account in an analysis, unless analytical and experimental evidence is provided that indicates its effectiveness in providing additional stiffness.

6.4.5.4 Controlled deformation

Internal pressure and temperature can lead to transverse movements if the pipeline is not restrained, e.g. by burial. For exposed pipes in contact with the land and not on a formalized pipe rack structure, lateral movement is more likely and analysis for snaking and buckling should be performed. For buried pipelines, upheaval buckling analysis should be performed (see **6.4.5.5**).

*NOTE Annex H, **H.1** gives information on the critical strain limits. **H.1.7** provides a conservative estimate of the bending strain.*

6.4.5.5 Upheaval buckling

For exposed pipelines in contact with the land surface, lateral buckling can develop at relatively low levels of effective compression and checks should be carried out to demonstrate the pipeline's fitness for purpose.

An upheaval buckling design should demonstrate integrity of the buried pipeline with an overall agreed safety margin, taking into account the variability of all design parameters. The design should establish cover levels along the route taking into account the as-laid vertical, out-of-straight pipeline profile and the long-term and short-term characteristics of the cover material. Additionally, the stress/strain levels along the pipeline should be shown to be within allowable limits.

The effect of soil liquefaction should be taken into account.

6.4.6 Fracture

6.4.6.1 Fracture control

A pipeline should be designed to prevent brittle and ductile fracture.

*NOTE 1 The principal means of fracture control is by the selection of materials with adequate toughness through notched bar impact testing (see **8.2.5**).*

The material properties should be in accordance with **8.2.5** such that brittle fracture initiation or propagation does not occur, and that ductile fracture propagation is limited in length.

NOTE 2 Pipelines conveying a gas or a volatile liquid are susceptible to long running fractures (also known as propagating fractures). Toughness requirements for preventing long running fractures are given in BS EN ISO 3183:2012, Annex G.

6.4.6.2 Engineering critical assessments (ECA)

Weld flaw acceptance criteria may be based on workmanship acceptance levels or fitness-for-service limits, determined by either an engineering critical assessment (ECA), or segment or full-scale testing. Fitness-for-service limits should take into account all static and cyclic (dynamic) loading that occurs during installation and operation. It should be demonstrated that fabrication flaws in the weld metal and heat-affected zone (HAZ) will not cause failure during installation or operation.

ECA should be conducted in accordance with BS 7910. The equations of BS 7910 are potentially non-conservative for strain-based design (>0.4% strain). In this case assessment should be confirmed by numerical simulation [finite element analysis (FEA) crack modelling]. If necessary, account should be taken of relevant results of full scale pipe tests, with pre-cracked girth welds, subjected to internal longitudinal strain and internal pressure.

NOTE 1 Guidance on conducting an ECA of pipeline girth welds is given in DNV-OS-F101:2013, Appendix A and DNV-RP-F108.

NOTE 2 An ECA is not normally required if the maximum total strain is less than or equal to 0.4%.

NOTE 3 Full scale testing is time consuming and complex to produce a statistically significant amount of data. ECA based on small scale (segment) tests is the main method.

ECA requires fracture toughness testing of representative welds to determine the fracture toughness of the weld and HAZ. The fracture toughness should be determined under representative environmental and service conditions. Fracture toughness testing should be conducted in accordance with BS EN ISO 15653 and BS 7448 as appropriate.

NOTE 4 BS 7910 gives guidance on the fracture toughness testing required for an ECA. DNV-OS-F101 and DNV-RP-F108 give guidance on testing pipeline girth welds.

6.4.7 Fatigue

6.4.7.1 General

All cyclic stresses due to pressure, thermal, or external loading, occurring during the entire life of the pipeline, should be taken into account when establishing the predicted significance or effect of fatigue.

In the assessment of stress ranges, the effect of construction activities that can cause stress concentrations should be taken into account.

All cyclic stresses between the threshold limit and the maximum allowable design stress should be addressed (see ASTM E1049).

NOTE Typical sources of cyclic stresses include:

- *transportation, installation and testing activities;*
- *dynamic stresses (wind, waves, currents, rivers, vortex shedding, road/rail and other traffic-induced stresses);*
- *pulsation-induced vibration (at or near stations, reciprocating pumps and compressors);*
- *vibrations caused by surge and product flow;*
- *full stress cycles (start-up to shutdown cycles);*
- *fluctuations in operational (pressure and thermal) cycles;*
- *external thermal stress cycles (above-ground pipelines);*
- *earthquakes and ground movements.*

6.4.7.2 Fatigue life

The fatigue life of a pipeline is determined from the total number of full stress cycles together with the number of equivalent stress cycles (i.e. range of stress cycles that are expected or experienced by the pipeline) which could cause fatigue failure. Pipelines should be designed to provide a fatigue life that exceeds the proposed design life of the pipeline.

The need for a fatigue analysis depends upon the number and value of stress cycles predicted to occur over the operational life of the pipeline and should be assessed in accordance with **6.4.7.3**. In the case of revalidation it should be based on the actual number and known stresses experienced by the pipeline, plus the predicted life. Where required, the fatigue analysis should be carried out in accordance with **6.4.7.4**.

6.4.7.3 Assessment of need for fatigue analysis

Any engineering assessment undertaken to revalidate a pipeline for a change of operating conditions, including an extension of the design life, should include an assessment of the fatigue life.

A simplified assessment should be carried out to establish whether a pipeline fatigue analysis is required. A fatigue analysis is not required if either:

a) the maximum hoop stress cycle experienced by the pipeline is less than 35 N/mm^2; or

b) the system designed can be shown to replicate closely a previously analysed acceptable design.

The 35 N/mm^2 criterion should not be used for girth welds or circumferential flaws.

NOTE 1 Fatigue of girth welds depends mainly on the longitudinal stress range rather than hoop stress range.

NOTE 2 Additional guidance on the requirement for a fatigue analysis can be obtained from:

- *IGEM/TD/1 Edition 5:2012, which provides guidance on determining the fatigue life of pipelines constructed and tested to IGE standards, made from materials conforming to API 5L:2012 and subjected to a high-level hydrostatic test (Clause **11**);*
- *BS EN 13480-3:2012, Clause **10** for above-ground pipelines;*
- *ASME B31.3 and ASME BPVC-VIII-1 for pipelines designed in accordance with ASME standards;*
- *PD 5500:2012+A3, Annex C, which includes criteria for establishing whether a detailed fatigue analysis is required, and gives guidance on how to conduct a fatigue analysis.*

BS EN 13480-3 and PD 5500 may be used in combination with BS 7608 for the appropriate equivalent material S–N curves.

6.4.7.4 Fatigue analysis

A fatigue analysis should be carried out to determine the fatigue life of the pipeline unless shown otherwise in **6.4.7.3**.

NOTE 1 The fatigue life is dependent upon the number and range of stress cycles that are expected to occur, and the maximum size of defect that can exist.

The fatigue analysis should be carried out using one of the standards listed in the Note to **6.4.7.3** together with an appropriate *S–N* curve (i.e. one that is specific to the material type, environment, frequency, workmanship and quality achieved during construction).

Account should be taken of stress concentrations owing to pipe ovality, misalignments, material type change and local shape deviations.

The fatigue analysis method, material properties and other input data used in the assessments should be documented and fully justified.

The actual cycles accumulated during operation should be recorded and maintained for future evaluation of the pipeline.

Where an appropriate *S–N* curve is not available then an *S–N* curve should be produced through fatigue testing or a fracture mechanics based fatigue analysis should be conducted.

NOTE 2 The S–N curves in BS 7608 might not be applicable to low cycle, high strain fatigue loading that might be encountered in a strain-based design.

The *S–N* curves recommended in BS 7608 have been developed for application to normal structural joints which are in general accessible to inspection and have a level of redundancy. Pipelines are non-redundant structures and accessibility for inspection is limited, so an appropriate factor of safety should be included on the fatigue life predicted using the *S–N* technique.

The safety factor should be selected and justified as part of the design fatigue analysis, taking into account accessibility for and reliability of inspection, uncertainty in the number and value of stress cycles and the severity of consequences of failure.

NOTE 3 Safety factors typically applied to pipeline fatigue design analysis range from 1 for non-hazardous, non-critical pipelines to between 3 and 10 for hazardous pipelines.

NOTE 4 These safety factors may be relaxed for pipelines that are located above ground provided the area of the defect can be fully mapped and assessed.

6.4.7.5 Re-qualification of pipeline design

A fatigue analysis should be carried out to re-qualify the pipeline if an extension to the current design life or a change in the duty of the pipeline (i.e. change in product or service causing a modification which raises the internal pressure, or introduces more pressure cycles) is proposed.

The analysis should demonstrate that the largest defect in the system will not grow through fatigue to failure during the re-qualified design life of the pipeline. The largest defect size should be determined through non-destructive testing (NDT) methods such as the use of an in-line inspection tool or, if necessary, a repeat hydrotest (conducted at a level determined by the largest defect that may be accepted). Any NDT approach should be capable of detecting and reliably sizing crack-like defects, particularly in the longitudinal direction.

Mid-wall (lamellar) defects should be taken into account in the fatigue analysis, and a specific fitness-for-purpose assessment of these defects undertaken.

NOTE API RP 579 contains guidance on the assessment of dents, gouges and laminations.

6.5 Stability

Pipelines should be designed to prevent horizontal and vertical movement, or should be designed with sufficient flexibility to allow predicted movements within the strength criteria as recommended in **6.4** and stress limits as stated in **6.4.3**.

Factors that should be taken into account in the stability design include:

a) hydrodynamic and wind loads;

b) axial compressive forces at pipeline bends and lateral forces at branch connections;

c) lateral deflection due to axial compression loads in the pipelines;

d) exposure due to general erosion or local scour;

e) geotechnical conditions including soil instability, e.g. due to seismic activity, slope failures, frost heave, thaw settlement and groundwater level;

f) construction method;

g) trenching and/or backfilling techniques.

NOTE Stability for pipelines 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.

6.6 Spanning pipelines

Spans in pipelines should be controlled to ensure compliance with the strength criteria as recommended in **6.4** and stress limits as stated in **6.4.3**. Factors that should be taken into account in spanning design include:

a) support conditions;

b) interaction with adjacent spans;

c) possible vibrations induced by wind;

d) axial force in the pipeline;

e) soil accretion and erosion;

f) possible effects from third-party activities;

g) soil properties;

h) excessive yielding.

6.7 Seismic analysis

Pipelines should be designed against the seismic loads listed in Annex G.

NOTE 1 The risk from seismic loadings in the UK is low.

NOTE 2 Further guidance on seismic design criteria is given in IGEM/TD/1 Edition 5:2012.

6.8 Other activities

6.8.1 Corrosion allowance

A corrosion allowance on design thickness need not be included provided the substance to be conveyed is non-corrosive or measures are taken to prevent corrosion. Where internal corrosion, external corrosion or erosion is expected, a corrosion allowance should be made following a study or test that takes into account the type of corrosion expected and the intended life of the pipeline. No external corrosion allowance is needed if both an anti-corrosion coating system and cathodic protection are installed. Where a corrosion allowance is applied it should be added to the value of the design thickness (see **6.2.2**).

6.8.2 Thermal insulation

Where pipelines are designed to convey substances that are either heated or refrigerated, thermal insulation can be necessary in addition to an anti-corrosion coating. Account should be taken of the differences between installation and operating temperatures in relation to axial stresses and movement. Thermal insulation systems should be designed to retain the operating temperature of the substance being conveyed within its process design limits at the lowest design flow rates.

NOTE Further information on the design of thermally insulated pipelines is given in BS 4508.

Thermal insulation may be built up from layers of different materials selected according to the temperature gradient through the system. Differences in coefficient of thermal expansion of the various materials and the pipe should be taken into account. Vapour barriers should be installed to prevent the migration of moisture within the insulation and subsequent damage to the pipeline material.

The design of insulation and anti-corrosion coatings should take account of the maximum operating temperature. Since the likelihood of external corrosion at elevated temperatures is higher than at ambient temperatures, and since above-ground coating damage inspection techniques are ineffective, the pipeline should be designed to accommodate internal inspection devices.

The depth of cover of heated or refrigerated pipelines in agricultural land should be sufficient to prevent adverse thermal effects on crop growth.

For refrigerated pipelines the possibility of frost heave should be taken into account.

6.8.3 Pipeline cover

Buried pipelines should be installed with a depth of cover not less than that shown in Table 4, unless a similar level of protection is provided by alternative methods.

Table 4 **Pipeline cover**

Location	Minimum depth of cover A)
Areas of limited or no human activity	0.9
Agricultural or horticultural activity B)	1.1
Watercourses, canals, rivers C)	1.2 D)
Roads E)	1.2 D)
Railways	1.4 to 1.8 D)
Residential, industrial, and commercial areas	1.2 D)
Rocky ground F)	0.5

A) Depth of cover should be measured from the lowest possible ground surface level to the top of the pipe, including coatings and attachments.

B) Cover should be not less than the depth of normal cultivation.

C) To be measured from the lowest anticipated true clean bed level.

D) Refer to the appropriate authorities.

E) To be measured from the true clean bottom of the drainage ditches.

F) The top of the pipe should be not less than 0.15 m below the surface of the rock with a total cover not less than 0.5 m. Impact protection should be used in vulnerable locations

NOTE An increased depth of cover can apply under the following cases:

- *situations where frost heave could occur;*
- *areas where agriculture or horticultural practices require a greater depth;*
- *areas which could be subject to erosion;*
- *main rivers and other waterways;*
- *pipeline route sections where future construction is planned or likely to occur.*

If a waterway is navigable, the pipeline should be protected against damage from ships' anchors or other hazards, e.g. existing or known future dredging activities.

6.8.4 Location of cathodic protection stations

The selection of sites for cathodic protection stations should take account of:

a) distance from the pipeline route;

b) ground resistivity;

c) ease of access for maintenance;

d) proximity to other buried metallic services and railways;

e) proximity to power supplies;

f) existing ground beds for other pipelines;

g) minimum interference with agricultural operations.

Cathodic protection should be designed in accordance with ISO 15589-1.

6.9 Crossings and encroachments

6.9.1 Road crossings

6.9.1.1 General

NOTE Major roads would normally include motorways and trunk roads. Minor roads would normally include all other public roads.

The design of pipeline road crossings and parallel encroachments to roads should take account of daily and seasonal traffic density and risk of external interference in the area.

Private roads or tracks should be classified as minor roads only if there is reason to believe that they might be used regularly by heavy traffic. Assessments of traffic densities should be carried out by consultation with the national and local highway authorities concerned.

The design should take into account the intended method of installation of the road crossing, e.g. open-cut, boring or tunnelling, which is determined following consultation with the relevant highway authorities. The crossing design should take account of the ground conditions and include temporary works design.

6.9.1.2 Category A, category B and category C substances

For pipelines designed to convey category A, category B or category C substances, no revision to design factor or wall thickness is needed at road crossings.

For pipelines designed to convey category A or category B substances, impact protection should be provided at open-cut crossings of major roads, where necessary.

For pipelines designed to convey category C substances, impact protection should be provided at open-cut crossings of major roads.

6.9.1.3 Category D and category E substances

For pipelines designed to convey category D or category E substances, roads should be classified as major roads or minor roads for allocation of design factor and wall thickness.

For pipelines designed to convey category D or category E substances the design factor, *a*, should be 0.30 for both major and minor road crossings. However, the design factor may be raised to a maximum of 0.72 if this can be justified to a statutory authority by a risk analysis carried out as part of a safety evaluation for the pipeline (see Annex E).

Pipeline crossings of major roads should be carried out using either:

a) pipe with a nominal wall thickness of 11.91 mm or greater without impact protection; or

b) pipe with a wall thickness appropriate to the design factor and with impact protection in accordance with **6.9.7** (see also **E.9**).

For major roads the design factor, wall thickness or impact protection should extend for a distance equal to the minimum building proximity distance shown in IGEM/TD/1 Edition 5:2012 for methane, or the final minimum distance (see **5.5.3.2**) for other category D and category E substances, measured at a right angle from the edge of the carriageway.

Pipeline crossings of minor roads should be carried out using either:

1) pipe with a nominal wall thickness of 9.52 mm or greater without impact protection; or

2) pipe with a wall thickness appropriate to the design factor and impact protection in accordance with **6.9.7** (see also **E.9**).

For minor roads the design factor, wall thickness or impact protection should extend between highway boundaries on each side of the crossing.

NOTE API 1102 gives detailed methods for analysis of road and rail crossings.

6.9.2 Rail crossings

Pipeline rail crossings should be designed and classified in the same manner as described in **6.9.1** for road crossings.

NOTE 1 Major rail routes would normally include intercity and high-density commuter routes. Minor rail routes would normally include all others.

The minimum distance between the top of the pipe or sleeve and the top of the rail should be 1.4 m for open cut crossings and 1.8 m for bored or tunnelled crossings. Assessment of traffic densities and crossing requirements should be carried out by consultation with the appropriate railway authority.

NOTE 2 Issues of settlement and settlement monitoring can arise on some routes.

6.9.3 Water crossings

Pipeline water crossings, e.g. river and canal crossings, should be designed in consultation with the water and waterways authorities to determine the minimum depth of cover and additional protection needed. The design of additional protection should take account of potential pipeline damage by ship's anchors, scour and tidal effects, flood defences and any known future works such as dredging, deepening and widening of the river or canal (see **10.13.4**).

NOTE Pipelines crossing rivers and estuaries which cannot be designed and constructed using normal land pipeline methods are classified as subsea pipelines and are outside the scope of this part of PD 8010. Recommendations for the design and construction of such pipelines are given in PD 8010-2.

6.9.4 Pipe bridge crossings

The preferred design for pipeline crossings is for the buried installation of pipe. Where it is necessary to utilize pipe bridges, these should be designed in accordance with good structural engineering practice. Pipe bridge design should take into account thermal and structural stresses, pipe carrier stresses and foundation loadings. Sufficient headroom should be provided to avoid possible damage from the movement of traffic or shipping beneath the pipe bridge. Account should be taken of accessibility requirements for maintenance and security, and of restrictions on access to the general public. The design should take account of potential cathodic protection interference between the pipeline and bridge supporting structure.

6.9.5 Sleeved crossings

The preferred design for pipeline crossings is for the installation of pipe without the use of sleeves to reduce the likelihood of corrosion and for ease of maintenance. Where particular circumstances indicate the need for a sleeved crossing, the guidance in **10.13.5** and IGEM/TD/1 Edition 5:2012, **7.21** should be followed, as necessary.

6.9.6 Parallel encroachments

Pipelines running parallel to major roads or major rail routes should have design factors appropriate to major road crossings if they encroach within the minimum building proximity distance shown in IGEM/TD/1 Edition 5:2012 for category D substances, or the final minimum distance (see **5.5.3.2**) for category C and category E substances.

For pipelines running parallel to other pipelines, the guidance given in IGEM/TD/1 Edition 5:2012, **6.11** should be followed.

6.9.7 Impact protection

At some crossings and in areas where the likelihood of third-party activity leading to interference with the pipe is increased, impact protection should be provided (see **E.9**).

Impact protection may take the form of increased cover, concrete surround, concrete slabbing or similar construction.

Unless otherwise recommended in this part of PD 8010, impact protection should extend between the highway or railway boundary at each side of the crossing.

6.10 Trenchless technologies

*COMMENTARY ON **6.10***

Trenchless technologies are used for crossings of roads, rivers, environmentally sensitive areas and major ground obstacles, e.g. cliffs and landslides.

The key techniques are:

a) directional drilling;

b) unmanned tunnelling moles;

c) pipe jacking and tunnelling;

d) auger boring and thrust boring.

The key elements to take into account when carrying out any of these techniques are:

1) safety aspects of excavations, proposed crossings and the technique itself;

2) location of buried services and buried objects along the route;

3) soil/ground conditions, and nature and type of the terrain along the route;

4) accuracy of the technique in line, level and direction.

Further information, recommendations, guidance and requirements are given in the standards listed in the "Trenchless technologies" section of the Bibliography.

Trenchless technologies may be used as an alternative to open cut crossings. The risk from drilling muds to the environment should be assessed.

6.11 Adverse ground conditions

Where pipelines are unavoidably located in areas with adverse ground conditions, appropriate protective measures should be taken to counter any potential harm to the pipeline.

NOTE These might include increased wall thickness, ground stabilization, erosion prevention, installation of anchors, provision of negative buoyancy, etc. as well as surveillance measures.

6.12 Location of section isolating valves

Section isolating valves should be installed at the beginning and end of the pipeline, and at a spacing along the pipeline appropriate to the substance being conveyed to limit the extent of a possible leak. The spacing of section isolating valves should reflect the conclusions of any safety evaluation prepared for the pipeline and should preferably be installed below ground. The location of section isolating valves should take account of topography, ease of access for operation and maintenance, protection from vandalism and proximity to normally occupied buildings. Section isolating valves should be installed at either side of a major river or estuary crossing where the pipeline could be damaged, e.g. by ships' anchors or scouring of the riverbed, unless otherwise justified by a safety evaluation.

For pipelines designed to convey category B substances, section isolating valves should be installed at locations which would limit drain down of pipeline contents at any low point.

For pipelines designed to convey category C, category D or category E substances, section isolating valves should be installed at intervals calculated by means of a safety evaluation.

For pipelines designed to convey category D, category E or toxic category B substances, automatic or remotely controlled section isolating valves should be installed unless non-installation can be justified to a statutory authority as part of a safety evaluation for the pipeline. Automatic or remotely controlled section isolating valves should be installed on pipelines conveying category C or non-toxic category B substances, when necessary.

6.13 Integrity monitoring

Account should be taken during design of the need to use internal inspection devices, unless such devices cannot be used due to the properties of the transmitted product.

Factors that should be taken into account include:

a) minimum radius of bends;

b) changes of internal diameter;

c) design of pig traps;

d) design of branch connections;

e) valve design (i.e. minimum bore);

f) internal girth weld profile.

6.14 Leak detection

A leak detection system should be included in the design of a pipeline. The method chosen for leak detection should be appropriate to and effective for the substance to be conveyed.

NOTE Typical leak detection methods include continuous mass balance of pipeline contents, detection of pressure waves, monitoring of rate of change of pressure and flow, and dynamic modelling by computer.

The leak detection system should be part of the overall pipeline management system, which should incorporate route inspection in accordance with **13.3.2**.

6.15 Fabricated components – Slug catchers

6.15.1 General

If slug catchers are used, they should be installed upstream of stations, terminals and other plant to remove slugs of liquid from multi-phase flow pipelines. The design pressure of the slug catcher should be equal to or greater than the internal design pressure of the pipeline (see **6.3.2**).

Thermal relief, pipeline and process-related relief measures to reduce fire exposure should be provided, as necessary. The design should take account of static loading, transients during slug arrival, anchor and support requirements and the provision of sample points to evaluate the build-up of solids. When carrying out flexibility and stress analysis calculations, account should be taken of momentum and dynamic effects.

6.15.2 Vessel-type slug catchers

Vessel-type slug catchers should be designed in accordance with PD 5500 or ASME BPVC-VIII-1.

6.15.3 Multipipe-type slug catchers

For buried multipipe-type slug catchers, the design pressure should be in accordance with **6.15.1**, with an appropriate design factor. For above-ground multipipe-type slug catchers, the design pressure should be in accordance with BS EN 13480-3 or ASME B31.3.

In both cases, nozzle reinforcement and saddle support design and construction quality should be in accordance with PD 5500 or ASME BPVC-VIII-1.

6.16 Supports and anchors

Pipe supports should be designed in accordance with an appropriate standard (e.g. BS EN 13480-3).

The forces and moments transmitted to connected equipment such as valves, strainers, tanks, pressure vessels and pumping machinery should be kept within limits specified by the supplier.

Pipe supports should not cause excessive local stresses in the pipe. Friction forces at the supports should be taken into account in evaluating the flexibility of the system.

NOTE 1 Braces and damping devices can be necessary to prevent vibration of piping.

Branch connections should be supported by consolidated backfill or provided with sufficient flexibility to avoid overstressing.

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

Supports not welded to the pipeline should be designed to allow access for inspection of the pipeline underneath. A low friction material seat should be placed between the pipe and the support to prevent coating damage.

Attachments to the pipeline should be designed to ensure that the additional stresses in the pipe wall caused by the attachment are within the maximum allowable design limits.

NOTE 2 Non-integral attachments such as pipe clamps are preferred where they will perform the supporting or anchoring functions.

Where a piping system or pipeline is designed to operate at, or close to, its allowable stress, all connections welded to the pipe should be made to an anchor flange incorporated in the pipeline with full penetration girth welds or to a separate cylindrical member which completely encircles the pipe. The encircling member should be welded by continuous circumferential welds.

6.17 Anchor blocks

The 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 axial compressive force necessary to restrain a pipeline should be calculated using equation (14) for thin wall or equation (15) for thick wall.

Thin wall:

$$F = A\left[E\alpha\left(T_2 - T_1\right) + 0.5S_{\text{hl}} - \nu S_{\text{hl}}\right] \qquad (14)$$

Thick wall:

$$F = A\left[E\alpha\left(T_2 - T_1\right) + \frac{S_{\text{hl}}}{k^2 + 1} - \nu\left(S_{\text{hl}} - p\right)\right] \qquad (15)$$

where S_{hl} is calculated using equation (3) or (4) as appropriate, but using the nominal pipe wall thickness instead of the minimum pipe wall thickness, and k is given by D_o/D_i.

7 Design – Stations and terminals

7.1 Selection of location

In selecting the locations for stations and terminals on land, account should be taken of factors including, but not limited to:

a) availability of land;

b) topography;

c) ground conditions;

d) geohazards;

e) ease of access;

f) availability of services;

g) necessity for inlet and outlet connections to and from the pipeline;

h) hazards from other activities and adjacent property;

i) public safety and the environment;

j) anticipated developments.

An assessment of noise levels should be made for a proposed station or terminal and account taken of predicted noise levels compared with existing background noise levels in the intended sites.

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

The location of pipeline facilities within installations 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 should be provided around stations and terminals for the free movement of fire-fighting equipment. Access and clearance should be provided at stations and terminals for the movement of fire-fighting and other emergency equipment.

Layouts of stations and terminals should be based on minimizing the spread and consequences of fire. Areas within stations and terminals with possible explosive gas mixtures should be classified in accordance with BS EN 60079-10-1 and the requirements for plant and equipment specified accordingly.

Spacing of tankage should be in accordance with NFPA 30.

Piping should 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. The necessity for access for replacement of equipment should also be taken into account when routeing primary piping.

Vent and drain lines should be designed to minimize the hazards associated with venting and with the discharge of fluids.

7.3 Security

Access to stations and terminals should be controlled, e.g. by the use of locked or attended gates. The likelihood of any uncontrolled access which could interfere with the operation of site equipment should be taken into account.

Permanent notices should 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.

7.4 Safety

7.4.1 General

NOTE Attention is drawn to EC Directive 94/9/EC [24] (commonly referred to as "ATEX") and to the Dangerous Substances and Explosive Atmospheres Regulations 2002 [25].

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

Fences should not hinder the escape of personnel to a safe location. Escape gates should open and be capable of being opened from the inside without a key when the enclosure is occupied.

Exits and unobstructed passage to a safe location should be provided for each operating floor of main pump and compressor buildings, basements and any elevated walkway or platform.

Tanks, dykes and firewalls should be in accordance with NFPA 30.

Ventilation should 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 should be provided.

Hot and cold piping which could cause injury to personnel should be insulated, protected and/or labelled.

7.4.2 Fire-fighting facilities

Terminals and intermediate stations should be provided with fire-fighting facilities that are appropriate to the size and nature of the site following consultation with the local fire authorities. Flame-detection instrumentation should be provided for outdoor fire detection, and heat and smoke detectors for indoor fire detection. An inert gas system should be used for protection of control rooms, where necessary.

NOTE 1 Recommendations for fire detection equipment are given in BS 5839. Recommendations for fire-fighting equipment are given in the BS 5306 series.

NOTE 2 Further information is given in the Model code of safe practice for the petroleum industry*, Part 2 [26].*

7.5 Buildings

Pumps and compressor buildings that house equipment or piping in sizes larger than 60 mm outside diameter, and equipment for conveying (except for domestic purposes) category D and category E substances, should be constructed of fire-resistant, non-combustible or limited combustibility materials as defined in NFPA 30.

7.6 Equipment

Pumps and compressors, prime movers, their auxiliaries, accessories, control and support systems, should be suitable for the intended system as defined and documented in accordance with **5.1**. Pumps, compressors and their prime movers should be designed for a range of operating conditions. These conditions should not exceed the maximum permitted by the design conditions of the components of the pipeline system in which they are installed, within the constraints of the pipeline system as limited by the control identified in **5.3.3**.

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

Protective devices such as relief valves, pressure-limiting stations or automatic shutdown equipment of sufficient capacity, sensitivity and reliability should be installed to ensure that the conditions recommended in **6.2.1.5** are met. Where high reliability of automatic shutdown equipment is necessary, high-integrity protective systems that rely upon instrumentation to protect against overpressure may be used. Where high-integrity protective systems are proposed, account should be taken of hazard rate, redundancy, voting systems and the design of equipment for on-line testing and maintenance of the high-integrity protective system.

7.7 Piping

7.7.1 Primary piping

Piping for conveying or storing fluids should meet the strength recommendations given in **6.4**.

The point of demarcation between the pipeline and the station or terminal should be either:

a) immediately downstream of the first inlet valve and immediately upstream of the last outlet valve; or

b) the isolating valves themselves; or

c) where pig traps are installed, the first isolation valve immediately downstream of the receiving pig trap and immediately upstream of the launching pig trap.

Piping should be protected against damage from vacuum pressures and overpressures. Pressure control and overpressure protection should be in accordance with **5.3.3**.

NOTE Piping can 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 of the pipeline.

The effects of vibration and resonance on piping and equipment should be taken into account in the design of stations. Particular attention should be given to the analysis of piping vibrations caused by connections to vibrating equipment or by gas pulsation associated with reciprocating pumps or compressors.

Account should also be taken of the noise generated by piping and equipment in the design of station piping. Acoustic cladding or enclosures should be used where noise levels cannot be further reduced by design or equipment selection.

7.7.2 Secondary piping

7.7.2.1 Fuel gas piping

Fuel gas piping within a station should be designed and constructed in accordance with BS EN 13480 or ASME B31.3.

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

The fuel gas system should 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 should not exceed the design pressure by more than 10%.

Provision should 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 connecting equipment.

7.7.2.2 Air piping

Air receivers and air storage bottles should be designed and constructed in accordance with PD 5500. Secondary piping should be designed and constructed in accordance with BS EN 13480-3 or ASME B31.3.

7.7.2.3 Lubricating oil and hydraulic oil piping

Lubricating oil and hydraulic oil piping within a station should be designed and constructed in accordance with BS EN 13480-3 or ASME B31.3.

7.7.2.4 Vent and drain lines

The sizing of vent and drain lines and the capacity of relief valves should be designed to accommodate the envisaged process capacity of the system.

7.8 Emergency shutdown system

Each pump or compressor station should be provided with an emergency shutdown system that is readily accessible, locally and/or remotely operated, and which will shut down all prime movers. The station should be isolated from the pipeline and provision for relieving or venting the piping system should be provided, where necessary.

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

Push-buttons or switches to initiate an emergency shutdown should be provided in at least two locations outside the area of hazard, preferably close to the exit gates.

An uninterrupted power supply should be provided for personnel protection systems and those systems necessary for protection of equipment.

7.9 Electrical

Electrical equipment and wiring installed in stations should conform to BS EN 60079-14. Electrical installations which remain in operation during an emergency should be based on the zone applicable during the emergency.

Measures for the protection against lightning strikes should be provided, where necessary. If such measures are provided they should conform to BS EN 62305.

7.10 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 (see **5.1**).

NOTE For heating stations, trace heating can be necessary on pipework pump bodies, drains and instrument lines to ensure satisfactory flow conditions following shutdown.

7.11 Metering and communication systems

Meters, strainers and filters should have the same design pressure as the pipeline system.

Components should be supported in such a manner as to prevent undue loading to the connecting piping system.

Design and installation should provide for access and ease of maintenance and servicing while minimizing interference with the station operations. The design should include for backflow, vibration or pulsation of the flowing stream, where necessary.

The retention size of any filtering medium should be selected to protect the facilities against the intrusion of harmful foreign substances and to prevent electrostatic charge accumulation.

7.12 Monitoring and communication systems

The requirements for monitoring pressure, surge pressure, temperature, flow rate, physical characteristics of the fluid being conveyed, information on pumps, compressors, valve positions, meters and tank levels, alarm conditions and the detection of fire and hazardous atmospheres, should be defined and included in the system design (see Clause **5**).

NOTE Alarm conditions include power supply failure, high temperature of electric motor windings and rotating machinery bearings, excessive vibration levels, low suction pressures, high delivery pressures, seal leakage and abnormal temperatures.

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

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

8 Design – Materials and coatings

8.1 General

The pressure-containing part of the pipeline should be formed from either low alloy or high alloy steel.

*NOTE Low alloy steels are carbon, carbon manganese and micro-alloyed steels with a ferritic-pearlitic or ferritic-bainitic microstructure. High alloy steels are generally stainless steels with an austenitic, austenitic-ferritic, or supermartensitic microstructure. Further guidance is given in **8.2**.*

When determining whether a pipe material is suitable for a particular application, the following material properties should be taken into account:

a) chemical composition of parent pipe and seam weld (see **8.2.4**);

b) weldability (see **8.2.4**);

c) tensile properties;

d) hardness;

e) fracture toughness and impact resistance (see **8.2.5**);

f) fatigue resistance (see **8.2.6**);

g) corrosion and environmental-induced cracking resistance (see **8.2.7**).

A detailed material specification for each application should be compiled (see also **8.2.2**).

For materials subjected to heat treatment, hot or cold forming, or other processes that can affect the material properties, achievement of mechanical performance in the final condition should be documented. Documentation demonstrating conformity should be provided for:

1) parent metal;

2) weld metal;

3) heat-affected zones;

4) welded pipe, where appropriate.

8.2 Line pipe

8.2.1 General

Carbon and low alloy steel line pipe conveying category A substances should conform to BS EN ISO 3183:2012, PSL 1, API 5L:2012, PSL 1 or BS EN 10224, as appropriate.

Line pipe conveying category B, category C, category D or category E substances should conform to BS EN ISO 3183:2012, PSL 2 or API 5L:2012, PSL 2.

Line pipe can be either seamless or welded and a suitable product for the application should be selected.

NOTE 1 Typically, seamless pipe is readily available in diameters up to 610 mm outside diameter in a variety of thicknesses. PSL1 seamless pipe is normally supplied in the hot finished "as rolled" condition. PSL2 pipe is supplied heat treated, either full body normalized (or normalized-rolled) or quenched and tempered (typically for grades L360 and above).

NOTE 2 Welded line pipe up to 508 mm or 610 mm outside diameter, in thicknesses up to 20 mm, is generally produced by the high frequency welding process (HFW). Typically PSL1 HFW pipe is supplied "as welded" whereas PSL2 HFW pipe is generally supplied either full body heat treated or weld line heat treated (where the strip feedstock is produced by either a thermo-mechanical or normalizing rolling process).

NOTE 3 Welded line pipe in diameters above 406.4 mm outside diameter can also be produced by the submerged arc welding (SAW) process. PSL1 SAW pipe is normally produced from hot-rolled plate and is supplied in the as-welded condition. PSL2 SAW pipe is normally produced from thermo-mechanically rolled plate in the as-welded condition with the weld metal being designed to provide equivalent properties to the pipe body. SAW pipe can also be supplied full body heat treated and can be cold expanded, within certain specified limits, to provide improved dimensional tolerances.

Line pipe conforming to BS EN ISO 3183:2012, Annex H should be used for sour service applications.

Line pipe conforming to BS EN ISO 3183:2012, Annex M should be used for natural gas transmission pipelines. Annex G should be used where resistance to ductile fracture propagation is necessary.

High alloy steel and other corrosion resistant alloy pipe should conform to an appropriate standard suitable for the purpose of the application, e.g.:

- API 5LC;
- ASTM A312, for austenitic stainless steels;
- ASTM A790, for duplex (austenitic-ferritic) stainless steels;
- ASTM B444 or ASTM B423, for Ni alloys.

13% chromium super-martensitic steels may also be used in predominantly CO_2 environments.

Clad pipe should conform to API 5LD and should comprise carbon steel line pipe conforming to BS EN ISO 3183:2012 or API 5L:2012 with a suitable corrosion-resistant alloy (CRA) liner. The design and internal corrosion evaluation should address whether the internal stainless steel or non-ferrous metallic layer needs to be metallurgically bonded (clad) or mechanically bonded (lined) or welded (weld overlay) to the outer carbon steel pipe. The minimum thickness of the internal layer should be established during design depending on the product type.

NOTE 4 Weld overlay CRA is frequently used for fittings such as pipe being used for induction bends.

For polymer-lined pipe, the polymeric lining material should be selected to take into account the required mechanical strength of the lining and the corrosion resistance and collapse resistance of the lining material under operational conditions.

NOTE 5 For gas distribution and service pipework, operating at ≤0.7 N/mm^2 (7 bar), suitable alternative grades may also be used, either seamless tubes in accordance with BS EN 10216-1 or BS EN 10216-2, or welded tubes in accordance with BS EN 10217-1, BS EN 10217-2 or BS EN 10217-5.

8.2.2 Dimensions

The following pipe dimensions should be specified:

a) diameter, quoting either outside diameter or inside diameter;

b) nominal wall thickness;

c) tolerances on diameter and wall thickness;

d) maximum permitted ovality.

The tolerances of clad pipeline systems should be specified to ensure good pipe weld alignment and adequate cladding thickness over the clad surface and at the welded joints.

Line pipe dimensions should be in accordance with the relevant material standard (see **8.2.1**) and the detailed material specification (see **8.1**).

8.2.3 Manufacturing specification

For all but PSL1 pipe, the manufacturer should produce a manufacturing specification, the structure and layout of which should clearly identify and mirror the specified pipe quality standard, including any additional requirements stipulated.

All materials for pipe should be manufactured and used in accordance with the appropriate product standard material specification and this part of PD 8010.

Recommendations in this part of PD 8010 that are not included in the relevant product standard should be specified in the manufacturing specification.

8.2.4 Chemical composition and weldability

The composition of the pipe should be such that weldability is adequate for all stages of manufacture, fabrication and installation of the pipeline. Welding consumables should be selected that avoid the formation of anodic weld metal, which can result in the selective corrosion of weld metal in corrosive environments. Where appropriate, weldability testing of girth welds should be specified at the procurement stage (BS EN ISO 3183:2012).

The susceptibility of carbon and alloy steel material to hydrogen (cold) cracking due to hardness in the HAZ should be controlled by restricting the allowable value of carbon equivalent (CE).

For traditional carbon manganese steel (C >0.12%), the CE formula shown in equation (16) should generally be used, although for PSL 1 pipes designed to convey category A substances, where the full chemical formula is typically not reported, the alternative CE formula shown in equation (17) may be used instead.

NOTE 1 All elements in equations (16), (17) and (18) are percentage (%) values.

$$\mathrm{CE} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15} \tag{16}$$

$$\mathrm{CE} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + 0.03 \tag{17}$$

For PSL 2 pipes of low carbon content (<0.12%), produced from micro-alloyed steel, the P_{cm} (cracking carbon equivalent) formula shown in equation (18) should be used.

$$P_{cm} = \mathrm{C} + \frac{\mathrm{Si}}{30} + \frac{\mathrm{Mn} + \mathrm{Cu} + \mathrm{Cr}}{20} + \frac{\mathrm{Ni}}{60} + \frac{\mathrm{Mo}}{15} + \frac{\mathrm{V}}{10} + 5\mathrm{B} \tag{18}$$

NOTE 2 If the boron composition of the steel cast is <0.000 5%, then it is not necessary for the product analysis to include boron, and the boron content may be assumed to be 0 for the purposes of the P_{cm} calculation.

NOTE 3 Guidance on the maximum values for CE and P_{cm} for PSL 2 pipes for non-sour and sour service applications is given in BS EN ISO 3183:2012.

For duplex stainless steel, welding consumables should be chosen to match the ferrite/austenite phase balance of the parent material (usually around 50:50). The phase balance in the HAZ tends towards higher ferrite levels. The maximum HAZ ferrite level should be specified, based on the results of weld testing in environments representing the worst anticipated corrosion conditions.

Supermartensitic stainless steels should undergo fitness-for-service testing in the as-welded or post-weld heat-treated condition to demonstrate their suitability for service in the anticipated corrosion conditions under both operating and shut-in conditions.

NOTE 4 Appropriate test methods are described in EFC 17 [27].

In the case of ferritic/austenitic (duplex) stainless steels, the phase ratio should be controlled so as to ensure compatibility between the base material and welding consumables. Tests should be carried out to demonstrate that the corrosion resistance of the HAZ and weld metal matches the parent material and is adequate for service. The weld procedure(s) should ensure that there are no detrimental intermetallic phases formed (e.g. sigma phase) which could impair the mechanical properties or the corrosion resistance.

NOTE 5 This might require supplementary testing to establish that the properties have not been degraded.

NOTE 6 NACE MR0175 and BS EN ISO 15156 give recommendations for materials for use in a sour service environment to prevent sulfide stress corrosion cracking (SSCC).

NOTE 7 NACE TM0284 gives recommendations for testing of materials for use in sour service environments.

8.2.5 Fracture toughness

Parent metal of line pipe for pipelines conveying category C, category D or category E substances should have adequate resistance to brittle and ductile fracture and, where feasible, be capable of arresting running shear fractures. Line pipe should meet the drop weight tear test and Charpy V-notch requirements specified in BS EN ISO 3183:2012. Line pipe for use in pipelines conveying category C, category D or category E substances should also meet the Charpy V-notch requirements given in BS EN ISO 3183:2012, Annex G. Testing should be conducted over a range of temperatures to determine the brittle to ductile transition curve. Charpy V-notch impact testing should be carried out in accordance with BS EN ISO 148-1. A 2 mm radius striker should be used.

The DWTT requirements in BS EN ISO 3183:2012 should be applied to diameters of 323.9 mm and above.

NOTE 1 For high strength steels or pipelines conveying fluids that exhibit two phase behaviour during decompression, the toughness requirements in BS EN ISO 3183:2012, Annex G might not be applicable. It might be necessary to use integral or mechanical crack arrestors to ensure an arrest of a running ductile fracture.

NOTE 2 BS EN ISO 148-1 contains two striker radius options, 2 mm and 8 mm. The 2 mm radius striker is commonly used in Europe, whereas in North America the 8 mm radius is the norm.

In determining the required fracture toughness, the validity of arrest equations should be demonstrated or mechanical crack arrestors should be installed.

In cases where there is no existing full scale fracture propagation test data to confirm crack arrest, or where there has been a change of pipeline parameters or in the fluid being transported, theoretical and experimental studies should be validated using a full scale fracture propagation test to demonstrate crack arrest.

NOTE 3 Full-scale testing has demonstrated that the Battelle Two Curve model for the calculation of fracture arrest toughness does not apply to dense phase CO_2.

8.2.6 Fatigue

Where the mechanical design has identified fatigue loadings, an analysis should be carried out based upon fracture mechanics methods (see BS 7910), or methods utilizing fatigue testing (*S–N* curve) data, to check that the design loading conditions do not exceed the line pipe fatigue resistance within the required design life. Where published *S–N* curves do not exist, fatigue testing of the line pipe should be carried out in accordance with BS 3518-1, BS 3518-3, BS ISO 1143 and BS ISO 12107 as appropriate.

8.2.7 Corrosion and cracking resistance

If CRA selection is the chosen method of internal corrosion control, the pipe material should be resistant to attack from the product and additives over the full range of operating temperatures, pressures and flow rates.

NOTE There are no standard test methods for this; test methods are determined by agreement between the interested parties.

The selection of a corrosion-resistant material should take into account the results of the internal corrosivity evaluations.

8.2.8 High and low temperature service

Where the pipeline is intended to operate below –20 °C or above 50 °C, the required mechanical properties should be clearly defined, documented (unless already specified in the relevant material or product standard) and used in all stages of the design process.

8.2.9 Marking

Marking of line pipe should be in accordance with the requirements of the relevant material or product standard.

8.2.10 Inspection documents

For all pipe materials, an inspection certificate conforming to BS EN 10204, BS ISO 10474 or equivalent should be obtained as a minimum unless otherwise justified by a low potential hazard posed by the pressure and substance to be conveyed.

8.3 Pipeline components

8.3.1 Branch connections

The design and fabrication of welded branch connections and reinforcement, where appropriate, should be in accordance with ASME B31.3 or ASME B31.8. Where welded or forged branch connections are installed in pipelines designed for pigging, special branch connections should be used to ensure that the pig is not damaged whilst passing the connection, and cannot enter the branch or become stuck.

8.3.2 Flanged connections

Flanged connections should meet the requirements of ISO 15590-3 or other internationally recognized standards such as BS ISO 7005-1, ASME B16.5, ASME B16.47 or MSS SP 44.

If proprietary flange designs are used, they should conform as far as is practicable to the relevant sections of PD 5500, ASME BPVC-VIII-1 or ISO 15590-3.

The flange bore should match with the bore of the adjoining pipe wall to facilitate alignment for welding.

External loadings should be taken into account in addition to operational loads. Engineering analysis should be conducted to verify the integrity of the joint.

NOTE 1 The flange standards contain tables giving the bending resistance of standard flanges.

NOTE 2 Finite element analysis can be useful in predicting the load envelopes for proprietary flanges and in reducing conservatisms in standard flanges.

8.3.3 Gaskets

Gaskets should be made of materials that are not likely to be damaged by the fluid in the pipeline system and should be capable of withstanding the pressure and temperature to which they are expected to be subjected in service. The risk of galvanic corrosion should be fully assessed in specifying gasket materials. CRA materials should be used where necessary in areas at risk from crevice corrosion such as ring-type joint grooves and flange facings.

Spiral-wound gaskets should be selected from ASME B16.20 or equivalent with ring material suitable for the product and environment.

Flat-faced and raised-face gaskets should be selected from suitable asbestos-free materials conforming to BS 3293 or ASME B16.21, with the specification and selection of gasket material and profile to suit the substance carried and the machined flange face.

Ring-type joints should be selected from ASME B16.20, API 6A or equivalent. Rings should be of a hardness lower than the flanges.

NOTE Gaskets not featuring reinforced steel brace on internal diameter have been known to crimp and cause obstruction to internal bore of pipelines.

8.3.4 Bolts and nuts

Bolt or studbolt materials should conform to BS 4882, ASTM A193/A193M or ASTM A320/A320M, as appropriate. Nut material should conform to BS 4882 or ASTM A194/A194M, as appropriate. For non-carbon steel pipelines, bolt materials should be compatible with the pipeline material.

Bolts or studbolts should be full length threaded and should completely extend through the nuts. A detailed assessment of preferred materials for bolting for high alloy flanged connections should be performed.

For sour service duties, bolting should be in accordance with BS EN ISO 15156 or NACE MR0175. For bolted connections where bolt-tensioning devices are to be used, additional bolt length should be provided as applicable.

Where bolting is to be exposed to corrosive conditions or cathodic protection, the material should be selected to take into account the necessary fracture toughness and hardness properties to prevent brittle fracture of high strength bolting.

Where feasible, bolting should be used with hydraulic tensioning equipment to ensure uniformity of loading through the joint.

NOTE The face-to-face dimension of flanged fittings might need to be increased from that stated in the appropriate standard when needed to accommodate specialist bolt tightening equipment.

8.3.5 Bends

8.3.5.1 General

The materials for bends should be similar to those recommended for line pipe (see **8.2.1**). Account should be taken of the properties of the material following the formation of bends, to determine whether any resultant variation from the specified values will be acceptable.

Bends made from straight pipe should be hot bent, cold bent or induction bent. Mitre bends should not be used in pipelines conveying category B, category C, category D or category E substances. They may be used for pipelines conveying category A substances (see ASME B31.3).

Bends should meet the requirements of ISO 15590-1, or other internationally recognized standards.

Longitudinal welds should be positioned on the neutral axis of the bend. There should be no wrinkling of the pipe surface.

Because the mechanical properties of a completed bend can differ significantly from those of the straight pipe from which it is made, the bend should be demonstrated to possess mechanical properties compatible with the design of the pipeline system. If necessary, test bends should be produced for destructive testing purposes.

8.3.5.2 Dimensions

Dimensions and tolerances of the ends of the bend cross-section should be compatible with those of the adjoining straight pipe to facilitate joining. If necessary, this may be achieved by the inclusion of straight tangent sections at either or both ends of the bends.

Ovality of cross-section should be restricted such that the bore diameter is reduced by no more than 2.5% of the nominal value at any point along the bend.

NOTE More severe restrictions might be required if inspection devices or well tools are to be used in the line.

The radius of a bend should be chosen to allow for in-line inspection if such inspection is required. The wall thickness of a bend should be not less than the minimum wall thickness of the pipeline.

An allowance should be made for the torus effect and thinning of the parent pipe during bending.

8.3.6 Fittings

The selection of fittings should be based on the same properties as for line pipe (see **8.2.1**). When selecting a fitting, the following should also be taken into account:

a) compatibility with line pipe and weldability;

b) compatibility with product at service temperature;

c) compatibility with product additives at service temperature;

d) compatibility with hydrotest medium and additives;

e) resistance to abrasion or other mechanical damage likely during installation or service.

In the case of fittings or equipment that contain components made of dissimilar metals, appropriate measures should be taken to prevent or control galvanic corrosion between these metals. Particular attention should be paid to areas where corrosive substances could accumulate or where chemical inhibition might be ineffective.

For materials subjected to heat treatment, hot or cold forming, or other processes that can affect the material properties, achievement of mechanical performance in the final condition should be documented. Documentation should be provided for parent metal and, in the case of welded components, for the weld metal and HAZ.

Fittings should meet the requirements of ISO 15590-2, or other internationally recognized standards such as ASME B16.9.

In-line fittings including connectors, elbows, tees, end caps, reducers and cast or forged transition pieces (e.g. weldolets, sweepolets, nipolets and forged reducers) should be made from fully killed steel. They should be made using recognized practices to provide the intended heat treatment response and notch toughness properties suitable for the duty and fluid category.

8.3.7 Threaded joints

All pipe threads on piping components should be taper pipe threads in accordance with BS 3799 or ASME B16.11. The installation of threaded joints (including compression fittings) should be avoided on buried piping systems. Use of screwed fittings on hydrocarbon systems should be subject to risk assessment. Particular account should be taken of fatigue problems.

8.4 Valves

8.4.1 Valve selection

When selecting valves, account should be taken of factors including, but not limited to:

a) intended duty;

b) system operating pressure and hydrostatic pressure;

c) differential pressure;

d) all fluids to which the valve might be exposed;

e) service temperatures;

NOTE 1 This can include low internal temperatures due to system depressurization.

f) service life;

g) duration of pre-commissioning period;

NOTE 2 Valves can remain static in open or closed positions for long periods but have to be able to function on demand.

h) presence of debris from product or construction activities;

i) system pigging;

j) in situ seal injection or replacement;

k) installation method;

l) ability to test the valve performance;

m) internal galvanic corrosion;

n) reliability;

o) maintenance aspects;

p) actuation;

q) integrity and achievement of isolation.

Ball, check, gate and plug valves should meet the requirements of ISO 14313.

The face-to-face dimension of flanged valves should be increased from that stated in the appropriate standard when necessary to accommodate specialist bolt tightening equipment. In-line valves should allow the passage of inspection devices.

8.4.2 Control of valves

When selecting and designing valve control systems, account should be taken of factors including, but not limited to:

a) type of actuator;

b) valve function;

c) response time;

d) distance from control source;

e) loss of control source and possible need for secondary control systems for emergency isolation valve;

f) power source;

g) material compatibility of hydraulic/electrical connectors and couplings.

8.5 Pig traps and closures

The design, fabrication and inspection of closures, including those designed for repeated opening and closing and details such as nozzle reinforcements, saddle supports and other items not classed as standard pipeline sections, should conform to PD 5500 or ASME BPVC-VIII-1.

Pig traps should be oriented to allow adequate space, and facilities should be provided to open the closure and load/unload pigs. Where possible, the layout and alignment of pig traps within a site should be such that buildings or other facilities are not sited immediately behind pig trap doors.

End closures for components including pig traps, filters and prover loops should incorporate an interlocked vent to prevent the closure being opened before the release of pressure from the component. The design should ensure that the hinges and locking mechanism are sufficiently robust to withstand repeated use.

Flat, ellipsoidal, spherical and conical closure heads should be designed in accordance with PD 5500 or ASME BPVC-VIII-1.

8.6 Isolation joints

Electrical isolation joints should be designed in accordance with PD 5500 or ASME BPVC-VIII-1.

The design should take account of vibration, fatigue, cyclic conditions, low temperature, thermal expansion, mechanical abrasion, corrosion, long-term solar or ultraviolet degradation, and construction installation stresses.

Isolation joints should be designed to facilitate travel of internal inspection devices where appropriate.

Before installation into the pipeline the joint should:

a) pass a hydrostatic pressure test without end restraint in accordance with Clause **11**;

b) be tested electrically to confirm the electrical discontinuity.

8.7 Transitions

Nozzle and pipe transitions should be designed to facilitate travel of internal inspection devices where appropriate.

8.8 Other pressure-containing parts

Other pressure-containing parts for which there is no product standard or material standard, e.g. sphere tees, surge and slug catchers, and filters, should be designed in accordance with PD 5500 or ASME BPVC-VIII-1.

8.9 Coatings

*NOTE General recommendations for corrosion coatings and internal coating systems are given in Clause **9**.*

8.9.1 General

The properties needed for a coating can vary along the pipeline and several types of coating could be required. When selecting each coating system, either for internal or external application, the following factors should be taken into account:

a) resistance to moisture penetration;

b) electrical resistivity;

c) ease of application and repair;

d) integrity of coating;

e) adhesion;

f) resistance to impact/damage, e.g. external damage during thrust boring or internal damage due to the passage of pigs;

g) resistance to weathering;

h) flexibility;

i) resistance to cathodic disbondment;

j) suitability at operating temperatures;

k) resistance to ultraviolet light;

l) thermal insulating properties;

m) resistance to slippage.

The coating materials, the coating applicator and the applicator's procedures should be pre-qualified if they are not covered by a British Standard or acceptable equivalent European, international or other recognized national standard.

8.9.2 Concrete weight coating

Concrete weight coating should conform to a specification that covers at least:

a) composition of the concrete;

b) mechanical properties and tests;

c) thickness and mass, including tolerances;

d) dimensions and extent of reinforcement;

e) adhesion to the pipe;

f) application and curing;

g) sacrificial anode installation;

h) water absorption.

NOTE See PD 8010-2 for further details.

8.9.3 External coating for corrosion prevention and thermal insulation systems

Corrosion coating should be in accordance with **9.5**.

All external coatings should be able to withstand the environmental conditions, including any mechanical loads applied either accidentally or intentionally during construction and in service.

8.9.4 Internal coatings/linings

Internal coatings should in general be in accordance with **9.3.6** if applied to mitigate internal corrosion.

Anti-friction coatings should as a minimum conform to API RP 5L2 and have a thickness of not less than 40 μm.

9 Design – Corrosion management

9.1 General

Buried or submerged pipeline sections can be affected by external corrosion arising from the formation of corrosion cells in the surrounding ground or from stray electrical earth currents, and should be protected by a combination of anti-corrosion coatings and cathodic protection. If cathodic protection is unlikely to be effective on or is not applicable to minor parts of the pipeline section, extra care should be taken to eliminate coating defects as far as is practicable.

Above-ground sections of pipelines should be protected from atmospheric corrosion by a suitable coating or paint system.

Internal corrosion can be caused by the corrosive effect of the substance being transported and may be controlled by a combination of corrosion inhibitors, internal lining, dehydration or frequent pigging.

Internal and external corrosion of pipeline systems should be managed to minimize the risk of pipeline failure or loss of operability from corrosion within the intended design life of the pipeline. Corrosion management should include:

a) identification and evaluation of potential sources of corrosion (see **9.2** and **9.4**);

b) selection of the pipeline materials;

c) operating regime and eventual siting of the pipeline components (e.g. above or below ground);

d) identification of the necessary corrosion mitigation (see **9.3** and **9.5**);

e) definition of the requirements for corrosion monitoring and inspection (see **9.6**);

f) review of the findings from corrosion monitoring and inspection;

g) periodic modification of the requirements of corrosion management, as dictated by experience and changes in the design conditions and environment of the pipeline;

h) maintenance of corrosion mitigation equipment, e.g. cathodic protection facilities, inhibitor injection equipment, etc.

Internal and external corrosion evaluations should be carried out to determine whether, 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, corrosion monitoring, inspection 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 should be included in the evaluations.

*NOTE Examples of the issues that need to be taken into account when selecting a coating system are given in **8.9**.*

Where coated line pipe is to be stored in the open, a protective outer coating should be applied to within 150 mm to 300 mm from each end.

Anti-corrosion coatings should be selected to reflect the varying ground conditions found during a soil and resistivity survey carried out along the pipeline route.

9.2 Internal corrosion evaluation

The design of pipelines should include an assessment of the corrosive nature of the substance being transported.

Possible loss or degradation of the pipeline materials should be determined for all design conditions. The possible formation of free liquid water should be evaluated for the fluid velocities, pressures and temperatures anticipated during operations.

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

EXAMPLES Components which might 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, and contamination from upstream process upsets.

The corrosion-related events that should be addressed include:

a) general material loss and degradation;

b) localized corrosion, such as pitting under deposits and mesa- or crevice-type attack;

c) microbiologically-induced corrosion;

d) stress cracking;

e) hydrogen-induced cracking or stepwise cracking;

f) stress-oriented, hydrogen-induced cracking;

g) erosion and erosion-corrosion;

h) corrosion fatigue;

i) bimetallic/galvanic couples including preferential weld corrosion.

9.3 Internal corrosion mitigation

9.3.1 General

The design of a system to control internal corrosion should take into account:

a) pipeline system and lining materials;

b) design life;

c) product composition throughout design life;

d) operating temperature range;

e) operating pressure range;

f) the need for and frequency of pigging.

9.3.2 Available techniques

Suitable means of controlling internal corrosion should be chosen from the following available options:

a) modification of operating conditions (see **9.3.4**);

b) use of corrosion-resistant materials;

c) use of chemical additives (see **9.3.5**);

d) application of internal coatings or linings (see **9.3.6**);

e) use of regular mechanical cleaning (see **9.3.7**);

f) elimination of bimetallic couples;

g) provision of a corrosion allowance.

The compatibility of the selected mitigation method with downstream operations should be taken into account.

9.3.3 Selection of techniques

The choice of techniques employed for internal corrosion control should be determined by:

a) effectiveness in protection or control of the corrosion mechanisms;

b) reliability of operation over the life of the pipeline;

c) accessibility of the pipeline (for monitoring purposes);

d) ability to monitor internal corrosion;

e) ability of pipeline to pass internal inspection devices.

9.3.4 Revision of design conditions

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

9.3.5 Chemical additives

Where chemical additives, e.g. corrosion inhibitors, are used to control internal corrosion, corrosion coupons or other monitoring equipment should be installed in suitable locations to monitor the effectiveness of corrosion control. Inhibitor injection equipment should be included in the design, and corrosion monitoring equipment should be designed to permit passage of pigs if required.

The corrosion inhibitor selected should not cause deterioration of any components in the piping system or of the substance being conveyed.

The effects of high turbulence on the performance of inhibitors should be taken into account.

Factors that should be taken into account during the selection of chemical additives include:

a) consequences of an unplanned interruption to the addition of the additive;

b) criticality of maximum and minimum dosage;

c) effectiveness at water-wetted areas over the full pipeline circumference and length;

d) velocity variation of pipeline fluids;

e) partitioning behaviour in multiphase systems;

f) influence of sediments and scales;

g) compatibility with other additives;

h) compatibility with the pipeline component materials, in particular non-metallic materials in pipeline accessories;

i) personnel safety in chemicals handling;

j) environmental effects in the event of discharge;

k) compatibility with operations downstream of the pipeline.

NOTE Attention is drawn to the Control of Substances Hazardous to Health Regulations 2002 [28].

9.3.6 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.

Where internal coatings are used to control corrosion they should take into account the conveyed substance and operating regime, and should be applied in accordance with the relevant specification and quality procedures to maintain the correct dry film thickness.

If pipes are joined by welding such that metal is exposed, internal coating of the joint area or inhibitor should be used, where necessary. Account should also be taken of the internal coating in the selection of pigs to prevent coating damage during pigging.

Factors that should be taken into account during coating or lining selection include:

a) application methods;

b) availability of repair methods;

c) operating conditions;

d) long-term effects of the conveyed fluid(s) on the coating/lining;

e) resistance to pressure change;

f) influence of temperature gradients over the coating;

g) compatibility with pigging operations;

h) physical durability;

i) level of quality control that can be achieved.

9.3.7 Cleaning

A schedule should be determined for the periodic internal mechanical cleaning of a pipeline. The cleaning should include:

a) the removal of accumulated solids and/or pockets of corrosive liquid to assist in the reduction of corrosion in these areas;

b) enhancement of the effectiveness of chemical additives.

In choosing a mechanical cleaning device, the following issues should be taken into account:

1) the possible consequences of removing protective layers of corrosion products or chemical additives, or damage to internal coatings or linings, by mechanical cleaning;

2) 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

9.4.1 General

The possibility of external corrosion occurring should be determined on the basis of pipeline operating temperatures (see **G.2.9**) and the external conditions along the pipeline (see **G.3**).

Pipelines should be designed and routed to take account of the possible corrosive effects of contaminated or industrial waste ground, naturally aggressive ground, parallelism with a.c. power lines or cables, pylons and stray d.c. earth currents.

NOTE Parallel a.c. power lines can induce a.c. voltages on pipelines, which can cause corrosion. A.C. corrosion can occur at very low a.c. voltages, even if the pipeline appears to be cathodically protected. Mitigation of induced a.c. is achieved by the installation of zinc ribbon or copper earthing strip parallel to and connected to the pipeline via polarization cell replacement (PCR) devices to prevent drainage of the cathodic protection. Sacrificial anodes or vertical earthing systems have been found to have only a localized mitigation effect and are therefore not suitable for this purpose. Computer modelling may be used at the design stage to assess the magnitude of the risk from induced a.c. and to identify those locations where remedial measures need to be taken and/or additional monitoring facilities installed. For existing pipelines, field measurements of a.c. current density can be used to assess the risk and to update any computer models that have been developed.

Environments that should be taken into account when evaluating the possibility of external corrosion include:

a) atmosphere (marine/industrial/rural);

b) sea water (tidal zone/shore approach);

c) fresh or brackish water;

d) marshes and swamps;

e) river crossings;

f) dry or wet soil, including seasonal variations;

g) inside tunnels, sleeves or caissons;

h) proximity of the pipeline to overhead or buried power cables, which can induce alternating current induced corrosion (ACIC) effects;

i) proximity to other pipelines and structures with cathodic protection.

Environmental parameters that should be taken into account include:

1) ambient temperatures;
2) resistivity, salinity and oxygen content of the environment;
3) bacterial activity;
4) water flow;
5) degree of burial;
6) the potential for damage to external protective coatings by tree roots;
7) the potential for soil pollution by substances detrimental to the external coating.

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. Account should be taken of any known planned changes in the use of the land traversed by the pipeline route which could alter the environmental conditions and thus soil corrosivity, e.g. irrigation of land previously arid or of low corrosivity.

9.4.2 Corrosion mechanisms

The types of external corrosion damage that should be taken into account include:

a) general metal loss and degradation;
b) localized corrosion, e.g. pitting under deposit or crevice attack;
c) microbiologically-induced corrosion;
d) stress-corrosion cracking, e.g. carbonate/bicarbonate attack;
e) corrosion beneath disbanded coatings.

9.5 External corrosion mitigation

9.5.1 General

The design of a system to control external corrosion should take into account:

a) pipeline system;
b) design life;
c) operating temperature range;
d) pipeline installation method;
e) environmental conditions (including soil properties);
f) presence of bacteria;
g) adjacent structures and cathodic protection;
h) degree of burial, whether planned or due to natural settlement.

The need for a corrosion allowance should be assessed if any corrosion of the pipeline is anticipated.

9.5.2 Available techniques

Suitable means of controlling external corrosion should be chosen from the following available options:

a) external coating, which should be provided for all metallic pipelines (see **9.5.3**);

b) cathodic protection, which should be installed for all buried or submerged sections of a pipeline (see **9.5.4**).

NOTE External corrosion is typically controlled by a combination of external coating and cathodic protection.

9.5.3 External coatings

9.5.3.1 General

External coatings for underground applications should possess suitable mechanical and electrical properties in relation to the pipe size, environment and operating conditions. Coatings should exhibit strong adhesion and resistance to disbonding adjacent to areas of coating damage, and resistance to cathodic disbondment. External line pipe coatings should be factory-applied, except for field joints and other special points, which may be coated on site.

NOTE 1 A factory-applied coating is preferred for all pipeline components to ensure adequate surface preparation and coating application under controlled conditions.

Parameters that should be taken into account when evaluating the effectiveness of external coatings include:

a) design/service conditions;

b) electrical resistivity of the coating;

c) moisture permeation and its relation to temperature;

d) required adhesion between the coating and the pipeline base material;

e) required resistance to shear forces between the coating and any additional coating, thermal insulation coating or environment;

f) susceptibility to cathodic disbondment;

g) resistance to ageing, brittleness and cracking;

h) resistance to chemical attack;

i) requirements for coating repair;

j) minimum and maximum climatic temperatures;

k) method of installation;

l) resistance to damage during handling, shipping, storage, installation and service, i.e. physical durability.

All field-welded joints, fittings and below-ground components should be coated with a material that is compatible with the line pipe coating and the cathodic protection. It should give a durable bond with both the factory-applied coating and the steel surface. The field-applied coatings and their application should meet or exceed the line pipe coating specification.

On sections where coated pipe is to be installed by thrust boring or similar trenchless methods, coatings with added abrasion-resistant properties should be used, where necessary.

Where mechanical damage mitigation (e.g. concrete slabbing) has been installed, direct contact should be maintained between the pipe coating and the surrounding soil.

Since the effectiveness of cathodic protection beneath insulation is questionable, a good quality external coating should always be applied beneath the insulation.

NOTE 2 For components of irregular shape, different external coating materials to those used for line pipe may be used (e.g. two-component resin system or mastic combined with tape wrapping).

At the point where the pipeline emerges from the ground, additional protection should be applied for a distance of not less than 500 mm centred at the air-to-soil interface (i.e. the additional coating should extend 250 mm above and 250 mm below the air-to-soil interface).

9.5.3.2 Coating for corrosion prevention

Plant-applied coating should conform to **9.5.3** and the applicable part of ISO 21809 as follows:

- three layer polyolefin coating: BS EN ISO 21809-1;
- fusion bonded epoxy (FBE) coating: BS EN ISO 21809-2;
- two-layer polyolefin: BS ISO 21809-4.

NOTE DIN 30670 gives additional guidance on polyethylene coating of small diameter tubes.

Field joint coatings should conform to ISO 21809-3.

9.5.3.3 Thermal insulation coatings

Thermal insulation coating design should address the following requirements:

- type of coating and reinforcement, where relevant;
- thickness of individual layers and total thickness;
- composition and/or base material;
- mechanical properties;
- thermal 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.

NOTE ASTM C177 and ASTM H518 give guidance on the testing of thermal conductivity.

9.5.4 Cathodic protection

9.5.4.1 General

Defects in external coating systems enable the pipeline steel to come into contact with its surroundings, resulting in pipeline corrosion. Cathodic protection should be installed for buried or submerged sections of pipeline to mitigate against external corrosion at coating defects. The pipeline section to be cathodically protected should be electrically continuous unless certain sections require isolation to mitigate corrosion due to induced a.c. or other electrical interference.

The guidance in IGEM/TD/1 Edition 5:2012 on a.c. corrosion and separation distances of pipelines from high voltage power cables should be followed.

Cathodic protection should be applied by either the sacrificial anode or the impressed current anode method and should be designed and constructed in accordance with ISO 15589-1.

Cathodic protection of long cross-country pipelines should normally be provided by impressed current anodes. Sacrificial anode systems should be used, where necessary, for short pipelines, particularly in built-up areas.

Cathodic protection should be brought into operation as soon as possible following pipeline construction. Where delays in commissioning of the cathodic protection are unavoidable, the use of temporary sacrificial anodes should be used where necessary, particularly in areas with corrosive ground conditions. The application of cathodic protection to a pipeline can cause adverse effects on other buried metallic structures close to the protected pipeline, and the procedures given in ISO 15589-1 should be followed to quantify and minimize these effects.

Buried pipelines should be electrically isolated from above-ground sections to avoid the loss of protection due to current drain to the earthing systems on adjacent above-ground facilities.

9.5.4.2 Cathodic protection potentials

Cathodic protection potentials should be maintained within the limits given in ISO 15589-1 or other recognized international standards throughout the design life of the pipeline.

Table 5 provides a summary of typical protection potentials that should be applied for a range of environments.

Table 5 **Least negative cathodic protection potentials for non-alloyed and low alloy carbon steel pipelines**[A)]

Soil type	Resistivity	Copper/copper sulfate ($Cu/CuSO_4$)	Silver/silver chloride/saturated potassium chloride (Ag/AgCl/saturated KCl)
	Ω·m	V	V
Water and low-resistivity soil	<100		
	Aerobic	–0.850	–0.750
	Anaerobic	–0.950	–0.850
High-resistivity aerated sandy soil regions	100 to 1 000	–0.750	–0.650
	>1 000	–0.650	–0.550

A) Potentials in this table apply to line pipe materials with SMYS of 550 N/mm^2 or less. The possibility for hydrogen embrittlement should be evaluated for steels with SMYS of 550 N/mm^2 or more. Alternative protection criteria may be applied provided it is demonstrated that the same level of protection against external corrosion is provided.

For all steels the hardness of seam and girth welds and their implications for hydrogen embrittlement under cathodic protection should be taken into account.

The protection potential at the metal-medium interface should not be more negative than –1.150 V in case of $Cu/CuSO_4$ reference electrodes, and –1.100 V in case of Ag/AgCl reference electrodes.

The recommended protection potentials for stainless steels are generally less negative than for non-alloyed and low alloyed carbon steels. However, the protection potentials shown above may be used. For duplex and martensitic stainless steels caution should be exercised and specialist advice sought to ensure that the latest information is utilized in determining the most appropriate protection potential criteria and to reduce the risk of hydrogen-induced embrittlement.

Where the environment cannot be characterized with confidence, then the more negative potential criteria should be adopted.

NOTE The protection potential criteria shown in Table 5 apply to the metal-medium interface. In the absence of interference currents this potential corresponds to the instantaneous "off" potential.

9.5.4.3 Design

9.5.4.3.1 General

Cathodic protection should be designed in accordance with ISO 15589-1 or other internationally recognized standards, and with the recommendations given in this subclause.

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

The design of cathodic protection should ensure that the cathodically protected pipeline is electrically isolated from other, non-protected electrically earthed structures.

The pipeline system should be protected against the effects of stray currents.

9.5.4.3.2 Sacrificial anodes

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

a) pipeline design life (see **5.1**);

b) pipeline operating conditions;

c) design criteria and environmental/ground conditions;

d) applicable standards (e.g. ISO 15589-1);

e) requirements for electrical isolation;

f) calculations of the pipeline area to be protected;

g) current density requirements;

h) performance of the anode material in the design temperature range;

i) protection against the effects of possible a.c. and/or d.c. electrical interference;

j) layout of ground beds, cable routes, etc.

9.5.4.3.3 Impressed current anodes

Impressed current anode protection systems should be designed to give a uniform current distribution along the pipeline and should define the permanent locations for the measurement of the protection potentials (see **9.5.4.2**).

The design of impressed current protection systems should be documented and should include reference to:

a) pipeline design life (see **5.1**);
b) pipeline operating conditions;
c) design criteria and environmental/ground conditions;
d) applicable standards;
e) requirements for electrical isolation;
f) calculations of the pipeline area to be protected;
g) current density requirements;
h) anode ground bed design and location, its current capacity and resistance;
i) cable installation and protection methods;
j) measures required to mitigate the effects of possible a.c. and/or d.c. electrical interference;
k) protection requirements prior to the commissioning of the impressed current system;
l) location of cathodic protection hardware, such as transformer rectifiers.

9.5.4.3.4 Connections

Cable-to-pipe connections may be made by manual welding, thermite welding, pin brazing, or by using conductive epoxy. The latter should not be used for current-carrying connections.

NOTE Manual welding normally involves the attachment of a doubler plate to the pipe before making the cable connection to the doubler plate.

The design of the connections should take into account:

a) the requirements for electrical conductivity;
b) the requirements for mechanical strength and protection against potential damage during construction;
c) the metallurgical effects of heating the line pipe during bonding.

Design layouts should clearly show all cable routes.

9.5.4.4 A.C. mitigation

If personnel safety is at risk from a.c. voltages on the pipeline or if an a.c. corrosion risk exists, measures should be taken to mitigate the risk. These should include:

- earthing laid parallel and connected to the pipe;
- earthing mats at valves;
- connection of polarization cells or their solid state equivalent across electrical isolating devices to connect the pipeline to earth and to protect the electrical isolating device;
- dead front test posts to prevent third-party contact.

NOTE 1 One of the methods of monitoring the a.c. corrosion risk is by measuring the a.c. current flowing at a buried coupon installed at the location where the a.c. interference is believed to be at its greatest. These coupons normally comprise a coated metal plate with an exposed bare steel area of 1 cm^2. The coupon is normally connected to the pipe via a shunt that enables both the a.c. current flow and the d.c. current flow to be measured.

The need for a.c. mitigation should be identified at the design stage and this may be done by computer-modelling the power line/pipeline interaction. However, the model should be updated following commissioning and monitoring, and further mitigation measures might therefore be required during the lifetime of the pipeline as more information is gained and/or the power line load changes.

NOTE 2 Mitigation measures may be installed retrospectively, but this carries a risk of a.c. corrosion occurring before installation is complete. The installation of further mitigation measures might be necessary if the power line load increases.

Mitigation measures for potential a.c. corrosion issues should be evaluated in conjunction with the electricity supply company concerned.

9.5.4.5 Cathodic protection commissioning

Cathodic protection based on impressed current should be commissioned as soon as possible following pipeline installation. Provision for temporary protection should be made in case of delays.

For all cathodic protection, commissioning should include the following activities:

a) completion of an initial cathodic protection survey, including:
   1) a base line survey with all temporary/permanent sacrificial anodes disconnected and all impressed current systems switched off;
   2) measurement of the cathodic protection potentials at all test locations along the length of the pipeline with the cathodic protection energized;
   3) testing for detrimental stray or interference currents;
   4) measurement of current demand;
   5) testing of isolating couplings;

b) corrective measures if the necessary protection is not achieved;

c) provision of commissioning records.

As soon as possible after commissioning, a close interval potential survey (CIPS) of the entire pipeline should be undertaken to confirm that the necessary levels of protection are achieved along the entire pipeline.

9.6 Monitoring programmes and methods

9.6.1 General

Corrosion monitoring programmes should 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. Internal inspection tools should be used where monitoring of internal or external corrosion or other defects is needed over the full length of the pipeline. Approximate rates or trends of corrosion degradation may be determined by analysis of the results of consecutive metal loss inspections.

An internal or external inspection of the pipeline soon after commissioning should be carried out to record and identify the as-installed condition of the pipeline, and to provide a baseline for the interpretation of future surveys.

9.6.2 Monitoring internal corrosion

9.6.2.1 Selection of methods

The selection of methods for monitoring internal corrosion should take into account:

a) anticipated type of corrosion;

b) potential for water separation, erosion, etc. (flow characteristics);

c) anticipated corrosion rate (see **9.2**);

d) required accuracy of metal loss measurement;

e) available internal and external access;

f) hindrance of passage of pigs or inspection devices by internal obstructions.

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

9.6.2.2 Location of test points for local corrosion monitoring

Subject to availability and practicability of access, 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.

Corrosion probes should be fitted flush with the internal wall of the pipe where pigging might occur. Additional probes in areas of high velocity flow should be installed where necessary.

9.6.3 Monitoring external pipeline condition

CIPSs should be carried out periodically to assess the level of protection being achieved between the test point locations. However, CIPSs do not always pinpoint areas of the worst corrosion and such surveys should be supplemented by exposure and visual inspection of the pipeline at suspect locations.

A schedule for periodic surveys of the coating of pipelines on land should be determined, taking into account the selected coating and predicted degradation, soil type, observed cathodic protection potentials and current demands, and known metal loss. The cathodic protection specification should be increased for sections of pipeline installed in inaccessible locations, where necessary.

NOTE In some circumstances it can be advantageous and/or economic to undertake CIPSs and coating surveys simultaneously.

9.6.4 Monitoring cathodic protection

Periodic surveys should be carried out to monitor the level of cathodic protection using, as a minimum, the test points identified in **9.5.4.5**.

The frequency of these surveys should be based on:

a) the method of cathodic protection;

b) the uniformity of soil properties along the pipeline and the degree of burial;

c) the coating quality;

d) safety and environmental concerns;

e) possible interference from electrical sources;

f) alteration in pipeline operating conditions (i.e. temperature);

g) results from previous surveys.

The possible hindrance from a.c. or d.c. interference during the surveys and the interpretation of the results should be taken into account during the selection of the survey method.

CIPSs of the coating should be carried out periodically along the pipeline route, as well as other specialist diagnostic techniques as necessary, to provide more detailed information concerning the corrosion protection of the pipeline as part of the overall pipeline integrity management programme.

CIPSs should be undertaken as close to on-line inspection as possible, if appropriate.

9.6.5 Evaluation of monitoring and inspection results

Permanent records of the corrosion control measures should be maintained. These include:

- internal and external coating;
- cathodic protection monitoring results;
- details and locations of bonding to third-party systems;
- results of surveys, e.g. Pearson, CIPSs, etc.

All findings of the monitoring and inspection activities should be analysed to:

a) review the adequacy of the corrosion management;

b) identify possible improvements;

c) indicate the need for further detailed assessment of the pipeline condition;

d) indicate the need to modify the corrosion management methods.

9.7 Corrosion management documentation

The following aspects of corrosion management should be documented:

a) assessment of the corrosion threats and associated potentials for failure (see **9.1**, **9.2** and **9.4**);

b) choice of materials and corrosion mitigation methods (see **9.1**, **9.3** and **9.5**);

c) selection of inspection and corrosion monitoring techniques and inspection frequencies (see **9.6**);

d) any specific decommissioning and abandonment issues associated with the selected corrosion management approach.

10 Construction – Fabrication and installation

10.1 General

Work should be carried out in such a way as to ensure the safety of the workforce, third parties and the protection of property and the environment.

Competent personnel, capable of assessing the quality of the work within the scope of this part of PD 8010, should be employed for the supervision, inspection and execution of the construction project.

Contractors appointed by the operator should possess the qualifications necessary for the execution of the work.

*NOTE The safety and reliability of a pipeline system can be improved by the application of quality assurance procedures in construction (see **4.3**).*

10.2 Safety plan and procedures

NOTE 1 Attention is drawn to the following legislation in respect of the health, safety and welfare of all employees and members of the public in connection with the design, construction, operation and maintenance of pipelines:

- *Construction (Design and Management) Regulations 2007 [1];*
- *Construction (Lifting Operations) Regulations 1961 [29];*
- *Control of Major Accident Hazard Regulations 1999 [30];*
- *Control of Major Accident Hazards (Amendment) Regulations 2005 [31];*
- *Factories Act 1961 [5];*
- *Factories Act (Northern Ireland) 1965 [6];*
- *Gas Safety (Management) Regulations 1996 [8];*
- *Health and Safety at Work, etc. Act 1974 [9];*
- *Health and Safety at Work (Northern Ireland) Order 1978 [10];*
- *Ionising Radiations Regulations 1999 [32];*
- *Offshore Installations (Safety Case) Regulations 2005 [33];*
- *Pipelines Safety Regulations 1996 [15];*
- *Pressure Systems Safety Regulations 2000 [20];*
- *all regulations enacted under these.*

Attention is also drawn to guidance notes and Approved Codes of Practice published by appropriate authorities.

The safety plan should describe requirements and measures for the protection of:

a) the health and safety of the public;

b) personnel involved in the construction;

c) the environment.

It should contain references to the relevant legislation and applicable standards, identification of hazards and measures needed for their control, and should highlight any emergency procedures needed in the completion of the construction.

High standards of safety should be maintained at all times. Safety training should be given to all employees engaged in supervision and construction of pipelines. Safety procedures and equipment should be provided for normal installation and contingency conditions.

*NOTE 2 See also **10.12**.*

Supervisors should be appointed who are responsible for ensuring that the necessary safety procedures are implemented.

10.3 Construction plan

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

a) a description of the construction;

b) a programme of the construction;

c) a quality plan;

d) a health and safety plan;

e) an environmental plan;

f) methods of controlling and handling materials;

g) traffic management plans.

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

NOTE Special construction methods, such as those needed for conventional and trenchless crossings (tunnels, landfalls and landslip areas, pipe bridges and directional drilling), require supplemental pipeline installation procedures.

10.4 Construction near other facilities

All facilities that could be affected by construction of a pipeline system should 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 operators of the facilities should be consulted when defining these temporary provisions and safety measures, and should be given timely notification of the commencement of construction.

NOTE Facilities that could be affected include existing crossings, roads and railways, watercourses, footpaths, pipelines, cables, walls, SSSIs, archaeology sites and buildings.

10.5 Plant and equipment

All major plant and equipment used for construction should be inspected before and during construction to determine its suitability for the intended work in accordance with good engineering practice.

10.6 Transport and handling of materials

A material control system should be adopted to monitor material throughout, from supplier, transport, lifting and handling, to receipt at site, quality checks, storage and issue.

A risk assessment should be carried out prior to the handling of materials to ensure that the activity is carried out in a safe manner and to avoid damage.

Transport and handling procedures might be needed, which should identify the equipment to be used and the stacking requirements.

NOTE 1 API RP 5L1 and API RP 5LW provide guidance on the transport of line pipe. IGEM/TD/1 Edition 5:2012, Supplement 1 provides guidance on the handling, transport and storage of steel pipe.

Care should be taken to prevent damage to pipes, fittings and coating during handling. Slings or equipment used for handling pipes should be designed to prevent pipe or coatings damage. Where minor damage to coatings has occurred, repairs should be carried out. Where extensive coating damage has occurred, there should be a complete re-coating of the area affected. Any damaged areas should be inspected for non-conformity to the relevant material specifications. Pipes should be visually inspected for possible damage in transit and rectified before stringing. Materials should not be installed until the material certification can be verified and any damage and/or defects have been removed or repaired.

If an electromagnet is used to lift the line pipe, the residual magnetism should be measured. If residual magnetism is found to exist, methods should be adopted to de-magnetize the pipe and enable arc welding to be carried out.

During storage the pipes should be protected against damage and corrosion, should be supported off the ground and, where necessary, should be separated from one another by suitable means (see **9.1**).

NOTE 2 It is essential that these storage facilities are safe and stable at all times.

Materials not conforming to the relevant material specification should be isolated and quarantined from all other materials, until the quality and correctness can be confirmed. If materials fail they should be returned to the manufacturer or supplier for replacement.

10.7 Construction supervision

Competent and experienced staff should be appointed to supervise the full range of pipeline construction activities.

Particular attention should be given to environmental matters, quality assurance and public safety aspects of pipeline construction.

10.8 Working season

Wherever possible, the construction period for pipelines laid through agricultural land should be limited to the period in each year when climatic conditions are such that pipeline construction will cause least harm to the soil condition.

NOTE In the UK this is generally between April and September with an additional period of one month for commissioning and reinstatement works.

Arrangements should also be made where possible for construction works in agricultural land to stop if extreme adverse weather conditions are encountered which could seriously affect the final condition of the land.

10.9 Administration

10.9.1 Communications

Good reliable communications should be established (e.g. radio, mobile phone, banksman or equivalent) within the working areas, and between the working areas and the construction central base office, to ensure safety, and quick emergency response. Modern communication equipment should be used and the workforce should be trained and competent in the use of this equipment.

10.9.2 Emergency services

The promoter should advise all emergency services of the works in hand prior to commencement. This notification should include the supply of maps and plans of any temporary access points.

10.9.3 Quality of materials and workmanship

A quality control system should be introduced to ensure that construction activities are carried out in accordance with the approved quality plan and design specifications. Items such as welding records, material and test certificates, and coating records should form part of the as-built documentation.

10.9.4 Trespass

Survey, investigation and construction personnel should not trespass outside the working limits of the pipeline route or other agreed areas. Goodwill should be maintained with owners, occupiers and representatives of authorities, by respecting their rights and causing the least possible damage or interference.

10.10 Environmental issues

Work should be carried out with minimum disturbance to the environment. Care should be taken not to create pollution, e.g. fuel and chemical spillage, especially in areas that could impact surface or ground watercourses.

NOTE 1 Attention is drawn to the Electricity and Pipe-line Works (Assessment of Environmental Effects) Regulations 1990 [3].

NOTE 2 SSSIs and archaeological and historical sites can require specific times, methods and procedures in addition to those identified in the general environmental management plan.

If an environmental management plan is required, it should include details of commitments made from the process of carrying out an environmental impact assessment (EIA) and in resulting environmental statements (ES), and of any local authority planning conditions.

NOTE 3 Attention is drawn to the Noise and Statutory Nuisance Act 1993 [34] and to the Noise at Work Regulations 1989 [35]. It can sometimes be necessary to provide special equipment such as acoustic screens to reduce noise levels.

In order to carry out the construction works efficiently, a traffic management plan should be developed. This plan should be discussed with the local authorities at the earliest opportunity. The plan should ensure that any disturbance to local traffic is minimized, and where necessary should include clearly defined plans for diverting traffic. The needs of pedestrians should also be taken into account when planning the works, by provision of safety barriers, signing and alternative walkways where necessary.

10.11 Preparation of the route

10.11.1 Entry upon land

NOTE 1 Attention is drawn to legal requirements in respect of entry on the land in areas infected by notifiable diseases. Notifiable diseases include foot and mouth disease, swine vesicular disease, fowl pest and swine fever. Infected areas are not necessarily declared when a notifiable disease outbreak is confirmed, although this action is invariably taken with foot and mouth disease. Entry is governed by conditions stipulated by the Department for the Environment, Food and Rural Affairs (DEFRA) or agreed with the occupier. Promoters in conjunction with owners and occupiers directly affected by the pipeline are expected to take such reasonable precautions as might be necessary to avoid the spreading of soil-borne pests and diseases, e.g. Rhizomania. Information is obtainable from the relevant authorities for England, Wales, Scotland and Northern Ireland.

NOTE 2 For legal guidance, definitions and clarity on pipeline land and access agreements associated with the preparation of pipeline routes, refer to Annex I.

10.11.1.1 Preparation

The promoter should arrange for representatives, e.g. agricultural liaison officers, to maintain close personal contact with occupiers. The owner/operator (promoter), planning officer and principal contractor should agree and nominate the agricultural liaison officers to negotiate way leaves, easements, access, construction access, installation and reinstatement, together with any permanent access to above-ground installations (AGIs), cathodic protection test posts, isolation valves, etc.

Initial contact should be made well before construction is to commence, and contact should continue until reinstatement is complete and any compensation for damage has been paid.

The promoter's representatives should discuss with the occupiers the impact and implications of the work and the construction programme. The representative should advise occupiers whether the work will be completed in one operation or if return will be necessary after the main pipe-laying has been completed; also whether night and/or weekend work will be involved. The representative should keep occupiers informed of any significant changes in the programme, and should advise owners of any changes affecting their interests before the land is entered for construction.

As much notice as possible should be given over and above any statutory notice period to individual owners and occupiers and to any authority affected.

Each occupier should be given the address and telephone number of the representatives of the pipeline promoter to whom any complaints or requests can be made.

Advance provision should also be made for any land required for storing of pipes and other materials, for parking and maintaining equipment, and for the siting of temporary offices, camps, sanitary facilities, signs, etc.

10.11.1.2 Working width

As far as practicable, the working width should be determined and documented with owners and occupiers as part of the overall land acquisition process.

Consultation should be undertaken by the promoter with occupiers at the earliest possible stage so as to determine the width of the working area for construction. Any later amendment to the working width needs to be agreed by the occupier before work is started or the working width is modified.
In deciding upon the extent of any working width there should be recognition of the ground terrain and conditions at the following locations:

a) entrances, and at major road, rail, river, canal, or lake crossings;

b) where deep pipelines are being installed;

c) where it is necessary to go beneath, or parallel with, existing underground services;

d) where it is necessary to go beneath ditch or stream crossings or land drainage crossings;

e) where ditches, streams or drainage are being diverted;

f) where it is necessary to stack separately various subsoil bands and topsoil to ensure correct order of replacement;

g) where construction traffic access is required.

10.11.2 Records of condition and site inspections

Before work starts, a record should be made of the condition of the land, including photographs where appropriate. A record should also be made of the depth of the topsoil and any special land features, so that they can be reinstated as found. This record should be agreed with the occupier and, wherever possible, the landowner.

Where there are trees growing within the proposed working width:

a) the local authorities should be consulted to determine whether there are any existing tree preservation or protection orders;

b) all work that could affect the trees should be agreed with the occupier before work commences. Where special protective works exist or are needed on account of an SSSI or notifiable disease, the fact should be noted in the record and all precautions should be adopted to carry out the work correctly.

NOTE Where trees within the proposed working width are not to be felled or removed, slight deviations in the alignment of the pipeline can be advisable to increase the working width to allow the passage of construction equipment.

Site inspections of existing conditions along the working width of the pipeline route should be undertaken after access to the route has been granted and before construction commences.

Reports of these inspections should state:

1) the requirements of the users/owners of the land during construction;
2) the condition of the items potentially affected by construction;
3) the requirements and effects of the EIA;
4) preparation for protection of identified species (e.g. erection of newt fencing).

The reports should also record the mutual approval of all parties concerned, set out the procedures for reinstatement of the site on completion of the work and detail any compensation owed to the user/owners.

Agreements should be sought regarding:

- the type of fencing to be used;
- the location of gates for access;
- the temporary provision of troughs and water supplies;
- the movement of livestock and any crossings of the working width.

The method of restoring disrupted land drains should be agreed with the owner and occupier concerned at the time of negotiating easements. This agreement should be sought for each individual case. In the event of a dispute, the advice of an agreed drainage expert with knowledge of local conditions should be taken and followed.

Information regarding the location of land drains in agricultural land should be obtained wherever possible from local sources or from DEFRA in England and Wales or SEERAD in Scotland.

10.11.3 Survey and marking

Prior to commencement of the construction works, the working width should be set out in accordance with the alignment sheets and associated drawings, and the accuracy of this should be checked. The positions of all existing third-party utility services affecting the works should be taken into account.

Following setting out and right-of-way preparation, a survey should be carried out along the pipeline route to determine the pipe bend requirements, taking into account the changes in direction in both horizontal and vertical planes and allowing for any grading that might be carried out. The position of bends should be marked at the side of the working width.

NOTE The number of bends may be reduced by judicious grading of the trench at approaches to crossings and other obstacles where practicable.

The limits of the working width should be marked by installing colour-coordinated pegs prior to installation of temporary fencing. All marking should be maintained in good condition during the construction period.

10.11.4 Preparation of the working width

10.11.4.1 Clearing and grading

Preliminary work in pipeline construction should include erection of temporary fencing and the clearing and disposal of all standing crops, scrub, hedges and debris from the route, together with the proper and adequate fluming or bridging of ditches and streams. These operations should be planned from the outset to cause the least possible disturbance to owners, occupiers and the environment.

Constraints or precautions to be observed within the working width should be defined in the construction specifications, including conducting an archaeological watching brief during the construction phase.

NOTE 1 Such constraints or precautions might include preservation of specific trees, animals, plants or the disposition of trees and stumps, the separation of topsoil, maintenance of drainage, and the prevention of scour or erosion.

Where trees have been felled, any resulting timber remains, in the absence of any arrangement to the contrary, the property of the landowner. The removal of any roots of felled trees should be agreed with the occupier.

In good agricultural land, unless agreed otherwise by the occupier, topsoil should be stripped from the whole of the working width apart from that area used for the stacking of the topsoil.

NOTE 2 The width and depth of stripping of topsoil is governed by individual circumstances; however, the depth does not normally exceed 300 mm unless otherwise agreed with the occupier.

NOTE 3 Heathland and moorland are generally designated as requiring special construction measures to protect heathers and grasses from permanent damage. Limits can be imposed for width and timing of topsoil stripping.

All topsoil should be deposited separately from subsoil, ready for replacement in its original position without contamination. Where possible, turf on lawns, sports and ornamental grounds, etc. should be carefully cut, rolled and kept in moist condition for subsequent replacement.

The height of stacked topsoil should be limited to avoid compaction.
If reinstatement of land is delayed beyond the current season then precautions should be taken to try to avoid loss of topsoil through erosion.

NOTE 4 This can necessitate the grassing over of the stacked topsoil. In addition, if prolonged exposure is encountered it can be necessary to carry out spraying of the stacked topsoil for weed control.

Care should be taken to avoid earth slippage out of the working width.
Travel along the working width should be minimized to avoid increasing compaction of the soil.

NOTE 5 To assist in maintaining dry working conditions, it might be appropriate in agreement with the landowner or occupier to install header drains parallel to and outside the working width boundaries.

10.11.4.2 Temporary fencing

All temporary fencing, access bridges and access roads should be to a reasonable standard agreed with the landowner or occupier.

In agricultural land, appropriate stock-proof fencing should be provided along each side of the working width to exclude animals kept on adjoining land.

NOTE 1 This is normally the first operation after pegging out.

Where no stock is kept, the limits of the working width should be marked in agreement with the landowner or occupier.

Temporary fencing for this purpose should be to a standard equivalent to the adjoining boundary hedge, wall or fence. A removable section or gates should be provided for contractors' plant access. Nails and staples should not be driven into trees under any circumstances.

NOTE 2 Temporary bridging and widening of access roads for the passage of plant and equipment might be necessary.

NOTE 3 Fencing might also be required to protect areas of special interest, e.g. SSSIs and environmentally sensitive areas, or where plant access is planned crossing existing underground pipelines.

In areas where special (e.g. anti-vermin) fencing has been erected, precautions should be taken at all times during construction not to nullify the purpose for which the fencing was provided. Gaps in hedges or walls at field and road boundaries should, where necessary, be temporarily closed during construction.

NOTE 4 Additional precautions might need to be undertaken where infectious diseases are encountered (e.g. tyre and vehicle washers, vehicle and foot chemical baths, double fencing, etc.).

The removal of temporary fencing should be carried out in consultation with the landowners or occupiers.

All temporary fences should be maintained until work on the section is completed, the ground fully restored and permanent walls, fencing or hedges reinstated.

10.11.5 Public safety

The contractor should ensure at all times that the general public is protected from any danger arising from the installation and testing of pipelines.

Provision should be made for restricting access to the working areas from public access points.

Barriers, goal posts and warning notices should be erected as necessary to facilitate safe access under overhead power lines.

Signs, fencing and gates should be provided to prevent free access to the site, with particular attention given to the fencing of trial pits and third-party service investigations, excavations, open pits and open boreholes.

If the entrance to a site crosses a public road or footpath this should be kept clear of obstructions, mud and spoil. Particular care should be given to safety at road crossings.

NOTE Attention is drawn to the Highways Act 1980 [36] in respect of visibility for vehicles entering or leaving a site, and in respect of the provision of car parks.

10.11.6 Blasting

NOTE 1 Attention is drawn to the Health and Safety at Work, etc. Act 1974 [9], the Construction (Design and Management) Regulations 2007 [1] and the Pipelines Safety Regulations 1996 [15] in respect of safety.

Blasting should be carried out in accordance with environmental constraints and should be performed by competent and qualified personnel.

If it is proposed to use explosives, agreement should be obtained from the owners, occupiers, authorities and all others affected concerning their use and the timing of blasting operations.

Determination of the size of explosive charge should take into account the location of adjacent underground structures, power lines or other above-ground structures. It is essential to carry out a condition survey of any structures that might be affected by blasting.

When explosives are used, the promoter's as-built records should indicate the location where the explosives were detonated.

WARNING. Attention is drawn to the danger of unexploded charges.

NOTE 2 Detailed guidance is given in BS 5607 on the use of explosives in the construction industry.

10.12 Installation of pipelines

10.12.1 Pipeline spread

Promoters should restrict the total length of each pipeline spread from the start of the temporary fencing to the point of the sub-soil backfilling operations.

10.12.2 Pipe stringing

Stringing of the pipes along the working width should be done in such a manner that the least interference is caused in the land crossed. Written procedures that define access limitations and provisions for minimizing interference with local and public land use should be utilized.

Gaps should be left at intervals to permit the passage of livestock and equipment across the working width.

Pipes should be laid out carefully and should be placed off the ground where possible to prevent damage to the pipe or coatings, and in such a manner as to ensure that they remain safely where placed until incorporated in the pipeline. The pipes should be padded at the interface points with the wooden skids used to keep the pipe off the ground to prevent damage to the external pipe coating.

Pipeline coatings might need protection from ultraviolet degradation if long-term, external storage is anticipated. On such projects, long-term storage should be under cover from solar ultraviolet light.

If straw is used for protecting pipes, e.g. in transit, it should all be collected and burned in a safe area immediately after use so as to avoid any possible agricultural contamination. No burning should be carried out on the pipeline spread or areas that are not easily accessible.

Measures should be taken to prevent rolling and to ensure stability of the pipe.

After stringing, before alignment for welding, pipe ends should be inspected for cleanliness, defects, bevel damage and dimensional errors. Any damage or errors found should be repaired by grinding or re-bevelling.

10.12.3 Maintenance of access

Where the trench and pipeline interfere with any normal access, an alternative access or a bridge should be constructed and maintained, together with access ways to provide temporary communications across the works until normal access has been restored. The temporary access across the working width should, where necessary, be provided with swing gates that effectively prevent livestock straying on to the working width.

10.12.4 Elastic bending

During construction, pipe may be flexed for installation purposes to a radius of curvature that does not induce a bending stress exceeding 85% of the SMYS. Parameters should be as specified in the construction specification.

For pipelines assuming a natural curvature that incurs a permanent elastic bending stress, the minimum bending radius should be determined at the design stage through stress analysis (see Clause **6**).

10.12.5 Field bending

Pipes may be bent cold in the field to fit pipeline alignment and topographical conditions.

Cold bends having a minimum radius of 40 pipe diameters may be made from the pipe intended for straight lengths.

Cold bends of a radius less than 40 pipe diameters may be made in the field providing that:

a) the quality control conditions are equivalent to those applicable to an established bending shop;

b) the finished bends are in accordance with **8.3.5**;

c) the line pipe material is selected in accordance with **8.2**.

Cold bends should be made on a suitable field bending machine, which provides sufficient support to the pipe cross-section to prevent buckling or wrinkling of the pipe wall. Pipe bending machines should be manned by trained operators.

When bending pipe with a diameter above 300 mm and with a D_o/t_{min} ratio of greater than 70:1, an internal mandrel to prevent local buckling should be used where necessary.

Cold bends should be checked for ovality, buckling, cracks, wall thinning and location of longitudinal seam. Pipes and bends should be swabbed before alignment and welding to ensure that all dirt and other objects likely to cause obstruction are removed.

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.

A gauging plate, to the same specification as that used on the main pipeline, should be pulled through each bend before installation to ascertain conformity to the specification.

During field bending, the contractor should make every effort to prevent damage occurring to external coatings or internal liners. Any damage caused by field bending should be repaired to meet the original design specification.

10.12.6 Factory bends

Factory bends may be used where topography or other restrictions exist. If used, factory bends should be in accordance with **8.3.5**.

10.12.7 Line pipe inspection

Gouges, grooves, notches and arc burns imparted to pipe during construction can cause subsequent pipeline failure in service. These should be carefully ground out, ensuring that the resulting wall thickness is not less than the design thickness given in **6.2.2.1**. If the wall thickness is decreased to below the design thickness, the damaged area should be cut out as a cylinder of length not less than one pipe diameter.

Any dent which contains a scratch, sharp edge, groove or arc burn should be removed. All dents that affect the curvature of the pipe at the longitudinal weld or any circumferential weld should also be removed. The removal of dents should be carried out by cutting a cylinder of length not less than one pipe diameter. Insert patching or knocking out of the dent should not be undertaken.

10.12.8 Lining up for welding

Care should be taken to ensure that pipes are supported during lining up for the welding operation to avoid damage to coating, and to enable sufficient clearance for the welding, weld inspection and coating activities to be carried out in a safe manner.

10.12.9 Welding

10.12.9.1 General

Welding of pipeline systems should be carried out in accordance with BS 4515-1 and BS 4515-2.

Welder qualification should be in accordance with BS EN ISO 9606-1. Welding procedures should be in accordance with BS EN ISO 15607 and BS EN ISO 15609. Welding consumables should be in accordance with BS EN ISO 15610. Welding procedure qualification should be in accordance with BS EN ISO 15614.

10.12.9.2 Night caps

Night caps should be placed on the open ends of welded sections of pipeline at the end of each day's production or when no work is in progress, to prevent the ingress of dirt or other objects, small animals and water. If there is a likelihood of trench flooding, appropriate action should be taken to prevent flotation of the pipeline section.

10.12.9.3 Pups

Pups may be welded into the pipeline but should not be shorter than twice the diameter of the pipe or 600 mm, whichever is the lesser. When a pipe is cut, the pup should be given a suffix number to trace its inclusion elsewhere in the pipeline. All cut ends should be non-destructively examined for laminations.

10.12.9.4 Non-destructive testing (NDT)

The percentage of welded joints inspected depends upon the intended contents of the pipeline. Where radiography is selected as the medium for NDT, safety measures should be in force to protect other local work activities.

In pipelines subjected to hydrostatic testing that are designed to convey category B, category C, category D or category E substances, welding quality should be established by 100% radiographic inspection, AUT or equivalent.

All tie-in welds and all welds made in road, rail and watercourse crossings for pipelines carrying any category of substances should be subjected to radiographic examination unless the safety of operatives and the general public is likely to be compromised. In addition, all tie-in welds made following any hydrostatic test should be in accordance with **11.10**.

10.12.10 Field coating

Welded joints between pipes should be protected against corrosion in accordance with Clause **9**.

The welded joints should be coated using a system compatible with the coating provided on the rest of the pipe.

The preparation of the pipe surface and the application of the field joint coating should be performed in accordance with a procedure that meets the coating manufacturer's recommendations.

Coating should be applied by competent operators who have received adequate instruction.

10.12.11 Trench excavation

10.12.11.1 General

NOTE 1 Trenching includes all excavation that is carried out by trenching machine, by excavator, or by hand, to prepare the trench to the required dimension for the pipeline.

The depth of the trench should be determined such that the pipe cover conforms to the drawings and documents established at the design and survey stage, taking into account the addition of any protection. Depth of cover should be in accordance with **6.8.3**.

The trench should be vertical, sloping or battered depending on the depth, width, type of terrain and soil conditions.

NOTE 2 It can be necessary to increase the depth of trench:

a) for pipelines following hydraulic gradients;

b) to avoid land drains, drainage systems, roads, railways or other crossings;

c) for other special reasons such as when a pipeline crosses fens, peat bogs and marsh areas and for improved pipeline security.

All excavation work, other earthmoving work and backfilling should, if possible, be carried out in dry trenches, if necessary by employing well-point de-watering.

A study should be made to determine the de-watering procedure and the quantity and quality of the water removed.

The depth of cover may be reduced in rocky or rough ground, provided the contents of the pipeline are not liable to be adversely affected by frost and the pipe material is strong enough to withstand the loading of any anticipated vehicular traffic (see also **6.9.1**).

Wherever possible, the trench bottom should be prepared to permit even bedding of the pipeline and should be free from sharp edges or objects which could cause damage to, or deterioration of, the pipe or its coating. If this is not possible, the pipe should be protected by installing bedding material or mechanical protection. Any bedding material or mechanical protection should not act as a shield to the passage of cathodic protection current to the pipe surface.

Temporary underpinning, supports and other protective measures for supporting building structures or apparatus in, or adjacent to, the trench should be fit for purpose and of sound construction.

When trenching occurs adjacent to existing underground structures, precautions should be taken to avoid damage to such structures. A minimum separation after any designed pipe movement of 0.3 m should 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.

When work is performed in the trench, measures should be taken such as widening, deepening and/or supporting the trench to allow safe working conditions. Appropriate precautions should be taken if toxic or flammable atmospheres are likely to be present.

Where a pipeline is to be laid through unstable ground, the support provided should be adequate to ensure the integrity of the pipeline.

The selection of equipment and associated working methods should take into account the nature of the ground, and the conditions with respect to safe excavation.

If the backfilled pipeline trench is likely to act as a drain, precautions should be taken to prevent loss of any bedding or fine pipeline support material. Precautions to prevent flow along the line of the trench should include the installation of clay plugs at intervals and at either side of watercourses. These should also be installed to protect against possible cross-flow of contamination along the trench.

10.12.11.2 Support of excavations

An excavation should be properly supported, or the sides sloped back to a safe angle, before the excavation reaches a depth of 1.2 m.

NOTE 1 At this depth persons working in it would be buried or trapped if there were a collapse.

A store of supports should be kept on the site to provide immediate shoring and strutting as found necessary. No timbering or other support for any part of an excavation should be erected or substantially added to, altered or dismantled, except under the direction of a competent person with experience of such work. All material for such work should be inspected by a competent person on each occasion before being taken into use, and material found defective in any respect should not be used.

NOTE 2 The condition of the ground being excavated can necessitate the sides of the excavation being closely supported. This is particularly important when temporary spoil heaps, material stacks, excavating plant, pipe handling devices, cranes or pile-driving apparatus are positioned adjacent to an excavation.

The shoring and strutting of excavations in proximity to a railway or a highway, whatever its use, should take into account the support of services such as gas and water mains, sewers and underground tunnels, in addition to the loading on the highway from foot and vehicular traffic.

The stability of the excavation should be investigated in relation to the safety of the services, their structural condition and likely movement. Likewise, structures on adjacent land can necessitate an appraisal of the live and dead loads, and whether the resultant of these loads is likely to have an adverse effect on the sides of the excavation, or whether the excavation is likely to affect the stability of the neighbouring structure. Temporary shoring, strutting, ground treatment or other support to the structure should be provided to safeguard its stability.

NOTE 3 Detailed information is given in BS 6031 and in the Construction Industry Research and Information Association publication R097 [37].

NOTE 4 Attention is drawn to the Construction (General Provisions) Regulations 1961 [38].

10.12.11.3 Crossing other services

All services crossing the proposed pipeline should be identified at an early stage so that planning and provision for the crossing can be made. Service crossings should be significantly marked at the side of the working width.

NOTE It is generally advantageous to lay the pipeline below existing services such as water and gas pipes, cables, cable ducts and drains, but not necessarily sewers.

Clearance between the pipeline and other services should be agreed between the parties, and arrangements should be made to protect and support the other services.

Where thrust boring, auger boring or pipe jacking methods are used, the clearances should be agreed between the parties concerned. The pipeline should be laid so as not to obstruct access to the other services for inspection, repair and replacement.

Particular care should be taken when operating under or near overhead services. In such cases, the authority concerned should be asked to give advice on:

a) the clearances which should be maintained between the overhead services and any equipment which is employed;

b) the use of height gauges on each side of the overhead service.

In the case of overhead power lines, the possibility of induced voltage should be discussed with the relevant authority in order that appropriate safety measures can be taken.

Where excavating around services is necessary, excavation should be carried out by hand.

Warning slabs, tape, tiles or other markers should be placed over and close to pipelines and any associated cables at their points of intersection with other services.

10.12.11.4 Land drains

It is essential that the course and general condition of all land drains used during pipeline construction be marked and recorded at the time.

Before backfilling, the landowner or occupier should be given adequate notice of the reinstatement of drains to enable inspection if they so wish.

The repair of land drains should keep pace with the progress of pipe-laying to ensure that drainage systems are out of action for the shortest possible time. However, such repairs should only be carried out in suitable ground conditions.

Prior to or immediately after the pipeline is commissioned, the drainage of the land affected should be restored to be as effective as before the work was started.

NOTE 1 This usually consists of laying one or more header drains parallel to the pipeline trench.

In the case of a single header drain it should be laid on the uphill side of the trench to collect water from all the disturbed drains, and graded to a free outfall. The drains on the downhill side of the trench should be sealed to prevent the intake of soil into the drains.

NOTE 2 The working width might need to be drained.

In the case of narrow trenches it might be possible to reconnect the existing drains across the pipeline. For wide trenches, reconnection across the pipeline should be used only where no suitable outfalls are available for header drains.

Where existing drains are reconnected, they should first be cleaned out at the junctions as far as possible, and then connected across the pipeline trench and supported in such a way as to be protected against displacement or settlement.

The backfilled pipeline trench itself usually collects water and can act as a drain. In some cases this water does not drain away, but collects, e.g. at a low point or where the backfill is impermeable. Arrangements should be made to drain these points to a free outfall.

NOTE 3 Defects in the system might not become apparent for a number of years.

The promoter should provide the landowner/occupier with a set of records relative to the drainage system as installed and modified.

10.12.11.5 Maintenance of services

It is essential that services such as water, gas and electricity supplies, sewerage and telephones be maintained during the progress of work. Pipes, cables and other apparatus belonging to statutory undertakers should not be interfered with or altered without the consent of the undertakers.

NOTE 1 Statutory undertakers might need to carry out alterations themselves.

Private pipes, cables and other service apparatus should not be interfered with or altered without the consent of the owner, and any alterations should be carried out so that interruption to the service is kept to a minimum.

NOTE 2 Privately owned apparatus can be subject to bylaws, regulations or other control.

Private water supplies affected by pipeline operations should be maintained during the progress of the work, protected from pollution and permanently restored as soon as possible after the pipeline is laid. If necessary, they should be replaced during the progress of the work by water from another suitable source.

Where fields containing animals are split, additional drinking troughs should be provided, where necessary.

10.12.11.6 Pollution

Steps should be taken to prevent pollution of watercourses by chemicals, fuels, oils, excavated spoil, silt-laden discharges or other materials. The disturbance of bed deposits should be minimized as far as practicable.

10.12.12 Coating inspection

Pipe coating and tape wrapping should be visually inspected at the time of application for conformity to the quality plan. Particular attention should be given during tape wrapping to ensure correct adhesion, tension and overlap between tapes. After field bending, the coating or wrapping should be inspected and any damage or disbondment repaired. Whilst lowering the pipe into the trench, the areas under skid, cradle or belt supports should be inspected, and any damage should be repaired.

Immediately before lowering the pipe into the trench, the whole of the coating should be inspected using a holiday detector set to a voltage that provides a sufficient arc length for the thickness and nature of the coating material. Any defects should be marked and repaired before the pipe is lowered. Where disbondment of the coating has occurred, the coating should be removed, replaced and re-tested.

After coating, the pipe should be re-inspected.

10.12.13 Lowering

Before the pipe is lowered, care should be taken to ensure that the bottom of the trench is clean, free from objects likely to cause coating damage and able to provide even support to the pipeline.

Where the trench contains rock or stones, either:

a) a 150 mm thickness of sand or other suitable material should be placed at the bottom of the trench; or

b) the pipe should be protected using coating that is fit for purpose.

Roller cradles or wide belt slings should be used to lift and lower the pipe into the trench using side-boom tractors or similar machinery.

NOTE Attention is drawn to the Factories Act 1961 [5].

All equipment in contact with the pipe coating should be suitably padded to prevent coating damage.

Account should be taken of the stresses in the pipeline during the lifting and lowering operation to prevent overstressing of the pipe.

10.12.14 Backfilling

To minimize the possibility of coating damage, backfilling operations should be undertaken as soon as possible after pipe-laying. Topsoil should not be used for backfilling as this should be preserved for reinstatement.

Where possible, flooded trenches should be pumped dry or drained prior to backfilling. When this is not possible, care should be exercised to ensure that liquefied backfill does not displace the pipe.

Care should be taken during backfilling operations to avoid damage to the pipeline.

The first 150 mm of cover to the pipe should comprise a carefully compacted finely graded material free from sharp-edged stones or other deleterious material. The trench should be backfilled with material salvaged from the excavation to preserve as far as possible the original soil sequence. The backfill should not contain any perishable material, including scrub or vegetable growth.

The backfill should be compacted to suit the type of bedding and the type of pipeline material, and to minimize subsequent settlement.

Backfill materials and installation methods under roads, footpaths, shoulders, banks and similar areas should be selected to ensure the stability and integrity of these facilities. When terrain, soil and/or water conditions could cause erosion, barriers to prevent land slippage or washout should be installed where necessary.

NOTE Trench barriers may be used in steeply sloping ground to prevent the loss of backfill material by land slip or washout.

Large stones should be removed from backfilling materials to avoid damage to the pipe coating.

Where possible, backfilling should be carried out before hydrostatic testing. In the event of work being necessary within the working width after hydrostatic testing, the position of the pipeline should be clearly marked and precautions taken to ensure that heavy plant crosses the pipeline at properly constructed and defined crossing places only.

Field drains, ditches and other drainage systems interrupted during the work should be reinstated.

10.12.15 Reinstatement

Reinstatement should generally be completed prior to the hydrostatic or pneumatic test. No activities should be undertaken within the working width during the test.

Final reinstatement work after testing should be carried out with written agreement and under supervision of the pipeline operator. This work should be carried out in accordance with a permit-to-work system, where necessary.

NOTE 1 Final reinstatement work carried out after testing, i.e. topsoil replacement, reseeding, fence removal, etc., might have to take place during the operation of the pipeline, dependent upon the particular activity and the season.

Where possible, the land should be restored to its original contours, and the topsoil replaced, as excavated unless otherwise arranged with the landowner.

Reinstatement of the working width and other areas affected by construction should be carried out in accordance with agreements with the landowners and occupiers and other interested third parties.

NOTE 2 The EIA and resulting ES might identify requirements for reinstatement additional to those agreed with landowners and occupiers and other interested third parties. Attention is drawn to the Electricity and Pipe-line Works (Assessment of Environmental Effects) Regulations 1990 [3].

Land drainage reinstatement should be carried out by a specialist using a method agreed with the landowner/occupier.

NOTE 3 Land drainage reinstatement can be achieved by reinstating existing header drains or installation of new ones, in addition to any cut-off drains installed prior to construction.

Special techniques for land drainage reinstatement should be agreed with the various authorities that are affected, e.g. highways and water authorities, prior to commencement of the work.

Unless otherwise arranged with the landowner or occupier, the topsoil should be reinstated. Top soiling and other reinstatement work should be carried out only when ground and weather conditions are suitable.

The topsoil of agricultural land should be left in a loose, friable and workable condition to its original full depth and over the whole working width, and should be as free from stones as the adjacent land.

Arrangements for final reinstatement and seeding of any land should be agreed in advance with the landowner or occupier.

The impact of ripping of subsoil due to compaction that might be caused by the passage of plant and equipment should be assessed and addressed.

Disposal of any surplus material from the site should be by agreement with the landowner, and such surplus should not include topsoil.

The permanent reinstatement of gaps made in fences, hedges, walls, etc. should be agreed with the landowner or occupier. Where hedges have to be re-planted, they should be protected on both sides by a fence together with wire netting turned out or buried at the bottom for protection against rabbits. The fencing and netting should be maintained until the hedge is fully established. All wire fences should be well strained when reinstated.

All constructional debris, tools, equipment and any temporary works should be removed and the working width reinstated so that the route of the pipeline is restored as near as possible to its original condition and handed back to the landowner or occupier without delay. Debris should not be buried without the consent of the landowner or occupier.

The reinstatement should include all permanent walls, fencing, hedges, footpaths, private roads and temporary accesses.

After final reinstatement, a joint inspection with the landowner or occupier should take place, before the land reverts to its former use.

Any certificate presented to the landowner or occupier for signature relating to the completed reinstatement should be limited to the condition ascertained at the time.

One year after completion of the work, the promoter should make a survey to check the adequacy of the reinstatement. Where possible, this should be done by reference to the agreed record of condition (see **10.11.2**).

Reinstatement affecting roads should be carried out in consultation with the local highways authority.

NOTE 4 Attention is drawn to the New Roads and Street Works Act 1991 [39] in respect of reinstatement in public roads and highways.

10.13 Crossings

10.13.1 General

Road and rail crossings should be constructed by open-cut, boring, tunnelling or horizontal directional drilling methods (see **6.9**). Open-cut road crossings should be carried out in a manner which minimizes the disruption to normal traffic flow.

NOTE Attention is drawn to statutory and local authority requirements for warning signs and lights during the construction of road crossings.

10.13.2 Roads

Where a pipeline crosses or passes along a highway, the exact siting and constructional details should be agreed with the highway authority, who can also specify the manner in which trenches should be backfilled and compacted, and the nature of reinstatement of the road surface.

In the event of a road closure being deemed necessary, agreement with the highway authority should be sought at an early stage, as statutory periods of notice are required for such closures.

NOTE 1 Where the highway authority considers that the road affected is of such importance as to justify the avoidance of traffic disruption, or the disturbance of the carriageway pavement, they can require the use of pipe-laying techniques that do not necessitate open trench excavation.

NOTE 2 Where work is being carried out on, or adjacent to, any public or private road, the body having jurisdiction over the road can require the provision and maintenance of warning signs (and at night, warning lights).

Particular care should be taken to avoid damage to drains, sewers and all other services laid within the highway. Where such services are disturbed, the highway authority and/or appropriate service authority can require reinstatement.

NOTE 3 Attention is drawn to the New Roads and Street Works Act 1991 [39] in respect of carrying out the work; the location of underground services; and the keeping of accurate detailed records of supplying data to highway authorities for the location of new underground pipelines and services.

10.13.3 Railways

The appropriate railway authority should be approached before any works are carried out on or adjacent to any railway property, or before a crossing is used to give access to the work site.

NOTE 1 Private level crossings are provided only for the landowner and tenant of the adjacent land. There is seldom any warning given of approaching trains, and the profile might be unsuitable for the equipment being used.

NOTE 2 It can take a significant amount of time to gain agreement with the rail authority regarding the design and what precautionary measures are to be taken.

10.13.4 Watercourses

Where a pipeline is intended to cross a watercourse, the appropriate drainage or water authorities and, in Scotland, the appropriate river purification board, should be approached to obtain access agreements and consent for the proposed design and method of construction. The design and method of construction should take into account the characteristics of the watercourse. If necessary, the work should be planned to take advantage of seasonal variations, and arrangements should be made to take action on receipt of flood warnings in order to prevent damage to the works or the surrounding country.

NOTE 1 Attention is drawn to the Control of Pollution Act 1974 [40] in respect of suspended solids and in respect of water authority requirements.

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

Where water crossings are installed by the open-cut method, temporary flume pipes or over-pumping should be used to ensure that there is no disruption to water flow during construction. To achieve stability of the pipeline at water crossings, a weight coating should be applied where necessary, such as concrete, to maintain negative buoyancy of the pipe both during construction and in service. Attention should be given to maintaining the integrity of flood or tidal barriers at river crossings during construction.

Precautions should be taken during installation to avoid impact, distortion of the pipeline, or other conditions that might cause pipe stress or strain to exceed the levels established in the design. Extra impact protection should be installed where necessary for crossings of navigable rivers.

Installation procedures for horizontal directionally drilled crossings should address the factors unique to such crossings, including:

a) containment and disposal of drilling fluid;

b) selection of an abrasion-resistant corrosion coating;

c) instrumentation for monitoring drilling profile, alignment and pulling forces.

Ditches, drains, culverts and watercourses that are in any way interfered with by the pipeline operations should be maintained in effective condition during the construction period, and should be restored to the same condition as before the work started.

Where a crossing has to be made above the bed of a ditch, but below the level of the banks, or across a culvert, the underside of the pipe should be at such a level above the bed of the watercourse that it will not obstruct any flow that can reasonably be expected. In such a case reasonable cover adjoining the ditch should be provided: normally 450 mm cover at a distance of 900 mm from the edge of the ditch is deemed to be reasonable.

*NOTE 2 See also **9.5.3** and ISO 15589-1.*

Where a pipeline runs parallel to a ditch, the edge of the pipeline trench nearest to the ditch should be kept at a distance from the edge of the ditch at least equal to the depth of the ditch, or the depth of the trench, whichever is the greater.

Fishing and sporting rights should at all times be protected. Where a watercourse is frequented by migratory fish, the flow should be maintained during the progress of the works in such a manner as will allow the passage of the fish. The local fisheries official should be consulted over the periods suitable for the execution of the works in order to take into account the needs of migratory salmonids and other freshwater fish.

The risk of the possibility of future cleaning and deepening operations on drainage ditches should be assessed and protection added where needed. Where such operations are likely and where the pipeline is installed by open-cut methods, protective slabs should be provided. For large drainage ditches and dykes a reinforced concrete slab, of sufficient dimensions to protect the pipe from damage during such operations, should be placed above the pipe and below the hard bottom of the ditch, bedded on firm ground on either side of the pipe trench. For smaller ditches, precast concrete marker slabs are expected to be adequate. The top of the slab should be at least 300 mm below the cleaned bottom of the ditch.

*NOTE 3 The use of concrete slabs can alter the distribution and intensity of external loads around the pipe. See **6.4.5** for stress calculations and criteria associated with buckling.*

10.13.5 Sleeved crossings

10.13.5.1 General

The use of sleeves for crossings should, where possible, be avoided in favour of an alternative method.

If the use of a sleeve is specified by the owner/authority, special precautions should be taken. The sleeve should preferably be made of concrete, or where this is not possible the sleeve should be made of steel.

10.13.5.2 Concrete sleeves

Concrete sleeves should be installed at a gradient that allows for a cementitious annular fill. Jointing should be carried out in accordance with the manufacturer's recommendations.

10.13.5.3 Steel sleeves

A high quality external coating should be provided where necessary for grouted steel sleeves that might not be cathodically protected. It is essential that current checks are carried out before and after grouting to ensure that there is no electrical contact between sleeve and carrier pipe.

If a steel sleeve is to be nitrogen-filled, forged end seals should be welded and the annulus air tested to 0.3 N/mm^2 (3 bar). The steel sleeve, joints, pipework and fittings should all be coated (see Clause **9**) as the installation forms part of the cathodic protection. Care should be taken not to damage the line pipe coating and the internal spacers.

Any welding should be carried out to approved procedures (see **10.12.9**).

10.13.5.4 Spacers

Spacers should be designed to support the pipe within the sleeve, particularly at the sleeve ends, to avoid electrical contact between sleeve and carrier pipe.

10.13.5.5 Annular filling

The total volume of the annulus should be calculated and the actual volume of material used should correlate to the calculated volume.

For grouted sleeves, the material used for grouting should conform to the corresponding material specification. It is essential to seal ends to prevent loss of material. The grouting pressures should be adequate to ensure complete filling of the annulus while retaining integrity of the system.

For nitrogen-filled sleeves, nitrogen should be used to pressurize the annulus to 0.15 N/mm^2 (1.5 bar) and the oxygen content should be not more than 2%.

10.14 Pipeline markers

Distinctive markers should be erected at all road, rail, river and canal crossings and elsewhere as necessary to identify the pipeline, and to indicate its position and other details. Markers should be placed at field boundaries and not in fields, in such a way that they are not obscured by vegetation and do not interfere with agricultural operations. Markers should also be included at points of change of pipeline direction.

Where aerial surveillance is intended, markers should be visible from the air to indicate the pipeline route. At all valve installations, plates should be provided to give the same information as on the markers.

NOTE Groups of marker posts can be avoided by the use of special marker plates bearing engraved dimensioned diagrams of the layout.

Markers should not be treated with any substance likely to be harmful to livestock.

10.15 Cleaning and gauging

Following construction, the pipeline sections should be cleaned in lengths of several kilometres by the passage of swabbing pigs to remove dirt and other matter. The type of pig and its materials of construction and propellant should be appropriate to the working fluid.

Gauging pigs should be equipped with a soft metal disc of diameter not less than 95% of the smallest internal diameter of pipeline up to 508 mm nominal; or that has a 25 mm clearance for larger pipes. Gauging pigs should be passed through each completed section before testing to ensure that it is free from internal obstruction. The progress of pigs through the pipeline should be carefully monitored.

Where temporary pig launchers or receivers are used for pigging operations during construction, they should be welded or bolted to the pipeline and not attached by friction clamps.

10.16 Tie-in welds

NOTE 1 Tie-in welds include closure welds made to connect installed crossings to adjacent ditched sections of pipeline.

NOTE 2 See also ***11.10*** *for non-pressure-tested closure welds (golden welds).*

Particular attention should be given to ensure the correct alignment of pipes at tie-in welds, without the use of jacks or wedges, to ensure that the welds remain in a stress-free condition during backfilling and subsequent operation.

Tie-in welds between long lengths of exposed pipe should not be made when the ambient temperature is above 30 °C or below 5 °C.

10.17 Coating survey following construction

On completion of pipeline construction, a suitable combination of the following should be carried out to locate any areas of coating damage on the buried pipeline:

a) signal attenuation coating survey;

b) Pearson type survey;

c) close interval potential survey (CIPS);

d) d.c. voltage gradient.

Any coating damage found should be repaired.

10.18 Directional drilling

Where geophysical and geotechnical surveys show that it is feasible, and where environmental and practical considerations restrict other methods, directional drilling should be used.

The following factors should be taken into account when planning a directional drill operation:

a) containment and disposal of drilling fluid;

b) selection of a corrosion protection system with high resistance to abrasion and low surface friction;

c) the stability of the pipeline before it is pulled into the directionally drilled hole;

d) the accuracy of determining the drill exit point and the impact of accommodating this on the construction works;

e) the implications of a breach of flood defences when using directional drilling for landfall construction. The relevant environmental authorities should be consulted.

10.19 Records

Permanent records in reproducible and retrievable form, which identify the location and description of the pipeline system, should be compiled upon completion of the work and should include the following, as a minimum:

a) as-built surveys;

b) welding and inspection documentation;

c) as-built drawings and technical specifications;

d) construction procedures.

A record plan showing the size and depth of the pipeline and its location related to surface features should be prepared and a copy given to the landowners and occupiers of the land concerned.

11 Construction – Testing

11.1 General

Following completion of construction and backfill, pipelines should be subjected to comprehensive inspection and assessment to confirm their integrity.

NOTE 1 Demonstration of post-construction mechanical integrity is generally confirmed by pressure-testing.

Pipelines should be pressure-tested after completion of the construction work and backfill, to establish the existence of a margin of safety against failure at operational pressure conditions, and to demonstrate their strength and leak-tightness prior to commissioning.

Where reliable information regarding safety margin can be obtained through technical approaches such as inspection and structural reliability analysis (SRA), the operator may select to use such an approach as an alternative to pressure-testing to demonstrate the safety margin of the pipeline. When applied, it is essential that such approaches are carried out and documented by persons with the relevant expertise and competence.

*NOTE 2 Prefabricated assemblies and tie-in sections may be pre-tested or subjected to an alternative assessment before installation, provided that no subsequent construction activity is likely to impair the component integrity. Testing or alternative assessment may be carried out in suitable sections as work progresses (see **11.4.1**).*

Topography or other considerations might necessitate testing in a number of sections and a final tightness test.

The tests should be carried out with the trench adequately backfilled to avoid the influence of temperature changes.

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

a) safety of personnel and the public, and the protection of the environment and other facilities;

b) construction sequence;

c) terrain, pipeline section profile and access;

d) availability and disposal of test water;

e) differences in elevation that could result in over- or under-pressurization within the section.

Equipment which is not to be subjected to the test pressures should be isolated from the pipeline or replaced by flanged test spools during testing. This should be achieved by introducing battery limit isolations to clearly limit portions of the system under test.

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 should have current certification defining sufficient strength to withstand the test pressure.

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

Pre-tested assemblies should be tested to at least the test pressure that is necessary for their location within the pipeline system (see **11.11**).

All testing should be carried out under the supervision of a competent and experienced test engineer.

11.2 Safety

11.2.1 General

Work on, or near, a pipeline under test should 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 conducting the test. Where appropriate, precautions such as reducing test pressure to allow test personnel to work on the pressurized pipeline should be applied.

The safety of the public, construction personnel, adjacent facilities and the protection of the environment should be ensured throughout testing operations. If air or gas is used as a test medium, depressurizing should be carried out by reducing the pressure in a controlled manner.

When carrying out pneumatic testing, suitable precautionary measures should be employed (see also **G.6.2**, **10.12**, **9.4**, **11.4.1**, **11.5.3** and **11.6.9**).

WARNING. Attention is drawn to:

a) potential hazards involved in pneumatic testing, due to the release of stored energy;

b) environmental noise limitations;

c) safety of personnel regarding gas dispersion to a safe area.

11.2.2 Precautions

Safety procedures should take into account the fact that pneumatic testing stores far greater energy in the pipeline than the equivalent hydrostatic testing (see also **11.4.1**).

All crossings and areas of public access should be patrolled during the period of the test to prevent access.

Warning notices should be erected indicating that testing is in progress.

Boundaries should be clearly marked around the test equipment at each end of the section being tested, to deter persons not involved with the testing from approaching closer than the recommended safety distances.

NOTE 1 The typical safety distance for hydrostatic testing is 15 m.

For high-level hydrostatic testing or pneumatic testing, safety distances should be established and enforced by persons with the relevant expertise and competence.

NOTE 2 Guidance is given in HSE publication GS 4 [41].

NOTE 3 PD 5500 gives a general list of issues to take into account for pneumatic testing.

11.2.3 Cold weather

In cold weather, after the completion of hydrostatic testing, all lines, valves and fittings should be drained completely to prevent frost damage.

11.2.4 Temporary pig traps

Care should be taken in the operation of temporary pig launchers and receivers during the test and these should not be opened unless the pressure in the launcher or receiver is zero.

Any temporary pig traps attached to a pipeline under test should be isolated from the pipeline, unless they are designed and fabricated to the same standard as the pipeline.

11.3 Equipment

11.3.1 General

Hydrostatic testing equipment should be selected to be appropriate to the test pressure and should include the following:

a) deadweight tester (DWT) or previously calibrated pressure data logger;

b) pressure gauges;

c) volume-measuring equipment;

d) temperature-measuring equipment;

e) pressure- and temperature-recording equipment.

Instruments and test equipment used for the measurement of pressure, volume and temperature should be certified for accuracy, repeatability and sensitivity. Gauges and recorders should be checked immediately prior to each test and be calibrated when necessary. DWTs should be certified within the 6 months preceding the test. All test equipment should be located in a safe position outside the boundary area (see **11.2.2**).

Test ends should be designed and fabricated to the same or higher standard as the pipeline and pre-tested to a minimum of 10% above the specified test pressure of the pipeline.

11.3.2 Measurement of pressure

Hydrostatic test pressure should be measured by a DWT having an accuracy greater than ±0.01 N/mm² (±0.1 bar) and a sensitivity of 0.005 N/mm² (0.05 bar). Where electronic pressure monitoring instruments are used on a vessel they should meet the same accuracy and sensitivity recommendations as a DWT. Pressure gauges should be selected with ranges that show between 50% and 90% of full-scale deflection at the test pressure.

11.3.3 Measurement of volume

The volume of liquid added or subtracted during a hydrostatic test should be measured by equipment having an accuracy greater than ±1.0% and a sensitivity of 0.1% of the calculated volume of liquid to be added after line filling has been completed, to produce, in the test section, the recommended test pressure (see **11.5**). Where pump strokes are used to determine the added volume, an automatic stroke counter should be used.

11.3.4 Measurement of temperature

Temperature-measuring equipment should have an accuracy of ±1.0 °C and a sensitivity of 0.1 °C.

11.3.5 Recording equipment

Pressure and ambient temperature recording equipment should be used to provide a graphical record of test pressure and above-ground ambient shade temperature for the duration of the test.

11.4 Pressure-testing

11.4.1 General

Pressure-testing should be carried out hydraulically where feasible, but may be carried out pneumatically in some circumstances.

NOTE 1 The principles of the test and the results obtained are the same for both methods, but the stored energy in the pressurized system, and therefore the severity of any failure which could result, is much greater in the case of pneumatic testing.

The selection of the test method should be based on a rigorous assessment of safety issues associated with the stored energy and the practical issues associated with the test arrangements.

NOTE 2 Re-routeing of short pipeline sections or short tie-in sections for pipelines in operation are examples of situations for which pressure tests with water might not be expedient.

*NOTE 3 Pipelines designed to convey category C substances that operate at a design factor of 0.3 or less may also be tested pneumatically using dry, oil-free air or nitrogen (see **11.4.2**).*

NOTE 4 Terrain issues can necessitate the use of a pneumatic test.

Reliable communications should be provided between all points manned during testing.

11.4.2 Test medium

Where possible, pressure tests should be conducted with water from a public utility supply.

Where this is not practicable, water may be taken from other sources. In this case, samples should be analysed and suitable precautions taken to remove or inhibit any harmful substances.

NOTE 1 Special care is needed in dealing with water sources containing potentially harmful chemicals or bacteria; it is advisable to take specialist advice and notify the local water authority.

Water for testing and any subsequent flushing should be clean and free from any suspended or dissolved substance that could be harmful to the pipe material or internal coating (where applied) or form deposits within the pipeline.

NOTE 2 Attention is drawn to the need to obtain extraction and disposal licences from the appropriate Environmental Agencies.

If the test medium is subject to thermal expansion during the test, provisions should be made for relieving excess pressure and measuring the displaced fluid volume.

If the ground temperature in the immediate vicinity of the pipes is less than 2 °C, antifreeze should be added.

Air or a non-combustible gas should be used for a pneumatic test.

11.4.3 Inhibitors and additives

If test water analysis indicates that inhibitors and additives, such as corrosion inhibitors, oxygen scavengers, biocide and dyes, are necessary, then account should be taken of their interaction and the effect on the environment during test water disposal. Account should also be taken of the effect of any such additives on the materials throughout the pipeline system.

11.5 Type and level of test

11.5.1 General

The type and level of test and the associated test pressure should be selected according to the proposed operation of the pipeline.

NOTE There are three basic types of test:

- *hydrostatic strength test (**11.5.2**), which can be either high-level or standard;*
- *pneumatic strength test (**11.5.3**);*
- *leak test (**11.5.4**).*

For the safety margin between the test pressure and the MAOP to be deemed adequate, the pipeline should meet the criteria given in **11.7**.

The pressure at the point of application should be such that the test pressure is generated at the highest point in the section under test. The additional hydrostatic head at any point in the section should not cause a hoop stress in excess of the SMYS of the material at that point.

11.5.2 Hydrostatic strength test

11.5.2.1 General

The hydrostatic test pressure should be not less than the sum of the MAOP plus any allowance for surge pressure and other variations likely to be experienced by the pipeline system during normal operation.

11.5.2.2 High-level hydrostatic strength test

*COMMENTARY ON **11.5.2.2***

A high-level pressure test involves testing to a pressure that generates a hoop stress 90% to 105% SMYS of the pipeline material. Successful completion of the test at this level demonstrates that any remaining defects are considerably smaller than would fail at the operating pressure.

It provides a rigorous demonstration of a quantified safety margin that accommodates an allowance for defect growth during service.

A high-level hydrostatic strength test should be carried out in cases where operational requirements could involve significant cyclic pressures, or where increases in the MAOP to design factors exceeding 0.72 are likely to be used.

The high-level testing should be performed in accordance with IGEM/TD/1 Edition 5:2012, Section **8** and Appendix 5.

NOTE Where limit state design has been used for natural gas pipelines, see BS EN 1594 for guidance on maximum hydrostatic test pressures.

11.5.2.3 Standard hydrostatic strength test

*COMMENTARY ON **11.5.2.3***

A standard pressure test involves testing to the lower of a pressure of not less than 150% of the MAOP or a pressure that produces a hoop stress level equivalent to 90% SMYS. This test level is intended to determine whether the quality of the pipeline materials and construction is adequate for future operation of the pipeline.

A standard hydrostatic strength test should be carried out in cases where significant cyclic pressures and/or increases in the pipeline MAOP are not anticipated in the future operation of the pipeline.

The standard hydrostatic strength test pressure should be the lower of 150% of the MAOP or a pressure that produces a hoop stress level equivalent to 90% SMYS.

11.5.3 Pneumatic strength test

For pipelines designed to convey category C substances, which are to be operated at a design factor of not more than 0.3, the pneumatic strength test pressure should be not less than 1.25 times the MAOP.

The test pressure hoop stress (**6.4.2.1**) should as a general rule not exceed the maximum allowable hoop stress, S_{ah}, in **6.4.3.1** calculated with a design factor of 0.375. Alternative test levels may, however, be employed if this can be justified by means of a fracture mechanics analysis.

The minimum temperature at which a pipeline can be pneumatically tested should be established by means of a fracture mechanics analysis in accordance with BS 7910 or similar procedures (see also **8.2.5**).

11.5.4 Leak test

*COMMENTARY ON **11.5.4***

A leak test, which can be either hydrostatic or pneumatic, involves testing to a pressure of not less than 110% of the MAOP. Successful completion of the test at this level demonstrates pressure containment at the MAOP for future operation.

A leak test should be carried out in cases where the pipeline safety margin has been demonstrated by alternative methods not requiring high-level or standard testing (i.e. SRA and inspection).

11.5.5 Pressure variations

*COMMENTARY ON **11.5.5***

Pressure variations during strength testing are acceptable if they can be demonstrated to be caused by factors other than a leak, e.g. by variations in ambient temperature or pressure.

In cases where a pipeline section is found to be leaking under test, an investigation should be carried out to establish the cause. If appropriate, the leak should then be repaired and the pipeline section re-tested.

11.6 Test procedure

11.6.1 General

Unless pipeline valves have a provision for pressure equalization across the valve seats, the need to pre-fill the valve body cavities with an inert liquid should be assessed. All valves should be left fully open during line filling and may be partially closed prior to pressure-testing. Where possible, flanged valves should be removed and replaced with test spools.

11.6.2 Filling rate

Filling should be performed at a controlled rate.

Vent and drains points to facilitate filling and emptying should be provided to accommodate local pipeline and pipework configurations.

NOTE During filling, one or more pigs or spheres may be used to provide a positive air/water interface and to minimize air entrainment.

All spaces in which air could be trapped, such as valve bodies, bypass pipework, etc., should be vented during filling and sealed prior to commencement of the hydrostatic test.

Where the fill rate is slow and there are steep downhill sections it can be necessary to maintain an air pressure to inhibit pigs running ahead of the line-fill. A safe limit of any such air backpressure should be established and carefully maintained.

A pig location device should be used to track or locate the pig and hence the interface position, and to control the pig speed. Pumps should be selected to achieve a fill rate of not less than 0.3 m/s. The maximum velocity of the pig should be limited to equal the water injection rate, to avoid pump cavitation and therefore the possible introduction of air.

11.6.3 Temperature stabilization

After filling and prior to beginning the hydrostatic strength test or hydrostatic leak test, time should be allowed for the temperature of the water in the pipeline to stabilize with the ground temperature at pipeline depth.

11.6.4 Pressurization

The pressure in the test section should be raised at a controlled rate.
The volume of water added, the corresponding pressure rise and the time should be logged during this operation, and the air content calculated in accordance with **11.6.5**. On attaining test pressure, a period should be allowed for pressure stabilization during which residual air continues to go into solution and time-dependent straining of the pipe can take place. On completion of the stabilization period the pressure should be returned to the nominated test pressure and locked in. The pressure should then be held for a period of not less than 24 h.

NOTE The reason for the 24 h hold period is to ensure the detection of small leaks in large pipelines, and to cover the possibility of creep mechanisms causing failure after a number of hours.

The rate of pressurization may be 0.1 N/mm^2/min (1 bar/min) up to 95% test pressure and 0.05 N/mm^2/min (0.5 bar/min) up to test pressure. Hold periods for checking leakage of a minimum duration of 30 min should be made for checking air content and at 60% and 90% test pressure.

11.6.5 Air content

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

The measurement of air content should be carried out by constructing a plot of pressure against volume (see Figure 4) during the initial stage of pressurization until a definite linear relationship is apparent. By extrapolating this linear curve back to the volume axis, the air volume can be assessed, and compared with the total volume of the test section.

A comparison should also be made between the linear slope of the pressure/volume relationship for 100% water content. If these two slopes differ by more than 10%, the test section should be refilled.

The theoretical slope should be calculated using equation (19).

$$\frac{\Delta_V}{\Delta_P} = V\left(0.044\frac{D}{t} + 4.50\right)10^{-4} \tag{19}$$

The air content should not normally exceed 0.2% of the calculated capacity of the pipeline section under test, except by agreement for low-pressure systems where this might not be achievable. However, the hydrotest may be allowed to proceed with a higher air content provided that:

a) allowance is made for the additional residual air in the evaluation;

b) the test duration is extended accordingly;

c) additional safety measures are taken.

NOTE For short sections of pipework within the system, where insufficient air venting facilities are available, a higher air content might be unavoidable (see Figure 4).

11.6.6 Pressure and temperature monitoring

A continuous record of the pipeline pressure and temperature should be made throughout the pressurizing, stabilizing and hold periods. The pressure and temperature should also be logged simultaneously at least every 30 min.

11.6.7 Written procedures

Written procedures for pressure tests should be prepared prior to the beginning of testing. These should address the issues highlighted in **11.4**, **11.5**, **11.7** and the following as appropriate:

a) type of test to be carried out;

b) profile, including the pipe grade and wall thickness, and length of each test section with the test pressure determined in **11.5.2** or **11.5.3** as appropriate for each end of pipe section being tested;

c) section minimum pressure and maximum pressure related to the profile;

d) safety provisions;

NOTE 1 Attention is drawn to the Health and Safety at Work, etc. Act 1974 [9] and to HSE publication GS 4 [41].

e) need for continuous monitoring (see **11.6.10**);

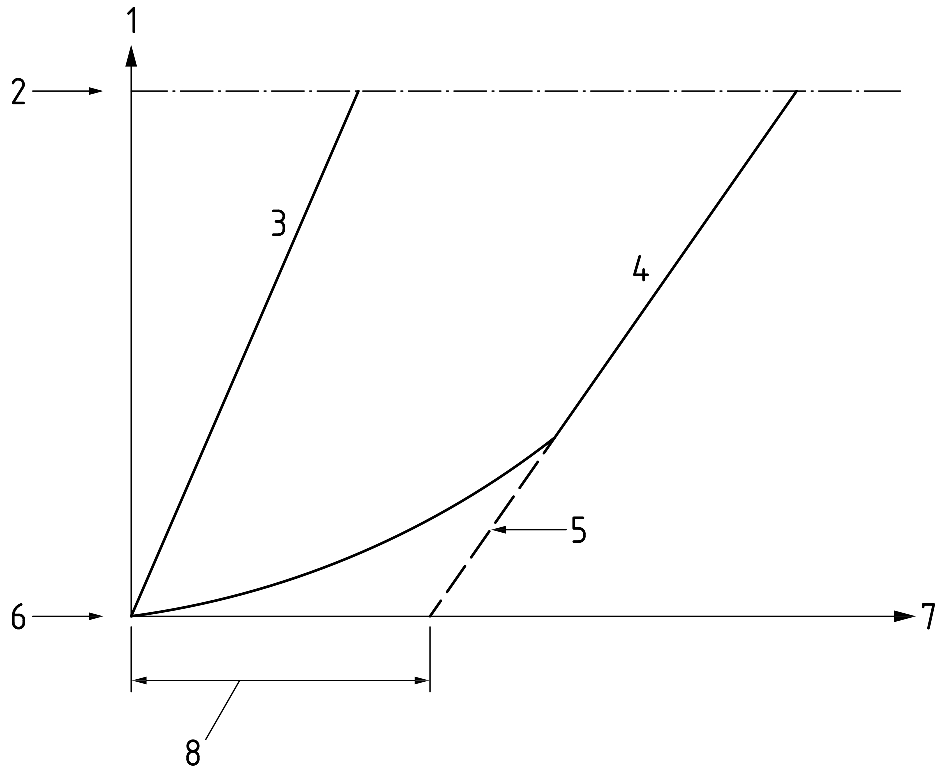
f) source and composition of test water and its disposal;

g) equipment to be used in the test (see **11.3**);

h) all pressures and durations;

i) evaluation of the test results;

Figure 4 **Measurement of air content**



Key

1 Pressure

2 50% of internal design pressure or 3 N/mm² (30 bar), whichever is lower

3 Theoretical pressure/volume plot

4 Elastic line

5 Extrapolated

6 Static head pressure

7 Volume of water added

8 Volume of air

j) acceptance criteria;

k) leak-finding procedure.

NOTE 2 It might be necessary to give notice to a statutory authority of the intention to carry out a pressure test.

11.6.8 Hydrostatic testing

The hydrostatic test should be performed using the standard test procedure or the cyclic test procedure.

For the standard test procedure, the pressure in the test section should be raised at a controlled rate to the test pressure determined in accordance with **11.5**. The volume of water added, the corresponding pressure rise and the time should be logged during this operation, and the air content calculated. A period should be allowed for stabilization, during which residual air continues to go into solution and time-dependent straining of the pipe can take place. Test pressure should then be held for a period of 24 h. Pressure and temperatures should be recorded every 30 min, and the volume of any water added to maintain test pressure should be noted.

NOTE For volumes of less than 20 m³ or for uncovered sections which can be fully inspected visually, this duration may be reduced.

Pressure, temperature and volume should be logged throughout the test (see **11.6.10**).

As an alternative to the standard test sequence above, a cyclic testing procedure may be followed, which accentuates time-related straining. Pressure is initially raised to test pressure for a period of 2 h, then reduced to half the value and then raised again to test pressure for a further 2 h. Pressure is again reduced to half the test pressure, then raised again and the test pressure held for 24 h.

11.6.9 Pneumatic testing

Pneumatic testing may be carried out if hydrostatic testing is not possible, and all applicable safety precautions should be taken.

A pneumatic pre-test should be carried out on the pipeline section at a pressure of 0.15 N/mm^2 (1.5 bar) before commencing the full pneumatic test. At this stage the pipeline section should be carefully inspected for signs of leakage.

The full pneumatic test should be carried out by raising the pressure in the test section at a controlled rate in increments of 0.7 N/mm^2 (7.0 bar) to the test pressure determined in **11.5.3** for a strength test and held for a period of 45 min. The pressure should be lowered at a controlled rate in similar decrements to 110% of the MAOP of the pipeline and held for a period of 24 h as a leak test.

A pressure-relieving device should be fitted to compressors used in pneumatic testing to prevent over pressurizing the pipeline.

The test method should be assessed to determine the minimum items of personal protective equipment that will be necessary during testing (e.g. protective glasses).

Pressure, temperature and volume should be logged throughout the test (see **11.6.10**).

11.6.10 Test data recording

A record of pressure, volume change, underground temperature and ambient temperature should be compiled over the full duration of a pipeline pressure test. The record of pressure and temperature should be monitored and recorded every 45 min throughout the test. For hydrostatic testing, underground temperature measuring equipment should be installed at least 2 days before the pressure test is planned, to establish an underground temperature trend over several days including the 24 h hold period.

NOTE 1 Temperature trends can be measured to a sensitivity of greater than 0.1 °C if plotted graphically over several days.

NOTE 2 A graphical plot of pressure, underground temperature and ambient temperature against time prepared during the test period can assist in the interpretation of test results.

11.6.11 Leak-finding

Leak detection and location procedures should be developed as part of the hydrostatic or pneumatic test procedure.

11.7 Acceptance criteria

11.7.1 General

The pressure test should be carried out in accordance with **11.4, 11.5** and **11.6**.

The pipeline being tested should be deemed to have passed the test if it is free from leaks and if no observable pressure variation occurs during the hold period which cannot be accounted for by temperature change, taking into account the accuracy and sensitivity of the measuring equipment or by making allowance for temperature variation and/or volume of liquid bled off.

11.7.2 Method of assessment for hydrostatic test

The relationship between pressure and temperature should be calculated in accordance with equation (20).

$$\Delta_P = 0.1\left(\frac{264.7T_f}{D/t + 100}\right) \quad (20)$$

The temperature factor change, T_f, should be read from Figure 5 at the mean test temperature. Δ_P should be multiplied by the temperature change during the test to find the pressure correction.

Account should be taken of both ambient and underground temperatures according to the respective lengths of pipeline involved, when calculating the pressure/temperature relationship.

NOTE 1 It has been observed that a significant time lag can occur between a change in ground temperature and a corresponding change in pressure in the test section.

NOTE 2 Chill or heat factors on exposed pipe can have an effect on pressure readings.

11.7.3 Method of assessment for pneumatic test

The relationship between pressure and temperature should be calculated in accordance with the gas laws. Owing to the difficulty in assessing the actual gas temperature within the test section, the results of such calculations can sometimes be inconclusive. In this event the pneumatic test hold period should be extended to obtain more conclusive results.

11.8 Post-test procedures

11.8.1 Depressurization

The rate of depressurization should be recorded in the test specification.

NOTE After completion of the test, the pipeline may be depressurized at a rate of 0.1 N/mm²/min (1 bar/min) down to 90% test pressure and thereafter at a rate of 0.2 N/mm²/min (2 bar/min).

11.8.2 Disposal of test fluids

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

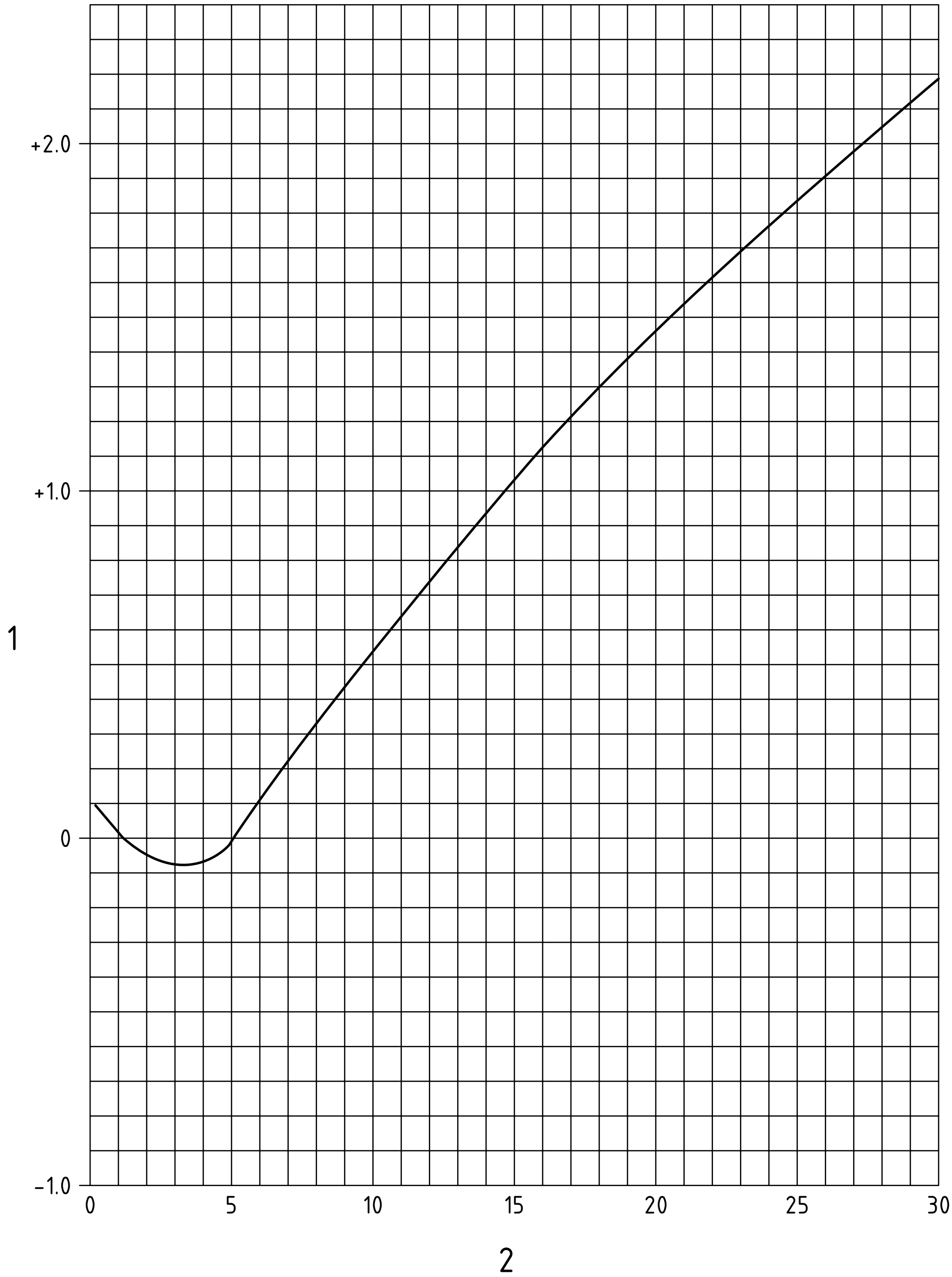
Arrangements should be made for the disposal of test water from the pipeline section after completion of pressure testing, bearing in mind that it might be heavily discoloured with rust particles. Consents should be obtained from the relevant authorities.

11.9 Repairs to test failures

Any pipeline which fails a pressure test should be repaired and re-tested. The failed portion should be replaced and the welds subjected to both radiographic and ultrasonic inspection in accordance with BS 4515-1 and BS 4515-2.

For pipelines subjected to high-level testing, repairs should be carried out using pre-tested pipe. The pipeline or section should then be re-tested for an aggregate period of not less than 24 h.

Figure 5 **Effects of temperature on pressure**



Key

1 Temperature factor

2 Temperature, in degrees Celsius (°C)

11.10 Non-pressure-tested closure welds (golden welds)

Consecutive test sections should be constructed to overlap so that the tie-in can be made with a single weld. If the tie-in cannot be made without using a length of pipe or a pup, this length of pipe should be pre-tested in accordance with **11.11** before installation. All tie-in welds not subject to subsequent pressure testing should be subject to a regime which should be not less than the following:

a) visual inspection of the preparation;

b) dye penetrant (DP) or magnetic particle inspection (MPI) of weld preparation looking for laminar and pipewall defects;

c) visual inspection of the total welding process;

d) 100% radiography and/or 100% ultrasonic testing (UT) and DP or MPI on completion of welding.

Where post-weld heat treatment (PWHT) is required, it should be carried out after step c) and prior to step d).

The number of golden welds should be kept to a minimum on a pipeline.

11.11 Pre-testing

11.11.1 General

Pipe and fittings should be pre-tested in the following circumstances:

a) when they cannot be tested after installation in subassemblies to be incorporated into an existing installation;

b) when they are to be installed in close proximity to operating plant which cannot be protected against test failure;

c) when it is considered that the potential consequences of a test failure justify pre-testing.

Pre-testing of pipe or fabrications should be carried out in accordance with **11.4**, **11.5** and **11.6** except that:

1) the pre-test pressure should be at least 1.05 times the test pressure appropriate to the section into which the crossing is to be installed, taking into account the elevation of the crossing within the test section; and

2) the duration of the final hold period should be not less than 3 h.

The pipeline being tested should be deemed to have passed the test if no leaks are detected on visual examination.

11.11.2 Fabricated components

Fabricated components (such as pig traps, slug catchers, insulation joints or manifolds) should be pre-tested before installation in the pipeline system. The test pressure should be calculated as described in **11.4**, **11.5** and **11.6**. The test duration should be not less than 6 h and should ideally be 24 h. In the unusual circumstances where assemblies will be not subjected subsequently to the full pipeline hydrotest, the test duration should be not less than 24 h.

This test should be carried out using the same procedures as the main pipeline (see **11.4**, **11.5** and **11.6**).

11.12 Test documentation and records

All certificates and records produced in connection with pressure-testing a pipeline should be retained by the operator for the lifetime of the system. The documentation should include:

a) test scope and procedure;
b) pressure and volume change at 30 min intervals over the test period;
c) seawater, underground temperature and air temperature, where appropriate, and weather conditions at hourly intervals;
d) pressure-recording charts;
e) test instrument calibration data;
f) name of the pipeline system operator;
g) name of the person responsible for carrying out the test;
h) name of the test company, if used;
i) date and time of the test;
j) minimum and maximum test pressures at the test site;
k) test medium, including source;
l) test duration;
m) test acceptance signature;
n) description of the facility tested and the test apparatus;
o) an explanation and disposition of any pressure discontinuities, including test failures, that appear on the pressure-recording charts;
p) where elevation differences in the section under test exceed 30 m, a profile of the pipeline showing the test sections.

11.13 Protection of pipeline following test

Test fluids should not be left in the pipeline following testing, unless provisions identified in accordance with **9.3** have been incorporated.

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

11.14 Integrity leak-testing

Where the component parts of the installed pipeline have been hydrostatically or pneumatically strength-tested and assembled using mechanical connections (e.g. flanges, forged connectors) or such a connection has been disturbed following the strength test and has subsequently been reassembled, then the assembled system should be leak-tested.

In order for the joints under test to be deemed leak-free, there should be no leaks when a test pressure of not less than 1.1 times the MAOP of the pipeline is held for a period at least long enough to ensure that all leak paths can be verified.

NOTE 1 The test duration may be very short under some circumstances, e.g. where any leakage would be visible.

NOTE 2 Relief valves might need to be isolated or locked to achieve the test pressure.

12 Pre-commissioning and commissioning

12.1 General

Written procedures should be established for pre-commissioning and commissioning. Procedures should take into account 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.

Pre-commissioning and commissioning procedures, devices and fluids should be selected to ensure that nothing is introduced into the pipeline system that is likely to be incompatible with the fluids, or with the materials in the pipeline components.

When a significant time lag is expected between completion of testing and commissioning, the pipeline should be filled with a suitable fluid to reduce the likelihood of internal corrosion of the pipe. Suitable fluids should be selected from dry inert gas, gas oil and water. If water is used, care should be taken to ensure that all air is excluded from the pipeline and that the water is free of corrosive material. The pipeline should remain under a small positive pressure, which should be periodically checked, until commissioning commences.

12.2 Disposal of pipeline content

The appropriate regulatory authorities should be consulted before any material is discharged from the pipeline.

Any drinking water plant within 1 km of the discharge point should be closed for the duration of the discharge and for 24 h thereafter.

NOTE A plant outside a 1 km radius from the disposal point can still be affected because of its catchment area.

The location of any drinking water plant should be reviewed with respect to the groundwater hydrology.

12.3 Cleaning

Additional cleaning of the pipe and its components, beyond that recommended in **10.15**, should be carried out where necessary.

NOTE 1 Additional cleaning can be necessary to remove:

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

Pipeline cleaning procedures should take into account the need for:

a) protection of pipeline components from damage by cleaning fluids or devices;

b) removal of particles that could contaminate the fluid;

c) removal of metallic particles that could affect intelligent pigging devices.

Measures should be taken to dispose of debris, and gels if used.

NOTE 2 Debris from the pipeline can block or contaminate small-bore branches or instrument tappings. It might be necessary to block off or remove the items.

12.4 Drying

12.4.1 General

Measures should be taken to remove residual water from a pipeline after de-watering in order to reduce corrosion or hydrate formation. Drying methods should be selected on the basis of the need for dryness to meet the quality specifications of the transported fluids. Dryness criteria should be established as at water dew-point temperature.

12.4.2 Drying procedures

Drying procedures should take into account:

a) compatibility with the quality specification for the transported fluid;

b) the effect of drying fluids and devices on valve seal materials, pipeline internal coating and other components;

c) the corrosion potential caused by a combination of free water and the drying fluids, especially for H_2S and CO_2 corrosion potential;

d) removal of water and drying fluids from valve cavities, branch piping and other cavities in the system where such fluids might be retained;

e) the effect of hydrate formation during commissioning.

12.4.3 Drying methods

Drying should be performed using one or more of the following methods:

a) propelling pigs through the pipeline by dry air or nitrogen;

b) passing a liquid drying agent (glycol or methanol) through the pipeline;

c) removing water vapour with vacuum pumps until the desired dewpoint is reached then purging with dry oil-free air or nitrogen.

The effects of drying using chemicals or a vacuum on seals of valves and pig traps should be taken into account.

An inert gas such as nitrogen should be used to separate methanol swabs and air.

NOTE IGEM/TD/1 Edition 5:2012 contains guidance for running methanol swabs.

Methanol should be used only where other methods are not practical.
If methanol is used, attention should be given to its hazardous and toxic nature.

> **WARNING**. Methanol has a low flashpoint and forms explosive mixtures with air. It is poisonous when breathed or swallowed and can be absorbed through skin contact.

In large quantities methanol and glycol can be harmful to land-based and marine life. Prior consent for disposal should be obtained (see **12.2**).

12.5 Introduction of product

12.5.1 Start-up procedures

Written start-up procedures should be prepared before introducing the transported fluid into the system. Start-up procedures should include instructions to ensure that:

a) the system is mechanically complete and operational;

b) all functional tests are performed and accepted;

c) all necessary safety systems are operational;

d) operating procedures are available;

e) a communication system is established;

f) the completed pipeline system is formally transferred to those responsible for its operation.

During pipeline filling with the fluid, the rate of fill should be controlled and the fluid pressure should not be allowed to exceed permitted limits. Inhibitors should be introduced in the product stream where necessary to inhibit corrosion or prevent the formation of hydrates.

Leak checks should be carried out periodically during the filling process. Pigs or spheres should be used to minimize mixing at the interface of a liquid product and water.

12.5.2 Gas systems

For gas systems, measures should be taken to avoid the formation of the potentially explosive mixture of hydrocarbon gas and air when a gas product is introduced into a pipeline. Dry inert gas should be used to purge the pipeline of air prior to the introduction of product.

The gas injection rate should be controlled to ensure that the gas temperature does not drop below allowable limits for the pipeline material or the dewpoint of the gas.

12.6 Connections to operating pipelines

Where it is necessary to commission a pipeline that is connected to an operating pipeline, two-valve isolation with bleed facilities should be provided where practicable.

NOTE If this is not practicable, other options, e.g. a single valve with double block and bleed facilities, may be used provided that they are suitable for the category of fluid and the perceived level of risk.

12.7 Functional testing of equipment and systems

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

12.8 Documentation and records

Pre-commissioning and commissioning records should include:

a) cleaning and drying procedures;

b) cleaning and drying results;

c) function-testing records of pipeline monitoring and control equipment systems (e.g. CCTV inspection).

Pre-commissioning and commissioning records should be retained.

13 Operation, maintenance and integrity assurance management

13.1 Management systems

13.1.1 General

An integrity management system should be established and implemented with the objectives of:

a) ensuring safe operation of the pipeline system;

b) ensuring ongoing compliance with the design;

c) managing processes that could affect the continuing integrity of the pipeline system, e.g. corrosion, erosion, control systems;

d) ensuring safe and effective execution of maintenance, modifications and abandonment;

e) dealing effectively with incidents and modifications.

The management system should include:

1) identification of personnel responsible for the management of the operation and maintenance of the pipeline, and for key activities;

2) establishment of rules and responsibilities of personnel within a formal organizational structure;

3) a written plan covering operating and maintenance procedures (see **13.1.2**);

4) a written emergency response plan, covering failure of pipeline systems and other incidents (see **13.1.3**);

5) a written permit-to-work system (see **13.1.4**);

6) a written plan for the control of change of design conditions;

7) requirements for training (see **13.1.5**);

8) requirements for monitoring of developments in the vicinity of the pipeline resulting in population density infringements (see **13.1.6**);

9) requirements for liaison with third parties (see **13.1.7**);

10) requirements for the retention of records (see **13.1.8**).

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

*NOTE Abandonment is covered in Clause **14**.*

The management systems should be reviewed on a regular basis as experience dictates, and as required by changes in the operating conditions and in the pipeline environment.

13.1.2 Operating and maintenance plan

The operating and maintenance plan should include, where appropriate:

a) procedures for normal operations (see also **13.2**) and maintenance (see also **13.3**), which should define as a minimum:

   1) the pipeline system, including pumping stations, terminals, tank farms and other installations, the operational envelope, the fluid to be conveyed and the process conditions;

2) means of controlling and monitoring the pipeline system, including manning levels, instrumentation, location and hierarchy of control centres;
3) individual and functional responsibilities and tasks;
4) means of managing pipeline integrity;
5) necessary safety precautions;
6) interfaces with other pipeline systems and installations, upstream and downstream facilities. Procedures for dealing with interfaces with other pipeline systems and installations should be developed in consultation with their operators;
7) relevant information and references to applicable rules and guidelines, schedules, inspection and maintenance specifications and instructions for each element of the pipeline system;
8) relevant drawings and route maps;

b) requirements for personnel communications (voice and/or data);
c) requirements for spares and equipment;
d) a plan for the issue of procedures to cover non-routine operations and maintenance;
e) emergency shut-in procedures;
f) marine operations procedures (where applicable);
g) scheduling and dispatching procedures;
h) venting and flaring procedures;
i) any requirements identified from hydraulic analysis;
j) references to relevant legislation.

13.1.3 Incident and emergency response plan

NOTE 1 Attention is drawn to the Pipelines Safety Regulations 1996 [15], Regulations 12, 24 and 25 in respect of emergency procedures. Guidance is also available in HSE publication Further guidance on emergency plans for major accident hazard pipelines *[42].*

An incident and emergency response plan should be developed to meet the particular requirements of an individual pipeline system. The following aspects should be taken into account when developing the plan.

a) A description of the pipeline system should be compiled, including:
   - all related or interconnected facilities such as other pipelines, storage, pumps and terminals;
   - all relevant technical data such as dimensions and the normal operational envelope parameters of working fluid, pressure, flow rate and temperature;
   - maps illustrating the geographic location of the pipeline and its isolation facilities.

b) The organization and personnel responsible for dealing with an emergency, including the person nominated to be in overall control, should be established and procedures developed to ensure that individuals understand their role. Appropriate training should be undertaken.

c) The role and location of the nominated control centre for dealing with an emergency should be established, and details should be identified of the communication media to be employed in contacting all parties involved.

d) Data regarding the significant characteristics of the working fluid and any other products that might be used during an emergency situation, together with any associated hazards, should be identified and documented.

e) Details of the notification of an incident should be recorded.

NOTE 2 This could result from observation of abnormal conditions at a control facility or by information received from an outside source. This enables the control centre to establish and assess the nature and location of the incident and the resources to be deployed.

f) A procedure should be developed for mobilizing the necessary resources to deal with an incident and alerting the appropriate authorities. This should include a comprehensive list of contact telephone numbers and other communication media details. It should also include any known restrictions on entering land.

g) A clear procedure and understanding with the relevant authorities regarding the isolation and shutdown of the pipeline in an emergency situation should be established.

NOTE 3 It is important that the control centre take charge of these events in the interests of safety of all involved.

h) Emergency equipment, including tools, plant, vehicles, communications, electrical power, lighting, fire control, hazardous substance detection instruments, personal safety clothing, breathing apparatus, warning signs and any specialist items, should be detailed and kept in a state of readiness at nominated locations.

i) Remedial works required vary according to the nature of the specific incident. Procedures and guidelines should be developed as and when appropriate for particular tasks such as:

- establishing cordon distances (in the event of potential fires or toxic releases);
- protection of watercourses/drains;
- dealing with pollution, fires or toxic releases;
- protection of adjacent facilities;
- venting/flaring of products, etc.

j) There should be provision for safe isolation of electrical or cathodic protection systems on damaged pipelines, to enable repair operations to be carried out.

The effectiveness of the plan should be tested periodically through desk and field simulations of incidents and emergencies.

NOTE 4 Such 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. Other parties likely to be involved include personnel not normally involved with the routine operations, e.g. the public emergency services, local authorities and utility service authorities.

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

All occupiers of land traversed by the pipeline should be requested by the pipeline operator to assist by speedy notification of any abnormal occurrences that could affect or could have been caused by the pipeline.

Pipeline operators should provide land occupiers with current telephone numbers for contact in an emergency. Similarly, pipeline operators should notify occupiers and any authority concerned of incidents that might affect their interests.

13.1.4 Permit-to-work system

The permit-to-work system should 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 be managed in parallel with an engineering change control system and should specify requirements for:

a) training and instruction in the issue and use of permits;

b) reviewing the effectiveness of the permit-to-work system;

c) informing personnel controlling the pipeline system of the work activity and all related safety requirements;

d) display of permits;

e) control of pipeline operation in the event of suspension of the work;

f) 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;
- refer to 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:

a) familiarization with the pipeline system, equipment, potential hazards associated with the pipeline fluid, and procedures for operation and maintenance;

b) the use of permits-to-work;

c) the use of protective equipment and fire-fighting equipment;

d) provision of first aid;

e) response to incidents and emergencies.

13.1.6 Infringement monitoring

A process for identifying developments resulting in population density infringements should be established. Risks associated with population density infringements identified by this process should be evaluated, and mitigation measures implemented where necessary.

13.1.7 Liaison

Contacts should be established and maintained with appropriate organizations and individuals, such as:

a) fire, police and other emergency services;

b) regulatory and statutory authorities;

c) operators of public utilities;

d) operators of other pipelines which connect to, cross, or run in close proximity to the pipeline;

e) members of the public living in close proximity to the pipeline;

f) owners and occupiers of land crossed by the pipeline;

g) 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 on the presence of these facilities. Local legislation can stipulate a requirement for soliciting information on the presence of underground utilities before commencement of work.

13.1.8 Records

In addition to as-built records and engineering changes, records of operation and maintenance activities should be prepared and retained to:

a) demonstrate that the pipeline system is operated and maintained in accordance with the operating and maintenance plans;

b) provide the information necessary for reviewing the effectiveness of the operating and maintenance plans;

c) provide the information necessary for assessing the integrity of the pipeline system.

As-built information should be provided to the owner/operator of the pipeline as soon as practicable after completion of the work. A documented handover of information before commissioning, including the as-built pipeline engineering dossier and the operation and emergency procedures, should be carried out to maintain safety. No pipeline should be commissioned without a handover of as-built engineering and operational information to all the relevant parties, i.e. the responsible people who will be filling, operating or taking from the pipeline.

13.2 Operation

13.2.1 General

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 should be investigated and reported, and measures to minimize recurrence should be implemented.

13.2.2 Affirmation of MAOP

The affirmation of the MAOP requires a formal integrity and risk assessment to be carried out. The MAOP should be affirmed in accordance with the requirements of IGEM/TD/1 Edition 5:2012.

13.2.3 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.

13.2.4 Pigging

A pigging philosophy should be established for each pipeline system as part of the design. Procedures for pigging operations should include requirements for:

a) confirming that the pipeline is free of restraints or obstructions for the passage of pigs;

b) control of pig travelling speed;

c) safe isolation of pig traps;

d) contingencies in the event of a stuck pig.

13.2.5 Decommissioning

NOTE Attention is drawn to the Pipe-lines Act 1962 [14], Regulation 25 and the Pipelines Safety Regulations 1996 [15], Regulation 14 in respect of decommissioning.

Pipelines that are planned to be out of service for an extended period should be decommissioned. The removal of fluids should be in accordance with **12.2**.

Decommissioned pipelines should be maintained in a safe condition, including maintenance of cathodic protection where necessary. Where no further use of the pipeline is planned, abandonment should be carried out in accordance with Clause **14**.

13.2.6 Re-commissioning

NOTE Attention is drawn to the Pipelines Safety Regulations 1996 [15], Regulation 21 in respect of re-commissioning.

The condition of a decommissioned pipeline system should be established and its integrity confirmed before re-commissioning.

Pipeline filling should be in accordance with **12.5**.

13.3 Integrity assurance management

13.3.1 Maintenance programme

NOTE 1 Attention is drawn to the Pipelines Safety Regulations 1996 [15], Regulation 7 in respect of maintenance access; Regulation 10 in respect of work on the pipeline; Regulation 13 in respect of maintenance; and Regulation 23 in respect of major accident prevention documents and safety management systems.

NOTE 2 Attention is drawn to the Pressure Systems Safety Regulations 2000 [20] in respect of written schemes of examination.

NOTE 3 Integrity management guidance is given in PD 8010-4.

Maintenance programmes should be prepared and executed to monitor the condition of the pipeline and to provide the information necessary to assess its integrity.

Factors which should be taken into account when defining the requirements for condition monitoring include:

a) pipeline system design;

b) as-built condition;

c) results of earlier inspections;

d) predicted deterioration in the condition of the pipeline;

NOTE 4 Possible deteriorations in pipeline condition include general and pitting corrosion, changes in the pipe wall, 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.

e) adverse site conditions;

f) inspection time intervals.

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

The maintenance programmes should cover the complete pipeline system. Particular attention should be paid to pipeline protection and safety equipment.

13.3.2 Route inspection

The pipeline route, including the right of way, should be periodically patrolled/surveyed to detect factors that could affect the safety and the operation of the pipeline system. The results of surveys should be recorded and monitored.

The right of way should be maintained to provide the necessary access to the pipeline and associated facilities.

Pipeline markers should 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:

a) encroachments;

b) mechanical damage to above-ground and exposed pipeline sections;

c) indications of leakage, e.g. discoloured vegetation;

d) third-party activities;

e) change of land use;

f) fire;

g) mineral extraction/mining operations;

h) ground movement;

i) soil erosion;

j) the condition of water crossings, such as sufficiency of cover, accumulation of debris, flood or storm damage;

k) soft and waterlogged ground.

NOTE 1 PD 8010-2 gives recommendations for the route inspection of sections of pipelines on land crossing large rivers and estuaries.

NOTE 2 IGEM/TD/1 Edition 5:2012 gives guidance on the inspection of exposed crossings and water course crossings.

NOTE 3 The frequency of inspection can vary with local conditions. Urban areas and intensively farmed agricultural land are likely to require more frequent and closer inspection than heathland.

Particular attention should be paid to areas where problems could occur, e.g. disused underground workings and river and watercourse crossings. Any excavation or development occurring near buried pipelines should be monitored.

Arrangements should be made with landowners and occupiers to permit a routine programme of inspection of the route. In the absence of any such arrangement, except in cases of emergency, prior written notice of all pipeline inspections involving entry on land should be given to the occupiers.

All persons carrying out inspections should carry and produce on request means of identification.

Where air patrols are used, aircraft should fly at such a height as to avoid nuisance or harm to poultry or livestock.

Certain areas can be declared an infected area on account of foot and mouth disease, fowl pest, swine fever, or other notifiable diseases including soil-borne pests and diseases.

NOTE 4 Where this occurs, routine pipeline inspections involving entry on such land can be suspended unless there are exceptional circumstances. If there is a clear necessity to enter such land, approval might need to be obtained from DEFRA in England and Wales or SEERAD in Scotland. Entry is then governed by any conditions stipulated by these bodies.

13.3.3 Monitoring pipeline integrity

13.3.3.1 Corrosion control

The maintenance programmes should include procedures for corrosion monitoring established for corrosion management in accordance with **6.13** and Clause **9**.

The quality and performance of corrosion inhibitors should be tested periodically to determine whether or not they are still effective, and appropriate remedial action should be taken where necessary.

13.3.3.2 Leak detection and surveys

The performance of the leak detection system should be reviewed and tested periodically to determine whether or not it continues to meet the recommendations given in **6.14**, and appropriate remedial action should be taken where necessary. Records should be kept of alarms and leaks to assist the performance review. Where appropriate, leakage surveys should be carried out to determine whether potentially hazardous leakage exists, and appropriate remedial action should be taken where necessary.

13.3.4 Monitoring pipeline facilities, equipment and components

13.3.4.1 Above-ground pipework and overhead crossings

Above-ground pipework and pipe supports should be inspected for corrosion, mechanical integrity, stability and concrete degradation, and appropriate remedial action should be taken where necessary.

13.3.4.2 Valves

Valves should be inspected periodically, moved and/or tested for correct operation. Where it is necessary 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 check the correct functioning of the whole system, and appropriate remedial action should be taken where necessary.

Pressure vessels associated with valve actuators should be inspected and tested periodically.

13.3.4.3 Protection devices

Protection devices, including actuators, associated instrumentation and control systems, should be inspected and tested periodically.

The inspection and testing should cover:

a) condition;

b) verification of installation and protection;

c) correct setting and activation;

d) inspection for leaks.

NOTE 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 determine whether the whole system functions correctly and whether valve-seal leakage rates are acceptable.

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

Appropriate remedial action should be taken where necessary.

13.3.4.4 Pig-traps and instrumentation

Instrumentation, telemetry systems, temporary pig traps and the data acquisition, display and storage systems essential for the safe operation of the pipeline system should be examined, tested, maintained and calibrated, and appropriate remedial action should be taken where necessary.

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

13.3.4.5 Pipeline sleeves or casings

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

a) the condition of the pipeline and the sleeve or casing;

b) the electrical isolation between the pipeline and the sleeve or casing;

c) leakage into, or from, pressurized sleeve or casing systems.

Appropriate remedial action should be taken where necessary.

13.3.5 Pipeline defects and damage

13.3.5.1 Initial actions

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

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

NOTE At the time of reporting, the pressure might not necessarily be as low as the pressure within the pipeline at the time of occurrence.

13.3.5.2 Examination, inspection and assessment of defects

The rights acquired for the construction of a pipeline usually include the rights necessary to maintain and repair the pipeline. Except in emergencies, maintenance and repair work should follow the same procedures as those for the original construction, particularly in relation to notices to landowners and occupiers.

Care should be taken during preparation and examination of damaged and pressurized pipelines because of the possibility of sudden failure.

The pipeline operating pressure should be reduced to ambient conditions, e.g. when divers are to conduct an examination of an underwater pipeline, or to a stress level that is unlikely to lead to pipeline rupture.

Procedures should be established for assessment of pipeline defects and damages (see BS 7910 or API RP 579).

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 any requirement for pressure de-rating, repair or other corrective action. These assessments should include:

a) review of inspection and measurement data, including orientation of the defect and proximity to other features such as welds or HAZ;

b) details of the original design and fabrication specifications;

c) actual pipe-material mechanical and chemical properties;

d) possible modes of failure;

e) possible growth of the defect;

f) operating and environmental parameters, including effect on pigging operations;

g) possible consequences of failure;

h) monitoring of the defect where possible.

13.3.6 Pipeline repairs and modifications

13.3.6.1 General

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

NOTE Pipeline defects and damage can be grouped under a number of headings, including:

a) pipewall defects, e.g. cracks including cracking caused by stress corrosion and fatigue, gouges, dents, corrosion, weld defects, laminations;

b) pipe coating defects, e.g. loss of wrap or concrete coating;

c) loss of support, e.g. spanning of pipelines;

d) pipe movement, e.g. upheaval buckling, frost heave and landslip, which can also result in buckling, denting or cracking.

13.3.6.2 Pipeline isolation

The selection of an isolation method should take into account:

a) hazards associated with the fluid;

b) required availability of the pipeline system;

c) the duration of the work activity;

d) the need for redundancy in the isolation system;

e) possible effect on pipeline materials;

f) possible locations for isolation points.

13.3.6.3 Venting and flaring

Hazards and constraints that should be taken into account when planning to vent or flare include:

a) asphyxiating effects and other localized effects (e.g. gas cloud formation) of vented gases;

b) ignition of gases by stray currents, static electricity or other potential ignition sources;

c) noise level limits;

d) hazard to aircraft movements, particularly helicopters in the vicinity of installations and terminals;

e) hydrate formation;

f) valve freezing;

g) embrittlement effects on steel pipework.

13.3.6.4 Draining

Liquids should be pumped, or pigged, out of a pipeline using water or an inert gas. Hazards and constraints that should be taken into account when planning to drain include:

a) asphyxiating effects and other localized effects (e.g. gas cloud formation) of inert gases;

b) protection of reception facilities from overpressurization;

c) drainage of valve cavities, "dead legs", etc.;

d) disposal of pipeline fluids and contaminated water;

e) buoyancy effects if gas is used to displace liquids;

f) compression effects leading to ignition of fluid vapour;

g) combustibility of fluids at increased pressures;

h) accidental launch of trapped pigs by stored energy when driven by inert gas.

13.3.6.5 Purging

Hazards and constraints that should be taken into account when preparing for purging include:

a) asphyxiating effects and other localized effects (e.g. gas cloud formation) of purge gases;

b) minimizing the volume of flammable or toxic fluids released to the environment;

c) combustion, product contamination or corrosive conditions when reintroducing.

13.3.6.6 Cold cutting or drilling

Procedures for cold cutting and drilling should specify 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 should be:

a) isolated;

b) depressurized by venting, flaring or draining; or

c) purged.

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

13.3.6.7 Hot work

The following should be taken into account prior to carrying out hot work on pipelines in service:

a) possible physical and chemical reactions, including combustion of the pipeline fluids or their residues;

b) the type, properties and condition of the pipe material, and the wall thickness at the location of the hot work;

c) possible corrosion of pipe and welds.

Welding should be carried out in accordance with **9.5.4.3.4** and **10.12.9**.

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

All welds should be fully inspected during and after welding by visual examination and appropriate NDT techniques, such as radiography, ultrasonic testing and surface testing methods (magnetic particle and dye penetrant). Leak-testing of welds of sleeves, saddles, reinforcing pads or any associated fitting should be carried out before introducing fluids.

13.4 Changes to the design condition

13.4.1 Change control

A change control plan should be implemented that defines and documents procedures to be followed when handling changes in the design condition.

It should be demonstrated that the revised pipeline system and integrity meets the recommendations of this part of PD 8010 before implementing changes to the design condition, such as an increase in MAOP or change of fluid.
All documentation relating to the pipeline design and management-of-change records should be updated to reflect the revised design condition.

NOTE Any alteration to the pipeline registration under the Pipelines Safety Regulations 1996 [15] needs to be notified prior to a change in operation.

13.4.2 Operating pressure

An increase in MAOP can necessitate additional hydrostatic testing, inspection, additional cathodic protection surveys and other measures. 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 de-rated from pressures that cannot subsequently be reapplied to the pipeline because of a reduction in wall thickness through corrosion, stringent data and supporting calculations should be maintained to record the changes.

13.4.3 Service conversion

Prior to a change in service, including change of fluid, it should 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 should be made before implementing a change in service. Data to be reviewed should include:

a) original pipeline design, construction, inspection and testing;

b) all available operating and maintenance records, including corrosion control practice, inspections, modifications, pipeline incidents and repairs.

Particular attention should be paid to the welding procedures used, other jointing methods, internal and external coatings and pipe, valve and other materials.

13.4.4 New crossings and developments

When a pipeline is crossed with another pipeline, it should meet the recommendations for strength given in **6.4**. The effect of a new crossing on the existing cathodic protection should be investigated.

13.4.5 Testing of modified pipelines

All prefabricated pipeline assemblies, including spool pieces, should be pressure-tested in accordance with Clause **11** before installation in the pipeline.

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

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

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 should be inspected in accordance with **11.10** if not pressure-tested.

Small diameter pipework and secondary piping (see **7.7.2**) should be tested to ensure the integrity of all joints and connections after any work activity where pipework has been disturbed.

14 Abandonment

14.1 Arrangements for abandonment

NOTE Attention is drawn to the Pipe-lines Act 1962 [14], Regulation 25 in respect of pipeline abandonment, and to the Pipelines Safety Regulations 1996 [15] in respect of general duties to preserve safety throughout the lifetime of the pipeline (including abandonment).

Pipeline systems planned to be abandoned should be decommissioned in accordance with **13.2.5** and disconnected from other parts of the pipeline system remaining in service.

A pipeline should be deemed to be disused when it has been abandoned or when the owners cease to inspect it regularly and are no longer prepared to maintain it in an operable condition.

When the owners are no longer prepared to maintain a disused pipeline in an operable condition they should take precautions to prevent the pipeline from becoming a source of danger or nuisance or having an undesirable effect on any watercourses.

Before being abandoned, the pipeline should be completely disconnected at both ends and if necessary divided into sections. All open ends should be capped and sealed. In certain areas, e.g. those subject to subsidence or where heavy external loads can occur, it can be necessary to close the pipeline at both ends and to fill the abandoned line with a suitable filler.

Where an abandoned pipeline cannot be made safe by this method, it should be removed. In all cases where the fluid conveyed is deemed to be an environmental or safety hazard, or could become so after contact with the soil, the fluid should be completely removed from the pipeline.

The pipeline section being abandoned should always be emptied and then cleaned to ensure that no toxic materials remain within the pipe.

All above-ground sections of the pipeline system should be removed to not less than 900 mm below ground level. Backfilling and land reinstatement should be carried out in accordance with **10.12.14** and **10.12.15**.

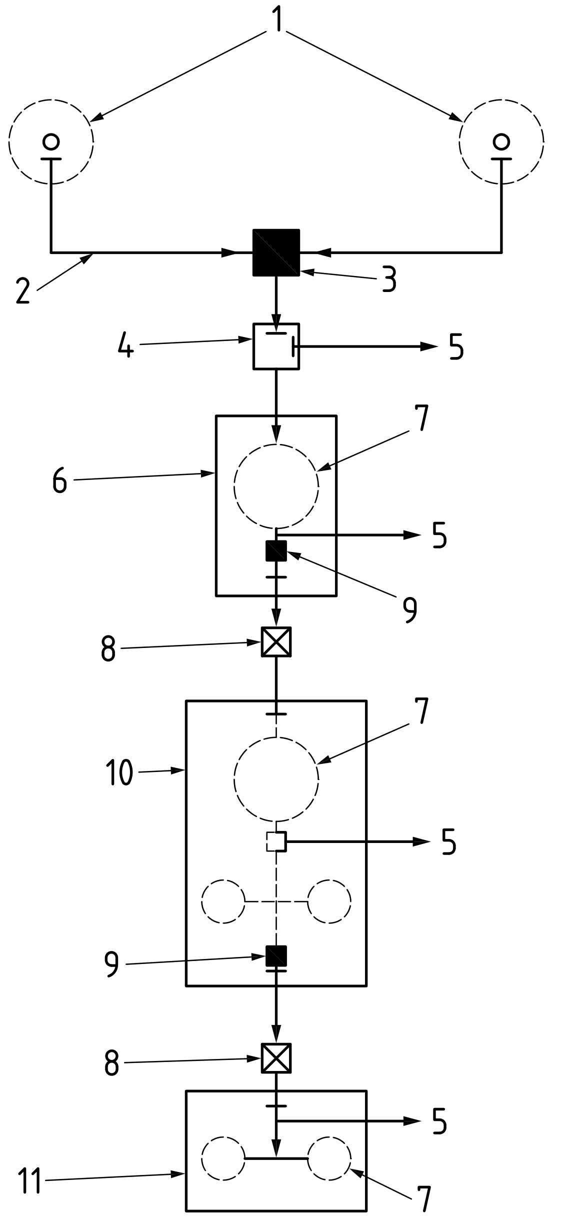
14.2 Records

A record should be kept by the operator of a pipeline to indicate that they have taken the necessary precautions. A record plan showing the size and depth of the pipeline and its location related to surface features should also be prepared and a copy given to the owners and occupiers of the land concerned.

Annex A (informative) Extent of pipeline systems for conveying oil and gas that are covered by this part of PD 8010

Figure A.1 shows the full range of onshore oil and gas pipeline systems covered by this part of PD 8010.

Figure A.1 **Extent of pipeline systems for conveying oil and gas that are covered by this part of PD 8010**



Key

1	Wellheads
2	Flow line
3	Gathering station
4	Separation plant
5	Distribution
6	Terminal with storage and pump or compressor station
7	Storage
8	Intermediate facility
9	Pump or compressor facility
10	Process plant with storage and pump or compressor station
11	Terminal with storage
——	Pipeline system covered by PD 8010-1
– – –	Pipeline and facilities not covered by PD 8010-1
┼	Pigging facilities
⊠	Intermediate station: pump, compressor, valve, pressure control, heating or metering station, etc., not covered by PD 8010-1
■	Pump, compressor or gathering station covered by PD 8010-1

Annex B (normative) Quality assurance

B.1 Quality plan

The quality plan should set out specific procedures, resources and activities appropriate to the project, including control points and certificates of compliance and conformity. It should include procedures for:

a) environmental impact assessment;

b) integrity management;

c) risk management;

d) project and design auditing;

e) material source and identification;

f) welding, including welder qualifications;

g) inspection and acceptance;

h) pipe coating;

i) testing;

j) commissioning;

k) corrosion controls;

l) assessment of defects;

m) repairs and assurance;

n) modifications;

o) infrastructure and supports.

B.2 Design quality assurance

B.2.1 Design basis

A design basis manual should be prepared that includes details of as many of the following as are appropriate to the project:

a) site investigation;

b) design life;

c) ground surveys;

d) bore holes;

e) process design;

f) mechanical, civil, control, electrical and instrumentation design and specifications;

g) bills of materials;

h) environment and risk analysis;

i) maps, drawings and schedules and equipment details;

j) operating and emergency procedures;

k) modifications and fitness for service assessments.

NOTE A typical design flowchart is illustrated in Figure 2.

B.2.2 Supervision

The design and construction of the pipeline system should be carried out under the supervision of a suitably experienced chartered engineer or equivalent.

B.3 Materials quality assurance

B.3.1 Pipe

The quality plan should specify the tests and documentary evidence required to ensure that the pipe, as delivered, meets the specification against which it has been ordered. Each heat of steel should be certified. Pipe mill inspection should be specified.

It should be possible to trace all materials used on the project back to material certificates. For MAHPs, each accepted pipe should be given a unique identification number, cross-referenced to the inspection certification so that it can be identified and its quality verified. Each pipe used for the construction of such pipelines should be clearly marked with the unique pipe identification number, which should be maintained and transferred to any pipe offcuts.

NOTE Attention is drawn to the Pipelines Safety Regulations 1996 [15] in respect of MAHPs.

B.3.2 Stock material

Where material is purchased from stockholders, documentary certification (either of original manufacture or by appropriate testing) should be obtained from the supplier to demonstrate that the material supplied is in accordance with the required specification.

Fabrication should not commence until written certification is available or a means of traceability put in place to locate all uncertified materials.

B.3.3 Shop-fabricated or manufactured items

Shop-fabricated or manufactured items (e.g. pig traps, manifolds, slug catchers, valves, flanges, insulation joints, meters and meter provers) should not be used unless they are constructed from materials that can be identified and verified as to quality and specification.

B.4 Construction quality assurance

The construction quality plan should detail the procedures to be employed so as to control the construction process and the means of ensuring compliance. A method of recording and accepting or rejecting non-conformities should be developed.

The construction quality plan should identify the organization and responsibilities of those controlling the workmanship criteria. The procedures should include instructions for training, qualifying and periodic re-examination of personnel. Where the quality of workmanship is dependent on highly skilled or specially trained personnel, only those qualified to perform the work should be used.

The construction quality plan should also identify the inspection, certification and construction records and reports required to confirm the quality and safety of the constructed pipeline.

Annex C (normative) Records and document control

C.1 Design documentation

The following design documents should be included as appropriate for the nature of the pipeline:

a) design basis manual;

b) design audits, resultant change instructions and their implementation;

c) calculations and justification of assumptions relating to design, construction, testing, commissioning and operation;

d) materials and construction specifications;

e) maps, drawings, schedules and sketches;

f) design verification;

g) modifications;

h) environmental impact and risk assessments;

i) external supports and infrastructure;

j) defect assessments;

k) cathodic protection documents.

C.2 Procurement documentation

The following procurement documents should be included as appropriate for the nature of the pipeline:

a) certificates of compliance, testing and identification of material;

b) NDT results and radiographs;

c) inspection reports;

d) weld procedure qualification certificates;

e) welder and NDT inspector qualification certificates;

f) manufacturing and fabrication procedures;

g) heat treatment certificates;

h) quality plans and manuals;

i) results of performance testing;

j) certificates and test results for support materials, infrastructure, and components;

k) material certificates;

l) route markers, marker posts and cathodic protection posts.

C.3 Construction documentation

The following construction documents should be included as appropriate for the nature of the pipeline:

a) weld procedure qualification certificates;

b) welder and NDT inspector qualification certificates;

c) NDT inspection reports and radiographs;

d) weld repair reports and radiographs;

e) land drainage plans and alterations;

f) records of geographic location of pipe lengths and pipe joints by unique identification number;

g) coating inspection records;

h) field inspectors' records covering such items as pipe condition, field joint wrapping, trench condition and depth, coating repairs, and sand padding;

i) inspection records relating to special constructions, e.g. crossings of watercourses, railways, roads and services, thrust bores, valve sites, cathodic protection bonding;

j) coating survey results and repair records;

k) weld bending reports;

l) civil ground survey reports;

m) concrete coating records;

n) location of additional impact protection;

o) support infrastructure reports;

p) pipe bridge and barrier reports;

q) material and weld records for infrastructure and supports;

r) location sketches of cathodic protection anodes;

s) cathodic protection test post conductivity reports.

C.4 Pressure-testing and pre-commissioning documentation

The following pressure-testing and pre-commissioning documents should be included as appropriate for the nature of the pipeline:

a) selection of test sections with respect to hydrostatic head between high and low points;

b) filling procedure and records of pig run;

c) test procedure;

d) instrument calibration certificates;

e) test records including calculation of air content, half-hourly pressure log and pressure and temperature charts.

f) pre-commissioning records;

g) test diagrams showing test limits and the extent of each section tested, and relating this back to the various test reports;

h) location of non-pressure-tested closure welds and weld records.

C.5 Survey documentation

The following survey documents should be included as appropriate for the nature of the pipeline:

a) control network survey;

b) as-built survey records;

c) soils survey records;

d) bore hole surveys;

e) land drainage drawings;

f) third-party crossing records;

g) cathodic protection survey records.

C.6 Inspection and maintenance documentation

The following inspection and maintenance documents should be included as appropriate for the nature of the pipeline:

a) written scheme of examination;

b) inspection reports;

c) defect reports;

d) defect assessment and fitness for service reports;

e) pig run reports;

f) records of repairs.

Annex D (informative) Hazards in pipeline design

D.1 Substances conveyed as a liquid

Crude oil and refined petroleum products (heavier than butane) are flammable and are released as a liquid that can infiltrate ground water and migrate from the point of release along the ground or in watercourses. Toxic liquids behave in a similar manner. Crude oil and petroleum products radiate a high level of heat on ignition.

D.2 Substances conveyed as a gas

Nitrogen and carbon dioxide readily mix with air but can form a heavier-than-air cloud on release (due to temperature reduction), increasing the risk of asphyxiation in the immediate vicinity. In addition, carbon dioxide has a degree of toxicity (see HSE publication EH 40 [43]).

Oxygen readily mixes with air and can also form a heavier-than-air cloud on release. This supports combustion and increases the flammability of combustible materials in the immediate vicinity of a release.

NOTE EIGA publication IGC 13/02/E [44] gives guidance on oxygen pipeline practice.

Hydrogen is flammable, lighter than air and easily ignited. When ignited it radiates heat and can produce a vapour cloud explosion.

Methane is flammable, lighter than air, radiates heat on ignition and can form a vapour cloud that can migrate from the point of rupture.

Ethane is flammable, slightly heavier than air, radiates a high heat on ignition and can form a vapour cloud at low level that can migrate from the point of rupture.

D.3 Substances conveyed as liquid or gas or in dense phase

Ethylene is flammable, slightly lighter than air but can form a heavier-than-air cloud on release due to temperature reduction. Ethylene radiates a high heat on ignition and can form a vapour cloud that can migrate from the point of rupture. Ethylene has the lowest critical pressure of commonly transported gases, can decompose exothermically and is capable of detonation.

Natural gas liquid (NGL) on release behaves in relation to its constituents, ethane, propane and butane, etc. depending on its particular composition. NGL is flammable, radiates a high heat on ignition and can form a vapour cloud at ground level that can migrate from the point of rupture.

Liquefied petroleum gas (LPG) is flammable and, although conveyed in pipelines as liquid or gas, is released as a heavier-than-air gas (propane and butanes) that can migrate some distance at ground level. LPG radiates a high level of heat on ignition. The behaviour of gases and associated liquids in two-phase flow pipelines depends upon their particular composition on release.

Ammonia is flammable and toxic, and is released as a heavier-than-air gas that can migrate some distance at ground level. Ammonia radiates heat if ignited; the gas has a toxic effect.

Carbon dioxide readily mixes with air but can form a heavier-than-air cloud on release (due to temperature reduction), increasing the risk of asphyxiation. In addition, carbon dioxide has a degree of toxicity (see HSE publication EH 40 [43]).

Annex E (normative) Safety evaluation of pipelines

NOTE This annex provides guidelines for the planning, execution and documentation of safety evaluations of pipelines recommended in ***5.4.2****. This annex refers principally to the evaluation of the effect of loss of fluids on public safety. The principles in this annex may, however, also be used for other safety evaluations.*

E.1 General recommendations

Safety evaluations, in the form of risk assessments, should be carried out to demonstrate whether the pipeline is designed, constructed and operated in accordance with the safety recommendations in this part of PD 8010.

NOTE 1 More detailed guidance is given in PD 8010-3:2009+A1.

NOTE 2 Figure E.1 shows a typical safety evaluation.

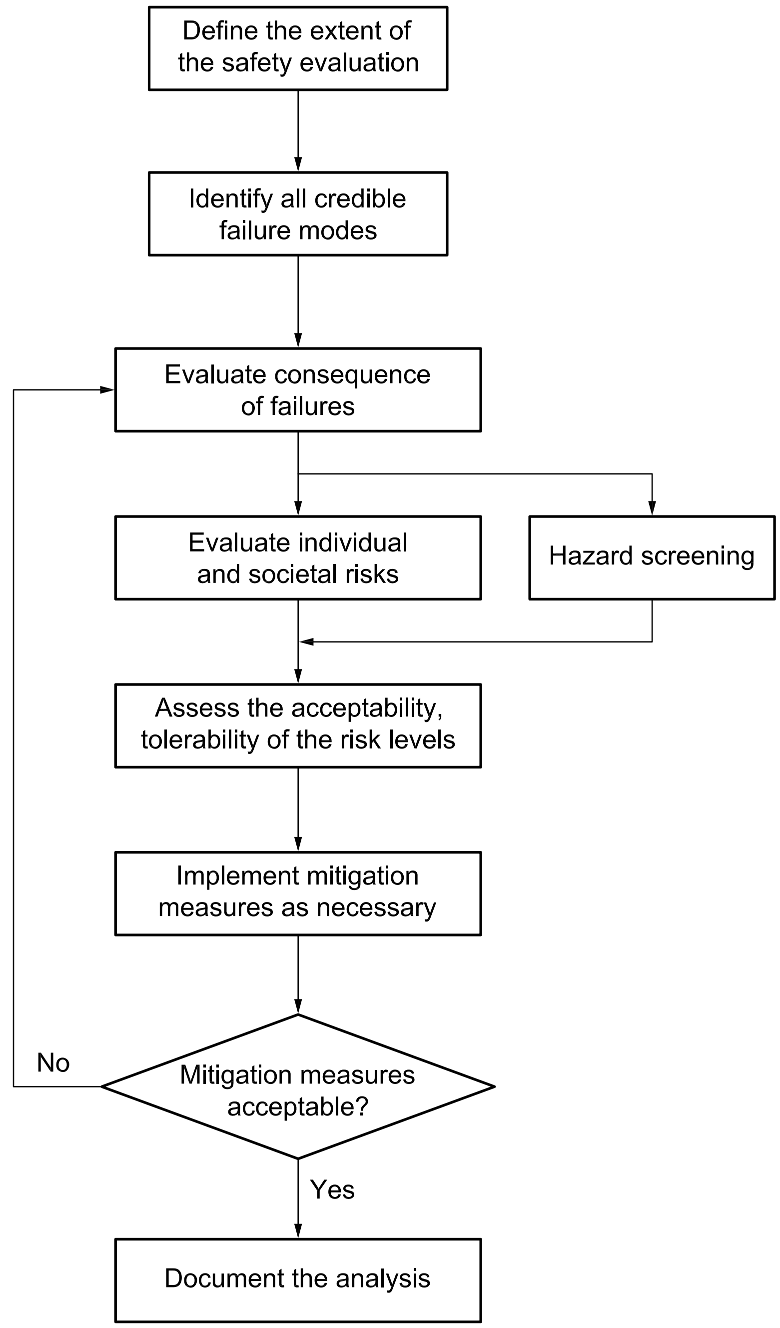
Risk assessments should be performed according to the following steps:

- define the extent of the risk assessment (**E.2**);
- identify all credible failure causes and failure modes (**E.3**);
- evaluate failure frequencies for each credible failure mode (**E.4**);
- evaluate consequences of failure (**E.5**);
- carry out hazard screening (**E.6**);
- evaluate individual and societal risk levels (**E.7**);
- assess the acceptability/tolerability of the risk levels (**E.8**);
- implement mitigation measures as necessary (**E.9**);
- re-evaluate acceptability (**E.10**);
- document the analysis (**E.11**).

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

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

Figure E.1 **Safety evaluation**



E.2 Definition of the extent of a risk assessment

The extent of the risk assessment should be defined and formulated to provide the basis for the evaluation plan. This should include:

a) the reason(s) for performing the assessment and case-specific objective(s) and outputs;

b) a collection of relevant and necessary data;

c) a definition of the pipeline, its contents and their properties, methods of operation, maintenance and assurance measures;

d) a definition of the environment, e.g. human habitation and activities near the pipeline; surrounding infrastructure, location, traffic loadings and meteorology;

e) identification of the measures that might be practical and effective in removing or mitigating adverse effects on public safety;

f) a description of assumptions and constraints governing the assessment.

E.3 Hazard identification resulting from credible failure modes

The hazard scenarios with the potential to result in a loss of fluid should be identified along the route of the pipeline, together with their root causes.

These should include:

a) design, construction or operator error;

b) material or component failure;

c) degradation due to corrosion or erosion, leading to loss of wall thickness;

d) third-party activity (e.g. external damage);

e) natural hazards (e.g. earthquake, flood, lightning, ground movement);

f) fatigue and design life.

NOTE Methods applied for identifying hazards and defining failure modes may include reviews of checklists and historical incident data, brainstorming, and hazard and operability studies.

E.4 Evaluation of failure frequencies

The likelihood of loss of fluid for each of the hazards identified should be estimated by either or both of the following options as appropriate for each hazard:

a) use of relevant historical data (statistical analysis);

NOTE 1 Historical failure rate data can be obtained from company databases and from published data sources such as the United Kingdom Onshore Pipeline Association (UKOPA), European Gas Industries Data Group (EGIG), NTSB, or CONCAWE.

b) predictive methodologies (probabilistic analysis).

NOTE 2 Supporting data for these analyses can be obtained from pipeline damage records.

The mitigation measures assumed when assessing the failure frequencies should also be reported, including proposals for pipeline monitoring and inspection during operation together with emergency procedures.

All such data or record sources should be relevant to the product being transported, the pipeline and its environment, and should not lead to an underestimate of the failure frequency.

Some or all of the following modes of failure should be taken into account, as appropriate for each pipeline:

- full bore rupture;
- large holes;
- minor holes;
- pinhole leaks.

E.5 Evaluation of the consequences of failure

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

a) the nature of the fluid (e.g. flammable, toxic, reactive);

b) pipeline design;

c) buried or above-ground topography;

d) environmental conditions;

e) likely size of hole or rupture;

f) mitigating measures to restrict loss of containment (e.g. leak detection and use of isolation valves);

g) the mode of escape of fluids (e.g. vertical plume, impacted jet, free jet horizontal plume);

h) dispersion of fluid and probability of ignition (fireball, bleve, local fire, pool fire, or other resultant phenomena);

i) possible accident scenarios following a fluid loss, which can include:

 1) pressure waves following fluid release;

 2) combustion/explosion following ignition;

 3) toxic effects or asphyxiations;

 4) extended run off field;

 5) dispersal resulting in contamination or pollution;

j) level of exposure and estimated effect;

k) the operating parameters of the pipeline;

l) pressure control and emergency shutdown systems;

m) monitoring and communications systems.

NOTE The aim is to construct an event tree, which defines overall frequencies of occurrence for each failure mode, location and type of release.

E.6 Hazard screening

An initial assessment of the significance of the identified hazards should be carried out based on the failure frequency 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:

a) curtailment of the assessment because the failure frequency or consequences of the hazard are insignificant;

b) continuation with the detailed evaluation of the risk level.

E.7 Evaluation of individual and societal risk level

The risk level should be determined for:

a) any individuals who might be present along the route of the pipeline ("individual risk"); and

b) if appropriate, any large groups of people that might be present along the route ("societal risk"). The risk level should include contributions from all credible hazards or failure mode.

NOTE 1 Further information is given in HSE publications Reducing risk, protecting people *[45] and* Risk criteria for land-use planning in the vicinity of major industrial hazards *[46].*

NOTE 2 For general methodology, refer to PD 8010-3:2009+A1.

E.8 Assessment of acceptability/tolerability of the risk levels

The results of the risk assessment should be compared with the following HSE risk criteria, and if the level of risk is found to be unacceptable, mitigating measures should be taken.

a) **Individual risk**. In the UK, the HSE criteria for the tolerability of individual risk are divided into three broad categories:

- broadly acceptable;
- tolerable;
- unacceptable.

The "broadly acceptable" category covers individual risk levels that might be considered insignificant, for which no further mitigation is required to reduce the risk further. As a guideline in the UK, this category covers an individual risk of death below one in a million (10^{-6}) per annum (see HSE publication *Reducing risk, protecting people* [45]).

The "tolerable" category requires that mitigation measures be employed to drive the risk levels down to the "broadly acceptable" category. A risk is deemed to be tolerable once further risk reduction is impracticable or requires action that is disproportionate to the risk reduced (i.e. the risk is "as low as reasonably practicable" or ALARP). In the UK, the HSE has proposed an individual risk of death of one in ten thousand (10^{-4}) per annum as the upper boundary of what might be considered tolerable (see HSE publication *Reducing risk, protecting people* [45]). However, this level of individual risk is also likely to give rise to societal concerns and these can play a greater role in determining the acceptability of a risk.

The "unacceptable" category covers risks that are unacceptable whatever the benefits. Mitigation would be required to reduce the level of risk.

NOTE The casualty criterion used in the HSE publication Risk criteria for land-use planning in the vicinity of major industrial hazards *[46] is the risk to an individual of receiving a dangerous dose or worse (equivalent to 1% lethality). This casualty criterion is more conservative than the risk of death (equivalent to 50% lethality).*

b) **Societal risks**. Societal risk criteria recognize the need to ensure that major incidents that could lead to a significant number of casualties in a single event occur far less frequently than those that could lead to an individual casualty.

In the UK, the most common form of representing societal risk is known as the *F–N* approach. The *F–N* approach expresses and manages the risk in terms of the frequency, *F*, of *N* or more casualties occurring. The HSE has not published an agreed *F–N* criterion; however, they propose that the risk of an accident causing the death of fifty people or more in a single event should be less than one in five thousand per annum (see HSE publication *Reducing risk, protecting people* [45] and PD 8010-3:2009+A1).

An acceptable *F–N* criterion can also be derived from knowledge of the risk levels that are implicit on existing pipeline systems.

E.9 Implementation of mitigation measures

The aim of the incorporation of mitigation measures should be to reduce the unacceptable calculated levels to be as low as reasonably practicable (ALARP).

NOTE Additional measures of pipeline protection can be necessary to prevent damage arising from unusual conditions such as can occur at river crossings and bridges, or due to exceptional traffic loads, long self-supported spans, vibration, mass of special attachments, ground movement, abnormal corrosive conditions, any *other abnormal forces and in areas where the depth of cover is less than recommended. Typical examples of extra protection are:*

a) *increased pipe wall thickness;*

b) *additional protection above the pipe;*

c) *application of concrete or similar protective coating to the pipe;*

d) *use of thicker coatings to improve corrosion protection;*

e) *increased depth of cover;*

f) *use of extra markers to indicate the presence of the pipeline;*

g) *provision of a sleeve to protect from live loads;*

h) *provision of impact protection for above-ground pipelines;*

i) *warning marker tape placed directly over the pipeline.*

The residual risk level following the adoption of additional mitigation measures should be assessed (see **E.8**).

E.10 Re-evaluation of acceptability

Where mitigation measures have changed the initial failure modes, the consequence and risk analyses should be re-evaluated for conformity to the ALARP principle. An assessment should be performed which demonstrates that all reasonably practicable measures to reduce risk have been included. Where specific areas are found not to conform, those areas should be reappraised and further mitigation measures put in place until all conform.

E.11 Documentation of the analysis

The safety evaluation should be documented and the documentation should include as a minimum:

a) table of contents;

b) summary;

c) objectives and extent of the evaluation;

d) safety requirements;

e) limitations, assumptions and justification of hypotheses;

f) description of system;

g) clear map of pipeline and plans illustrating all buildings and infrastructure on route;

h) analysis methodology, including software used;

i) hazard identification results;

j) models description with assumptions and validation;

k) data and their sources;

l) risk assessments performed;

m) effect on public safety;

n) sensitivity and uncertainties;

o) discussion of results;

p) conclusions;

q) references.

This report should be maintained for the life of the pipeline.

Annex F (normative) Pipeline route selection

F.1 Route selection process

F.1.1 General

Economic, technical and safety considerations should be the primary factors governing the choice of pipeline routes. The shortest route might not be the most suitable, and physical obstacles, environmental constraints and other factors should be taken into account.

The main factors that should be taken into account when choosing a route are:

a) safety of the public and personnel (**F.2.1**);

b) content of the pipeline and operating conditions (**F.2.1**);

c) environmental impact (**F.2.2**);

d) terrain and subterranean conditions, including geotechnical and hydrographical conditions (**F.2.3**);

e) existing and future land use (**F.2.4**), including:

   1) third-party activities;

   2) agricultural practice;

   3) existing facilities and services;

   NOTE 1 Guidance is given in HSE publication HSG 47 [47].

f) permanent access (**F.2.5**);

g) transport facilities and utility services (**F.2.6**);

h) construction, testing, operation and maintenance (**F.2.7**);

i) security (**F.2.8**);

j) any site-specific hazards.

In order to develop the pipeline route efficiently, the following three phases of routeing should usually be adopted:

1) route corridor selection (**F.1.2**);

2) route investigation and consultation (**F.1.3**);

3) design and approval of final route (**F.1.4**).

NOTE 2 Aspects of the route selection process are covered in the ASCE publication Pipeline route selection for rural and cross country pipelines *[48].*

F.1.2 Route corridor selection

A desk study and visual appraisal making use of all information available within the public domain should precede the adoption of a provisional route within the selected route corridor. Desk studies may include the use of aerial photography and/or satellite imagery.

Information regarding geological, ecological, archaeological and environmental features should, in the first instance, be obtained from published sources to establish possible route corridors prior to discussions with the relevant institutions.

The geographic limits within which pipeline route selection is to take place should be defined by identification of the start and end points of the proposed pipeline system and any intermediate fixed points. These points should be marked on suitably scaled plans (see **4.6.1**) covering the area, for further investigation during the routeing procedure.

Possible route corridor options should then be identified based on the constraints and the fixed points. The width of the route corridors should depend upon the nature of terrain traversed, current and likely future population, and degree of complexity expected with regard to environmental, constructability and archaeological aspects. Where practicable, this corridor should be selected to avoid urban areas, major road, rail and water crossings, and the features described in **F.2.3.**

A key routeing issues study should be performed where necessary, to ensure as far as possible that the corridor selected is suitable and is not likely to create significant problems at a later stage. Existing and planned constraints to route selection occurring within the area of interest should be identified to assist the selection of route corridor options. The constraints identified should take into account the complexity of terrain and information gathered.

A preferred route corridor should finally be selected, taking into account all the technical, environmental and safety-related factors that might be significant during installation and operation of the pipeline system.

NOTE It can be advantageous to use a GIS to record and manage the data collected.

F.1.3 Route investigation and consultation

The next stage should identify more detailed information highlighting constraints within the preferred route corridor to assist in the selection of a preferred final route. All the constraints and potential planning problems that could affect the pipeline (e.g. timing or method of construction) should now be addressed and recorded.

Consultations should be held as early as possible during the route selection process with the planning, statutory and regulatory authorities, non-statutory consultees, and any other appropriate organizations, which can include (not in order of importance):

a) appropriate government departments;

b) British Geological Survey;

c) British Waterways:

d) Civil Aviation Authority;

e) Country Landowners Association and Scottish Landowners' Federation;

f) county, district and parish councils and London boroughs;

g) Crown Estate;

h) environmental bodies;

i) heritage bodies;

j) independent developers of mineral rights;

k) internal drainage boards;

l) landowners and occupiers;

m) local trusts for nature conservation and archaeology;

n) mine owners;

o) National Farmers' Union;

p) national park authorities;

q) navigation and harbour authorities;

r) pipeline operators;

s) railway authorities;

t) utilities, i.e. electricity, gas, telecommunications and water authorities, etc.

Reviews of the preferred route should be carried out in the field. These should initially be based on the desk study (see **F.1.2**).

Accompanied by the relevant landowner/occupier and the appointed land agent, the proposed route should be examined in more detail, in particular those areas that might have been difficult to determine from maps and public rights of way during the desk study. Negotiations should be carried out as necessary for use of access roads for construction or maintenance purposes.

NOTE Annex I gives information on land referencing, contacting landowner/occupiers, land rights and legal considerations.

Land and environmental surveys should be made that 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.

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

F.1.4 Design and approval of final route

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, crossings 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 the need for a vertical profile of the route should be established.

Local planning authority and statutory approvals, and landowner/tenant agreements, should now be finalized.

The route of the pipeline should be identified by a locating system such as markers.

F.2 Factors influencing routeing

F.2.1 Public safety, content of the pipeline and operating conditions

NOTE 1 The main operating conditions in pipelines that can affect route selection are:

a) the nature of the contents;

b) operational envelope;

c) pipeline material, diameter and thickness.

*NOTE 2 See also **5.5.2** and **F.2.4**.*

Pipelines conveying category B, category C, category D or category E substances should, where practicable, avoid built-up areas or areas with frequent human activity, e.g. class 3 locations. The possibility of external damage should be taken into account in determining the route.

Appropriate authorities should be consulted regarding the risk categories of areas being traversed, in order to determine measures required to deal with potential accidents.

A system of area classification should be used. Design factors should be chosen relevant to the classification levels described in **5.5.1**.

If a safety evaluation is requested by the approving authority, this should be carried out before a preliminary route is put forward.

For a given pipeline material, diameter and content, account should be taken of the probability of failure and associated consequences (see Annex E), including:

a) the maximum possible size of any fracture;

b) the consequent maximum rate of release of contents;

c) any change of state of the contents under atmospheric conditions;

d) the total volume that can escape under emergency conditions.

The route of the pipeline should be an appropriate distance from buildings (see **5.5.3**).

The minimum depth for the pipeline should be greater than that of normal agricultural/horticultural activities expected in the area.

F.2.2 Environmental impact

Detailed investigations should be undertaken as part of the EIA to ascertain the impact of the pipeline. When selecting the route and station locations, care should be taken to identify and minimize any possible effects on aspects such as:

a) Ramsar sites (wetland protection);

b) special areas of conservation (SACs) or special protection areas (SPAs);

c) sites of special scientific interest (SSSIs);

d) national parks and country parks;

e) areas of outstanding natural beauty (AONBs);

f) ancient monuments, archaeological, cultural heritage and ornamental sites;

g) natural resources, such as catchment areas and forests;

h) flora and fauna;

i) tree preservation orders;

j) nature reserves;

k) mineral resources.

An attempt should also be made to achieve the following, as far as is reasonably practicable:

1) reduce noise and vibration;

2) avoid odour and dust and deterioration of air quality;

3) avoid contamination of ground water and watercourses;

4) minimize the volume of traffic;

5) minimize the number of trees to be removed.

NOTE 1 Further guidance can be obtained from IGEM/TD/1 Edition 5:2012.

Where there is a possibility of pipeline construction and permanent facilities giving rise to noise complaints, an environmental noise survey should be carried out by suitably qualified persons before the pipeline route is established, so that prior noise assessment can be made and the route or the construction method changed if necessary to minimize disruption.

NOTE 2 Particulars of previous noise complaints can be obtained from local authorities.

The relevant planning authorities should be contacted at an early stage to determine whether an EIA will be required for a pipeline and its associated AGIs. If required, an EIA should cover the effect of pipeline works on local amenities and future developments.

NOTE 3 Attention is drawn to the Electricity and Pipe-lines Works (Assessment of Environmental Effects) Regulations 1990 and subsequent amendments [3], the Environmental Protection Act 1990 [4] and the Planning Act 2008 [18].

F.2.3 Terrain and subterranean conditions, including geotechnical and hydrographical conditions

NOTE 1 The geography of the terrain traversed can be broadly separated into surface topography and subterranean geology, and it is usually convenient to assess both natural and man-made geographical features under these two headings.

The potential impact to local water supplies and ground water regimes should be minimized.

The principal geographical features which are likely to be encountered and should be taken into account include:

a) land surface:
   1) agricultural: crops, livestock, woodlands;
   2) heritage: natural beauty, archaeological, ornamental;
   3) natural barriers: rivers, mountains;
   4) natural resources: water catchment areas, forestry;
   5) occupation: population, communications, services;
   6) physical: contouring, soil or rock type, water, soil corrosivity;
   7) environmental: designated areas, protected habitats, flora and fauna;
b) subterranean:
   1) geological features;
   2) infill land and waste disposal sites, including those contaminated by disease, radioactivity or chemicals;
   3) the proximity of past, present and future mineral extractions, including uncharted workings, pipelines and underground services;
   4) areas of geological instability, including faults, fissuring and earthquake zones;
   5) existing or potential areas of land slippage, subsidence and differential settlement;
   6) tunnels;
   7) ground water hydrology, including flood plains.

Adverse geotechnical and hydrographic conditions should be identified and mitigating measures defined. Where necessary, meteorological conditions should also be reviewed.

NOTE 2 Local authorities, local geological institutions and mining consultants are available for consultation on general geological conditions, slippage areas, tunnelling and other possible adverse ground conditions.

Where there is a possibility that any of these conditions might arise during the lifetime of a pipeline, monitoring of the conditions should be incorporated in the regular surveillance procedures adopted.

NOTE 3 This can include measurement of local ground movements, fluctuation in water table levels and indicative changes in pipeline stresses.

F.2.4 Existing and future land use

Existing areas of development should be avoided as far as possible, but at locations where this is unavoidable, the proximity of pipelines to structures should be related to design parameters for particular contents.

NOTE 1 In exceptional circumstances it can be advantageous to override normal design limitations, and provide alternative installation methods or additional protective measures giving the same degree of reliability and safety.

The possibility of future development works should be taken into account to minimize the need for diversions or alternative works at a later date.

Permanent above-ground apparatus, located on or adjacent to the route of pipelines, should be sited with the agreement of the landowners and occupiers concerned to minimize future obstruction.

The routes of pipelines conveying substances that could cause contamination of water supplies should, wherever reasonably practicable, avoid crossing exposed aquifers or land immediately upstream of waterworks intakes or impounding reservoirs.

NOTE 2 Where avoidance is not possible, statutory water undertakers and private abstractors can require additional precautions to be taken.

Water authorities should be consulted about all watercourse crossings, particularly in relation to future widening and deepening. The larger watercourses are classed as "main rivers" and are directly controlled by water authorities; lesser watercourses draining low-level areas might come within the control of internal drainage boards. In other cases the riparian owners and occupiers should be consulted. The jurisdiction of water authorities includes river embankments, sea and tidal defences and secondary works to reduce the spread of floodwater. Where pipelines cross or are laid adjacent to any such embankments, it is essential that the agreement of the relevant water authority be sought.

The availability and suitability of water for hydrostatic test purposes and its subsequent discharge should be assessed.

Third-party activities along the route should be identified and should be evaluated in consultation with these parties. A control zone should be established to control all third-party activities in order to safeguard the pipeline against interference as well as to protect the safety of the parties involved.

*NOTE 3 The probability of third-party interference to the pipeline decreases if a depth greater than the minimum recommended in **6.9.3** is used.*

Pipelines should be located to produce minimum disturbance to established agricultural practice.

F.2.5 Permanent access

The final route should permit ready and adequate access from public highways for the equipment and materials necessary to carry out planned inspections, maintenance and emergency repairs. This aspect should be taken into account at the time pipeline routeing is being negotiated with landowners and occupiers.

NOTE Access might have to be negotiated with parties other than those through whose land pipelines will be laid.

Access facilities should be determined by the frequency of use, the testing and repair equipment likely to be required, and the anticipated urgency of repairs.

F.2.6 Transport facilities and utility services

Particular regard should be given to the layout and levels of existing transport facilities and utility services, and enquiries made regarding their foreseeable development.

NOTE 1 The authorities concerned can impose special conditions for pipeline routes. Normally pipelines are routed to minimize disruption to existing facilities and services. However, at locations where this is not possible, the most appropriate solution might be to relocate existing services rather than divert the pipelines.

All relevant authorities should be approached in good time, requesting details of their facilities and services. In certain cases they might arrange to excavate exploratory trial holes, or might carry out other locational tests on site in order to provide plans of the actual positions.

The number and lengths of crossings under or over transport facilities should be minimized, and the recommendations of the relevant transport authorities should be taken into account.

NOTE 2 Attention is drawn to the New Roads and Street Works Act 1991 [39] in respect of pipelines laid in highways.

F.2.7 Construction, testing, operation and maintenance

The route should permit the necessary 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.

F.2.8 Security

The pipeline system should be routed to minimize security concerns, particularly due to trespass and sabotage, during both construction and operation. Issues that should be taken into account include:

a) restriction of access to construction site (pipeline and facilities);

b) security of personnel and equipment during construction;

c) restriction of access to associated pipeline facilities during operation;

d) potential of sabotage to buried operating pipeline;

e) potential of sabotage to above-ground pipework and facilities;

f) requirements for additional mitigation to reduce likelihood of interference from third-party activity (see **E.9**).

F.2.9 Wind turbines

The distance between a pipeline and a commercial/industrial wind turbine should be not less than 1.5 times the fixed mast height of the wind turbine.

Annex G (normative) Loads

G.1 General

The following types of load should be taken into account:

a) functional (see **G.2**);

b) environmental (see **G.3**);

c) construction (see **G.4**);

d) accidental (see **G.5**);

e) test (see **G.6**);

f) a combination of some or all of these (see **G.7**).

G.2 Functional loads

G.2.1 Classification

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

NOTE 1 The mass 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, 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.

NOTE 2 Dead loads are constant loads such as the mass of the pipe, components, coating, backfill and unsupported attachments to the pipeline.

G.2.2 Allowance for variations from normal operation

Account should be taken of surge pressures produced within the pipeline affecting piping systems (see **6.2.1.4**).

G.2.3 Overpressure protection

Controls and protective equipment should be provided for system overpressure protection (see **6.2.1.5**).

G.2.4 Maximum allowable operating pressure (MAOP)

*NOTE The MAOP is related to the test pressure established by carrying out a hydrostatic or pneumatic test on the pipeline in accordance with Clause **11**.*

The MAOP should not exceed the internal design pressure.

G.2.5 Shock effects

Effects caused by sudden changes in external or internal pressure should be taken into account.

G.2.6 Discharge reactions

The pipeline should be designed to withstand reaction forces and temperature changes that can occur during discharges or pressure release.

G.2.7 Pressure expansion

The effects of longitudinal expansion due to internal pressure should be taken into account.

G.2.8 Subsidence

The design should take into account pipelines located in mining areas, made-up ground or other areas where subsidence is known to occur or is likely to occur.

G.2.9 Temperature

The following aspects of temperature should be taken into account.

a) **Design temperature**. The design temperature should be established by assessing temperature variations resulting from pressure changes and extreme ambient temperatures, but should not include post-rupture conditions or emergency blow-down conditions. Account should be taken of possible fault conditions that can give rise to low temperature.

b) **Solar gain**. Where piping is exposed to the sun, account should be taken of the metal temperature rise resulting from solar gain.

c) **Fluid expansion effects**. Provision should be made to withstand or relieve increased pressure caused by heating of static fluid in a pipeline or component.

d) **Cooling effects**. The cooling of vapour or gas can reduce pressure to vacuum and account should be taken of this in the pressure design.

e) **Minimum test temperature**. See **8.2.5** and **11.5.3**.

G.2.10 Thermal expansion and contraction loads

Provision should be made for the effects of thermal expansion or contraction. Account should be taken of stresses induced as a result of restriction of free thermal movement owing to restraints.

G.2.11 Relative movement of connected components

The effects of relative movement of connected components or buried piping should be taken into account in the design of pipelines and pipe supports.

G.3 Environmental loads

G.3.1 Classification

Loads arising from the environment should be classified as environmental, except where they need to be classified as functional (see **G.2**) or, due to a low probability of occurrence, as accidental (see **G.5**).

NOTE 1 Environmental loads can occur on above-ground pipework, buried pipelines and pipelines within water crossings. Above-ground pipework is subject to wind, snow and ice.

NOTE 2 Buried pipelines are affected by road and rail traffic but could also be subject to subsidence due to mining, earthquake or other surface and sub-surface instability.

NOTE 3 Loads from vibrations of equipment and displacements caused by structures on the ground are also examples of environmental loads.

G.3.2 Wind

The effects of wind loading should be taken into account in the design of exposed pipelines.

G.3.3 Vibration

Stresses induced by vibration and resonance should be minimized.

G.3.4 Hydrodynamic loads

Hydrodynamic loads should 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 or 100 years, whichever is shorter.

Loads from vortex shedding should be taken into account for aerial crossings and on submerged pipelines as a result of hydrodynamic loading.

G.3.5 Seismic loads

The following effects should be taken into account when designing pipelines in regions of known seismic activity: direction, magnitude and acceleration of fault displacements. In particular, the following should be taken into account:

a) flexibility of the pipeline to accommodate displacements for the design case;

b) mechanical properties of the carrier pipe under pipeline operating pressure (conditions);

c) design for mitigation of pipeline stresses during displacement caused by soil properties for buried crossings and inertial effects for above-ground fault crossings;

d) induced effects (liquefaction, landslides);

e) mitigation of exposure to surrounding area by pipeline fluids;

f) engineered backfill that can flow around pipe and reduce twisting and sagging or hogging.

G.3.6 Sand-induced loads

The effects of the following should be taken into account when designing for sand conditions:

a) depth of cover;

b) sand dune movement;

c) sand encroachment;

d) pipeline spanning.

G.3.7 Ice loads

The effects of the following should be taken into account when designing for ice conditions:

a) ice frozen on pipelines or supporting structures;

b) bottom scouring of ice;

c) drifting ice;

d) impact forces due to thaw of the ice;

e) forces due to expansion of the ice;

f) higher hydrodynamic loads due to increased exposed area.

G.3.8 Road and rail traffic

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

G.3.9 Water crossings

Water crossings should be designed to withstand the depth of water and to avoid the effects of scouring, and should be of sufficient negative buoyancy to ensure stability.

NOTE Pipelines crossing rivers and estuaries which cannot be designed and constructed using normal land pipeline methods are classified as subsea pipelines and are outside the scope of this part of PD 8010. Recommendations for the design and construction of such pipelines are given in PD 8010-2.

G.3.10 Mining

Loads due to ground vibrations from the use of explosives should be taken into account. Loads from subsidence arising from mining activities should be classified as functional (see **G.2**).

G.4 Construction loads

Loads necessary for the installation (pipe-laying and alignment, e.g. tie-in conditions), impact protection and pressure-testing of the pipeline, should be classified as construction loads.

The effect of dynamic behaviour of installation equipment should be taken into account where appropriate.

NOTE Installation includes transportation, handling, storage, construction and testing. Increases in external pressure, pressure grouting and sub-atmospheric internal pressure by draining and vacuum drying also give rise to construction loads.

G.5 Accidental loads

Loads imposed on the pipeline under unplanned circumstances should be classified as accidental. Both the probability of occurrence and the likely consequence of an accidental load should be taken into account when determining whether the pipeline should be designed for an accidental load.

NOTE Examples of accidental loads are those 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.

G.6 Test loads

G.6.1 Hydrostatic testing

The designer should take into account the additional loads involved in the hydrostatic test (see Clause **11**).

G.6.2 Pneumatic testing

The implications and potential hazards inherent in conducting a pneumatic test should be taken into account at the design and materials specification stage.

a) Adequate fracture toughness should be specified to arrest running shear fractures during operational and test conditions of maximum pressure and minimum temperature (see **8.2.5** and **11.5.3**).

b) 100% radiography or ultrasonic inspection of all welds should be carried out (see **10.12.9.4**).

c) If pneumatic testing is to be carried out, a design factor of 0.3 should be used.

d) All manufactured components should be subjected to a hydrostatic test prior to pneumatic testing.

G.7 Combination of loads

When calculating equivalent stresses (see **6.4.2.5**) or strains, the most unfavourable combination of functional, environmental, construction and accidental loads that can be predicted to occur simultaneously should be taken into account.

If the operating philosophy is such that operations are likely to be reduced or discontinued under extreme environmental conditions, then the following load combinations should be taken into account for operations:

a) design environmental loads plus appropriate reduced functional loads;

b) design functional loads and coincidental maximum environmental loads.

NOTE It is not necessary to take into account combinations of accidental loads, or accidental loads in combination with extreme environmental loads, unless they can be reasonably expected to occur together.

Annex H (informative) Buckling

H.1 Local buckling

H.1.1 General

*NOTE 1 Local buckling of the pipe wall can be avoided if the various loads to which the pipe is subjected are less than the characteristic values in **H.1.2** to **H.1.7**.*

NOTE 2 Guidance on buckling is given in DNV-OS-F101.

Where the concrete cladding is thick enough and reinforced to provide a structural member conforming to BS 6349-1-4 and BS EN 1992-1-1, it may be used to provide support against buckling provided that appropriate justification is given.

H.1.2 External pressure

The characteristic external pressure, P_c, that causes collapse when the external pressure is acting alone, can be calculated using equations (H.1) to (H.4).

$$\left\{\left(\frac{P_c}{P_e}\right)-1\right\}\left\{\left(\frac{P_c}{P_y}\right)^2-1\right\}=\frac{P_c}{P_y}\left(f_o\frac{D}{t}\right) \qquad (H.1)$$

$$P_e=\frac{2E_b}{(1-v^2)}\left(\frac{t}{D}\right)^3 \qquad (H.2)$$

$$P_y=2\sigma_y\frac{t}{D} \qquad (H.3)$$

$$f_o=\frac{D_{max}-D_{min}}{D} \qquad (H.4)$$

NOTE See also Ultimate pipe strength under bending, collapse and fatigue *[49].*

H.1.3 Axial compression

If D/t is less than 60, local buckling under axial compression does not occur until the mean axial compression load, F_{xc}, reaches the yield load, F_y, i.e. as shown in equation (H.5).

$$F_{xc}=F_y=\pi(D-t)t\sigma_y \qquad (H.5)$$

H.1.4 Bending

The characteristic bending moment, M_c, required to cause buckling when bending moments are acting alone, can be obtained using equations (H.6) and (H.7).

$$\frac{M_c}{M_p}=1-0.0024\frac{D}{t} \qquad (H.6)$$

$$M_p = (D - t)^2 t \sigma_y \qquad (H.7)$$

The characteristic bending strain, ε_{bc}, at which buckling due to bending moments acting alone occurs, can be obtained using equation (H.8).

$$\varepsilon_{bc} = 15\left(\frac{t}{D}\right)^2 \qquad (H.8)$$

H.1.5 Torsion

The characteristic value, τ_c, that causes buckling when torsion is acting alone, can be obtained using equations (H.9) to (H.13).

Equation (H.9) is used when $\alpha_\tau < 1.5$; equation (H.10) is used when α_τ is ≥1.5 and ≤9; and equation (H.11) is used when α_τ >9.

$$\tau_c/\tau_y = 0.542 \times \alpha_\tau \qquad (H.9)$$

$$\tau_c/\tau_y = 0.813 + 0.068(\alpha_\tau - 1.5)^{0.5} \qquad (H.10)$$

$$\tau_c/\tau_y = 1 \qquad (H.11)$$

$$\tau_y = \frac{\sigma_y}{3^{0.5}} \qquad (H.12)$$

$$\alpha_\tau = \frac{E_b}{\tau_y}\left(\frac{t}{D}\right)^{3/2} \qquad (H.13)$$

H.1.6 Load combinations

The maximum external overpressure, P, in the presence of compressive axial force, F_x, and/or bending moment, M, when f_o is less than 0.05 (5%), can be calculated using equation (H.14), where:

- γ is calculated using equation (H.15);
- σ_{hb} is calculated using equation (H.16);
- σ_{hcr} is calculated using equation (H.17) or equation (H.18) as appropriate.

$$\{(M/M_c) + (F_x/F_{xc})\}^\gamma + (P/P_c) = 1 \qquad (H.14)$$

$$\gamma = 1 + 300 \times \frac{t}{D} \times \frac{\sigma_{hb}}{\sigma_{hcr}} \qquad (H.15)$$

$$\sigma_{hb} = \frac{P \times D}{2t} \qquad (H.16)$$

$$\sigma_{hcr} = \sigma_{hE} = E\left(\frac{t}{D - t}\right)^2 \quad \text{for} \quad \sigma_{hE} \leq \frac{2}{3}\sigma_y \qquad (H.17)$$

$$\sigma_{hcr} = \sigma_y\left\{1 - \left(\frac{1}{3}\right) \times \left(\frac{2\sigma_y}{3\sigma_{hE}}\right)^2\right\} \quad \text{for} \quad \sigma_{hE} > \frac{2}{3}\sigma_y \qquad (H.18)$$

Values for P_c, F_{xc} and M_c can be obtained from equations (H.1), (H.5), (H.6) and (H.7) respectively.

H.1.7 Strain criteria

The bending strain, ε_b, required to cause buckling, in the presence of external overpressure, P, can be calculated using equation (H.19).

$$\frac{\varepsilon_b}{\varepsilon_{bc}} + \frac{P}{P_c} = 1 \qquad (H.19)$$

Values for ε_{bc} and P_c can be obtained from equations (H.8) and (H.1) respectively.

H.2 Propagation buckling

The potential for a pipeline to propagate local buckles is dependent on the external overpressure, P, and its relationship with the propagation pressure, P_p.

The external overpressure, P, can be calculated using equation (H.20).

$$P = P_o - P_i \tag{H.20}$$

The propagation pressure, P_p, can be calculated using equation (H.21).

$$P_p = 10.7\sigma_y (t/D)^{2.25} \tag{H.21}$$

If P is less than P_p, then, even though it is possible for the pipe to develop a local buckle, the buckle will not propagate.

If P is greater than or equal to P_p and a local buckle or local damage has occurred, then the pipeline is likely to undergo propagation buckling. It can be advisable to provide buckle arresters at strategic locations along the pipeline to limit the amount of pipeline damaged by a propagated buckle.

H.3 Upheaval buckling

Two major factors contribute towards the upheaval of pipelines: the effective axial driving force, arising from the internal pressure and temperature, and the presence of vertical out-of-straightness (OOS) in the profile. The resistance to upheaval is provided by the weight of the pipeline, plus any overburden, if present.

A typical imperfection is defined in terms of a characteristic length, L_c, and an imperfection height, H_c.

The download coefficient, Φ_w, is calculated using equation (H.22).

$$\Phi_w = \frac{\omega E_b \times I}{H_c P_{eff}^2} \tag{H.22}$$

Similarly, the imperfection length may be characterized by a dimensionless coefficient using equation (H.23).

$$\Phi_L = L_c \left(\frac{P_{eff}}{E_b \times I} \right)^{0.5} \tag{H.23}$$

It can be shown, from either numerical or experimental test results, that there exists a functional relationship of the form given in equation (H.24).

$$f(\Phi_w, \Phi_L) = 0 \tag{H.24}$$

The functional relationship shown in equation (H.24) may be used to assess the overburden requirement to prevent upheaval buckling of the pipeline.

The following issues need to be taken into account when determining the overburden requirement:

a) spacing of the vertical profile data;

b) uplift resistance of the backfill, remoulded clay, backfilled sand, etc.

The stress/strain level along the pipeline needs to be within allowable limits and remedial work needs to be carried out where these limits are exceeded.

H.4 Ovalization

The total ovalization, f, of a pipe due to the combined effects of unidirectional bending and external pressure can be calculated using equations (H.25) to (H.27).

$$f = C_p \left\{ C_f \left(\frac{D}{t} \varepsilon_b \right)^2 + f_o \right\} \tag{H.25}$$

$$C_p = 1/\left(1 - P/P_e\right) \tag{H.26}$$

$$C_f = 0.12\left\{1 + D/\left(120t\right)\right\} \tag{H.27}$$

Values for P_e and f_o can be obtained from equations (H.2) and (H.4) respectively.

NOTE If cyclic or reversed bending is applied, the resulting ovalization can be considerably greater than that predicted by the equation.

Annex I (informative) Planning and legal

I.1 General

The principal acts relating to the planning and legal aspects of pipelines are:

- Pipe-lines Act 1962 [14];
- Pipelines Safety Regulations 1996 [15];
- Electricity and Pipe-line Works (Assessment of Environmental Effects) Regulations 1990 and subsequent amendments [3].

This annex describes typical procedures and gives information relating to these and other national regulations that might be of use to pipeline owners and contractors.

NOTE Other relevant acts and regulations are listed in the Bibliography.

I.2 Planning permission

I.2.1 General

Except where exemption has already been provided for by statutory powers, pipeline construction may not be commenced until either planning permission has been obtained from local planning authorities or, where appropriate, authorization has been obtained from relevant government departments. Investigation with the local planning authorities needs to be carried out to determine whether other construction-related areas (e.g. construction camp and pipe storage areas) require planning permission.

I.2.2 Consultations with other parties

I.2.2.1 General

A pipeline usually crosses the routes of roads, railways, canals and watercourses. It is also likely to cross or lie adjacent to existing underground or overhead services operated by water, gas and electricity undertakings, telecommunication, drainage and sewerage authorities and other pipeline operators. Construction drawings of the relevant sections of the project need to be submitted to each appropriate authority in sufficient detail to enable informed consent to be given.

It is the responsibility of the pipeline promoter to ensure that all bodies or persons whose duties or interests are likely to be affected by the construction and operation of the pipeline are provided with sufficient information to enable them adequately to carry out their duties or safeguard their interests. The following list, which is not exhaustive, identifies some of the groups that have an interest in pipeline projects:

- British Geological Society;
- British Waterways;
- Campaign to Protect Rural England/Association for Protection of Rural Scotland/Campaign to Protect Rural Wales;
- Civil Aviation Authority;
- Coal Authority and local mining groups;
- Country Landowners' Association and Scottish Landowners' Federation;
- Crown Estates;
- Department for the Environment, Food and Rural Affairs, Scottish Executive Environment and Rural Affairs Department, Northern Ireland Agriculture and Rural Affairs Department;
- Department of Business, Innovation and Skills; Scottish Department for Fair Work, Skills and Training, Northern Island Department for Enterprise, Trade and Investment;
- Department of Transport, Scottish Infrastructure, Investment and Cities Department, Northern Island Department for Regional Development;
- English Heritage and Historic Scotland;
- Environment Agency, Scottish Rural Affairs, Food and Environment Department, Northern Island Department of Environment;
- Forestry Commission;
- Health and Safety Executive;
- independent developers of mineral rights;
- independent pipeline operators;
- internal drainage boards;
- landowners and occupiers;
- local trusts for nature conservation and archaeology;
- Ministry of Defence;
- National Farmers Union and National Farmers Union of Scotland;
- National Park authorities;
- Natural England, Natural Resources Wales and Scottish Natural Heritage;
- planning officers of County, District and Parish Councils, Local Unitary Authorities and, in Scotland, Regional Councils;
- rail authorities;
- river authorities;
- utilities, i.e. electricity, water, telephone and gas companies, etc.

I.2.2.2 Land easement details

At the easement negotiation stage, the boundary of each ownership/tenancy is established. It can be useful to obtain the services of a land agent to reference the land through which the pipeline is expected to traverse. Mapping, aerial photography or satellite photography/imagery can be marked up to give a reference number for each ownership (plot) and tenancy (parcel).

The appropriate information forms a book of reference that ties the landowner/occupier back to the given reference numbers recorded on the maps/images.

I.2.2.3 Railways

When pipelines are to be laid across or adjacent to rail tracks, the appropriate railway authority needs to be consulted well in advance. In the case of main lines, a year or more's notice of works can be necessary. A complete closure of all tracks for a 24 h period is unlikely to be available.

NOTE Guidance is given in RSSB publication GI/TE 7008 [50].

I.2.2.4 Rivers, canals and foreshores

Special methods of construction are sometimes required when pipelines cross canals, roads and railways. Pre-tested pipe might be required in crossings.

Where the proposed route crosses rivers, canals or foreshores it is advisable to consult the relevant owners/authority prior to finalizing the overall route. Restrictions which were not apparent during the desk study might exist, e.g. operational restrictions during periods of water traffic, environmental restrictions or fishing/riparian rights.

It is advisable to hold discussions regarding water abstraction and disposal at an early stage in the project to determine whether any restrictions will apply, e.g. to quantities of water available, timing of abstraction and disposal or other aspects affecting location of the crossing or abstraction point.

I.3 Legal

I.3.1 Types of rights

I.3.1.1 Land rights

The responsibility for acquiring the necessary land, easements and ancillary rights for the expected life of the pipeline (including the right to construct, use and maintain the pipeline) rests with the promoter. This is usually achieved through private negotiation but can also be achieved by obtaining statutory powers.

NOTE It is rare for statutory powers to be invoked.

During negotiations, it is advisable to keep landowners/occupiers informed as to the method and type of construction that is anticipated, including anticipated timing of the works, and where relevant any special works previously agreed in discussions.

Once this has been accepted and approved in principle, legal documentation can be prepared and issued to owner/occupiers for signature. It is efficient to record any agreements, timings, etc. on a pre-entry form which is signed by all parties.

Advice on land rights can be obtained from land agents, surveyors and engineers. It can also be advisable to obtain legal advice.

It is common practice to give a prior undertaking to landowners/occupiers that, on completion of construction and commissioning, the land will be reinstated to the owner's/occupier's satisfaction. This includes reinstatement, land drainage, access ways, replacement of hedgerows and fencing, etc.

I.3.1.2 Survey access

Although much can be done from plans and geological and aerial surveys, route selection requires access to the land, and can often necessitate on-site ground investigations. The consent of owners and occupiers needs to be sought individually for any such access.

The promoter normally obtains temporary rights that lapse after the survey is completed. It is common practice to give a prior undertaking to landowners and occupiers to make good damage or loss sustained during the survey and to pay compensation for any damage not made good.

Prior consultation with planning and other local authorities can avoid an unnecessarily large number of entries on to land.

I.3.1.3 Rights granted directly by Acts of Parliament

Statutory authorities and government bodies have powers under Acts of Parliament to lay, use and maintain pipelines.

I.3.1.4 Rights granted by agreement between landowner and promoter

Where a promoter is not granted rights directly by Acts of Parliament, the agreement of the landowner is necessary, conferring some interest in or over the land concerned, to lay and maintain a pipeline. The agreement can take any of a variety of names (such as easement or lease) but legally the interests which can be conferred, and the associated degrees of security to the promoter, are, in order of magnitude:

a) a freehold of the land;

b) a leasehold interest in the land for a term of years corresponding to the likely life of the pipeline;

c) an easement over the land;

d) a way leave from the landowner to place the pipeline on their land.

The acquisition of these rights is similar in all parts of the UK, although the legal terms are different in Scotland. The Scottish terms are described in the final paragraph of this subclause.

The interests in land which the promoter requires are as follows.

1) **Freeholds**. Generally, the only freeholds that need to be purchased outright are for land on which buildings are to be constructed (e.g. pumphouses), or land which it will be necessary to fence (e.g. where there are valves), but, as these are sometimes set back from a public highway, specific provision is required for permanent rights of access to and from the plots.

2) **Easements and leases**. Easements can be for a term of years or in perpetuity and, as they run with the land, they are not extinguished by a change of ownership; thus, if the landowner dies or sells the land or if the pipeline changes hands, the pipeline easement continues automatically, provided that it continues to serve the dominant tenement.

   Where the promoter needs to obtain rights for a pipeline, but is not entitled to obtain an easement, a different form of grant (such as long leases of subterranean strips) need to be acquired. Leases of subterranean strips are subject to the provisions of the Land Registration Act 2002 [51] as to registration of leases.

An easement or a lease covers pipeline works (including surface obstructions) and, where necessary, rights of way, cathodic protection beds and other apparatus. The document specifies the rights and liabilities of each party, the width of an easement and the terms under which the rights are granted.

The width of an easement is not necessarily as large as the temporary working width. It is essential that the temporary working width be agreed before work commences. Any amendment to the working width has to be agreed between promoter and occupier. The promoter's rights and obligations incorporated in the document usually include: the number of pipelines, associated cables, etc. permitted to be laid; their depth and provision for inspection, maintenance, operation, repair or relaying; the future use of the surface of the land and procedure on abandonment (see Clause **14**); and any restrictions on the grantor in respect of the protection of the pipeline.

Where an easement is acquired through registered land, notice of the grant of the easement or lease, together with notice of any ancillary covenants restricting the use of the land, has to be registered at the Land Registry by the pipeline promoters against the title of the land affected. For unregistered land, restrictive covenant and equitable easements (e.g. informal grants) have to be registered.

3) **Way leaves**. This confers no interest in the land as such, the contractual rights being binding only on the original contracting parties, and thus confers no security on the promoter if the original landowner sells the land.

4) **Additional rights**. Additional rights could be for construction, reconstruction and rights of way to and from the pipeline and provision for the installation and maintenance of cathodic protection outside the easement strip. In the case of a permanent installation, an additional grant of easement might be required for works not covered by the grant for the pipeline.

5) **Mineral rights**. If any mineral rights are owned or leased separately from the surface ownership, suitable arrangements are usually required to safeguard rights of support and to negotiate compensation to mineral owners and operators. An adaptation of one of the statutory mining codes might need to be incorporated in the deed of grant.

In Scotland, while the acquisition of these rights is similar in its practical effect, the separate statutory and legal system means that generally rights are acquired under the appropriate Scottish statutes, although rights can also be acquired through agreement with the landowner by the following:

i) acquisition of the dominium utile (similar to freehold purchase in England);

ii) leasehold;

iii) Deed of Servitude (similar to easement in England);

iv) way leave.

I.3.1.5 Rights granted indirectly by Acts of Parliament

If a promoter wishing to lay and maintain a pipeline over land fails to obtain the agreement of a landowner, it is possible to apply for compulsory rights to be granted under legislation.

I.3.2 Financial consideration and compensation

Landowners are generally entitled to receive payment for granting an easement or lease, or sale of freehold interest, or where rights are acquired by statute.

Landowners or occupiers or both are entitled to compensation for any land that cannot be fully reinstated. Compensation is therefore payable for damage to crops, loss of profits, loss of residual value, loss of or damage to sporting rights.

In cases where the promoter is exercising statutory powers, owners and occupiers have a duty to mitigate any losses that may arise.

Shooting and fishing rights are often sub-let but can still be subject to compensation for loss.

It is common practice for the promoter to reimburse any professional fees incurred by the owners and/or occupiers of any interest in land through which the pipeline might be routed.

I.3.3 Trees and hedgerows

In some instances a license is required from the Forestry Commission to authorize the felling of trees. It is advisable to liaise with the local authority to ascertain which trees are protected by a tree preservation order (TPO). Where a TPO exists special arrangements need to be made for protection of trees from damage.

Permission has to be obtained from local authorities before hedgerows can be removed.

I.3.4 Transmittable diseases

The Department for Environment, Food and Rural Affairs (DEFRA) can make available, on request, details of any restrictions in force regarding transmittable diseases, in the areas concerned. This includes notification in areas adjacent to those concerned. DEFRA also specify any necessary precautions to be taken in respect to the diseases encountered. It is advisable to contact the local DEFRA officer prior to commencement of construction.

I.3.5 Deposits of waste

Guidance on legal obligations regarding the removal of waste deposits is obtainable from local environmental officers.

I.3.6 Control of noise

NOTE Attention is drawn to the Noise and Statutory Nuisance Act 1993 [34] and to the Noise at Work Regulations 1989 [35].

Noise is generated by construction plant and equipment, and fixed plant employed for operation of the pipeline, i.e. compressors and pumps, etc.

The local authority has the right to serve an abatement notice on the promoter, which could have an impact on the efficiency of the construction activities or curtail operation of the pipeline.

Codes of practice for construction and operation are generally available from the regulating authorities.

I.3.7 Environmental protection

An environmental impact assessment (EIA) is mandatory for certain pipeline projects, dependent on the length of the pipeline and whether the pipeline route will traverse through environmentally sensitive areas. Such pipelines are subject to the approval of the Secretary of State for Energy and Climate Change (DECC).

NOTE Attention is drawn to the Electricity and Pipe-lines Works (Assessment of Environmental Effects) Regulations 1990 and subsequent amendments [3] and the Environmental Protection Act 1990 [4].

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