Draft for Public Comment

Form 36
Version 6.1

DPC: 02/710817 DC

Head Office
389 Chiswick High Road
London W4 4AL

Telephone: +44(0)20 8996 9000
Fax: +44(0)20 8996 7001

Date: 18 October 2002

Origin: National

Latest date for receipt of comments: 30.11.2002

Project no.: 2000/00937

Responsible committee: PSE/17/2 Transmission Pipelines

Interested committees: PSE/17

Title: Draft PD 8010-1 - Code of practice for pipelines

Part 1: Pipelines on land

Supersession information: If this document is published as a standard, the UK implementation of it will supersede BS8010 PT1 : 1989;BS8010-2-8 : 1992 . If you are aware of a current national standard which may be affected, please notify the secretary (contact details below).

WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD.
THIS DRAFT IS NOT CURRENT BEYOND 30.11.2002.

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on commenting.**

Further copies of this draft may be purchased from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email orders@bsi-global.com. British, International and foreign standards are also available from BSI Customer Services.

British Standards on CD or Online are available from British Standards Publishing Sales Limited.

Tel: 01344 404409 or email bsonline@techindex.co.uk.

Information on the co-operating organizations represented on the committees referenced above may be obtained from the responsible committee secretary.

Cross-references

The British Standards which implement International or European publications referred to in this draft may be found via the British Standards Online Service on the BSI web site http://www.bsi-global.com.

Responsible Committee Secretary: K Seyde (BSI)

Direct tel: 020 8996 7445

E-mail: keith.seyde@bsi-global.com

Introduction

Your comments on this draft are welcome and will assist in the preparation of the consequent British Standard. If no comments are received to the contrary, this draft may be implemented unchanged as a British Standard.

Submission

The guidance given below is intended to ensure that all comments receive efficient and appropriate attention by the responsible BSI committee. **Annotated drafts are not acceptable and will be rejected.**

All comments must be submitted, preferably electronically, to the Responsible Committee Secretary at the address given on the front cover. Comments should be compatible with Version 6.0 or Version 97 of Microsoft® Word for Windows™, if possible; otherwise comments in ASCII text format are acceptable. **Any comments not submitted electronically should still adhere to these format requirements.**

All comments submitted should be presented as given in the example below. Further information on submitting comments and how to obtain a blank electronic version of a comment form are available from the BSI web site at:

http://www.bsi-global.com/Standards+Development/Drafts/index.xalter

c -) r a 3 (1 . 0) -) - (Date . ([Document - - a D

BRITISH STANDARD

PD 8010-1:2001

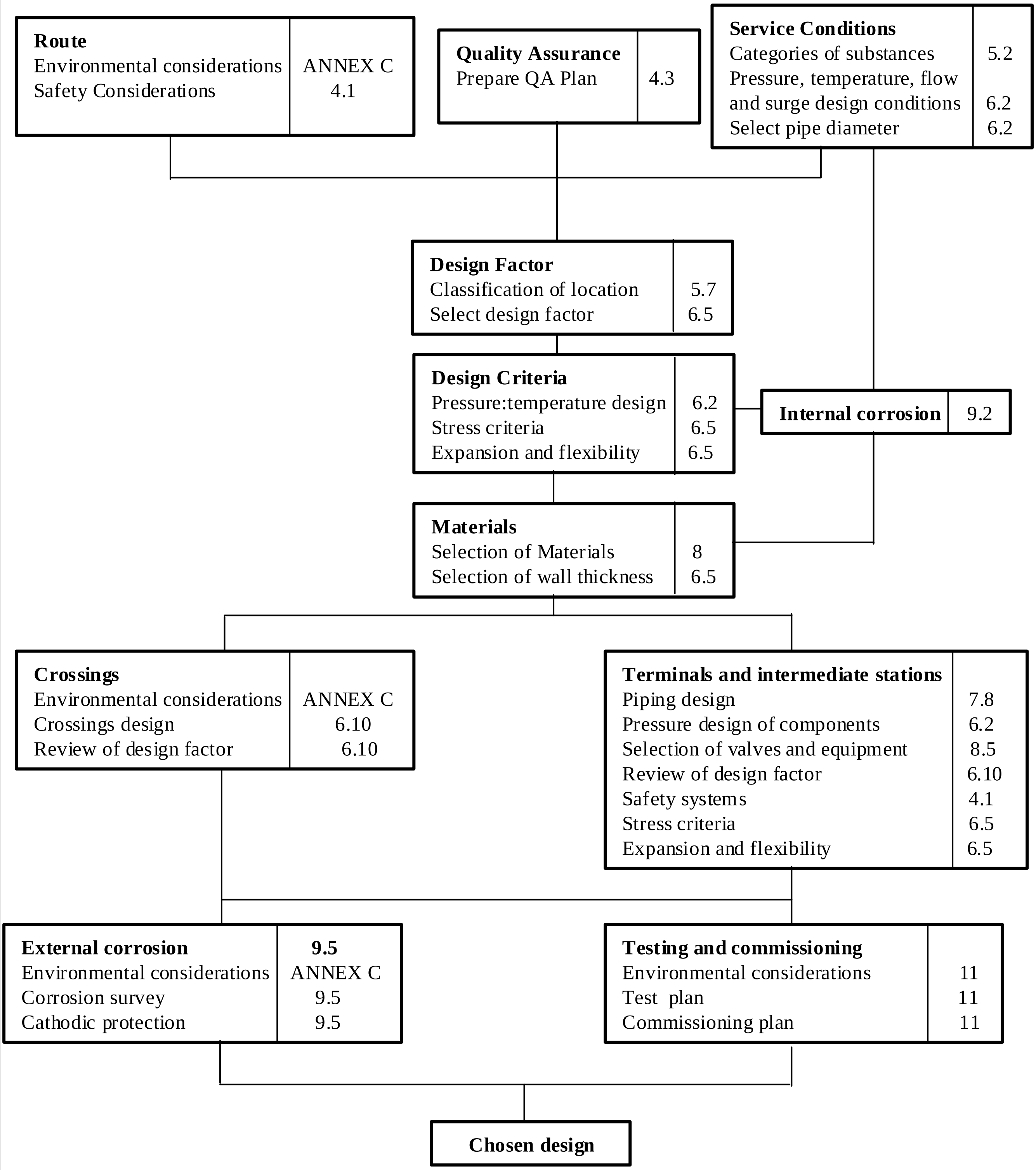
Code of practice for pipelines —Part 1: Pipelines on land

The preparation of this British Standard was entrusted to Subcommittee PSE/17/2, Transmission Pipelines, on which the following organisations were represented:

Advantica Technologies Association
Association of Consulting Engineers
British Compressed Gases Association
British Petroleum Group
Health and Safety Executive
Institute of Gas Engineers
Institute of Petroleum
Trevor Jee Associates
Pipeline Industries Guild
United Kingdom Onshore Pipeline Operators Association
United Kingdom Steel Association

Contents

Annex E. Pipeline design flowchart



Foreword

PD 8010 has been prepared under the direction of Technical Subcommittee PSE/17/2. PD 8010 reviews the requirements of BS 8010-1, BS 8010-2.8, BS 8010-3 and the latest revisions of the Institution of Gas Engineers publication, IGE/TD1 against the requirements of ISO 13623 and BS EN 1594. PD 8010 is published in two parts as follows:

— *Part 1: Pipelines on land*;

— *Part 2: Subsea pipelines*.

PD 8010-1 supersedes BS 8010-2.8 and BS 8101-1, which are withdrawn.

The guidance given in this code of practice on the design of pipelines for the transmission of methane is based directly on the philosophy and guidance contained in the Institution of Gas Engineers Recommendations on transmission and distribution practice. The Institution's guidance is specific to first and second family gases and can be supported by experimental data.

The International System of Units (SI) (see BS 5555) is followed in this part of PD 8010. Exceptions are pipeline diameters which are also given in inches and the unit used for pressure which is the bar.

NOTE 1 bar = 10^5 N/m^2 = 10^5 Pa.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Attention is drawn to the following Acts and Regulations and any regulations enacted under these:

Health and Safety at Work etc. Act (1974)
Health and Safety at Work (Northern Ireland) Order 1978
Pipelines Act (1962)
Pipelines Safety Regulations (PSR) 1996
Pressure Systems Safety Regulations 2000
Pressure Equipment Regulations 1999
Electricity and Pipelines Works (Assessment of Environmental Effects) Regulations
Environmental Protection Act 1990
Factories Act 1961
Factories Act (northern Ireland) 1965
Construction Design and Management (CDM) Regulations 1994

Attention is also drawn to guidance notes published by appropriate authorities.

Compliance with the Acts and Regulations requires knowledge of the relevant statutory notices, registers, records and forms. There are also British Standards that are particularly directed to health and safety considerations, and these will be referred to in this document.

As a Code of Practice, this Published Document 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.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

1 Scope

PD 8010-1 gives recommendations for the design, selection, specification and use of materials, routing, land acquisition, construction, installation, testing, operation, maintenance and abandonment of land pipeline systems constructed from steel. It is not intended to replace or duplicate hydraulic, mechanical or structural design manuals.

PD 8010-1 deals with pipelines that may be used to carry oil, gas and other substances that are hazardous by nature of being explosive, flammable, toxic or reactive.

A major application of PD 8010-1 is the transmission of substances for which low alloy carbon steel pipe meet the service conditions required. Service conditions include maximum operating pressure, maximum and minimum temperatures, extent of chemical and physical reaction between the substance conveyed and the pipe, and the flammability and/or toxicity of the substance conveyed.

NOTE 1 The latest revisions of IGE/TD1 or IGE/TD3 give the requirements for the transmission of dry natural gas (predominantly methane), at a maximum operating pressure (MOP) not exceeding 100 bar at temperatures between a range of –25 °C and +120 °C inclusive. These publications can be obtained from the Institution of Gas Engineers, 21 Portland Place, London W1B 1PY, UK (Tel: +44 (0)20 7636 6603). BS EN 1594 and BS EN 12007 also contain requirements for gas supply systems.

NOTE 2 ASME B31.3 and BS 806 give design stresses for pipe materials required to operate outside the temperature range –25 °C to +120 °C.

2 Normative references

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

BS 3518-1, *Methods of fatigue testing — Part 1: General principles*.
BS 3518-2, *Methods of fatigue testing — Part 2: Rotating bending fatigue tests*.
BS 3518-3, *Methods of fatigue testing — Part 3: Direct stress fatigue tests*.
BS 3518-5, *Methods of fatigue testing — Part 5: Guide to the application of statistics*.
BS 3799, *Specification for steel pipe fittings, screwed and socket-welding for the petroleum industry*.
BS 4508 (all parts), *Thermally insulated underground pipelines.*
BS 5306 (all parts), *Fire extinguishing installations and equipment on premises*.
BS 5423, *Specification for portable fire extinguishers*.
BS 5839-1, *Fire detection and alarm systems for buildings — Part 1: Code of practice for system design, installation and servicing*.
BS 6651, *Code of practice for protection of structures against lightning*.
BS 7361-1, *Cathodic protection — Part 1: Code of practice for land and marine applications*.
BS 7572, *Code of practice for thermally insulated underground piping systems*.
BS EN 287 (all parts), *Approval testing of welders for fusion welding*.
BS EN 288 (all parts), *Specification and approval of welding procedures for metallic materials*.
BS EN 1594, *Gas supply systems — Pipelines for maximum operating pressure over 16 bar — Functional requirements.*
BS EN 10208 (all parts), Steel pipes for pipelines for combustible fluids.
BS EN 10208-1, *Steel pipes for pipelines for combustible fluids — Technical delivery conditions —Part 1: Pipes of requirement class A.*
BS EN 10208-2, *Steel pipes for pipelines for combustible fluids — Technical delivery conditions —Part 2: Pipes of requirement class B*
BS EN 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*.
BS EN 60079-14, Electrical apparatus for explosive gas atmospheres — Part 14: Electrical installations in hazardous areas (other than mines).
BS ISO 3183-3, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions —Part 3: Pipes of requirement class C.*
PD 5500:2000, *Specification for unfired fusion welded pressure vessels*.
PD 8010-2, *Code of practice for pipelines — Part 2: Subsea pipelines*.
ISO 7005-1:1992, *Metallic flanges — Part 1: Steel flanges*.
ISO 10474: 1991, *Steel and steel products — Inspection documents.*
ISO 13847, *Petroleum and natural gas industries — Pipeline transportation systems — Welding of pipelines.*
ISO 14313, *Petroleum and natural gas industries — Pipeline transportation systems — Pipeline valves.*
API 620, *Design and construction of large, welded, low-pressure storage tanks.*[1)]

[1)] American Petroleum Institute (API) standards are available from BSI Customer Services, Tel: +44 (0)20 8996 9001.

API 650, *Welded steel tanks for oil storage.*
API RP 5L2, *Internal coating of line pipe for non-corrosive gas.*
ASTM A193/A193M-01a, *Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service.*
A194/A194M, *Specification for carbon and alloy steel nuts for bolts for high-pressure and high-temperature service*.
A320/A320M, *Specification for alloy steel bolting materials for low-temperature service*.
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 B16.5, *Pipe flanges And flanged fittings*.
ASME VIII-1, *Boiler and pressure vessel code: Section VIII Division 1:1998 — Design and fabrication of pressure vessels*.

IGE/TD1, *Steel pipelines for high pressure gas transmission, edition 4*.
IGE/TD/13, *Pressure Regulating Installations for Transmission and Distribution, 2001.*
MSS SP 4, *Specification for steel pipelines flanges.*[2)]
NACE MR 0175, *Sulphide stress cracking resistant metallic materials for oil field equipment.*[3)]
NACE TM0284, *Evaluation of pipeline and pressure vessel steels for resistance to hydrogen-induced cracking*.
NFPA 30, *Flammable and Combustible Liquids Code*.[4)]

3 Terms and definitions

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

3.1
availability
probability that a system will be in the operational state

3.2
cathodic protection
system that reduces the rate of external corrosion of steel pipes, and the ferrous compounds of other pipeline materials, by regulating the electrical potential between a pipeline and the surrounding ground

3.3
coating
durable material of high electrical resistance applied to the external surface of steel pipes and fittings to protect the metal from corrosion

---

2) Manufacturers Standardization Society (MSS) standards are available from BSI Customer Services, Tel: +44 (0)20 8996 9001.
3) National Association of Corrosion Engineers (NACE) standards are available from BSI Customer Services, Tel: +44 (0)20 8996 9001.
4) National Fire Prevention Association (NFPA) standards are available from BSI Customer Services, Tel: +44 (0)20 8996 9001.

3.4
commissioning
activities required to pressurize pipework, stations, equipment and assemblies with carrier material (e.g. gas or oil), and to put them into operation

3.5
component
general term for any item that is part of a pipeline other than a straight pipe or field bend

NOTE Also referred to as a fitting.

3.6
control zone
strip of land over which the pipeline operator has a right to control activities

3.7
decommissioning
activities required to take out of service any pipework, station, equipment or assemblies filled with carrier material and to disconnect them from the system

3.8
design factor
factor applied when calculating the wall thickness or pressure

3.9
design pressure
pressure on which design calculations are based

3.10
design temperature
maximum or minimum temperature which determines the selection of material for the duty proposed

NOTE This should represent the most arduous condition expected.

3.11
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

3.12
emergency
situation which could affect the safe operation of the pipeline system and/or the safety of the surrounding area, requiring urgent action

3.13
gas
fuid that has a gaseous state at a temperature of 15 °C under normal atmospheric pressure (1.013 25 bar)

3.14
gas distribution system
pipeline system including piping above and below ground and all other equipment necessary to supply gas to the consumers

3.15
gas distributor
private or public organization authorized to distribute gas to consumers through a gas distribution system

3.16
gas transmission
activity intended to convey gas from one place to another through pipelines in order to supply gas to distribution systems or to industrial consumers

3.17
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

3.18
holiday
flaw in the coating or lining

3.19
holiday detector
device for detecting flaws in the coating or lining

3.20
incident
unexpected occurrence, which could lead to an emergency situation

3.21
incidental pressure
level of pressure that occurs incidentally within a system, at which a safety device becomes operative

3.22
inspection
process of measuring, examining, testing, gauging or otherwise determining the status of items of the pipeline system or installation and comparing it with the applicable requirements

3.23
installation
equipment and facilities for the extraction, production, chemical treatment, measurement, control, storage or offtake of the transported fluid.

3.24
installation temperature
temperature arising from ambient or installation conditions during laying or during construction

3.25
isolation joint
fitting having high electrical resistance, which can be inserted in a pipeline to electrically insulate one section of pipeline from another

3.26
intermediate station
pump, compressor, valve, pressure control, heating or metering station, etc. located along the pipeline route between the pipeline terminals

3.27
internal design pressure
maximum sustained pressure exerted by the pipeline contents for which a pipeline is designed to withhold

3.28
lease
period of time, during which, essentially, the ownership of the land is transferred to the promoter for use during that period

3.29
lining
durable material applied to the internal surface of steel pipes and fittings to protect the metal from corrosion, erosion or chemical attack

3.30
maintenance
combination of all technical and associated administrative actions intended to keep an item in, or restore it to, a state in which it can perform its required function

3.31
maximum incidental pressure
MIP
maximum pressure that a pipeline system can experience during a short time, limited by the safety devices

3.32
maximum operating pressure
MOP
maximum pressure at which a system can be operated continuously under normal conditions at any point along the pipeline, which is the sum of the static head pressure, the pressure required to overcome friction loss and any required back pressure. The maximum operating pressure excludes surge pressure and other variations

3.33
national requirements
requirements following from national legislation or more detailed or stringent national standards

3.34
night cap
temporary closure at the end of a section of pipeline

3.35
on land
pipeline laid on or in land whose surface is above high water mark, including those sections laid under inland watercourses

3.36
operating pressure
pressure that occurs within a system under normal operating conditions

3.37
operating temperature
temperature that occurs within a system under normal operating conditions

3.38
pig
device propelled through a pipeline by fluid pressure, for cleaning, swabbing, inspection or batch separation

3.39
pig trap
device allowing entry to the pipeline for the launching and receiving of pigs and other equipment to be run through the pipeline

3.40
pipe
hollow cylinder through which fluid can flow, as produced by the manufacturer prior to assembly into a pipeline

NOTE Also known as linepipe.

3.41
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.

NOTE 2 A pipeline on land is a pipeline laid on or in land, including those sections laid under inland water courses. A pipeline subsea is a pipeline laid under maritime waters and estuaries and the shore below the high water mark.

NOTE 3 To establish the interface between a pipeline and other connecting pipe work systems reference can be made to the Health and Safety Executive Guidance on Regulations "A guide to the Pipelines Safety Regulations 1996." Within this document under Clause 18 Figures 1 to 7 inclusive, various examples of the interfaces of pipelines with other piping systems are given and while these are indicative they give an illustration of the limits where the application of PD8010 should be applied

3.42
pipeline operator
private or public organization authorized to design, construct, and/or operate and maintain the pipeline system

3.43
pipeline spread
continuous length of sequential pipeline installation on which the contractor is currently working

3.44
pipeline system
interconnected system of pipelines including piping within terminals and intermediate stations as shown in Figure 1

3.45
pipework
assembly of pipes and fittings

3.46
point of delivery
point of transfer of ownership of fluid from supplier to the customer

NOTE This can be at a valve or at the meter outlet connection.

3.47
precommissioning
series of activities, including cleaning and possibly drying, executed prior to pipeline commissioning

3.48
pressure
gauge pressure of the fluid inside the system, measured in static conditions

3.49
pressure control system
combined system including pressure regulating, pressure safety and eventually pressure recording and alarm systems

3.50
pressure regulating system
system which ensures that a pressure is maintained at the outlet system within required limits

3.51
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

3.52
promoter
organization that seeks to install, operate and maintain a pipeline under statutory powers

3.53
pup
short make-up piece of pipe

3.54
re-commissioning
activities required to put a decommissioned pipeline, associated stations and equipment into service again

3.55
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

3.56
reliability
probability of a device or system performing in the manner desired for a specified period of time

3.57
right of way
corridor of land within which the pipeline operator has the right to conduct activities in accordance with the agreement with the land owner

3.58
special crossing
point at which the pipeline has to pass a special feature

3.59
station
plant or facility for the operation of the pipeline system and/or the processing of the fluid.

3.60
statutory notice
notice issued under an Act of Parliament by the 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.

3.61
strength test
specific procedure used to verify that the pipework and/or station meets the requirements for mechanical strength

3.62
strength test pressure
pressure applied to a system during strength testing

3.63
test pressure
pressure to which the system is subjected to ensure that it can operate safely

3.64
tie-in welds
tie-in welds are welds carried out between two sections of pipe already welded together and installed in the ground

3.65
volume under normal conditions
a quantity of gas which in a dry state occupies a volume of 1 m^3 at normal atmospheric pressure (1.013 25 bar) at a temperature of 0 ºC

3.66
volume under standard conditions
quantity of gas which in a dry state occupies a volume of 1 m^3 at normal atmospheric pressure (1.013 25 bar) at a temperature of 15 ºC

3.67
voting systems
systems incorporating parallel components which operate only if a predetermined proportion of the components indicate that the system should operate

3.68
way leave
agreement (similar in nature but less specific than an easement) granted by a landowner to the promoter, permitting the promoter to execute works on the terms specified

3.69
working width
strip of land, usually wider than that covered by an easement, lease or way leave, which is used by the contractor for the purpose of installing a pipeline

4 General

4.1 Health, safety and the environment

4.1.1 *General*

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

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

Possible measures to ensure safety in design, construction and operation are listed below. The list is not intended to be exhaustive nor will it be necessary to incorporate all of the measures on each occasion.

When selecting measures, consideration should be given to the safety and environmental conditions existing at the time of construction, operation, maintenance and decommissioning for which firm details are known.

— An appropriate and specific Safety Management System should be developed.

— A control zone should be established to control all third party activities in order to safeguard the pipeline against interference.

— If an area classification system is used, design factors should be chosen, relevant to the classification levels.

NOTE 1 This design factor may be increased if additional measures are taken against third party interference

— The route of the pipeline should be at an appropriate distance from buildings. The distance should be fixed by the particular parameters and code requirements.

— For high strength pipe steels, appropriate toughness properties for fracture-arrest capability should be selected.

— The minimum depth for the pipeline should be greater than that of normal agricultural/horticultural activities expected in the area. The probability of third-party interference to the pipeline will decrease if a depth greater than the minimum specified in this code is adopted.

— Additional forms of mechanical protection can reduce interference by third-party activity. Designers should carefully select the forms of additional protection to minimise any adverse effects on the efficiency of the cathodic protection.

— The route of the pipeline should be identified by a locating system such as markers.

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

4.1.2 *Pipeline integrity*

The pipeline should be designed utilizing established material and construction engineering standards. The integrity of the installed pipeline depends upon the strict adherence to these standards and each phase of the design and construction should be monitored.

Clause **5** clearly defines the recommended safety requirement guidelines required for the operation of the pipeline. All of these recommendations should be considered and implemented in conjunction with any special requirements deemed necessary for specific installations. Consideration should be given to the use of a flow chart to endorse the timing of integrity checks throughout the various design, construction and operation phases of the pipeline.

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 of the pipeline and to ensure that the specified requirements are met.

4.3 Quality assurance

4.3.1 *General*

Quality assurance procedures should be applied throughout design, procurement, construction and testing of a pipeline system to ensure compliance with specifications, procedures, standards and safety requirements. An efficient document control system is essential.

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

4.3.2 *Basic terms*

4.3.2.1 *Quality assurance*

Quality assurance should embrace all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements of quality.

4.3.2.2 *Quality plan*

The quality plan should set out specific quality procedures, resources and activities, which are appropriate and relate to the particular project, including the required written certificate inspection and hold points. It should include procedures for:

a) environmental controls;

b) design auditing;

c) material source and identification;

d) corrosion controls;

e) pipe coating;

f) welding operations;

g) welder qualifications;

h) welding inspection and acceptance;

i) testing;

j) commissioning.

4.3.2.3 *Inspection*

Inspection is the process of controlling quality by examining, measuring, testing, gauging or otherwise comparing the material or item with the specified requirements. The level of inspection should be such as to satisfy the requirements of the quality plan. Inspection activities should be certified by appropriately qualified personnel.

4.3.3 ***Design quality assurance***

4.3.3.1 *Design basis*

A design basis manual should be prepared, taking account of the process illustrated in annex E.

4.3.3.2 *Supervision*

The design and construction of the system should be carried out under the supervision of a suitably experienced chartered engineer.

4.3.4 ***Materials quality assurance***

4.3.4.1 *Pipe*

The quality plan should specify the tests and documented evidence required to ensure that the pipe, as delivered, meets with the specification against which it has been ordered. Each heat of steel should be certified. Pipe mill inspection should be specified. 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 the pipeline should be clearly marked with the unique pipe identification number which should be maintained and transferred to any pipe offcuts.

4.3.4.2 *Stock material*

Where material is purchased from stockholders, it is essential that the supplier provides satisfactory documentary certification (either of original manufacture or by appropriate testing) that the material supplied is in accordance with the required specification.

4.3.4.3 *Shop fabricated equipment*

Shop-fabricated or manufactured equipment (such as pig traps, manifolds, slug catchers, valves, flanges, insulation joints, meters and meter provers) should be constructed only from material that can be identified and verified as to quality and specification. Fabrication should not commence until written certification is available.

4.3.5 ***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 with them. The method of recording and accepting or rejecting non-conformities should be fully developed. It should also 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.

4.3.6 ***Records and document control***

4.3.6.1 *General*

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.

4.3.6.2 *Design documentation*

The following documents should be included:

a) design basis manual;

b) design audits, resultant change instructions and their implementation;

c) calculations relating to construction and operation;

d) materials and construction specifications;

e) drawings and sketches.

4.3.6.3 *Procurement documentation*

The following documents should be included:

a) certificates of compliance, testing and identification of material;

b) non-destructive testing (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.

4.3.6.4 *Construction documentation*

The following documents should be included:

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) field bending reports.

4.3.6.5 *Pressure testing and pre-commissioning documentation*

The following documents should be included:

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.

4.3.6.6 *Survey documentation*

The following documents should be included:

a) control network survey;

b) as-built survey records;

c) soils survey records.

4.3.6.7 *Retention of documents and records*

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

4.4 Documentation and records

4.4.1 *Preliminary routing plans*

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

4.4.2 *Field reconnaissance plans*

For field reconnaissance plans, Ordnance Survey maps of either 1:10 000 or 1:25 000 scale should be used. The use of 1:10 000 maps may obviate duplication, since this is the smallest scale acceptable for applications under the Pipelines Act.

4.4.3 *Final field survey plans*

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

4.4.4 *Strip plans*

Strip plans (also commonly referred to as Alignment Sheets) should be prepared from Ordnance Survey sheets of 1:2 500 scale. In built-up areas, consideration should be given to the use of plans of 1:1 250 scale. 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. Special 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.

4.4.5 *Plans for attachment to legal documents*

Plans for attachment to legal documents should 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.

4.4.6 *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 original recipients on completion of the work.

> NOTE If found more convenient the strip plans detailed in **4.4.4** may be used for this purpose.

4.4.7 *Digital mapping*

Consideration should be given to the method in which the horizontal and vertical alignments of a pipeline are recorded in digital form, known as the Coordinated Method.

Consideration should be given to using a system based on a geographic information system (GIS) together with a terrain modelling system.

> NOTE 1 Ordnance Survey Maps and Sheets may not be reproduced or copied without the permission of the Director-General of Ordnance Survey[5)].

> NOTE 2 A publication "Coordinated Pipelines Practice" is available from the Institution of Civil Engineering Surveyors.

Records of the pipeline should be kept and maintained throughout its lifetime to demonstrate compliance with the requirements of this standard.

In addition, the following records should be maintained by the promoter:

a) land drainage drawings;

b) pressure test records;

c) factory and construction inspection records;

d) welding records showing the location of each pipe and component giving pipe number, grade, wall thickness, coating type, coating thickness and weld number.

The use of computerized records systems should be considered for these records.

[5)] Ordnance Survey, Romsey Road, Southampton, SO16 4GU. Tel: 08456 05 05 05, Fax: 023 8079 2615, http://www.ordsvy.gov.uk.

4.5 Pipeline design flowchart

The pipeline design flowchart shown in annex E may be used by the pipeline designer as a guide through the design process. The flowchart does not attempt to show all the various pathways required to arrive at the chosen design. The numbers shown in the flow chart boxes refer to the subclause numbering of this part of PD 8010-1.

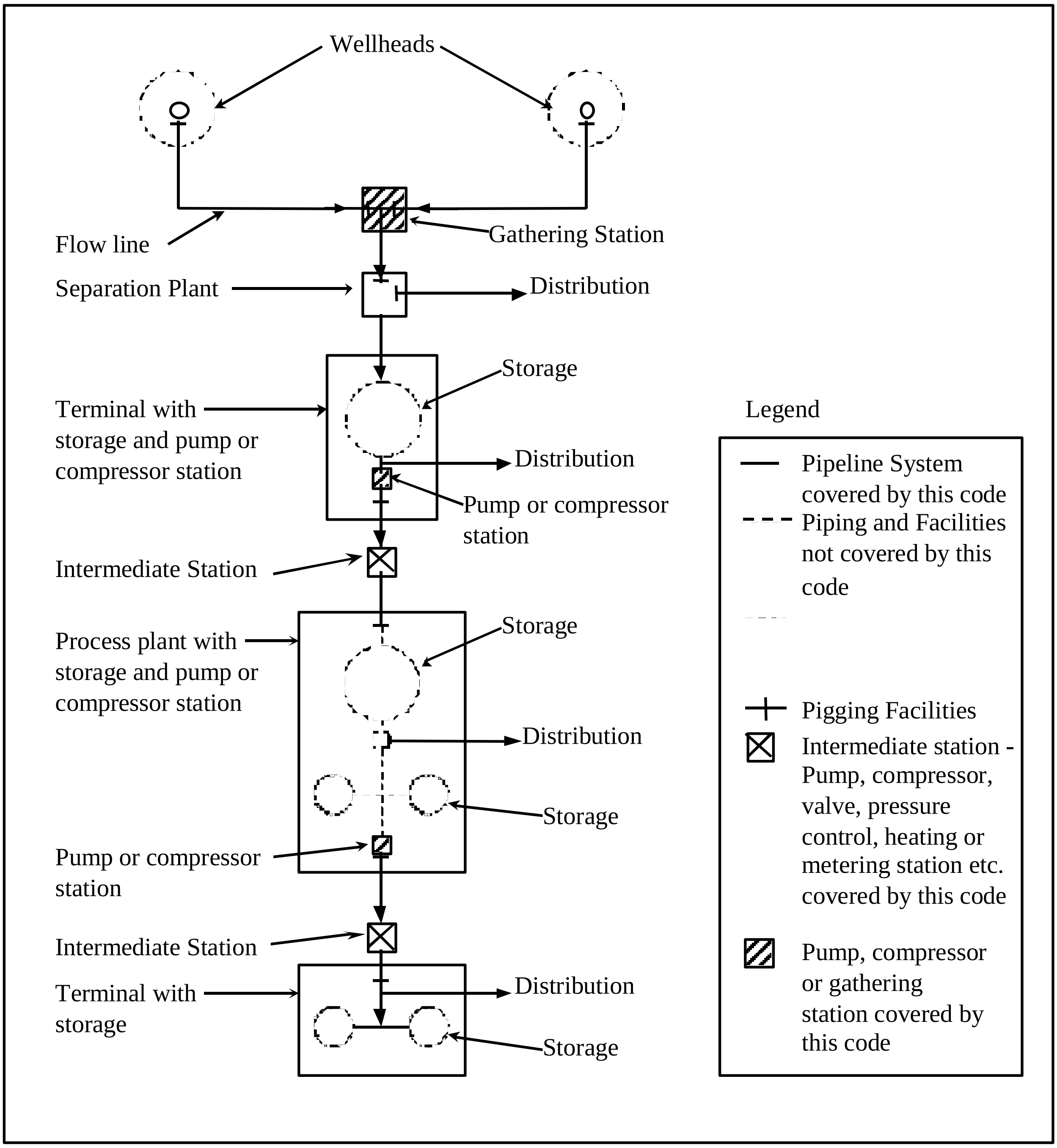


Figure 1 — Extent of pipeline systems for conveying oil and gas that are covered by PD 8010-1

5 Pipeline system design

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, including the facilities with their general locations and the demarcations and interfaces with other facilities.

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

5.2 Categorization of fluids

5.2.1 *General*

The fluids to be transported should be classified as belonging to one of the five categories given in Table 1 according to the hazard potential in respect of public safety:

Table 1 — Categorization of fluids according to hazard potential

Category A	Typically non-flammable water-based fluids
Category B	Flammable and/or toxic fluids that are liquids at ambient temperature and at atmospheric pressure conditions. Typical examples are oil and petroleum products. Methanol is an example of a flammable and toxic fluid.
Category C	Non-flammable fluids that are non-toxic gases at ambient temperature and atmospheric pressure conditions. Typical examples are nitrogen, oxygen, carbon dioxide, argon and air.
Category D	Non-toxic, single-phase natural gas
Category E	Flammable and/or toxic fluids which are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases and/or liquids. Typical examples are hydrogen, natural gas (not otherwise covered in category D), ethane, ethylene, liquefied petroleum gas (such as propane and butane), natural gas liquids, ammonia and chlorine. Also included are mixtures of petroleum or chemical substances, having a read vapour pressure greater than 31 KPa absolute, e.g. spiked or live crude oil.

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

Guidance on this may be found in publications such as the Health and Safety Executive(HSE) Guidance on Regulations 'A guide to the Pipelines Safety Regulations 1996' and 'Hazard definition: nomenclature for hazard and risk assessment in the process industries', published by the Institution of Chemical Engineers.

It should also be noted that the Pipelines Safety Regulations 1996 (PSR) contains additional definitions of dangerous fluids, those that would cause the pipeline carrying them to be classified as a major accident hazard pipeline. Fluids in categories B, D and E may be classified as dangerous fluids according to the PSR.

5.2.2 ***Hazard potential***

5.2.2.1 *General*

In the unlikely 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 will have a much lower blast effect owing to the relatively incompressible nature of liquids. Gases conveyed as liquids will have an intermediate effect. The characteristics of some hazardous substances commonly conveyed in pipelines have been included in **5.2.2.2** to **5.2.2.4**, to assist the designer in determining the category into which hazardous substances should be placed.

5.2.2.2 *Substances conveyed as a liquid*

Crude oil and refined petroleum products (heavier than butane) are flammable and will be released as a liquid that may infiltrate ground water and migrate from the point of release along the ground or in water courses. Toxic liquids will behave in a similar manner. Crude oil and petroleum products radiate a high level of heat on ignition.

5.2.2.3 *Substances conveyed as a gas*

Nitrogen and carbon dioxide readily mix with air but may 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 the latest issue of HSE Guidance Note EH40, Occupational exposure limits).

Oxygen readily mixes with air and can also form a heavier than air cloud on release. This supports combustion and will increase the flammability of combustible materials in the immediate vicinity of a release.

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.

5.2.2.4 *Substances conveyed as liquid or gas or in dense phase*

Ethylene is flammable, slightly lighter than air but may 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) will on release behave in relation to its constituents, ethane, propane and butane etc. depending on its particular composition. NGL is flammable, will radiate a high heat on ignition and 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, will be released as a heavier than air gas (propane and butanes) that can migrate some distance at ground level. LPG will radiate a high level of heat on ignition. The behaviour of gases and associated liquids in two phase flow pipelines will depend upon their particular composition on release.

Ammonia is flammable and toxic, and will be released as a heavier than air gas that can migrate some distance at ground level. Ammonia will radiate heat if ignited; the gas has a toxic effect.

5.3 Hydraulic analysis

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

EXAMPLES Examples of constraints and operational requirements are:

a) allowances for pressure surges;

b) prevention of blockages, e.g. caused by the formation of hydrates and wax deposition;

c) measures to prevent unacceptable pressure losses from higher viscosities at lower operating temperatures;

d) measures for the control of liquid slug volumes in multi-phase fluid transport;

e) flow regime for internal corrosion control;

f) erosional velocities and avoidance of slack line operations.

5.4 Pressure control and overpressure protection

If the operating pressure can exceed the maximum allowable operating pressure anywhere in the pipeline system, provisions such as pressure control valves or automatic shutdown of pressurising equipment should be installed. Such provisions or procedures should prevent the operating pressure exceeding MOP 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 specified in **6.2.2.5** anywhere in the pipeline system.

5.5 Requirements for operation and maintenance

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

a) requirements for identification of pipelines, components and fluids transported;

b) principles for system control, including consideration of manning levels and instrumentation;

c) location and hierarchy of control centres;

d) communications (voice and/or data);

e) corrosion management;

f) condition monitoring;

g) leak detection;

h) pigging philosophy;

i) access, sectionalising and isolation for operation, maintenance and replacement;

j) interfaces with upstream and downstream facilities;

k) emergency shut-in;

l) depressurisation with venting and/or drainage;

m) shutdown and restart;

n) requirements identified from the hydraulic analysis.

5.6 Public safety and protection of the environment

5.6.1 *General*

The recommendations of **5.6** are considered to be adequate for public safety under conditions usually encountered in pipelines, including those within towns, cities, water catchments and industrial areas. Although certain recommendations are given, these do not replace the need for appropriate experience and competent engineering judgement. Fundamental principles should be followed throughout, and materials and practices not recommended in **5.6** may be used providing they can be shown to achieve comparable safety standards.

The design and location of a pipeline should take account of the hazard potential of the substance to be conveyed, the proximity of the pipeline to normally occupied buildings and the density of population in the areas through which the pipeline passes. Potential causes of pipeline damage which may 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.

On-land pipeline systems for category D and E fluids should meet the requirements for public safety of annex A.

Consideration should be given at the design stage to any requirement to provide suitable and safe access for in-service inspection.

The safety and reliability of a pipeline system can be improved by the application of quality assurance procedures in design. In this respect reference should be made to **4.3.3**.

5.6.2 *Extra protection*

The design of a pipeline should take into account the extra protection which may be required to prevent damage arising from unusual conditions such as may occur at river crossings and bridges, or due to exceptional traffic loads, long self-supported spans, vibration, weight of special attachments, ground movement, abnormal corrosive conditions, any other abnormal forces and in areas where the depth of cover is less than recommended.

The effect of the extra protection should be assessed during the safety evaluation to determine whether the risks have been reduced to as low as reasonably practicable.

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.

5.6.3 *Safety evaluation*

5.6.3.1 *General*

The pipeline designer should give consideration to the preparation of a safety evaluation for pipelines designed and constructed in accordance with this Standard.

NOTE Refer to annex A for specific guidelines.

The evaluation should include the following:

a) critical review of the pipeline route;

b) description of the technical design of the pipeline system including potential hazards of the substance to be conveyed and design and construction aspects of the pipeline system;

c) details of pressure control, monitoring and communications systems, emergency shutdown facilities and leak detection (where incorporated);

d) proposals for pipeline monitoring and inspection during operation together with emergency procedures.

5.6.3.2 *Risk analysis*

Where a risk analysis is required as part of the safety evaluation it should include the following:

a) the identification of all potential failure modes;

b) a statistically based assessment of failure mode and frequency;

c) a detailed evaluation of the consequences of failure from small holes up to full bore rupture including reference to population density;

d) prevailing weather conditions;

e) time taken to initiate a pipeline shutdown.

The risk analysis should culminate in an evaluation of risk along the pipeline.

5.7 Classification of location

5.7.1 *General*

The location of category C, category D and category E substance pipelines 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. The location of category A and category B substance pipelines need not be classified in relation to population density but category B substance pipelines may require extra protection or be subject to a safety evaluation (refer to Annex A). Table 2 should be used for population density classification.

Table 2 — Classifying population density

Class 1 location	areas with a population density less than 2.5 persons per hectare
Class 2 location	areas with a population density greater than or equal to 2.5 persons per hectare and which may be extensively developed with residential properties, schools and shops etc.
Class 3 location	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 **5.7.3**.	

Additional factors should be considered when classifying pipeline location such as future development, 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 considered, especially where the effects of a pipeline failure could be experienced by population centres outside the immediate vicinity of the pipeline.

5.7.2 ***Proximity to occupied buildings***

5.7.2.1 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.

5.7.2.2 At the pipeline feasibility study stage the initial route and population density assessment for pipelines conveying category C, D or E substances should be established using individual risk contours calculated for the pipelines. The minimum distance for routing purposes between a pipeline and occupied buildings should be no less than the distance to the 10cpm risk contour and in some cases local planning requirements may require this distance to increase to the 0.3 cpm individual risk contour.

In cases where individual risk contours are not available, the initial route and population density assessment for pipelines conveying category C, category D and category E substances should be established, taking account of the proximity to occupied buildings.

The minimum distance (in metres) for routing purposes between a pipeline having a design factor not exceeding 0.72, and occupied buildings should be determined from the following formula:

$$\text{Minimum distance} = Q\left(\frac{D^2}{32000} + \frac{D}{160} + 11\right)\left(\frac{P}{32} + 1.4\right)$$

where

D is the pipe outside diameter (in mm);
P is the maximum operating pressure (in bar);
Q is the substance factor (see Table 3).

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

Table 3 — Substance factors

Substance	Substance factor, Q
Ammonia	2.5
Ethylene	0.8
Hydrogen	0.45
Methane	0.55
LPG	1
NGL	1.25
Category C	0.3
NOTE Substances not specifically listed by name in Table 2 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.

5.7.3 ***Population density***

5.7.3.1. For category C, category D and category E substance pipelines 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.

5.7.3.2 Where individual risk levels are not available, the population density for category C substance pipelines 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 **5.7.2.2** for any 1.6 km length of pipeline. For category D and category E substance pipelines 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 **5.7.2.2** for any 1.6 km length of pipeline.

5.7.3.3 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 areas. The population should be estimated following consultation with local authorities to assess the population level in the area concerned.

It is recommended that the boundary between class 1 and 2 in relation to population density is determined in a manner equivalent to that used in IGE TD/1 to determine the boundary between R and S areas. On this basis, the point at which the required degree of protection changes adjacent to the boundary between 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 2 times the 0.3 cpm risk contour distance from the pipeline or 8 times the distance calculated in accordance with Section 5.7.2.2 above. By considering 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 class1/2 boundary.

Occasionally the method of population density assessment may lead to an anomaly in classification of location such as may occur in a ribbon development area or for pipelines conveying toxic substances. In such cases consideration should be given to a more stringent classification than would be indicated by population density alone.

6 Pipeline design

6.1 Design principles

Representative values for loads and load resistance 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.

The use of higher design factors, such as those determined through structural reliability-based design methods or by reference to other design codes, may be applied for all or part of a pipeline system, provided that all relevant ultimate limit states are considered and that the limit state principles and requirements are applied consistently and comprehensively throughout the design. It is also recommended that due consideration be given to serviceability limit states. All relevant sources of uncertainty in loads, include fatigue, and load resistance should be considered and sufficient statistical data should be available for adequate characterisation of these uncertainties. BS EN 1594 provides some general guidance on the application of limit state design principles.

Higher design factors may be adopted if it can be demonstrated that the increase in failure probability and risk due to the ultimate limit states, is not significant when compared to operation at the code-allowable design factors (**6.5.1**).

> NOTE 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.

6.2 Design criteria

6.2.1 *Pressure:temperature ratings*

6.2.1.1 *Components having specific ratings*

The pressure ratings for components should conform to those standards listed in [Reference]

6.2.1.2 *Components not having specific ratings*

Piping components not having specific ratings may be used if the pressure design is based on sound engineering analysis supported by proof tests, experimental stress analysis or engineering calculations as appropriate.

6.2.1.3 *Normal operating conditions*

For normal operation the maximum operating pressure should not exceed the internal design pressure and pressure ratings for the components used.

6.2.1.4 *Allowance for variations from normal operation*

Surge pressures in liquid pipelines may be produced by sudden changes in flow which occur 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 piping system. Account should be taken of surge pressures produced within the pipeline affecting piping systems outside the scope of this standard, such as upstream of pumping stations or downstream of pipeline terminals.

6.2.1.5 *Over-pressure protection*

Adequate controls and protective equipment should be provided to ensure that the sum of the surge pressure, other variations from normal operations and the maximum operating pressure does not exceed the internal design pressure at any point in the pipeline system and equipment by more than 10 %.

6.2.1.6 *Consideration for 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, should not be less than the design thickness, t, used in the calculation of hoop stress in **6.5.2.2**. A nominal pipe wall thickness should be selected to give adequate performance in construction handling and welding.

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

6.2.2.2 *Straight pipe under external pressure*

The pipe wall thickness should be adequate 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.

6.2.2.3 *Bend*s

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. Pipes bent cold should not contain a butt within the bent section.

The wall thickness of finished bends, taking into account wall thinning at the outer radius, should be not less than the design thickness, *t*, shown in **6.2.2.1**. An indication of wall thinning as a percentage may be given by the following empirical formula:

$$\text{wall thinning} = \frac{50}{n+1}$$

where

n is the inner bends radius divided by pipe diameter.

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

Reference should be made to **8.3.3** for materials aspects of bending and to **10.3.5** for field bending during construction.

Mitred, wrinkle or gusseted bends should not be used in pipeline systems. Account should be taken of the use of cleaning, scraper and internal inspection devices when specifying the radius of bends intended for installation in pipelines.

Factory-made bends and factory-made wrought steel elbows may be used provided they conform to the recommendations of **8.3** and this clause.

NOTE Additional forces may need to be considered.

6.3 Route selection

6.3.1 *General*

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

Route selection should further take into account the design, construction, operation. maintenance and abandonment of the pipeline. Annex C should be referred to for specific details on pipeline route selection.
To minimize the possibility of future corrective work and limitations, anticipated urban and industrial developments should be considered.

Factors which should be considered as a minimum during route selection include:

a) safety of the public and personnel working on or near the pipeline;

b) contents of the pipeline and operating conditions;

c) protection of the environment;

d) other property and facilities;

e) third-party activities;

f) geotechnical, corrosive and hydrographical conditions;

g) requirements for construction, operation and maintenance;

h) future exploration;

i) existing and future land use;

j) agricultural practise;

k) any other hazards.

6.3.2 ***Public safety***

The operating conditions of pipelines affect route selection. The main parameters concerned are:

a) the nature of the contents;

b) maximum working pressure;

c) peak flow rate;

d) pipeline material and diameter.

Pipelines conveying category B, C, D and E fluids should, where practicable, avoid built-up areas or areas with frequent human activity, e.g. Class 3 locations. Consideration should be given to routing that will minimize the possibility of external damage, which could lead to incidents and attendant damage to third parties. Fire authorities should be consulted in appropriate cases in order that they may take into account the risk categories of areas being traversed, to determine measures required to deal with accidents.

A system of area classification should be used. Design factors should be chosen relevant to classification levels in accordance with the information given in **5.7**.

For a given pipeline material, diameter and content, consideration should be given to:

a) the probability of fracture and its consequences;

b) the maximum possible size of the fracture;

c) the consequent maximum rate of release of contents;

d) any change of state of the contents under atmospheric conditions;

e) the total volume that can escape under emergency conditions.

A safety evaluation should be performed in accordance with annex A for:

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

— pipelines conveying category E fluids.

A control zone should be established to control all third party activities in order to safeguard the pipeline against interference.

The route of the pipeline should be an appropriate distance from buildings, and reference should be made to **5.7.2**.

The minimum depth for the pipeline should be greater than that of normal agricultural/horticultural activities expected in the area.

NOTE The probability of third-party interference to the pipeline will decrease if a depth greater than the minimum specified in **6.9.3** is used.

The route of the pipeline should be identified by a locating system such as markers.

6.3.3 *Environment*

Early reference should be made to the relevant planning authorities to determine whether an Environmental Impact Assessment (EIA) will be required for a pipeline and its associated above ground installations. If required, an EIA should cover the effect of pipeline works on local amenities and future developments. Pipeline promoters should also ascertain, at the planning stage, whether they are or are likely to be subject to European Union Directives.

An assessment of any pipeline route should be approached systematically to identify and record environmental issues that could be affected. Detailed assessments should be undertaken to ascertain the impact of the pipeline on environmentally sensitive areas. When selecting the route and station locations, care should be taken to identify the possible effects on the following:

a) RAMSA sites

b) sites of special scientific interest;

c) national parks and country parks;

d) areas of outstanding natural beauty;

e) ancient monuments, archaeological and ornamental site;

f) natural resources, such as catchment areas and forests;

g) flora and fauna;

h) tree preservation;

i) nature reserves;

j) mineral resources.

Also the following aspects should be considered:

a) the reduction of noise and vibration;

b) the avoidance of odour and dust and deterioration of air quality;

c) the avoidance of contamination of ground water and water courses;

d) minimize volume of traffic.

NOTE Further guidance can be obtained from IGE/TD/1 and the www.dti.gov.uk website.

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.

NOTE Particulars of previous noise complaints can be obtained from local authorities.

6.3.4 ***Other facilities***

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

6.3.5 ***Third party activities***

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

6.3.6 ***Geotechnical, hydrographical and meteorological conditions***

Adverse geotechnical, corrosive and hydrographic conditions should be identified and mitigating measures defined. In some instances, it may be necessary also to review meteorological conditions.

The following ground conditions should be considered and carefully investigated during the route planning stage:

a) areas of geotechnical instability, including faults and fissures;

b) soft or waterlogged ground;

c) corrosive nature of the soil;

d) rock and hard ground;

e) flood plains;

f) areas with seismic risk;

g) mountainous areas;

h) existing or potential areas of land slippage, subsidence and differential settlement;

i) mining and quarry areas;

j) infill land and waste disposal site, including those contaminated by disease or radioactivity

If any of these are expected during the lifetime of the pipeline, monitoring of these aspects should be incorporated into the regular surveillance procedures. This can include measurement of local ground movements, fluctuation in water table levels and changes in pipeline stresses.

6.3.7 ***Construction, testing, operation and maintenance***

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

6.3.8 ***Surveys***

An essential prelude to pipeline projects is to acquire from records, maps and physical surveys, a complete set of data on each of the geographical and geological features that are relevant to the safe, reliable and economic operation of the pipeline.

The adoption of a tentative route should be preceded by a desk study, making use of all available material. In addition to current editions of maps and records, reference should be made to superseded editions.

Before a route is finally adopted for construction, a physical survey should be made, aided as necessary by aerial photography, soil surveys and underwater observations.

The route survey should cover a sufficient width and be sufficiently accurate to identify features that could adversely influence the installation and operation of a pipeline.

Maps and plans used for land surveys are obtainable from the Ordnance Survey. Geological information may be obtained from the British Geological Survey. For information on mining, application should be made in the first instance to the owners of mineral rights in the case of privately owned mines and quarries.

NOTE Many independent sources of specialist information exist which may assist in route determination.

The pipeline promoter should employ professional advisers as early as possible on those aspects requiring expert knowledge.

6.4 Loads

6.4.1 *General*

Loads, which may cause or contribute to pipeline failure or loss of serviceability of the pipeline system, should be identified and accounted for in the design. The following types of load should be considered:

a) functional;

b) environmental;

c) construction;

d) accidental.

Pipeline systems should be designed for the most severe coincident conditions of pressure, temperature and loading which may occur during normal operation or testing.

6.4.2 *Functional loads*

6.4.2.1 *Classification*

Loads arising from the intended use of the pipeline system and residual loads from other sources should be classified as functional.

NOTE 1 The weight of the pipeline, including components and fluid, and loads due to pressure and temperature are examples of functional loads arising from the intended use of the system. Pre-stressing, residual stresses from installation, soil cover, external hydrostatic pressure, 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 weight of the pipe, components, coating, backfill and unsupported attachments to the pipeline system.

6.4.2.2 *Internal design pressure*

The internal design pressure used in design calculations should never be less than the maximum operating pressure at that point. The maximum operating pressure is the sum of the static head pressure, the pressure required to overcome friction losses and any required back pressure. The 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. (See Figure 2 for a review of pressure definitions.)

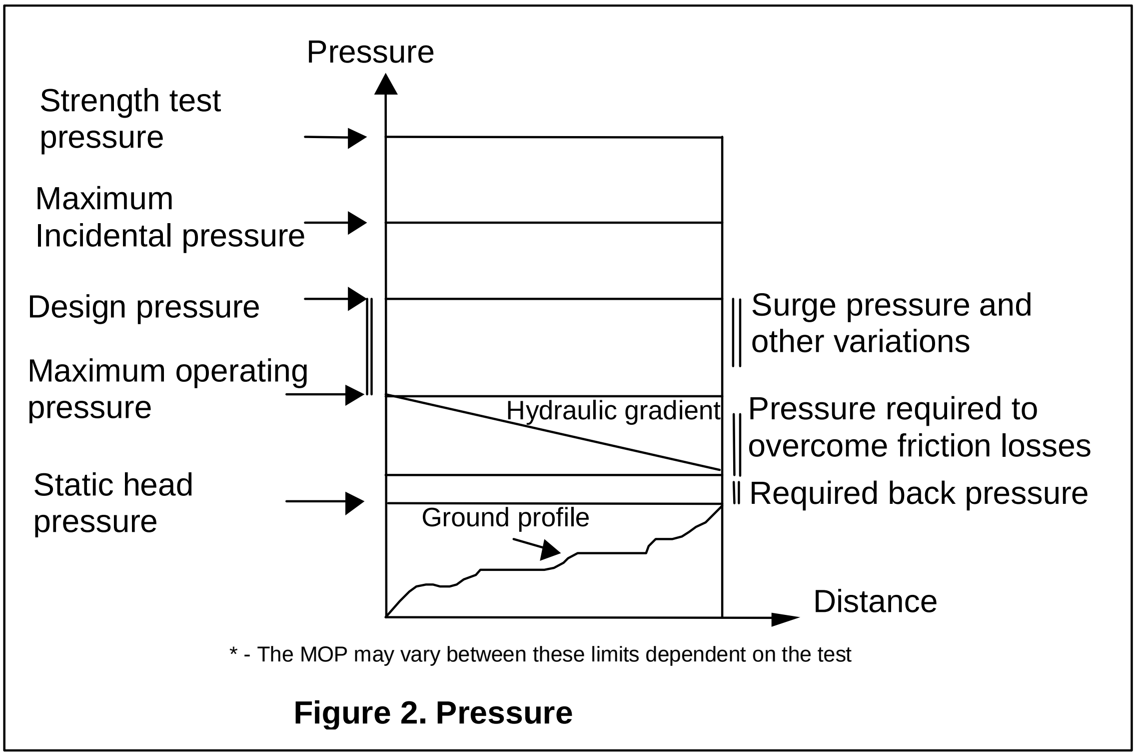


Figure 2 — Pressure definitions

6.4.2.3 *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**).

6.4.2.4 *Over-pressure protection*

Adequate controls and protective equipment should be provided for system over pressure protection (see **6.2.1.5)**.

6.4.2.5 *Maximum operating pressure (MOP)*

The MOP is related to the test pressure established by carrying out a hydrostatic or pneumatic test on the pipeline in accordance clause **11**. It is essential that the MOP does not exceed the internal design pressure.

6.4.2.6 *Shock effects*

Effects caused by sudden changes in external or internal pressure should be considered in the pipeline system design.

6.4.2.7 *Discharge reactions*

The pipeline system should be designed to withstand reaction forces and temperature changes, which may occur during discharges or pressure release.

6.4.2.8 *Pressure expansion*

The effects of longitudinal expansion due to internal pressure should be taken into account in the design of pipeline systems.

6.4.2.9 *Subsidence*

Consideration in the design should be given to pipelines located in mining areas, made up ground or other areas where subsidence is known to occur or is likely to occur.

6.4.2.10 *Temperature*

6.4.2.10.1 *Design temperature*

The design temperature should be established by considering temperature variations resulting from pressure changes and extreme ambient temperatures, but should not include post rupture conditions or emergency blow-down conditions.

Consideration should be given to possible fault conditions which can give rise to low temperature.

6.4.2.10.2 *Solar gain*

Where piping is exposed to the sun, consideration should be given to the metal temperature rise resulting from solar gain.

6.4.2.10.3 *Fluid expansion effects*

Provision should be made to withstand or relieve increased pressure caused by heating of static fluid in a pipeline system or component.

6.4.2.10.4 *Cooling effects*

The cooling of vapour or gas may reduce pressure in a pipeline system to vacuum and account should be taken of this in pressure design.

6.4.2.10.5 *Pneumatic testing*

The implications and potential hazards inherent in conducting a pneumatic test shall be considered at the design and materials specification stage. i.e. Adequate fracture toughness to arrest running shear fractures during operational and test conditions of maximum pressure and minimum temperature (see **8.2.5** and **11.3.4**).100 % radiography or ultrasonic inspection of all field welds (see **10.12.9.5**). A Design Factor of 0.3 and all manufactured components to have been subjected to a prior hydrostatic test are recommended (see **11.2.1**).

6.4.2.10.6 *Thermal expansion and contraction loads*

Provision should be made for the effects of thermal expansion or contraction in the design of pipeline systems. Account should be taken of stresses induced as a result of restriction of free thermal movement owing to restraints.

6.4.2.11 *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 pipeline systems and pipe supports.

6.4.3 *Environmental loads*

6.4.3.1 *Classification*

Loads arising from the environment should be classified as environmental, except where they need to be considered as functional (see **6.4.2**) or when, due to a low probability of occurrence, as accidental (see **6.4.5**).

Environmental loads can occur on the above ground pipework, buried pipelines and pipelines within water crossings above ground pipework will be subject to wind, snow and ice.

Buried pipe lines will be affected by road and rail traffic but also could be subject to subsidence due to mining, earthquake or other surface and sub surface instability.

Water crossings should be designed to withstand the depth of water and be of sufficient negative buoyancy, and avoid the effects of scouring.

Loads from vibrations of equipment and displacements caused by structures on the ground are also examples of environmental loads.

6.4.3.2 *Wind*

The effects of wind loading should be taken into account in the design of exposed pipeline systems.

6.4.3.3 *Vibration*

The pipeline system should be designed to minimize stresses induced by vibration and resonance.

6.4.3.4 *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 system or 100 years, whichever is shorter.

Loads from vortex shedding should be considered for aerial crossings.

6.4.3.5 *Earthquakes*

Consideration in the design should be given to pipelines located in regions of known earthquake activity.

The following effects should be considered when designing for earthquakes: direction, magnitude and acceleration of fault displacements. In particular, the following should be considered:

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.

6.4.3.6 *Sand loads*

The effects of the following should be considered when designing for sand loads:

a) sand dune movement;

b) sand encroachment.

6.4.3.7 *Ice loads*

The effects of the following should be considered when designing for ice loads:

a) ice frozen on pipelines or supporting structures;

b) bottom scouring of ice;

c) drifting ice;

d) impact forces due to thaw of the ice;

e) forces due to expansion of the ice;

f) higher hydrodynamic loads due to increased exposed area.

6.4.3.8 *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.

6.4.3.9 *Major water crossings*

Pipelines crossing rivers and estuaries which cannot be designed and constructed using normal land pipeline methods should be classified as submarine pipelines and designed and constructed in accordance with PD 8010-2.

6.4.3.10 *Mining*

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

6.4.4 *Construction loads*

Loads necessary for the installation (pipe-laying and alignment, e.g. tie-in conditions), impact protection and pressure testing of the pipeline system should be classified as construction loads.

The effect of dynamic behaviour of installation equipment should be considered 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.

6.4.5 *Accidental loads*

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

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

6.4.6 *Combination of loads*

When calculating equivalent stresses (see **6.5.2.6**) or strains, the most unfavourable combination of functional, environmental, construction and accidental loads that can be predicted to occur simultaneously should be considered.

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

a) design environmental loads plus appropriate reduced functional loads;

b) design functional loads and coincidental maximum environmental loads.

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

6.5 Strength requirements

6.5.1 *Selection of design factors*

NOTE 1 See **5.2** for fluid categorization.

NOTE 2 See **5.7.1** for location classifications.

6.5.1.1 *Category B substances*

The design factor, a, should not exceed 0.72 in any location. In areas of high population density extensively developed with residential properties, schools, shops, public buildings and industrial areas consideration should be given to providing extra protection to the pipeline as described in **5.6.2**.

6.5.1.2 *Category C, D and E substances*

The design factor a should not exceed 0.72 in class 1, 0.30 in class 2 and 0.30 in class 3 locations. However, the design factor may be raised to a maximum of 0.72 in class 2 locations providing it can be justified to a statutory authority by a risk analysis carried out as part of a safety evaluation for the pipeline.

Pipelines designed to convey category D and E substances in class 2 locations should have either a nominal wall thickness of 9.52 mm or be provided with impact protection in accordance with **5.6.2** to reduce the likelihood of penetration from mechanical interference.

It is essential that pipelines designed to operate in class 3 locations be limited to a maximum operating pressure of 7 bar.

6.5.2 *Calculation of stresses*

6.5.2.1 *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 **6.5.3.1**. The hoop stress should be calculated by using either the thin wall or thick wall design equations. The thick wall formula may be used when the D_o/t_{min} ratio is ≤ 20. This gives the maximum hoop stress encountered at the inside face of the pipe wall.

Thin wall

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

Thick wall

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

where

S_h is the hoop stress (N/m^2);
p is the internal design pressure (N/m^2)(see **6.5.2.3**);
D_o is the outside diameter (m);
t_{min} is the design minimum wall thickness (m);
D_i is the inside diameter ($D_o - 2t_{min}$) (m).

NOTE 1 bar = 10^5 N/m^2

The thick wall design equation gives a more accurate calculation of hoop stress and always gives the smallest 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 %.

6.5.2.2 *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 on buried and above-ground pipelines where flexibility is in doubt, and where significant temperature changes are expected such as occur in heated oil or refrigerated pipelines. Thermal expansion or contraction of buried pipelines may 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 which may be imposed on pipelines laid in unstable land (see **6.3.6**).

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

Calculations should take into account stress intensification factors found to be present in components 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 shown in BS 806 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. Consideration should be given to elastic instability due to longitudinal compressive forces.

Where movement is unrestrained, flexibility should be provided by means of loops, offsets or special fittings.

The total operating temperature range should be 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 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, reference should be made to either ASME B31.3 or IGE/TD1 (see Normative references) for the assessment of stress range reduction factors.

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

6.5.2.3 *Longitudinal stress*

The total longitudinal stress should be the sum of the longitudinal stress arising from pressure, bending, temperature, weight, other sustained loadings and occasional loadings (see **6.4.6**).

A pipeline should be considered 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 resulting from the combined effects of temperature and pressure change alone should be calculated as follows.

Thin wall:

$$S_{\mathrm{L1}} = \nu S_{\mathrm{h}} - E\alpha(T_2 - T_1)$$

Thick wall:

$$S_{\mathrm{L1}} = \nu\,(S_{\mathrm{h}} - p) - E\alpha\,(T_2 - T_1)$$

where:

S_{L1} is the longitudinal tensile stress ($\mathrm{N/m^2}$);
ν is the Poissons ratio (0.30 for steel);
p is the internal design pressure ($\mathrm{N/m^2}$);
S_{h} is the hoop stress calculated in **6.5.2.2**, but using the nominal pipe wall thickness ($\mathrm{N/m^2}$);
E is the modulus of elasticity (in $\mathrm{N/m^2}$);
α is the linear coefficient of thermal expansion (per °C);
T_1 is the installation temperature (°C);
T_2 is the maximum or minimum metal temperature (°C).

For unrestrained sections of a pipeline, the longitudinal tensile stress resulting from the combined effects of temperature and pressure change alone should be calculated as follows.

Thin wall:

Use $k = 1$

Thick wall:

$$S_{L2} = \frac{S_h}{k^2 + 1} + \frac{M_b i}{Z}$$

where:

S_{L2} is the longitudinal tensile stress (N/m^2);
M_b is the bending moment applied to the pipeline (N·m);
i is the stress intensification factor (see BS 806);
k is the ratio D_o/D_i (see **6.5.2.1**);
Z is the pipe section modulus (m^3).

6.5.2.4 *Shear stress*

The shear stress should be calculated from the torque and shear force applied to the pipeline as follows:

$$\tau = \frac{T}{2Z} + \frac{2S_F}{A}$$

where

τ is the shear stress (N/m^2);
T is the torque applied to the pipeline (N·m);
S_F is the shear force applied to the pipeline (N);
A is the cross sectional area of the pipe wall (m^2);
Z is the pipe section modulus (m^3).

6.5.2.5 *Equivalent stress*

The equivalent stress (S_e) should not exceed the allowable equivalent stress (S_{ae}) given in **6.5.3.2**. The equivalent stress should be calculated using the von Mises equivalent stress criteria as follows:

$$S_e = \left(S_h{}^2 + S_L{}^2 - S_h S_L + 3\tau^2\right)^{1/2}$$

where

S_h is the hoop stress calculated in **6.5.2.1**, but using the nominal pipe wall thickness (in N/m^2);
S_L is the total longitudinal stress (as defined in **6.5.2.3**) (in N/m^2);
τ is the shear stress (in N/m^2).

NOTE The von Mises equivalent stress has been derived from the full equation by assuming that the third principal stress is negligible.

6.5.3 *Limits of calculated stress*

6.5.3.1 *Allowable hoop stress*

The allowable hoop stress (S_{ah}) should be calculated as follows:

$S_{ah} = aeS_y$

where

S_{ah} is the allowable hoop stress (N/m^2);
a is the design factor;
e is the weld joint factor (see below);
S_y is the specified minimum yield strength of pipe (N/m^2).

The weld joint factor *e* should be 1.0 for pipe conforming to ISO 3183-1, ISO 3183-2 and/or BS ISO 3183-3 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 (4.5 inch) outside diameter or smaller, or 0.80 for pipe larger than 0.114 m (4.5 inch) outside diameter.

6.5.3.2 *Allowable equivalent stress*

The allowable equivalent stress (S_{ae}) should be calculated as follows:

$S_{ae} = 0.9\ S_y$

where

S_{ae} is the allowable equivalent stress (N/m^2);
S_y is the specified minimum yield strength of the pipe (N/m^2).

6.5.4 *Strength criteria*

6.5.4.1 *General*

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

a) excessive yielding;

b) buckling;

c) fatigue.

6.5.4.2 *Buckling*

The following buckling modes should be considered:

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

b) buckle propagation;

c) restrained pipe buckling due to axial compressive forces induced by high operating temperatures and pressures.

NOTE Restrained pipe buckling can take the form of horizontal snaking for unburied pipelines or vertical upheaval of trenched or buried pipelines.

6.5.5 ***Fatigue***

6.5.5.1 *Fatigue loads*

All fluctuating loads during the entire life of the pipeline should be considered in establishing the effect of fatigue on the pipeline system. Loads producing stresses below the threshold for fatigue damage need not be considered further. In the assessment of stress ranges, the effect of construction detail that can cause stress concentration such as misalignment and wall thickness changes should be taken in to consideration.

Typical sources of fluctuating loads include the following:

a) installation loads;

b) dynamic loads (wind, waves currents)

c) vibrations caused by vortex shedding, product flow, or other phenomena;

d) operational cycles;

e) alternating movements (ground movements).

6.5.5.2 *Fatigue life*

The pipeline system should be designed to have a fatigue life with an adequate safety margin with respect to the design life of the system.

The maximum number of stress cycles expected for a pipeline should be evaluated by multiplying the number of daily cycles occurring for the principal stress within a given stress range by the constant C in Figure 3. More complex daily stress cycles should be evaluated by multiplying the number of individual stress cycles, within the daily cycle, by the constant C in Figure 3. The sum of factored and unfactored cycles should not exceed 15 000.

NOTE A detailed fatigue assessment may not to be needed if this simplified method is satisfied. An introduction to a more detail fatigue assessment and factors that influence the fatigue life is given in PD 5500:2000 annex C. The assessment approach described in PD 5500 is the application of the S-N curves, in which the fluctuating stress range S, is plotted against number of cycles to failure, N. The S-N curves for different materials and weld details have been derived from fatigue test data.

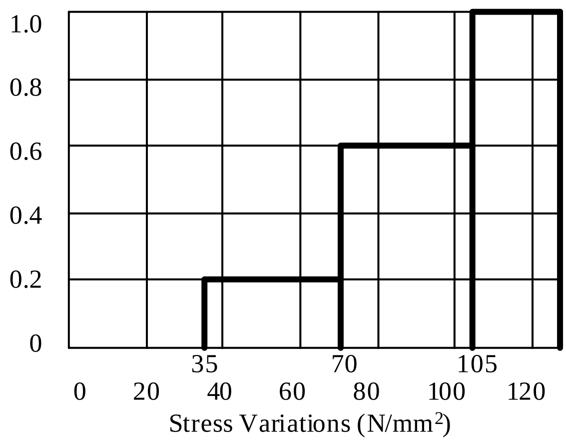


Figure 3. Fatigue life, constant C for stress variations

Figure 3 — Fatigue life, constant C for stress variations

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

In case of multiple stress cycles, the cumulative effect should be evaluated based on the linear damage hypothesis (Miner's Rule).

It should be noted that when total strain range due to any source of loading is known from theoretical or experimental stress analysis, a pseudo-elastic stress range should be used (i.e. total strain range multiplied by elastic modulus).

Consideration should also be given to the acceptability of flaws expected or found in service in relation to their effect on the fatigue strength. It is necessary to ensure that defects do not grow to a critical size under the influence of cyclic loading, and when appropriate a fatigue analysis based upon methods set out in BS 7910 can be adopted. Flaws can be found in both welded and unwelded sections, and for planer flaws fracture mechanics principles may be used to describe the growth behaviour. The assessment of non-planer flaws should only be assessed based on experimental S-N data as described in BS 7910.

6.5.5.3 *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.

6.6 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 of this Standard.

Factors which should be considered 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, for example 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.

6.7 Pipeline spanning

Spans in pipelines should be controlled to ensure compliance with the strength criteria in **6.5.4**. Due consideration should be given to:

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.

6.8 Other activities

6.8.1 *Corrosion allowance*

A corrosion allowance on design thickness need not be included providing 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 an appropriate study, taking into account the type of corrosion expected and the required life of the pipeline. No external corrosion allowance is required if both an anti-corrosion coating system and a cathodic protection system 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 which are either heated or refrigerated, thermal insulation may be required 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 substance being conveyed within its process design limits at the lowest design flow rates. Reference should be made to BS 7572 and BS 4508 for the design of thermally insulated underground pipelines.

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 considered. Vapour barriers should be installed to prevent the migration of moisture within the insulation and subsequent damage to the pipeline material.

Careful consideration should be given to the maximum design operating temperature for anti-corrosion coatings. 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 system should be designed to accommodate internal inspection devices (intelligent pigs).

Consideration should be given to the depth of cover of heated or refrigerated pipelines in agricultural land in respect of thermal effects on crop growth. For refrigerated pipelines the possibility of frost heave should be considered.

6.8.3 ***Pipeline cover***

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

Table 4 — Pipeline cover

Location	**Cover depth**[a] m
Areas of limited or no human activity	0.9
Agricultural or horticultural activity [b]	1.1
Canals, rivers [c]	Refer to appropriate authorities
Roads [d]	1.2 (Refer to appropriate authorities)
Railways	1.4 to 1.8 (Refer to appropriate authorities)
Residential, industrial, and commercial areas	1.1
Rocky ground [e]	0.5

[a] Cover depth should be measured from the lowest possible ground surface level to the top of the pipe, including coatings and attachments.
[b] Cover should not be less than the depth of normal cultivation.
[c] To be measured from the lowest anticipated true clean bed level.
[d] To be measured from the true clean bottom of the drainage ditches.
[e] The top of the pipe should be at least 0.15 m below the surface of the rock with a minimum total cover of 0.5 m.

An increased depth of cover may apply under the following cases:

a) situations where frost heave may occur.

b) areas where agriculture or horticultural practices require a greater depth;

c) areas which could be subject to erosion;

d) main rivers and other waterways.

If a waterway is navigable, consideration should be given to protection of the pipeline against damage from ship’s anchors.

6.8.4 ***Location of cathodic protection stations***

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

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 systems should be designed in accordance with BS 7361-1.

6.9 Crossings and encroachments

6.9.1 *Road crossings*

6.9.1.1 *General*

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. For category C and category D and E substance pipelines, roads should be classified as major roads or minor roads for allocation of design factor and wall thickness.

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

Private roads or tracks should only be classified as minor roads if there is reason to believe that they may be used regularly by heavy traffic. Assessments of traffic densities should be carried out by consultation with the Department for Transport, Local Government and the Regions (DTLR) and local highway authorities concerned.

Road crossings should be installed by open-cut, boring or tunnelling methods following consultation with the relevant highway authorities. Particular care should be exercised in the consideration of ground conditions and temporary works design. The minimum distance between the road surface and the top of the pipe or sleeve should be 1.2 m.

6.9.1.2 *Category B substances*

For pipelines designed to convey category B substances, no revision to design factor or wall thickness is required at road crossings. Consideration should be given to the provision of impact protection at open-cut crossings of major roads.

6.9.1.3 *Category C substances*

For pipelines designed to convey category C substances, no revision to design factor or wall thickness is required at road crossings. However, impact protection should be provided at open-cut crossings of major roads.

6.9.1.4 *Category D and E substances*

For pipelines designed to convey category D and 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 A).

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 **5.6.2**.

For major roads the design factor, wall thickness or impact protection requirements should extend for a distance equal to the minimum distance shown in IGE/TD1 for methane, or the final minimum distance (see **5.7.2.2**) for other category D and E substance pipelines, measured at a right angle from the edge of the carriageway.

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

a) pipe with a nominal wall thickness of 9.52 mm or greater without impact protection; or
b) pipe with a wall thickness appropriate to the design factor and impact protection in accordance with **5.6.2**.

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

6.9.2 ***Rail crossings***

Pipeline rail crossings should be designed and classified in the same manner as described in **6.9.1.1** for road crossings.

NOTE Major rail routes would normally include inter city 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.

6.9.3 ***Major water crossings***

Pipelines crossing rivers and estuaries which cannot be designed and constructed using normal land pipeline methods should be classified as submarine pipelines and designed and constructed in accordance with PD 8010-2.

6.9.4 ***Canal, ditch, dyke and other water crossings***

Pipelines crossing rivers and canals should be designed in consultation with the water and waterways authorities to determine the minimum depth of cover and additional protection required. In considering additional protection, account should be taken of potential pipeline damage by ship's anchors, scour and tidal effects, flood defences and any future works such as dredging, deepening and widening of the river or canal. (See **10.4.4**.)

6.9.5 ***Pipe bridge crossings***

The preferred design for pipeline crossings is for buried installation of pipe. Where it is necessary to utilize pipe bridges these should be designed in accordance with good structural engineering practice and with an appropriate design factor. Pipe bridge design should consider 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 of restrictions on access to the general public. Potential cathodic protection interference between the pipeline and bridge supporting structure should be considered.

6.9.6 ***Sleeved crossings***

The preferred design for pipeline crossings is for 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, reference should be made to section **7.21** of the Institution of Gas Engineers publication IGE/TD1 and to BS 7361-1.

6.9.7 ***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 distance shown in IGE/TD1 for methane or the final minimum distance (see **5.7.2.2**) for category C and other category D and E substance pipelines.

6.9.8 ***Impact protection***

At some crossings and in areas where the likelihood of third party activity leading to interference with the pipe is increased, the use of impact protection is recommended.

Impact protection may take the form of increased cover, concrete surround, concrete slab over or similar construction (see **5.7.2.2**).

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

6.10 Adverse ground conditions

Where pipelines are unavoidably located in such areas, appropriate protective measures should be taken to counter any potential harm to the pipeline. These might include increased wall thickness, ground stabilization, erosion prevention, installation of anchors, provision of negative buoyancy, etc. as well as the surveillance measures.

6.11 Location of section isolating valves

6.11.1 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. In the locating of section isolating valves account should be taken 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 by ship's anchors or scouring of the river bed.

6.11.2 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.

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

6.11.4 For pipelines designed to convey category D and E and 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. Consideration should be given to similar installation on pipelines conveying category C and non-toxic category B substances.

6.12 Integrity monitoring

6.12.1 ***Use of internal inspection devices***

Consideration should be given to the design of pipelines to accommodate internal inspection devices (intelligent pigs), unless such devices cannot be used due to the properties of the transmitted product.

Important factors that should be considered include:

a) minimum radius of bends;

b) changes of internal diameter;

c) length of and access to pig traps;

d) design of branch connections.

6.13 Leak detection

Consideration should be given to the incorporation of a leak detection system into the design of a pipeline. The method chosen for leak detection should be appropriate and effective for the substance to be conveyed. 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 **13.3.4**.

6.14 Fabricated components

6.14.1 *Slug catchers*

6.14.2 *General*

Slug catchers should be installed upstream of stations, terminals and other plant to remove slugs of liquid from multi-phase flow pipelines. The design pressure should be equal to the internal design pressure of the pipeline system (see **6.4.2.3**).

Consideration should be given to thermal relief, pipeline and process-related relief requirements and measures to reduce fire exposure. 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.

6.14.3 *Vessel-type slug catchers*

Vessel-type slug catchers should be designed in accordance with PD 5500 or ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

6.14.4 *Multipipe-type slug catchers*

For buried multipipe-type slug catchers the pressure design should be in accordance with this Section with an appropriate design factor. For above-ground multipipe-type slug catchers the pressure design should be in accordance with ASME B31.3.

In both cases reference should be made to PD 5500 or ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 for nozzle reinforcement and saddle support design and for construction quality requirements.

6.15 Supports and anchors

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

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

NOTE Braces and damping devices may be required to prevent vibration of piping.

Branch connections should be supported by consolidated backfill or provided with adequate flexibility.

When openings are made in a consolidated backfill to connect new branches to an existing pipeline, 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.

Attachments to the pipeline should be designed to keep within safe limits the additional stresses in the pipe wall caused by the attachment.

NOTE 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 butt welds or to a separate cylindrical member which completely encircles the pipe. The encircling member should be welded by continuous circumferential welds.

6.16 Anchor blocks

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 required to restrain a pipeline should be calculated using the following formulae.

Thin wall:

$$F = A\left(E\alpha\left(T_2 - T_1\right) + 0.5\,S_\mathrm{h} - \nu S_\mathrm{h}\right)$$

Thick wall:

$$F = A\left(E\alpha\left(T_2 - T_1\right) + \frac{S_\mathrm{h}}{k^2 + 1} - \nu\left(S_\mathrm{h} - \frac{p}{10}\right)\right)$$

where:

F is the axial force (in N);
A is the cross sectional area of the pipe wall (in mm^2);
E is the modulus of elasticity (in N/mm^2);
α is the linear coefficient of thermal expansion (per °C);
T_1 is the installation temperature (in °C);
T_2 is the maximum or minimum metal temperature (in °C);
S_h is the hoop stress calculated in **6.5.2.2**, but using the nominal pipe wall thickness (in N/mm^2);
k is the ratio of outside diameter to inside diameter, $D_\mathrm{o}/D_\mathrm{i}$ (see **6.5.2.2**);
ν is the Poissons ratio (0.30 for steel);
p is the internal design pressure (in bar).

7 Design of stations and terminals

7.1 Selection of location

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

a) topography;

b) ground conditions;

c) geohazards

d) ease of access;

e) availability of services;

f) requirements for inlet and outlet connections to and from the pipeline;

g) hazards from other activities and adjacent property;

h) public safety and the environment;

i) 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 choice of sites.

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

The location of pipeline facilities within installations, 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. Sufficient access and clearance should be provided at stations and terminals for 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 and the requirements for plant and equipment defined 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. Requirements for access for replacement of equipment should also be considered when routing primary piping.

Vent and drain lines that open to the atmosphere should be extended to a location where fluids may be discharged safely.

7.3 Security

Access to stations and terminals should be controlled. They should be fenced, with gates locked or attended, controlled, and consideration given to terrorist activity.

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

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.

Adequate 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 meet the requirements of 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 may cause injury to personnel should be suitably insulated or protected.

7.4.1 *Fire-fighting facilities*

Terminals and intermediate stations should be provided with fire-fighting facilities which are appropriate to the size and nature of the site following consultation with the local fire authorities. Fire-detection outdoors should be by the use of flame-detection instrumentation. For indoor fire-detection, heat and smoke detectors should be provided. For protection of control rooms consideration should be given to inert gas systems (see BS 5306 series).

Fire detection equipment should be installed to BS 5839-1 recommendations. Fixed fire-fighting equipment should conform to the BS 5306 series.

Portable fire equipment should conform to BS 5423 and be installed in accordance with BS 5306-3.

Reference should be made to the IP Model Code of Safe Practice, Part 2, Marketing Safety Code.

7.5 Environment

Attention is drawn to national and local environmental legislation concerning the disposal of effluent and other discharges.

7.6 Buildings

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

7.7 Equipment

Pumps and compressors, prime movers, their auxiliaries, accessories, control and support systems, should be suitable for the service specified in the system definition 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 component of the pipeline system in which they are installed, within the constraints of the pipeline system as limited by the control identified in **5.4**.

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.

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

Protective devices such as relief valves, pressure-limiting stations or automatic shutdown equipment of sufficient capacity, sensitivity and reliability should be installed to ensure the conditions of **6.2.2.5** are met. Where high reliability of automatic shutdown equipment is required, high integrity protective systems that rely upon instrumentation to protect against overpressure may be used. Where high integrity protective systems are proposed, consideration should be given to hazard rate, redundancy, voting systems and the design of equipment for on-line testing and maintenance of the high integrity protective system.

7.8 Piping

7.8.1 *Primary piping*

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

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

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

b) the station fence or isolating valves themselves may be taken as the point of demarcation.

Piping should be protected against damage from vacuum pressures and overpressures. Pressure control and over-pressure protection should comply with the requirements of **5.4**.

NOTE Piping may be subjected to overpressure or vacuum conditions as a result of surge following a sudden change in flow during valve closure or pump shutdown, excessive static pressure, fluid expansion, connection to high pressures 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 considered 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 noise generated by piping and equipment in the design of station piping. Where noise levels cannot be further reduced by design or equipment selection, consideration should be given to the use of acoustic cladding or enclosures.

7.8.2 *Secondary piping*

7.8.2.1 *Fuel gas piping*

Fuel gas piping within a station should be designed and constructed in accordance with 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.

7.8.2.2 *Air piping*

Air receivers or air storage bottles should be designed and constructed in accordance with PD 5500**.**

7.8.2.3 *Lubricating oil and hydraulic oil piping*

Lubricating oil and hydraulic oil piping within a station should be designed and constructed in accordance with EN 13480.

7.8.2.4 *Vent and drain lines*

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

7.9 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. Consideration should also be given to isolating the station from the pipeline and to relieving or venting the piping system when required.

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

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.

7.10 Electrical

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

Consideration should be given to providing measures for the protection against lightning strikes. These measures should conform to BS 6651.

7.11 Heating and cooling stations

Temperature indication and controls should be provided where heating or cooling of the fluids is required for operation of the pipeline in accordance with **5.1**.

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

7.12 Metering and communication systems

Meters, strainers and filters should be designed for the same internal pressure, and should meet the pressure test requirements of this standard.

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. Consideration should be given to backflow, vibration or pulsation of the flowing stream.

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.

7.13 Monitoring and communication systems

The requirements for monitoring pressure, temperature, flowrate, physical characteristics of the fluid being conveyed, information on pumps, compressors, valve positions, meters and tank levels, alarm conditions and the detection of fire and hazardous atmosphere, 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.

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 Materials and coatings

8.1 General material requirements

8.1.1 *Pipe*

The following material properties should be taken into account to ensure suitability for the application:

a) chemical composition of parent pipe and seam weld;

b) weldability;

c) tensile properties;

d) hardness;

e) fracture toughness and impact resistance;

f) fatigue resistance;

g) corrosion and environmental induced cracking resistance.

For materials subjected to heat treatment, hot or cold forming, or other processes that can affect the material properties, conformance with the specified requirements in the final condition should be documented. Documentation should be provided for parent metal and, as appropriate for welded pipe, for the weld metal and heat-affected zones.

8.1.2 ***Bends***

The requirements for bends should be similar to those required for linepipe. Consideration should be given to properties of the material following formation of the bends.

8.1.3 ***Flexible pipe***

The design information required for the selection of the materials and fabrication of flexible pipes, hoses and end fittings is similar to that required for pipeline materials selection.

The type of service, design life, bore size and working pressure should determine the basic type of flexible fabrication, which should accommodate the following:

a) any additional mechanical requirements for the following:
    1) fatigue resistance;
    2) vacuum resistance;
    3) resistance to external pressure;
    4) tensile strength;
    5) stiffness;
    6) minimum bend radius;
b) materials changes necessitated by likely degradation by the product being carried or by the external environment;
c) materials changes necessitated by possible galvanic corrosion between contacting dissimilar metals in an internal or external environment;
d) materials changes necessary to prevent or restrict the escape of product through the pipe wall, such as permeation by product gas.

8.1.4 ***Fittings***

The selection should be based on the same properties as considered for line pipe and the suitability of the materials for particular requirements such as the following:

a) compatibility with line pipe;
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, consideration should be given to the prevention or control of galvanic corrosion between these metals. Special consideration should be given to areas where corrosive substances may accumulate or where chemical inhibition may be ineffective.

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

8.1.5 *Coatings*

The properties required of a coating may vary along the pipeline and several types of coating may be required. When selecting each coating system, either for internal or external application, the following should be considered:

a) resistance to moisture penetration;

b) electrical resistivity;

c) ease of application and repair;

d) integrity of coating;

e) adhesion;

f) resistance to damage;

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.

8.2 Line pipe

8.2.1 *General*

the following:

Carbon and alloy steel pipe should conform to BS EN 10208-1, BS EN 10208-2 or BS ISO 3183-3, as appropriate. Line pipe conforming to BS EN 10208-2 or BS ISO 3183-3 should be used for applications where fracture toughness is required. BS ISO 3183-3 should be used for applications in sour service.

High alloy steel and other corrosion resistant alloy pipe should conform to an appropriate standard suitable for the proposed application.
Consideration should be given to the need for conformance with BS EN 10208-1, BS EN 10208-2 or BS ISO 3183-3, as appropriate.

For clad pipe, carbon steel line pipe should conform to BS EN 10208-1, BS EN 10208-2 or BS ISO 3183-3, as appropriate. The design and internal corrosion evaluation should address whether the internal stainless steel or non-ferrous metallic layer should be metallurgically bonded (clad) or be mechanically bonded (lined) to the outer carbon steel pipe. The minimum thickness of the internal layer should not be less than 3 mm in the pipe and at the weld.

For polymer lined pipe, the basis for selection of the polymeric lining should be demonstrated. This should include, as a minimum, a full test program of the bond strength, the mechanical strength of the liner and the corrosion resistance of the liner material under operational conditions.

8.2.2 *Dimensions*

The following pipeline dimensions should be specified:

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

b) nominal wall thickness;

c) tolerances on diameter and wall thickness.

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.

The dimensions specified should be in accordance with the defined material standard, see **8.2.1**.

8.2.3 *Materials specification*

All materials for line pipe should be manufactured and used in accordance with the relevant material specification and this standard.

The specification should clearly identify the linepipe quality standard. The structure and layout of the material specification should reflect the structure of the appropriate referenced linepipe standard.

8.2.4 *Chemical composition and weldability*

The material should have a weldability adequate for all stages of manufacture, fabrication and installation of the pipe. Weld consumables should be selected to avoid the formation of anodic weld metal, which can produce the selective corrosion of weld metal in corrosive environments. Consideration should be given to weldability testing of girth welds at the procurement stage.

The susceptibility of carbon and alloy steel material to hydrogen cracking, due to hardness in the heat affected zone (HAZ), should be controlled by restricting the allowable value of carbon equivalent, CE. For traditional carbon manganese steel, the carbon equivalent formula should be used, where:

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

For low carbon content micro-alloyed steel, the P_{cm} formula should be used where:

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

The maximum values for CE and P_{cm} used should be obtained from published literature or weldability tests.

The hydrogen induced cracking (HIC) resistance of pipeline steels for sour service should be demonstrated by testing in accordance with NACE TM0284, with the exception of high alloy steels and non-ferrous materials, for which this testing is unnecessary.
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 will tend 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.

> NOTE NACE MR0175 gives recommendations on materials for use in a sour service environment to prevent sulphide stress corrosion cracking (SSCC).

8.2.5 ***Fracture toughness***

The material's fracture toughness properties should be based on the product, service conditions and avoidance of a running shear fracture.

Consideration should be given to testing at a range of temperatures to obtain a Charpy impact transition curve.

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

For high strength steels it may be necessary to use integral or mechanical crack arrestors to ensure an arrest of a running ductile fracture.

Linepipe for use in pipelines conveying category D fluids should meet the Charpy Energy values in BS EN 10208-1, BS EN 10208-2 and/or BS ISO 3183.

It may be necessary to supplement the Charpy testing with CTOD testing carried out in accordance with the appropriate material standard.

Data from the CTOD test (if necessary) should be used to establish fracture control limits and to perform an engineering critical assessment (ECA) for a known, or postulated, future defect.

NOTE BS 7910 provides guidance on carrying out ECAs.

Consideration should be given to other techniques such as J-integral, wide plate testing or drop weight tear testing.

8.2.6 ***Fatigue***

Where the mechanical design has identified fatigue loadings, analysis should be based upon fracture mechanics methods (see BS 7910) or methods utilizing fatigue testing (S-N curve) data. Fatigue testing should be carried out in accordance with BS 3518.

8.2.7 ***Corrosion and cracking resistance***

If corrosion resistant alloy (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.

8.2.8 ***Elevated temperature service***

The mechanical properties at the maximum operating temperature of materials for operations above 50 °C should be documented unless specified in the relevant product standard or complimentary justification.

8.2.9 ***Marking***

Marking should be in accordance with the requirements of the relevant material standard.

8.2.10 ***Inspection documents***

All linepipe materials should be supplied with an inspection document in accordance with ISO 10474. For linepipe, an inspection certificate type 3.1.B should generally be supplied as a minimum.

8.3 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 is not allowed to enter the branch or become stuck.

8.3.2 ***Flanged connections***

Flanged connections should meet the requirements of ISO 7005-1, or other recognized codes such as ASME B16.5 or MSS SP-44. Proprietary flange designs are permissible. They should conform to relevant sections of PD 5500 or ASME Section VIII, Division 1.

Compliance with the design requirements should be demonstrated when deviating from the flange dimensions and drillings specified.

External loadings should be considered in addition to operational loads. Engineering analysis should be conducted to verify the integrity of the joint. Finite element analysis may be considered.

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

Gaskets should be made of materials which are not damaged by the fluid in the pipeline system and should be capable of withstanding the pressures and temperatures to which they should be subjected in service. The risk of galvanic corrosion should be fully assessed. Consideration should be given to use of corrosion resistant alloy materials in areas at risk from crevice corrosion such as ring type joint grooves and flange facings.

Bolt materials should conform to grade B7M in accordance with ASTM A193 and nut material should conform to grade 2HM in accordance with ASTM A194 for carbon steel flanges, except where operational temperatures fall below the design limitations of the stated materials when ASTM A320 grades L7 and 7should be used, respectively.

For non-carbon steel pipelines, bolting 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 requirements should be in accordance with NACE MR0175. For bolted connections where bolt tensioning devices are to be used, additional bolt length should be provided as applicable.

The specification of materials fracture toughness and hardness, to prevent brittle fracture of high strength bolting, should be considered if the bolting is to be exposed to corrosive conditions or cathodic protection.

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

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

8.3.3 *Bends*

8.3.3.1 *Methods of manufacture*

Bends made from straight pipe should be hot bent, cold bent or induction bent. It is essential for pipeline integrity that mitre bends are not used.

8.3.3.2 *Pipe properties*

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

8.3.3.3 *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 may be required if inspection vehicles or well tools are to be used in the line.

If the wall thickness falls below the minimum specified for the pipeline, the bend should be rejected. An allowance should be made for thinning of the parent pipe during bending.

Longitudinal welds should be positioned on the neutral axis of the bend.

Wrinkling of the pipe surface should not be permitted.

8.3.4 ***Fittings***

8.3.4.1 *General*

Other pipeline fittings including connectors, elbows, tees, end caps, reducers and cast or forged transition pieces should be made from fully killed steel and should be made using recognized practices to provide the intended heat treatment response and notch toughness properties.

Steel should be compatible with the adjoining line pipe.

8.3.4.2 *Threaded joints*

All pipe threads on piping components should be taper pipe threads in accordance with BS 3799 or ANSI B16.11. The installation of threaded joints (including compression fittings) should be discouraged on buried piping systems.

8.3.5 ***Valves***

8.3.5.1 *Valve selection*

Valve selection should include consideration of the following service characteristics:

a) system operating pressure and hydrostatic pressure;

b) all fluids to which the valve may be exposed;

c) service temperatures (this may include low internal temperatures due to system depressurization);

d) service life;

e) duration of precommissioning period (valves may remain static in open or closed positions for long periods but have to be able to function on demand);

f) presence of debris from product or construction activities;

g) system pigging;

h) in situ seal injection or replacement;

i) installation method;

j) ability to test the valve performance;

k) internal galvanic corrosion;

l) reliability;

m) maintenance aspects;

n) actuation;

o) 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 required to accommodate specialist bolt tightening equipment. In-line valves should allow the passage of inspection vehicles.

8.3.5.2 *Control of valves*

Control system selection and design should include consideration of the following:

a) type of actuator;

b) valve function;

c) required response time;

d) distance from control source;

e) specification of secondary control systems for emergency isolation valve;

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

8.3.6 ***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 comply with PD 5500 or ASME Boiler and Pressure Vessel Code, Section VIII Div. 1.

The pig trap should be oriented to allow adequate space and facilities should be provided to open the closure and load/unload pigs.

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 Boiler and Pressure Vessel Code, Section VIII Div. 1.

8.3.7 *Insulation joints*

Insulation joints should be designed in accordance with PD 5500 or ASME VIII Div 1.

The design should take account of vibration, fatigue, cyclic conditions, low temperature, thermal expansion and construction installation stresses.

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.

8.3.8 *Other pressure-containing parts*

Other pressure-containing parts for which there is no product standard should be designed with reference to PD 5500 or ASME VIII Div. 1.

8.4 Coatings

8.4.1 *General*

General requirements for corrosion coatings and internal coating systems are given in clause **9**.

8.4.2 *External coatings – concrete*

Concrete weight coating should conform to a specification that covers the following requirements as a minimum:

a) composition of the concrete;

b) required mechanical properties and test requirements;

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.

8.4.3 ***External coating for corrosion prevention and thermal insulation systems***

Corrosion and insulation coating should conform to **9.4** and **9.5**.

All materials should have an established capability for the intended duty including the ability to withstand the hydrostatic load for the design life, as required, depending on the their exposure to the environment.

A suitable outer coating or sheathing should be applied to protect the insulation coating.

8.4.4 ***Internal coatings/linings***

Internal coatings should in general conform to**9.3.5** if applied to mitigate internal corrosion.

Anti-friction coatings should as a minimum conform to API RP 5L2 and have a minimum thickness of 40 µm.

NOTE The coating may consist of an epoxy base and a curing agent based on epoxy aliphatic/cycloaliphatic amine or polyamide.

9 Corrosion management

9.1 General

Buried or submerged pipeline sections may 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 suitable anti-corrosion coatings and effective cathodic protection. If cathodic protection will not be effective on or is not applicable to minor parts of the pipeline section, extra care should be taken to exclude coating defects on these parts.

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

Internal corrosion may 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.

Consideration should be given during the design and construction of the pipeline to the requirements and recommendations for coatings and cathodic protection when selecting an appropriate corrosion protection system. Whenever possible, all components of the pipeline should be factory coated before delivery to site.

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

a) identification and evaluation of the potential sources of corrosion;

b) selection of the pipeline materials;

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

d) identification of the necessary corrosion mitigation;

e) definition of the requirements for corrosion monitoring and inspection;

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.

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

The evaluations should be based on relevant operating and maintenance experience, 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.

Coating property requirements are outlined in **8.1.5**.

Where coated line pipe is to be stored in the open, a protective outer coating should be applied to within 300 mm from each end.

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

The 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 *Methods*

Methods for the mitigation of internal corrosion include:

a) modification of operating conditions;

b) the use of corrosion-resistant materials;

c) the use of chemical additives;

d) the application of internal coatings or linings;

e) the use of regular mechanical cleaning;

f) the elimination of bimetallic couples.

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

9.3.2 *Revision of design conditions*

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

9.3.3 *Corrosion-resistant materials*

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

NOTE External corrosion issues may be overcome through selection of an appropriate external coating.

9.3.4 ***Chemical additives***

Where chemical additives, i.e. corrosion inhibitors, are used to control internal corrosion, sufficient 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 considered.

Factors to be considered during the selection of chemical additives should 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.

9.3.5 ***Internal coatings or linings***

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

Where internal coatings are used to control corrosion they should be applied in accordance with the quality specifications and dry film thickness requirements established for suitable protection of the pipe material from the substance being conveyed, and the operating regime employed. Reference should be made to API RP 5L2 for recommended practice for internal coating of pipelines.

If pipes are joined by welding such that metal is exposed, consideration should be given to internal coating of the joint area or the use of a suitable inhibitor. Account should also be taken of the internal coating in the selection of pigs to prevent coating damage during pigging.

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

a) internal coating of field joints;

b) application methods;

c) availability of repair methods;

d) operating conditions;

e) long-term effects of the conveyed fluid(s) on the coating/lining;

f) resistance to chemical attack;

g) resistance to pressure change;

h) influence of temperature gradients over the coating;

i) compatibility with pigging operations;

j) physical durability.

k) level of quality control that can be achieved

9.3.6 *Cleaning*

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

— the possible consequences of removing protective layers of corrosion products or chemical additives, or damage to internal coatings or linings, by mechanical cleaning;

— the possible adverse effects of contacts between pipeline materials, such as stainless steels, and the materials of mechanical cleaning devices.

9.4 External corrosion evaluation

The possibility of external corrosion occurring should be determined on the basis of pipeline operating temperatures (see **6.2.2**) and the external conditions along the pipeline (see **6.3**).

Pipelines should be designed and routed to take account of the possible corrosive effects of contaminated or industrial waste ground, naturally aggressive ground, parallel encroachments to a.c. power lines or cables, pylons and stray d.c. earth currents. Parallel a.c. power lines can induce a.c. voltages on pipelines. These voltages can be a shock hazard during construction and operation of the pipelines and can cause a.c. corrosion. A.C. corrosion can occur even at very low a.c. voltages, if the pipeline is cathodically protected. Computer modelling may be required to assess the risk from induced a.c. at the design stage, field measurements can be used on existing pipelines.

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.

Environments which should be considered when evaluating the possibility of external corrosion include:

a) pipelines on land;

b) atmosphere (marine/industrial/rural);

c) sea water (tidal zone/shore approach);

d) fresh or brackish water;

e) marshes and swamps;

f) river crossings;

g) dry or wet soil;

h) inside tunnels, sleeves or caissons.

Environmental parameters that should be considered include:

— ambient temperatures;
— resistivity, salinity and oxygen content of the environment;
— bacterial activity;
— water current;
— degree of burial;
— potential in-growth of tree roots;
— potential soil pollution by hydrocarbons and other pollutants.

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

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

— general metal loss and degradation;
— localized corrosion, e.g. pitting under deposit or crevice attack;
— microbiologically induced corrosion;
— stress-corrosion cracking, e.g. carbonate/bicarbonate attack.

9.5 External corrosion mitigation

9.5.1 *Protection requirements*

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

9.5.2 *External coatings*

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

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 adequate resistance to cathodic disbondment. External line pipe coatings should be factory-applied, except for field joints and other special points which would be coated on site. A factory-applied coating is preferred for all pipeline components to ensure adequate surface preparation and coating application under controlled conditions.

Parameters to be considered when evaluating the effectiveness of external coatings should 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 pipeline and the linepipe coating and the cathodic protection system. It should give a durable bond with both the factory applied coating and the steel surface. The field applied coating should meet or exceed the line-pipe coating specification and allow satisfactory application under the predicted field conditions.

Consideration should be given to the use of a hard, abrasion-resistant, compatible external coating such as a polyurethane, FBE or two component epoxy resin system where coated pipe is to be installed by thrust boring or similar “trenchless” methods.

Where additional mechanical protection has been installed, direct contact with the surrounding soil should be maintained.

In order to avoid corrosion under any insulasion, an external coating may be required between the pipeline and the insulation.

> NOTE For components of irregular shape, different external coating materials to those used for linepipe 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 minimum distance of 500 mm.

9.5.3 ***Cathodic protection***

9.5.3.1 *General*

Defects in the external coating systems enable surrounding corrosive environments to come into contact with the pipeline steel and allow electric corrosion currents to flow, resulting in pipeline corrosion. A cathodic protection system should be installed to mitigate against corrosion. The pipeline section to be cathodically protected should be electrically continuous and should have adequate longitudinal conductivity.

Cathodic protection may be applied by either the sacrificial anode or impressed current anode method and should be designed and constructed in accordance with BS 7361-1 or other internationally recognised standards.

The cathodic protection system should be brought into operation as soon as possible following pipeline construction. Where delays are unavoidable, the use of temporary sacrificial anodes should be considered, particularly in areas with corrosive ground conditions. The application of cathodic protection to a pipeline may cause adverse effects on other buried metallic structures close to the protected pipeline and the procedures of BS 7361-1 or other internationally recognised standards should be followed.

Above-ground sections of pipelines should be electrically isolated from the buried sections and should not carry cathodic protection currents.

9.5.3.2 *Cathodic protection potentials*

Cathodic protection potentials should be maintained within the limits given in Table 5 and accompanying Notes throughout the design life of the pipeline.

Table 5 — Cathodic protection potentials for non-alloyed and low-alloyed carbon steel pipelines

Reference electrode		$Cu/CuSO_4$	Ag/AgCl
Water and low-resistivity soil Resistivity <100 Ω.m	Aerobic T < 40 °C	–0.850 V	-0.800 V
	Aerobic T > 60 °C	–0.950 V	-0.900 V
	Anaerobic	–0.950 V	-0.900 V
High-resistivity aerated sandy soil regions	Resistivity 100 Ω.m to 1000 Ω.m	–0.750 V	-0.700 V
	Resistivity > 1000 Ω.m	–0.650 V	-0.600 V

NOTE 1 Potentials in this Table and in NOTE 4 apply to line pipe materials with (specified minimum yield strengths of 550 MPa or less).

NOTE 2 The possibility for hydrogen embrittlement should be evaluated for steels with (specified minimum yield strengths of 550 MPa or less).

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

NOTE 4 The protection potential at the metal-medium interface should not be more negative than –1,150 V in case of $Cu/CuSO_4$ reference electrodes, and -1,100 V in case of Ag/AgCl reference electrodes. However, the protection potentials given can be used.

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

NOTE 6 If the protection levels for low-resistivity soils cannot be met, then these values may be used subject to proof of the high-resistance conditions. Where the environment cannot be characterised with confidence, then the more negative potential criteria should be adopted.

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

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

The protection potential criteria shown in Table 5 apply to the metal-medium interface. In the absence of interference currents this potential corresponds to the instantaneous “off” potential.

9.5.3.3 *Design*

9.5.3.3.1 *General*

The cathodic protection system should be designed in accordance with BS 7361-1 or other internationally recognized standards.

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 effect current demand. Coating degradation, coating damage during construction and from third-party activities, and metal exposure over the design life should be predicted and taken into account when determining the design current densities.

The design of the cathodic protection system should ensure 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 by appropriate measures.

9.5.3.3.2 *Sacrificial anodes*

The design of sacrificial anode 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 conditions;

d) applicable standards;

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) number and design of the anodes and their distribution;

j) protection against the effects of possible a.c. and/or d.c. electrical interference.

9.5.3.3.3 *Impressed current*

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

Design documentation should include reference to:

a) pipeline design life (see **5.1**);

b) pipeline operating conditions;

c) design criteria and environmental conditions;

d) requirements for electrical isolation;

e) calculations of the pipeline area to be protected;

f) current density requirements

g) anode ground bed design and location, its current capacity and resistance and the proposed;

h) cable installation and protection methods;

i) measures required to mitigate the effects of possible a.c. and/or d.c. electrical interference;

j) protection requirements prior to the commissioning of the impressed current system;

k) applicable standards.

9.5.3.3.4 *Connections*

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

The design of the connections should consider:

a) the requirements for adequate electrical conductivity;

b) the requirements for adequate mechanical strength and protection against potential damage during construction;

c) the metallurgical effects of heating the line pipe during bonding.

9.5.3.4 *AC Mitigation*

If personnel safety is at risk from ac voltages on the pipeline or if an a.c. corrosion risk exists, unacceptably high a.c. voltages on a pipeline should be prevented by designing and installing mitigation measures. These may include:

— earthing laid parallel and connected to the pipe;

— earthing mats at valves;

— connection of polarisation 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

Any earthing must have a very low resistance to remote earth and must be compatible with the cathodic protection system. Its effect on specialised pipeline surveys must also be considered.

A method of monitoring the risk of ac corrosion e.g. 1cm^2 coupons, may need to be installed at the test posts.

Mitigation measures should be considered at the design stage and this may be done by computer modelling the power line/ pipeline right of way. This modelling should take into account future variations in load on the power line. The retrospective installation of mitigation measures may also be considered but carries a risk of ac corrosion occurring before installation is complete and the installation of further mitigation measures may be required if the power line load increases.

9.5.3.4 *Specific requirements for pipelines*

Cathodic protection of long cross-country pipelines should normally be provided by impressed current.

Sacrificial anode systems should be considered for short pipelines particularly in built-up areas. Consideration should be given to the suitability of backfill material at anode locations.

Protected pipelines should, where practical, be electrically isolated from other structures, such as compressor stations and terminals by suitable in-line isolation components to confine cathodic protection to the buried pipeline system.

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

The cathodic protection system should be designed and the pipework installed in such a way as to minimize adverse effects on other buried metallic structures.

Low-resistance grounding to other buried metallic structures should be avoided as far as is reasonably practical.

Pipelines should be isolated from structures such as wall entries and restraints made of reinforced concrete, earthing conductors of electrically operated equipment and from bridges.

The possibility of corrosion on the unprotected side of isolation joints should be considered when low-resistance electrolytes exist internally or externally.

Electrical continuity should be provided across components, other than isolation joints/insulated flanges, which would otherwise increase the longitudinal resistance of the pipeline.

Spark gaps should be installed across isolation joints/insulated flanges to protect the insulation materials from breakdown due to high voltage surges. Careful note should be taken of hazardous area requirements for such equipment.

The corrosion protection requirements of pipeline sections within sleeves or casing pipes should be identified and applied.

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

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

a) crossings with d.c. traction systems;

b) road, rail and river crossings and large embankments;

c) sections installed in sleeve pipes or casings;

d) isolating couplings;

e) where pipelines run in the vicinity of power transmission systems.;

f) sheet piles;

g) crossings of other major metallic structures with, or without, cathodic protection.

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

NOTE The required test point spacing depends on soil conditions, terrain and location but is normally limited to a maximum of 1 km.

The use of doubler plates should be considered when connecting anodes and cables to pipelines.

Possible interference from extraneous current sources in the vicinity of a pipeline and the possible effect of the cathodic protection of a new pipeline on existing protection systems should be evaluated. The possible shielding by thermal insulation and pipeline protection systems (slabs, covers, etc.) should also be considered where appropriate. .

9.5.3.5 *Cathodic protection system commissioning*

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

For all cathodic protection systems, the appropriate actions from the list below should be executed early in a system's life:

a) visual inspection of anodes and pipeline coatings during installation;

b) testing of power supplies;

c) completion of an initial cathodic protection survey including:

   1) testing for detrimental stray or interference currents;

   2) measurement of current demand;

   3) testing of isolating couplings;

   4) measurement of the cathodic protection potentials along the length of the pipeline;

d) corrective measures if the specified protection is not achieved;

e) provision of commissioning records.

As soon as possible after commissioning, a close interval potential survey (CIPS) of the entire pipeline should be undertaken to prove the system.

9.6 Monitoring programmes and methods

9.6.1 *Requirement for monitoring*

The requirements for 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.

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

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

9.6.2 *Monitoring internal corrosion*

9.6.2.1 *Selection of techniques*

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

a) anticipated type of corrosion;

b) potential for water separation, erosion, etc. (flow characteristics);

c) anticipated corrosion rate (see **9.2**);

d) required accuracy;

e) available internal and external access;

f) hindrance of passage of pigs or inspection vehicles by internal obstructions.

NOTE Possible techniques 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*

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 may occur. The installation of additional probes in areas of high velocity flow should be considered.

9.6.3 ***Monitoring external pipeline condition***

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

> NOTE Periodic close interval potential surveys of the pipeline can be considered for this purpose when the area of possible severe attack cannot readily be visually examined.

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

9.6.4 ***Monitoring cathodic protection***

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

The frequency of these surveys should be based on:

a) the method of cathodic protection;

b) the uniformity of soil properties along the pipeline;

c) the coating quality;

d) safety and environmental concerns;

e) possible interference from electrical sources

f) alteration in pipeline operating conditions (i.e. temperature).

The possible hindrance from a.c. or d.c. interference during the surveys and the interpretation of the results should be considered during the selection of the survey method.

Close interval potential surveys (CIPS) 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 program. Such surveys are recommended when abnormal coating damage, severely corrosive conditions and/or stray current interference are suspected.

9.7 Evaluation of monitoring and inspection results

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, CIPS 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 a requirement for further detailed assessment of the pipeline condition;

d) indicate the need to modify the corrosion management requirements.

9.8 Corrosion management documentation

Documentation should be prepared describing the following in accordance with the requirements for corrosion management given above (see **9.1** to **9.6**):

a) the assessment of the corrosion threats and associated potentials for failure;

b) the choice of materials and corrosion mitigation methods;

c) the selection of inspection and corrosion monitoring techniques and inspection frequencies;

d) any specific decommissioning and abandonment requirements associated with the selected corrosion management approach.

10 Construction

10.1 General

Work should be carried out in such a way as to ensure the safety of the workforce and third parties and the protection of property.

Competent personnel, capable of assessing the quality of the work within the scope of this standard, should be employed for the supervision and execution of the construction project.

Contractors appointed by the operator should possess the qualifications necessary for the execution of the work. The operator should satisfy itself that the necessary qualifications are held.

The safety and reliability of a pipeline system may be improved by the application of quality assurance procedures in construction. In this respect reference should made to **4.3**.

10.2 Safety and legislation

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.

There is a statutory requirement to provide for the health, safety and welfare of all employees and members of the public in connection with the design, construction, operation and maintenance of pipelines under the Factories Act 1961, the Factories Act (Northern Ireland) 1965, the Health and Safety at Work etc. Act 1974, the Health and Safety at Work (Northern Ireland) Order 1978, the Construction Design and Management (CDM) Regulations 1974 and Regulations enacted under these. Attention is also drawn to guidance notes published by appropriate Authorities.

Account should be taken of the Construction Design and Management Regulations (CDM) Construction (Lifting Operations) Regulations [9]. Reference should also be made to the Ionising Radiations Regulations 1985 and The Pressure Systems and Transportable Gas Containers Regulations 1989.

NOTE Compliance with the Acts and Regulations requires knowledge of the relevant statutory notices, registers, records and forms.

A safety management plan should be outlined, highlighting the relevant procedures, codes of practice and standards to be implemented in managing the works.

Instruction, training and equipment should be provided, along with adequate supervision for employees working on all elements of the project.

Supervisors should be responsible to ensure that the approved safety procedures are implemented.

10.3 Construction plan

A construction plan should be prepared 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 health, safety and environment plan;

c) a quality plan.

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

NOTE Special construction, such as that needed for tunnels, landfalls for offshore pipelines, pipeline bridges and horizontal directional drilling, may require supplemental pipeline installation procedures.

The health, safety and environment plan should describe requirements and measures for the protection of:

a) the health and safety of the public;

b) personnel involved in the construction;

c) the environment.

It should contain the requirements of the relevant legislation and applicable standards, identification of hazards and measures required for their control, and emergency procedures.

10.4 Construction near other facilities

All facilities that may be affected by construction of the 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/or 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.

> EXAMPLES Facilities that may be affected include existing roads and railways, watercourses, footpaths, pipelines, cables and buildings.

10.5 Plant and equipment

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

10.6 Transport and handling materials

A material control system should be adopted to monitor material through receipt at site, storage and issue.

The handling of material should be carried out in a diligent manner to avoid damages.

Transport and handling procedures may be required, which should identify the equipment to be used and the stacking requirements.

> NOTE American Petroleum Institute publications API RP 5LW and API RP 5L1 provide guidance for the transport of line 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 coating damage. Where minor damage to coating 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-conformance with the relevant specifications. Pipes should be visually inspected for possible damage in transit and rectified before stringing. These materials should not be installed unless the damage and/or defect has been removed or corrected.

If an electromagnet is used to lift the line pipe, the residual magnetism should be measured. If residual magnetism exists it should be considered that problems can occur when arc welding is used.

During storage the pipes should be protected against corrosion, supported off the ground and, where required, separated from one another by suitable means (refer to **9.1**).

10.7 Construction supervision

The pipeline designer and construction contractor should ensure that competent and experienced staff are 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. In the U.K. this is generally between the spring and late October with an additional period of one month for 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*

It is essential to have direct communications between the construction central base office and the working areas to ensure efficiency in operations. Modern equipment should be used and the work force should be competent in the use of this equipment.

10.9.2 *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.

10.9.3 *Contract documents*

The construction contract documents should clearly define the scope of work required to install the works. They should include any constraints and special methods of installation that have been agreed with any third parties, this allowing the contractor to include for these requirements in his tender submission.

10.10 Environmental considerations

10.10.1 *General*

Work should be carried out with minimum disturbance to the environment. Care should be taken not to create pollution, especially in areas which could impact surface or ground water courses.

It is essential that the project establishes an environmental management plan so that the work can be conducted within current codes of practice.

10.10.2 ***Noise abatement***

Existing regulations that establish acceptable levels of noise generated during construction operations are in force. The requirements for noise thresholds should be stipulated in the contract documentation so that suitable plant and equipment can be sourced for the works. In certain scenarios it may be necessary for the contractors to provide special equipment such as acoustic screens to reduce noise levels.

10.10.3 ***Water***

Fuel and chemical spillage should be avoided. Where necessary provisions should be made to ensure that water courses are not polluted.

10.10.4 ***Traffic***

In order to carry out the construction works efficiently, consideration shall be given to the implementation of a traffic plan. This plan should be discussed with the local authorities at the earliest opportunity to ensure that local requirements are catered for. The plan shall ensure that minimal disturbance is caused to local traffic, and where necessary should include for clearly defined plans for diverting traffic. Consideration should be given to pedestrians when planning the works, by provision of signing and alternative walkways where necessary.

10.11 Preparation of the route

10.11.1 ***Entry upon land***

10.11.1.1 *Preparation*

The promoter should arrange for representatives, e.g. agricultural liaison officers, to maintain close personal contact with occupiers. Initial contact should be well before construction is to commence and should continue until reinstatement is complete and compensation for damage has been paid. The promoter’s representatives should discuss with the occupiers the 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 over and above any statutory period should be given to individual owners and occupiers and to any authority affected. Each of these should be given the address and telephone number of the representatives of the pipeline promoter to whom any complaints or requests are to be made.

Advance provision should also be made for any land required for storing pipes and other materials, for parking and maintaining equipment, and for the siting of temporary offices, camps, sanitary facilities, etc.

10.11.1.2 *Working width*

As far as practicable, the working width should have been 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 should be negotiated by the promoter. In deciding upon the extent of any extra working width there should be recognition of the ground terrain and conditions at the following locations:

a) at major road, rail, river and canal crossings;

b) where deep pipelines are being installed;

c) where it is necessary to go beneath existing underground services;

d) where it is necessary to go beneath ditch and stream crossings and land drainage;

e) where it is necessary to stack separately various subsoil bands and topsoil to ensure correct order of replacement.

10.11.1.3 *Infected areas*

Wherever an area has been declared an infected area on account of foot and mouth disease, swine vesicular disease, fowl pest, swine fever or other notifiable disease, entry on the land for any purpose should be suspended, except with the approval of the Department for the Environment, Food and Rural Affairs (DEFRA) in England and Wales, the Scottish Executive Rural Affairs Department (SERAD) in Scotland or the Department of Agriculture and Rural Development (DARD) in Northern Ireland.

Reference should be made to annex D.

Entry will be governed by such conditions as may be stipulated or agreed. Promoters in conjunction with owners and occupiers directly affected by the pipeline should take such reasonable precautions as may be necessary to avoid the spreading of soil borne pests and diseases, e.g. *Rhizomania*.

Infected areas are not necessarily declared when a notifiable disease outbreak is confirmed, although this action is invariably taken with foot and mouth disease.

Precautions should therefore be taken when there are outbreaks in an area or when individual infected farms are declared to have animals infected with notifiable disease.

10.11.1.4 *Record of condition*

Before work starts, a record should be made of the state of the land including photographs where appropriate. Particular note should be made of the depth of the topsoil and any special features, so that they may be adequately reinstated if disturbed. This record should be agreed with the occupier and, wherever possible, the owner. The cost of preparing it will be borne by the promoter.

The method of dealing with any trees growing within the working width should be agreed before work commences. Where trees within the proposed working width are not to be felled, it may be necessary to make slight deviations in the alignment of the pipeline or additional working width may be required to allow the passage of equipment. Where special protective works exist or are required on account of a notifiable disease, the fact should be noted in the record.

10.11.2 ***Site inspections***

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:

a) the requirements of the users/owners of the land during construction; and

b) the condition of the items potentially affected by construction.

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 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 the Divisional Office of DEFRA (in England and Wales), SERAD (in Scotland) or DARD (in Northern Ireland).

10.11.3 ***Trespass***

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.

10.11.4 ***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 considered.

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 practical.

The limits of the working width should be marked by installing colour co-ordinated pegs prior to installation of temporary fencing. All marking should be maintained in good condition during the construction period.

10.11.5 ***Preparation of the working width***

10.11.5.1 *Clearing and grading*

Preliminary work in pipeline construction should include, erection of temporary fencing, 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 and occupiers.

Constraints or precautions to be observed within the working width should be defined in the construction specifications.

> NOTE 1 Such constraints or precautions may include preservation of specific trees, disposition of trees and stumps, separation of topsoil, drainage, and scour and erosion prevention.

Trees should not be felled unless absolutely necessary and special precautions will need to be taken where any tree within the working width is subject to a preservation order.

Where trees have been felled, any resulting timber will, in the absence of any arrangement to the contrary, remain the property of the landowner. The removal of any roots of trees felled 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. The width and depth of stripping of topsoil will be governed by individual circumstances, however, the depth will not normally exceed 300 mm (12 in) unless otherwise agreed with the occupier.

NOTE 2 Heathland and moorland are generally designated as requiring special construction measures to protect heathers and grasses from permanent damage. Limits may 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 top soil 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 3 This may necessitate the grassing over of the stacked topsoil. In addition if prolonged exposure is encountered it may be necessary to carry out spraying of the stacked topsoil for weed control.

The land should be restored to its original contours and the topsoil replaced, unless otherwise arranged with the landowner.

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 4 To assist in maintaining dry working conditions it may be appropriate to install header drains parallel and outside the working width boundaries.

10.11.5.2 *Temporary fencing*

Provision should be made for restricting access to the working areas from public access points.

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 adequately marked in agreement with the occupier.

NOTE 2 Fencing may also be required to protect areas of special interest i.e. trees and environmentally sensitive areas.

All temporary fences should be maintained until work on the section is completed, the ground fully restored and permanent walls, fencing, or hedges reinstated. In no case should nails or staples be driven into trees. 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. 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.

NOTE 3 Temporary bridging and widening of access roads for the passage of plant and equipment may be required.

All temporary fencing, access bridges and access roads should be to a reasonable standard agreed with the occupier. Additional precautions may need to be undertaken where infectious disease is encountered.

The removal of temporary fencing should be carried out in consultation with the occupiers.

10.11.5.3 *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.

Fencing should be provided to prevent free access to the site with particular attention given to excavations, open pits and boreholes. Care should be taken to avoid accidents to children who may trespass on the site. If the entrance to a site crosses a public road or footpath this should be kept clear of obstructions, mud and spoil.

10.11.5.4 *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.

10.11.6 *Blasting*

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 consideration 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 may be affected by blasting.

Attention is drawn to the danger of unexploded charges. The promoter's as-built records should indicate where explosives were used.

NOTE Detailed guidance may be found 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.

> NOTE Where the spread exceeds 15 km it is advisable to appoint additional Agricultural Liaison Officers.

10.12.2 *Pipe stringing*

Stringing of the pipes end to end 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 utilised.

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 on suitable cushioned packaging to prevent damage to the pipe or coatings, and in a manner to ensure that they remain safely where placed until incorporated in the pipeline.

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.

Measures should be taken to prevent rolling and to ensure stability of pipe.

After stringing but before alignment for welding, pipe ends should be inspected for 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 adequate temporary communications across the works until normal access has been restored. The temporary access across the working width should, where necessary, be provided with properly hung swing gates which effectively prevent livestock straying on to the working width.

10.12.4 *Elastic bending*

Pipe may be flexed to a radius of curvature that does not induce a bending stress exceeding 85 % of the specified minimum yield stress. Parameters should be specified in the construction specification.

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 specified for straight lengths.

Cold bends of a radius less than 40 pipe diameters may be made in the field providing:

a) the quality control conditions are equivalent to those applicable to an established bending shop;

b) the finished bends comply with **8.3**;

c) pipe material is selected to comply 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} of greater than 70:1, consideration should be given to the use of an internal mandrel to prevent local buckling.

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 ensure compliance with the specification for ovality.

10.12.6 ***Factory bends***

Factory bends may be used where topography or other restrictions exist. Refer to **8.3.3** for details.

10.12.7 ***Linepipe 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 providing that the resulting wall thickness is not less than the design thickness given in **6.2.3.1**. 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 which 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.

CAUTION Insert patching or knocking out of the dent is not permitted..

10.12.8 *Lining up for welding*

Care should be taken to ensure that pipes are supported adequately during lining up for welding operation to avoid damage to coating, and to enable sufficient clearance for the welding, weld inspection and coating activities in a safe manner.

10.12.9 *Welding*

10.12.9.1 *General*

The welding of pipeline systems should be carried out in accordance with BS 4515-1 and BS 4515-2.

10.12.9.2 *Night caps*

Suitable 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 or off-cuts produced during construction 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 will depend 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 subject to hydrostatic testing that are designed to carry category B and category C substances, welding quality should be established by 100 % radiographic inspection or equivalent.

After satisfactory welding quality has been achieved, the level of radiographic inspection may be progressively reduced to a minimum of 10 % of field welds. If welding quality falls, the level of inspection should be increased back to 100 % radiography until welding quality is restored. In locations where possible leakage could cause pollution or other hazards, all welds should be subjected to 100 % radiography.

In pipeline systems designed to convey category C substances and tested by pneumatic rather than hydrostatic methods, or systems designed to convey category D and E substances, field welds should be subjected to 100 % radiographic inspection. If this is impracticable, ultrasonic testing should be performed instead.

All tie-in welds and all welds made in road, rail and watercourse crossings for pipelines carrying any category of substances should be subject to radiographic examination unless the safety of operatives and the general public may be compromized. In addition, all tie-in welds made following any hydrostatic test should be subject to ultrasonic inspection.

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 qualified procedure that meets the requirements of 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*

Trenching includes all excavation which is carried out by trenching machine, 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 consideration the addition of any protection. The depth of cover requirements are given in 6.8.3.

The trench should be vertical, sloping or battered depending on the depth, width and type of terrain and soil.

> NOTE It may be necessary to increase the depth of trench for:
> a) pipelines following hydraulic gradients;
> b) to avoid land drains, drainage systems, roads, railways or other crossings;
> c) 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 wellpoint 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 **6.9.3**).

The trench bottom should be prepared to permit even bedding of the pipeline and should be free from sharp edges or objects which may 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 of proper design and sound construction.

When trenching occurs adjacent to existing underground structures, precautions should be taken to avoid damage to such structures. A minimum separation 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, it should be widened and deepened to allow safe working conditions.

Precautions should be taken prior to personnel entering the trench to ensure that safe non-flammable atmospheres are 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 consideration the nature of ground conditions with respect to safety codes.

If the backfilled pipeline trench is likely to act as a drain, precautions should be taken to prevent loss of any fine material.

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. At this depth persons working in it would be buried or trapped if there were a collapse. An adequate store of suitable 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 adequate 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.

The condition of the ground being excavated may 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, will need to 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 lands may necessitate an appraisal of the live and dead loads, and whether the resultant of the loads will cause a loading on the sides of the excavation, or whether the excavation will affect the stability of the neighbouring structure. It may be necessary to provide temporary shoring, strutting, ground treatment or other support to the structure to safeguard its stability. Detailed information may be found in BS 6031 and Report 97 "Trenching Practice" published by the Construction Industry Research and Information Association.

NOTE Attention is also drawn to the Construction (General Provisions) Regulations 1961.

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.

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. Sufficient clearance between the pipeline and other services should be agreed between the parties and adequate arrangements should be made to protect and support the other services.

Where thrust boring, auger boring or pipe jacking methods are used, the clearances required should be the subject of consultation 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 may 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 a condition as efficient as that before the work was started. This will usually consist 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 properly sealed to prevent the intake of soil into the drains.

NOTE The working width may need to be drained.

In the case of narrow trenches it may be possible to reconnect the existing drains across the pipeline. For wide trenches, reconnection across the pipeline should only be considered 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 will usually collect water and may act as a drain. In some cases this water will not drain away, but collect, e.g. at a low point or where the backfill is impermeable. Arrangements should be made to drain these points to a free outfall. It should be recognized that defects in the system may not become apparent for a number of years.

It is recommended that the promoter provides 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 may need to carry out alterations themselves at the expense of the promoters.

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 may 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, consideration should be given to the need for additional drinking troughs.

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 to ensure conformance with 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 for damage and 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, using the procedure given in **10.3.7**.

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 pipe; or

b) the pipe should be protected using suitable coating.

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.

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 is 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.

Safe working practices should be adopted 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 is 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 may cause erosion, consideration should be given to the installation of barriers to prevent land slippage or washout.

> 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 test. No activities should be permitted within the working width during the test. There will be reinstatement work to be carried out after testing, i.e. topsoil replacement, reseeding, fence removal etc. and this may have to take place during the operation of the pipeline, dependent upon the particular activity and the season. This work should be carried out with written agreement and under supervision of the pipeline operator. Consideration should be given to carrying out this work in accordance with a permit to work system.

Where possible, the land should be restored to its original contours.

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

Land drainage reinstatement should be carried out by a specialist with a method agreed with the landowner/occupier. 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 should be agreed with the various authorities which are affected, e.g. highways and water authorities, =prior to commencement of the work.

Unless otherwise arranged with the landowners or occupiers, the topsoil should be reinstated. Top soiling and other reinstatement work should only be carried out 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. Any additional topsoil imported will be subject to the reasonable requirements of the occupier as to the testing of the suitability of the imported soil.

Arrangements for final reinstatement and seeding of any land should be agreed in advance with the owner or occupier.

Consideration should be given to ripping of subsoil due to compaction which may have been caused by the passage of plant and equipment.

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 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 and a joint inspection with the landowner/occupier, the land can revert to its former use.

Any certificate presented to the 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 **10.11.1.4**).

Reinstatement affecting roads should be carried out in consultation with the local highways authority.

10.13 Crossings

10.13.1 *General*

Road and rail crossings should be constructed by open-cut, boring,tunnelling or horizontal directional drilling (HDD) methods. Open-cut road crossings should be carried out in a manner which minimizes the disruption to normal traffic flow. Particular attention should be given to the 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 may 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 considered necessary, agreement with the highway authority should be sought at an early stage as statutory periods of notice are required for such closures.

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 may require the use of pipelaying techniques which do not necessitate open trench excavation.

Where work is being carried out on, or adjacent to, any public or private road, warning signs (and at night, warning lights) should be provided and maintained as required by the body having jurisdiction over the road.

Particular care should be taken to avoid damage to drains, sewers and all other services laid within the highway.

Where these services are disturbed they should be reinstated in accordance with the highway and appropriate service authority requirements.

10.13.3 *Railways*

The appropriate railway authority should be approached before any works are carried out on or adjacent to any railway property. 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 may be unsuitable for the equipment being used. The appropriate railway authority should be approached before the crossing is used as access to the work site.

10.13.4 *Watercourses*

Where a pipeline crosses a watercourse, the design and method of construction require consent from the drainage or water authorities concerned, and in Scotland from the appropriate river purification board. The design and method of construction should take into account the characteristics of the watercourse. Consideration should be given to the suspended solids generated and the particular requirements of the water authority under the Control of Pollution Act. It may be necessary to plan the work to take advantage of seasonal variations and to make arrangements to take action on receipt of flood warnings in order to prevent damage to the works or the surrounding country.

Where watercourses are crossed by the open-cut method, consideration should be given to 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 considered to ensure that there is no disruption to water flow during construction. To achieve stability of the pipeline at water crossings consideration should be given to the application of a weight coating such as concrete to maintain negative buoyancy of the pipe during both 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 which may cause pipe stress or strain to exceed the levels established in the design.

Installation procedures for horizontal directionally drilled crossings should address the requirements unique to such crossings, including:

a) containment and disposal of drilling fluid;

b) selection of 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 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 which can reasonably be expected.

In such a case reasonable cover adjoining the ditch should be provided: normally 450 mm (18 in) cover at a distance of 900 mm (36 in) from the edge of the ditch is considered reasonable.

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 works in order to take into account the needs of migratory salmonids and other freshwater fish.

Consideration should be given to the possibility of future cleaning and deepening operations on drainage ditches. 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 adequate dimensions should be placed above the pipe and below the hard bottom of the ditch, bedded on firm ground either side of the pipe trench. For smaller ditches precast concrete marker slabs should be adequate. The top of the slab should be at least 300 mm below the cleaned bottom of the ditch.

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, where this is not possible the sleeve should be made of steel.

10.13.5.2 *Concrete*

Concrete sleeves should be installed at a gradient that allows for a cementitious annular fill. Jointing requirements should be carried out in accordance with the manufacturer’s recommendations.

10.13.5.3 *Steel*

Grouted steel sleeves are not cathodically protected so consideration should be given to the provision of a high quality external coating. It is essential that current checks are carried out before and after grouting to ensure that there is no electrical contact between sleeve and pipe.

If the steel sleeve is specified to be nitrogen filled, the forged end seals should be welded and the annulus air tested to 3 bar.

Welding should be carried out to approved procedures. The steel sleeve, joints, pipework and fittings should all be coated to standard specification as the installation will form part of the CP system.

Care should be taken not to damage the line pipe coating and the internal spacers.

10.13.5.4 *Spacers*

The 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 material used for grouting should be tested to ensure conformity with the specification.

The total volume of the annulus should be calculated so that the actual volume of material used correlates to the calculated volume. It is essential to seal ends to prevent loss of material. The grouting pressures should not exceed those specified for the nitrogen so that an oxygen content of less than 2 % is achieved. Nitrogen should be used to pressurize the annulus to 1.5 bar.

All fittings should be leak tested and the pressure should be noted for maintenance records.

10.14 Pipeline markers

Distinctive markers should be erected at all road, rail, river and canal crossings and elsewhere as required 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.

Where aerial surveillance is intended, sufficient 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. 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.

Gauging pigs should be equipped with a soft metal disc of diameter not less than 95 % of the smallest specified 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

Tie-in welds also include closure welds made to connect installed crossings to adjacent ditched sections of pipeline. Particular attention should be given to ensure the proper 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.

Any coating damage found should be repaired.

10.18 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 documentation;

c) as-built drawings and technical specifications;

d) construction procedures.

A record should be kept by the owners 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.

11 Testing

11.1 General

Following completion of construction and backfill, it is essential that pipelines are subject to comprehensive inspection and assessment to confirm their integrity. Demonstration of integrity is mandatory, and in general it is confirmed by pressure testing.

It is recommended that pipelines are 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 prove their strength and leak-tightness prior to commissioning.

Where information regarding safety margin can be robustly 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 such approaches are carried out and documented by competent experts.

> NOTE 1 Prefabricated assemblies and tie-in sections may be pre-tested or subject to an alternative assessment before installation, provided no subsequent construction activity will impair the component integrity. Testing or alternative assessment may be carried out in suitable sections as work progresses (see **11.3.1**).

Topography or other considerations may require testing in a number of sections and consideration should be given to 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.

Equipment which should not be subjected to the test pressures should be isolated from the pipeline 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. Valves should be pretested to a minimum of the proposed test pressure and have a current test certificate stating that they have sufficient strength to withstand the proposed 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 required for parts of the pipeline system (refer to **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 pressurised 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, depressurising should be carried out by reducing pressure in a controlled manner.

Where public safety could be compromised by the release of energy during pneumatic testing, a limit of 30% SMYS is recommended to ensure that any failure should be limited to a stable leak rather than a propagating rupture or crack. In addition, all manufactured components should be subject to a prior hydrostatic test. All welds should be subjected to 100 % examination and adequate fracture toughness properties should be demonstrated

Consideration should be given to environmental noise limitations and safety of personnel regarding gas dispersion to a safe area.

11.2.2 *Precautions to be taken during a test*

Reference should be made to the Health and Safety Executive Guidance note, General series 4 Safety in pressure testing [12]. When formulating safety procedures it should be recognized that pneumatic testing will store far greater energy in the pipeline than the equivalent hydrostatic testing.

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 to deter persons not involved with the testing from approaching closer than the recommended safety distances. The typical safety distance for hydrostatic testing is 15 m. For high-level or pneumatic testing, greater distances should be enforced.

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 ***Use of 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 launcher or receiver is zero.

It is essential that any temporary pig traps attached to a pipeline under test are isolated from the pipeline unless they are designed and fabricated to the same standard as the pipeline.

11.3 Pressure testing

11.3.1 ***General***

Pressure testing should be carried out hydraulically where feasible, but may be carried out pneumatically in some circumstances. The principles of the test and the results obtained are the same for both methods, but the stored energy in the pressurised system, and therefore the severity of any failure which could result is much greater in the case of pneumatic testing. The method of testing should be selected and justified based on a rigorous assessment of safety issues associated with the stored energy and the practical issues associated with the test arrangements.

> NOTE 1 Re-routing of short pipeline sections or short tie-in sections for pipelines in operation are examples of situations for which pressure tests with water may not be expedient.
>
> NOTE 2 Pipelines designed to carry 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 3 Terrain issues may necessitate the use of a pneumatic test.

Reliable communications should be provided between all points manned during testing.

> NOTE 4 See also **11.4**.

11.3.2 ***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. Special care is needed in dealing with water sources containing potentially harmful chemicals or bacteria; it is advisable to take specialist advice and the local water authority should be notified.

Water for testing and any subsequent flushing should be clean and free from any suspended or dissolved substance that:

a) could be harmful to the pipe material or internal coating (where applied);

b) could form deposits within the pipeline.

NOTE Water extraction and disposal licences will be required 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.

If the ground temperature in the immediate vicinity of the pipes is less than 2ºC, antifreeze should be added.

Air or a non-toxic gas should be used for a pneumatic test.

11.3.3 ***Level of test***

The level of test and the associated test pressure should be selected in order to demonstrate a safety margin which is adequate for the proposed operation of the pipeline. The levels of test recommended in this document are:

11.3.3.1 *High level test*

A high level pressure test involves testing to a pressure which generates a hoop stress 85%-105% SMYS of the pipeline material. This test level removes defects which are considerably smaller than would fail at the operating pressure. It provides a rigorous demonstration of a quantified safety margin which accommodates an allowance for defect growth during service, and is therefore recommended in cases where operational requirements may involve significant cyclic pressures, or where increases in the MOP to design factors exceeding 0.72 may be considered.

For details of the requirements for high level testing , reference to IGE TD/1 Edition 4 Section 8 and Appendix 5 is recommended.

Note 1 Where limit state design has been used, reference to BS EN 1594 should be made for guidance on maximum hydrostatic test pressures.

11.3.3.2 *Standard test*

A standard pressure test involves testing to a pressure of not less than 150% of the MOP. This test level demonstrates that the quality of the pipeline materials and construction is adequate for future operation of the pipeline. It is recommended in cases where significant cyclic pressures and/or increases in the pipeline MOP are not anticipated in the future operation of the pipeline.

11.3.3.3 *Leak test*

A leak test involves testing to a pressure of not less than 110% of the MOP. This test level demonstrates pressure containment at the MOP for future operation. It is recommended in cases where the pipeline safety margin has been demonstrated by altwrnative methods not requiring high-level or standard testing (ie SRA and inspection).

> Note It is essential that the hydrostatic test pressure is not less than the sum of the maximum operating pressure plus any allowance for surge pressure and other variations likely to be experienced by the pipeline system during normal operation.

11.3.4 ***Type of test***

11.3.4.1 *Hydraulic test*

The pressure at the point of application should be such that the test pressure is generated at the lowest point in the section under test. The additional static head at any point in the section should not cause a hoop stress in excess of the specified minimum yield stress of the material at that point.

11.3.4.2 *Pneumatic test*

Pneumatic tests should be carried out in accordance with ambient temperature recommendations given in PD 5500:2000.

11.3.5 ***Pressure variations***

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.

11.3.6 ***Inhibitors and additives***

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

11.3.7 ***Filling rate***

Filling should be performed at a controlled rate.

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 may 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.

The use of devices to track the pig, and control the pig speed is recommended.

11.3.8 ***Air content***

Where the air content could affect the accuracy of the hydrostatic test, the air content 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 may be assessed, and compared with the total volume of the test section.

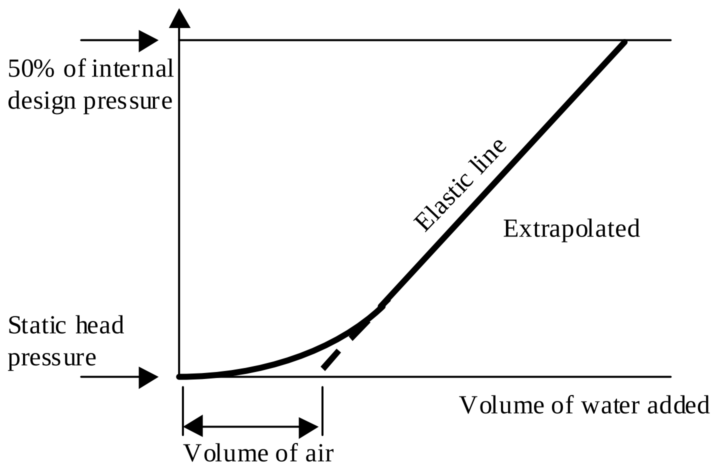


Figure 4. Measurement of Air Content

Figure 4 — Measurement of air content

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 may be calculated from the following formula:

$$\frac{\Delta V}{\Delta P} = V\left(0.044\frac{D}{t} + 4.50\right)10^{-5}$$

where

ΔV is the incremental volume of water added (in m^3);

V is the volume of test section (in m^3);
ΔP is the incremental pressure change (in bar);
D is the nominal pipe diameter (in m);
t is the nominal wall thickness (in mm).

11.3.9 ***Temperature stabilization***

After filling and prior to beginning the hydrostatic test, time should be allowed for the temperature of the water in the pipeline to stabilize with the ground temperature at pipeline depth.

11.3.10 ***Temperature effects and correlations***

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

11.3.11 ***Written procedures***

Written procedures for pressure tests should be prepared prior to the beginning of testing and should include the requirements of **11.3** and the following:

a) the profile, including the pipe grade and wall thickness, and length of each test section with the test pressure specified for each end of pipe section being tested;

b) the section minimum pressure and maximum pressure related to the profile;

c) safety provisions;

d) the requirements for continuous monitoring (see **11.6** and **11.7**);

e) source and composition of test water and its disposal;

f) the equipment requirements;

g) all pressures and durations;

h) evaluation of the test results;

i) acceptance criteria;

j) leak-finding procedure.

NOTE It may be necessary to give notice to a statutory authority of the intention to carry out the pressure test.

11.4 Test procedures

11.4.1 ***Hydrostatic testing***

The pressure in the test section should be raised at a controlled rate to the test pressure calculated in accordance with **11.3.3**. 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 this period residual air will continue 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 minutes, and the volume of any water added to maintain test pressure noted.

NOTE 1 For volumes of less than 20 m^3 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 **11.4.3**.

NOTE 2 *Cyclic testing*. As an alternative, 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.

11.4.2 ***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 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 7.0 bar to the test pressure specified in **11.3.4** 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 maximum operating pressure 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.

Pressure, temperature and volume should be logged throughout the test, see **11.4.3**.

11.4.3 ***Test data recording***

A record of pressure, volume change, underground 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 Temperature trends can be measured to a sensitivity of better than 0.1°C if plotted graphically over several days. A graphical plot of pressure, underground temperature and ambient temperature against time prepared during the test period will assist in the interpretation of test results.

11.4.4 ***Leak-finding***

Leak detection and location procedures should be developed as part of the hydrostatic or pneumatic test procedure.

11.5 Acceptance criteria

11.5.1 ***General***

The pressure test should meet the requirements of **11.3**.

The pressure test should be considered as satisfactory if no observable pressure variation occurs which cannot be accounted for by temperature change taking into account the accuracy and sensitivity of the measuring equipment.

11.5.2 ***Method of assessment for hydrostatic test***

The relationship between pressure and temperature should be calculated in accordance with the following formula:

$$\Delta P = \frac{264.7\, T_f}{D/t + 100}$$

where

ΔP is the pressure change (in bar/°C);
T_f is the temperature factor change (from Figure 5);
D is the nominal pipe diameter (in m);
t is the nominal wall thickness (in m).

The temperature factor change T_f should be read from Figure 5 at the mean test temperature. ΔP 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 may 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 may have an effect on pressure readings.

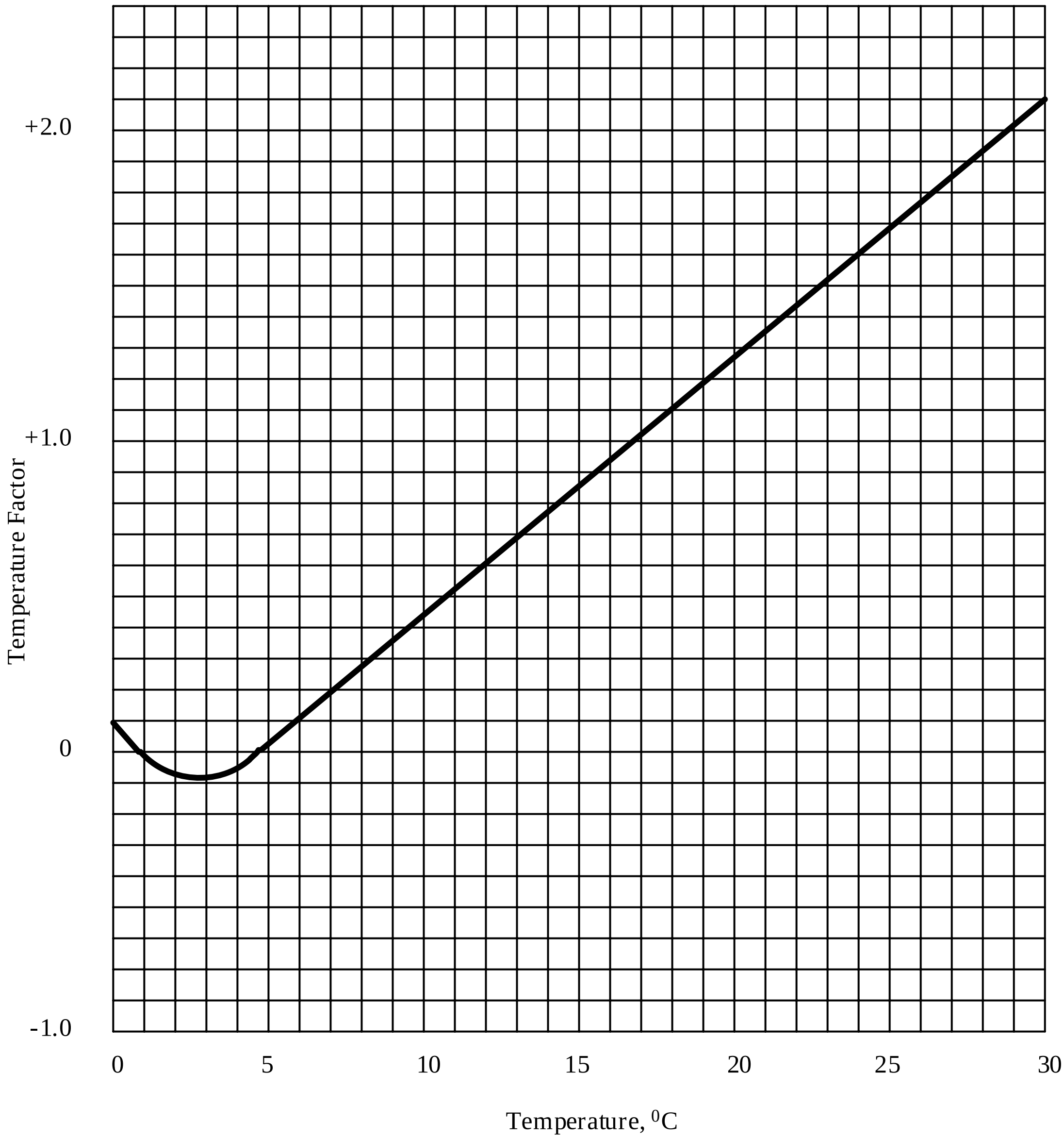


Figure 5 Effect of temperature on pressure

Figure 5 — Effects of temperature on pressure

11.5.3 *Method of assessment of 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, inconclusive results of such calculations may occur. In this event consideration should be given to extending the pneumatic test hold period to obtain more conclusive results.

11.6 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 ISO 13847.

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 aggregrate period of not less than 24 h.

11.7 Tie-ins following testing

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, this length of pipe should be pre-tested in accordance with **11.9** before installation. All tie-in welds not subject to subsequent pressure testing, should be subject to radiographic inspection supplemented by ultrasonic testing or other accepted examination method if radiography or ultrasonic testing are not possible.

Non-welded tie-in connections not pressure-tested after construction should be leak-tested at commencement of operation at the maximum available pressure but not exceeding the design pressure.

11.8 Pre-testing

Pipe and fittings should be pre-tested in 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 consequences of a test failure justify pre-testing.

Road and rail crossings classified as major crossings, river crossings, canal crossings and bridge crossings (see **10.4**) should be fabricated from pre-tested pipe or should be pre-tested after fabrication but before installation and final test. Pre-testing of pipe or fabrications should be carried out in accordance with **11.9** except that:

a) 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

b) the duration of the final hold period should be not less than 3 h.

The test should be considered acceptable if no leaks are detected on visual examination.

11.9 Testing of fabricated components

Fabricated components (such as pig traps, slug catchers, insulation joints or manifolds) should be pressure tested to limits equal to those required for the completed pipeline. If the components are also to be tested out as part of the completed system the tests should be designed in accordance with test procedures and pressure in **11.3**, **11.4** and **11.5**.

11.10 Testing equipment

11.10.1 *General*

Hydrostatic testing equipment should be selected to be appropriate to the test pressure and should include the following:

a) deadweight tester 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 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. Dead weight testers and other equipment should have been certified within the 12 months preceding the test. All test equipment should be located in a safe position outside the boundary area.

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

11.10.2 *Measurement of pressure*

Hydrostatic test pressure should be measured by a dead weight tester having an accuracy better than ±0.1 bar and a sensitivity of 0.05 bar. Pressure gauges should be selected with ranges which show between 50 % and 90 % of full scale deflection at test pressure.

11.10.3 *Measurement of volume*

The volume of liquid added or subtracted during a hydrostatic test should be measured by equipment having an accuracy better than ±1.0 % and a sensitivity of 0.1 % of the calculated volume of a liquid to be added after line filling has been completed to produce, in the test section, the required test pressure (see **11.4**). Where pump strokes are used to determine the added volume an automatic stroke counter should be used.

11.10.4 *Measurement of temperature*

Temperature-measuring equipment should have an accuracy of ±1.0 °C and a sensitivity of 0.1 °C.

11.10.5 ***Other measuring 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.

11.10.6 ***Test end design***

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.

11.11 Test documentation and records

All certificates and records produced in connection with pressure testing a pipeline should be retained by the registered operator for the lifetime of the pipeline system and should include the following:

a) test procedure;

b) pressure and volume change at half-hour intervals over the test period;

c) seawater, underground 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 making 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;

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 test sections.

11.12 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 may be heavily discoloured with rust particles. Consents should be obtained from landowners and occupiers, and from river, drainage and water authorities.

11.13 Protection of pipeline following test

Test fluids should not be left in the pipeline following testing, unless provisions identified in accordance with **9.2** 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.

12 Precommissioning and commissioning

12.1 General

Written procedures should be established for pre-commissioning and commissioning. Procedures should consider the characteristics of the fluids, the need to isolate the pipeline from other connected facilities and the transfer of the constructed pipeline to those responsible for its operation. Pre-commissioning and commissioning procedures, devices and fluids should be selected to ensure that nothing is introduced into the pipeline system that will be incompatible with the fluids, or with the materials in the pipeline components.

12.2 Disposal of pipeline content

The Regulatory Authority 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.

12.3 Cleaning

Consideration should be given to the need for cleaning the pipe and its components to a level beyond that recommended in **11.3.2**.

NOTE Additional cleaning may be required to remove the following:

a) non-metallic particles, including residue from testing and millscale;

b) metallic particles which may affect intelligent pig result interpretation;

c) chemical residue from test water inhibitor;

d) organisms resulting from test water;

e) construction devices such as isolation spheres used for tie-ins.

Pipeline cleaning procedures should consider the following:

a) protection of pipeline components from damage by cleaning fluids or devices;

b) removal of particles which may contaminate the fluid;

c) removal of metallic particles which may affect intelligent pigging devices.

Consideration should be given to the disposal of debris, and gels if used. Debris from the pipeline may block or contaminate small bore branches or instrument tappings. Consideration should be given to containing or removing these items.

12.4 Drying

12.4.1 *General*

Removal of residual water from a pipeline after dewatering should be considered 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 consider the following:

a) compatibility with the transported fluid quality specifications;

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 may be retained;

e) the effect of hydrate formation during commissioning.

12.4.3 *Drying methods*

One or more of the following drying methods should be employed:

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 by vacuum pumps and purging with dry air or nitrogen.

Consideration should be given to the effects of drying chemicals or vacuum on seals of valves and pig traps.

An inert gas such as nitrogen should be used to separate methanol swabs and air.

NOTE IGE/TD1 contains typical procedures for running methanol swabs.

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 marine life. Prior consent for disposal should be obtained (see **12.2**).

12.5 Introduction of product

12.5.1 *Start-up pocedures*

Written start-up procedures should be prepared before introducing the transported fluid into the system. Start-up procedures should require the following:

a) that the system is mechanically complete and operational;

b) that all functional tests are performed and accepted;

c) that all necessary safety systems are operational;

d) that operating procedures are available;

e) that a communication system is established;

f) that the completed pipeline system is formally transferred to those responsible for its operation.

During pipeline filling with the fluid (oil or gas), the rate of fill should be controlled and the fluid pressure should not be allowed to exceed permitted limits. Consideration should be given to the introduction of inhibitors in the product stream 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, it is important to avoid 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 dew point of the gas.

12.6 Connections to operating pipelines

Where it is necessary to commission a pipeline which is connected to an operating pipeline, two valve isolation with bleed should be provided.

NOTE In special circumstances a single valve with double block and bleed facilities may be sufficient.

12.7 Functional testing of equipment and systems

As a part of commissioning, all pipeline monitoring and control equipment and systems should be fully function-tested, especially safety systems such as pig-trap interlocks, pressure and flow-monitoring systems, and emergency pipeline-shutdown systems.

Consideration should also be given to performing a final test of pipeline valves prior to the introduction of the transported fluid to ensure that they operate correctly.

12.8 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.

Pre-commissioning and commissioning records should be retained.

13 Operation, maintenance and abandonment

13.1 Management

13.1.1 *Objectives and basic requirements*

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

a) ensuring safe operation of the pipeline system;

b) ensuring compliance with the design;

c) managing corrosion;

d) ensuring safe and effective execution of maintenance;

e) modifications and abandonment;

f) dealing effectively with incidents and modifications.

The management system should include the following:

— identification of personnel responsible for the management of the operation and maintenance of the pipeline, and for key activities;

— an appropriate organization;

— a written plan covering operating and maintenance procedures;

— a written emergency response plan, covering failure of pipeline systems and other incidents;

— a written permit-to-work system;

— a written plan for the control of change of design conditions.

The management system should specify the requirements for training, liaison with third parties and retention of records.

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

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:

a) procedures for normal operations and maintenance;

b) requirements for personnel communications;

c) requirements for spares and equipment;

d) a plan for the issue of procedures to cover non-routine operations and maintenance.

Operating and maintenance procedures should define:

— individual and functional responsibilities and tasks;

— necessary safety precautions;

— interfaces with other pipeline systems and installations;

— relevant information and references to applicable rules and guidelines.

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

13.1.3 ***Incident and emergency response plan***

The incident and emergency response plan should define the requirements for training, personnel and equipment and is subject to the minimum requirements of the appropriate regulations, e.g. Pipeline Safety Regulations...

The effectiveness of the plan should be tested periodically through desk and field simulations of incidents and emergencies.

> NOTE Simulations may be carried out in co-operation 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. Procedures should be developed to meet the needs of each individual pipeline and should include periodic emergency exercises that should be carried out in conjunction with the public emergency services.

Pipeline operators should ensure that all documentation required for an effective response is readily available, e.g. route maps.

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

All occupiers of land traversed by a pipeline should be requested by the pipeline operators to assist by speedy notification of any abnormal occurrences which may affect, or may 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 which 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 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;

— reference other relevant work permits;

— state the requirements for returning the pipeline system to service;

— state the authorization for execution of the work.

13.1.5 *Training*

Training of personnel should include:

a) familiarization with the pipeline system, equipment, potential hazards associated with the pipeline fluid, and procedures for operations 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 ***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 the requirement for soliciting information on the presence of underground utilities before commencement of work.

13.1.7 ***Records***

Records of operating and maintenance activities 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 operations and maintenance plans;

c) provide the information necessary for assessing the integrity of the pipeline system.

13.2 Operations

13.2.1 ***Fluid parameter monitoring***

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

Procedures for the operation of multi-product pipeline systems should include requirements for the detection, separation and prediction of arrival of batches.

Procedures for the operation of multi-phase pipeline systems should include requirements for control of liquid hold-up in the pipeline and free volume in the slug catcher.

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

13.2.2 ***Stations and terminals***

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

13.2.3 ***Pigging***

Procedures for pigging operations should include requirements for:

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 trapped pig.

13.2.4 ***Decommissioning***

Consideration should be given to decommissioning pipelines planned to be out of service for an extended period. The removal of fluids should be in accordance with **12.2**.

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

The decommissioning of a pipeline is subject to statutory regulations.

13.2.5 ***Re-commissioning***

The condition of a decommissioned pipeline system should be established and its integrity confirmed before re-commissioning.

Pipeline filling should meet the requirements of **11.5.5**.

The decommissioning of a pipeline is subject to statutory regulations.

13.3 Maintenance

13.3.1 *Maintenance programme*

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 considered 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;

e) adverse site conditions;

f) inspection time intervals;

g) requirements of relevant legislation and statutory authorities.

EXAMPLES 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.

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 may 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 and leakages;

c) third-party activities;

d) change of land use;

e) fire;

f) mineral extraction/mining operations;

g) ground movement;

h) soil erosion;

i) the condition of water crossings, such as sufficiency of cover, accumulation of debris, flood or storm damage.

NOTE Refer to PD 8010-2 for the requirements for the route inspection of sections of pipelines on land crossing large rivers and estuaries.

The frequency of inspection can vary dependent upon 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 may 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 owners 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 adequate means of identification.

Where air patrols are used, aircraft should fly at a suitable height to avoid nuisance or harm to poultry or livestock.

Certain areas may be declared an infected area on account of foot and mouth disease, fowl pest, swine fever, or other notifiable disease including soil borne pests and diseases. Where this occurs, routine pipeline inspections involving entry on such land should be suspended unless there are exceptional circumstances. If there is a clear necessity to enter land, approval from DEFRA, SERAD (Scotland) or DARD (Northern Ireland) should be obtained, and entry should be governed by any conditions stipulated.

13.3.3 *Pipeline mechanical condition*

13.3.3.1 *Corrosion control*

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

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

13.3.3.2 *Leak detection and surveys*

The performance of the leak detection system should be reviewed and tested periodically to confirm compliance with the recommendations of **6.13**. Records should be kept of alarms and leaks to assist the performance review. Where appropriate, leakage surveys should be carried out. The type of survey selected should determine if potentially hazardous leakage exists.

13.3.4 ***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.

13.3.4.2 *Valves*

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

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

Pressure vessels associated with valve actuators 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 proper installation and protection;

c) correct setting and activation;

d) inspection for leaks.

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

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

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

13.3.4.4 *Pig-traps and instrumentation*

Instrumentation, telemetry systems and temporary pig traps should be inspected before use for signs of mechanical damage caused during transit or installation.

13.3.4.5 *Instrumentation*

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

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

13.3.4.6 *Pipeline sleeves or casings*

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

a) the condition of pipeline and sleeve or casing;

b) the electrical isolation between the pipeline and sleeve or casing;

c) leakage into, or from, pressurized sleeve or casing systems.

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 competent person and, if any unsafe condition is found, appropriate action should be taken immediately.

13.3.5.2 *Examination, inspection and assessment of defects*

The rights acquired for the construction of a pipeline usually include rights necessary to maintain and repair the line. 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 exercised during preparation and examination of damaged and pressurized pipelines because of the possibility of sudden failure.

Consideration should be given to reducing the pipeline operating pressure to ambient conditions, e.g. when divers are to conduct an examination of an underwater pipeline, or to a stress level which will not lead to pipeline rupture.

Procedures should be established for assessment of pipeline defects and damages.

NOTE Defects and damage permitted under the original fabrication and construction specifications may remain in the pipeline without further action.

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

a) inspection and measurement data, including orientation of the defect and proximity to other features such as welds or heat-affected zones;

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) 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 cover 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 may 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 may 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.

13.3.6.3 *Venting and flaring*

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

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

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 stuck pigs by stored energy when driven by inert gas.

13.3.6.5 *Purging*

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

a) asphyxiating effects 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 the requirements for preventing the accidental release or ignition of the fluid, and other unsafe conditions.

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

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

13.3.6.7 *Hot work*

The following should be considered 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 procedures should be qualified and approved and the validity of the welder qualification checked before commencement of welding.

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 adequately inspected during and after welding in accordance with BS EN 287 and BS EN 288.

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

13.4 Changes to the design condition

13.4.1 ***Change control***

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

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

13.4.2 ***Operating pressure***

An increase in MOP may require additional hydrostatic testing, inspection, additional cathodic protection surveys and other measures to comply with this code of practice. 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 which cannot subsequently be reapplied to the pipeline because of 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***

Conformance with the strength requirements in **6.5** should be demonstrated when crossing the pipeline with another pipeline. The effect of a new crossing on the existing cathodic protection system should be investigated.

13.4.5 ***Testing of modified pipelines***

All prefabricated pipeline assemblies, including spool pieces, should be pressure-tested in accordance with **11.11**, or 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.

Joints should not show sign of leakage during the test.

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

a) water;

b) the normal pipeline fluid (if liquid);

c) an inert gas such as nitrogen (with a tracer element, if possible);

d) the normal pipeline fluid (if gas).

Modifications involving the use of welded tie-ins should be inspected in accordance with **11.11** if not pressure-tested.

Small diameter pipework and secondary piping (see **7.8.2**) should be tested to ensure the integrity of all joints and connections after any work activity where pipework has been disturbed.

13.5 Abandonment

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

A pipeline may be considered 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 an undesirable watercourse.

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 may occur, it may be necessary to close the pipeline at both ends and to fill the abandoned line with a suitable filler.

Where the abandoned pipeline cannot be made safe by the above method, it should be removed. In all cases where the fluid conveyed is considered an environmental or safety hazard, or could become so after contact with the soil, it will be necessary to remove completely the fluid from the pipeline. All above ground sections of the pipeline system should be removed to not less than 900 mm (36 in) below ground level. Backfilling and land reinstatement should be in accordance with **10.3.15**.

Abandoned pipeline sections should be left in a safe condition, in accordance with national requirements and industry codes of practice.

13.6 Records

A record should be kept by the owners 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 (normative)
Safety evaluation of pipelines

A.1 Introduction

This annex provides guidelines for the planning, execution and documentation of safety evaluations of pipeline required in **6.2.2**.

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

A.2 General recommendations

Safety evaluations should be performed according to a defined sequence of steps.

NOTE Figure A.1 shows a sequence of steps which may be followed.

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

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

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

A.3 Scope definition

The scope of the evaluation should be defined and formulated to provide the basis for the safety evaluation plan.

The scope definition should include:

a) reason(s) for performing the evaluation and case-specific objective(s);

b) a definition of the pipeline to be evaluated;

c) a definition of the environment, e.g. human habitation and activities near the pipeline;

d) identification of the measures that may be practical and effective in removing or mitigating adverse effects on public safety;

e) description of assumptions and constraints governing the evaluation;

f) identification of the required output.

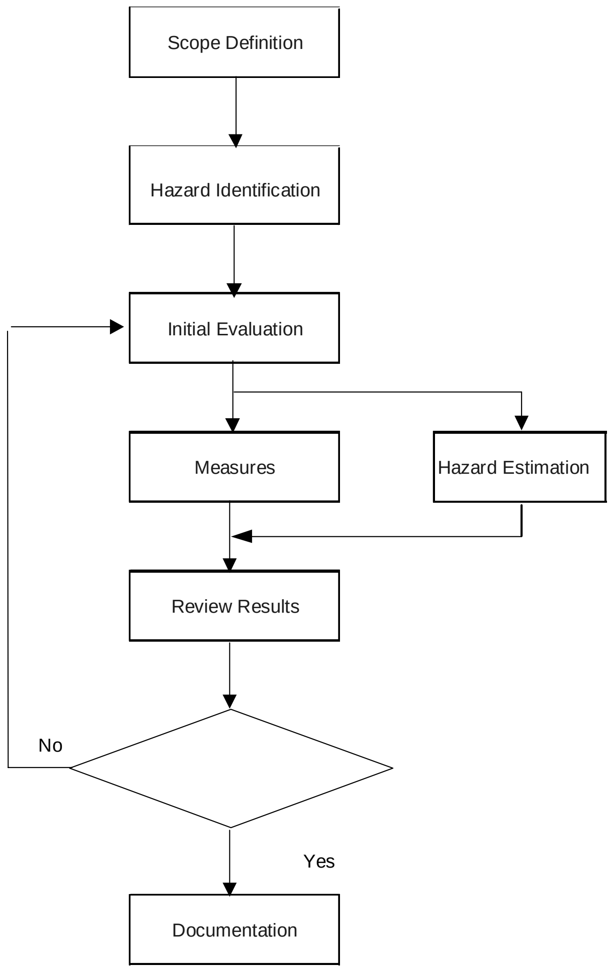


Figure A.1
Safety Evaluation

Figure A.1 — Safety evaluation

A.4 Hazard identification and initial evaluation

The hazard scenarios with the potential to result in a loss of fluid should be identified, together with their root causes. These 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) natural hazards.

NOTE Methods applied for identifying hazards may include review of checklists and historical incident data, brainstorming, and hazard and operability studies.

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

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

a) curtailment of the evaluation because the likelihood of occurrences or consequences of the hazard is insignificant;

b) recommended measures(s) to eliminate or reduce the hazard to a tolerable level;

c) estimation of risk.

A.5 Hazard estimation

A.5.1 *General*

Hazard estimation should produce a measure of the level of effect on public safety from a particular hazard.

> NOTE Estimates may be expressed quantitatively or qualitatively and determined in frequency of occurrence, consequence, risk or a combination as appropriate for accomplishing the objectives of the safety analysis.

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

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

A.5.2 *Frequency analysis*

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

a) use of relevant historical data;

b) synthesis of event frequencies using techniques such as failure mode and effect analysis;

c) judgement.

A.5.3 *Consequence analysis*

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

a) the nature of the fluid, e.g. flammable, toxic, reactive, etc.;

b) pipeline design;

c) buried or above ground topography;

d) environmental conditions;

e) size of hole or rupture;

f) mitigating measures to restrict loss of containment, such as leak detection and use of isolation valves;

g) the mode of escape of fluids;

h) dispersion of fluid and probability of ignition;

i) possible accident scenarios following a fluid loss, which may include:

   1) pressure waves following fluid release;

   2) combustion/explosion following ignition;

   3) toxic effects or asphyxiations;

j) level of exposure and estimated effect.

A.5.4 *Risk calculation*

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

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

A.6 Review of results

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

A.7 Documentation

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

a) a table of contents;

b) a summary;

c) the objectives and scope;

d) the safety requirements;

e) the limitations, assumptions and justification of hypotheses;

f) a description of system;

g) the analysis methodology;

h) the hazard identification results;

i) a model description with assumptions and validation;

j) data and their sources;

k) the effect on public safety;

l) the sensitivity and uncertainties;

m) a discussion of results;

n) conclusions;

o) references.

Annex B
Scope of procedures for operation and maintenance

B.1 Operating procedures

Operating procedures may include details of the following:

a) the organization showing the responsible persons;

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

c) the fluids that may be transported;

d) the pipeline system operating conditions including limitations, and permitted deviations from such limitations;

e) the control functions and communications;

f) the pipeline monitoring system and the means by which leaks may be detected;

g) marine operations procedures (where applicable);

h) scheduling and dispatching procedures;

i) pigging procedures and their purpose;

j) references to related documentation, e.g. permits to work, manufacturer's literature, drawings, maps, etc.;

k) co-ordination with third parties;

l) drawings showing demarcation of the pipeline system and limits of ownership and operatorship within the whole pipeline system;

m) venting and flaring procedures;

n) requirements of relevant legislation or statutory authorities.

B.2 Maintenance procedures

B.2.1 *General*

Maintenance procedures may include details of the following:

a) the organization, showing the responsible persons;

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

c) schedules, inspection and maintenance specifications and instructions for each element of the pipeline system;

d) reference to related manual and documentation, e.g. manufacturer's literature and permit to work systems;

e) relevant drawings and route maps;

f) stores and spares organisation;

g) specific procedures may be required for certain repairs or modifications.

B.2.2 ***Environmental conditions***

The geotechnical conditions that may need to be considered include:

a) uneven topography, outcrops and depressions;

b) instability, e.g. faults and fissuring;

c) soft and waterlogged ground;

d) soil corrosivity;

e) rock and hard ground;

f) flood plains;

g) earthquake areas;

h) muskeg and permafrost areas;

i) areas of land slippage, subsidence and differential settlement;

j) infill land and waste disposal sites including those contaminated by disease or radioactivity.

B.2.3 ***Construction and operation***

The hydrographic conditions that may need to be considered include:

a) access;

b) working width;

c) utilities;

d) availability and disposal of test water;

e) crossings;

f) logistics.

Annex C (normative)
Pipeline route selection process

C.1 General

Economic, technical and safety considerations should be primary factors governing the choice of pipeline routes. The shortest route may not be the most suitable, and physical obstacles, environmental and other factors should be considered.

The main factors influencing routing are:

a) contents of the pipeline and operating conditions;

b) terrain and subterranean conditions;

c) hazards;

d) existing and future land use;

e) permanent access;

f) transport facilities and utility services;

g) agricultural practice;

h) environmental impact.

In order to develop the pipeline route efficiently, two phases of routing should be adopted:

a) route corridor development;

b) final route.

C.2 Route corridor development

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

A corridor of interest should then be straddled across these points so that key issues affecting the selection of the route can be plotted onto plans and assessed. The width of the corridor will depend upon the nature of terrain traversed, population and degree of complexity expected with regard to environmental and archaeological aspects.

This corridor should be selected to avoid urban areas, major road, rail and water crossings, and the features described in **C.3**. Where possible, consultations with the relevant environmental bodies will allow their input to be incorporated into the proposed route corridor.

Information regarding geological, archaeological and environmental features should in the first instance, be obtained from published sources to establish route corridors prior to discussions with the relevant institutions.

Consideration should be given at this stage to performing a key issues study ensuring that the corridor selected is suitable and will not 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 options. The constraints identified should be plotted on suitably scaled maps, considering 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 may be significant during installation and operation of the pipeline system. It should be noted that the shortest corridor may not be the most suitable.

Consideration should be given to utilizing a geographical information system (GIS) to record and manage the data collected.

Consultations should be held as early as possible during route selection, with appropriate organizations, in respect of their existing and future developments. These organizations include:

a) mine owners;

b) British Geological Survey;

c) British Pipeline Agency;

d) Railtrack and other statutory railways owners;

e) Telecommunications operators;

f) British Waterways;

g) the Civil Aviation Authority;

h) the Country Landowners' Association;

i) English Heritage;

j) county, district and parish councils and London boroughs;

k) Electricity, Gas and Water Authorities;

l) appropriate government departments;

m) independent pipeline operators;

n) independent developers of mineral rights;

o) internal drainage boards;

p) landowners and occupiers;

q) local trusts for nature conservation and archaeology;

r) the National Farmers' Union;

s) National Park Authorities;

t) the Nature Conservancy Council;

u) Navigation: Harbour Authorities.

The next stage should identify more detailed information highlighting constraints within the route corridor which will assist in the selection of a preferred final route. This will allow the project to proceed into the next stage of negotiations. All the constraints and potential planning problems, which could affect the pipeline should now be addressed and recorded.

The constraints will generally involve the various environmental groups, but could also include other third parties, having an interest in the impact caused by construction or operation.

A desk study, consultation 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.

C.3 Final routing

Prior to the selection of the final route, consultations should take place as early as possible with the appropriate authorities/organizations in respect of their existing and future developments. Their comments should be considered before proceeding with a more detailed study.

Reviews of the route should be carried out in the field. These should initially be based on the desk top information collected.

> NOTE Annex D highlights the necessary requirements with regard to land referencing, contacting land owner/occupiers, land rights and legal considerations that should be made.

Accompanied by the relevant landowner/occupier and the land agent, it will be necessary to examine the proposed route in more detail. In particular, those areas that may have been difficult to determine from maps and public rights of way during the desk study.

At this stage, it would be appropriate to determine where constraints may apply, i.e. timing or method of construction, etc. Also the accommodation works, which will be required by the owner/occupier dependent upon land use, can be agreed and noted for incorporation into construction contract. Consideration should be given to the negotiations for use of access roads for construction or maintenance purposes.

Land and Environmental Surveys can now be made. These should cover sufficient width and depth around the provisional route and have sufficient accuracy to identify all features that could adversely influence installation and operation of the pipeline. This should be accompanied by further detailed consultation with all affected third parties.

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

A complete set of data relevant to design, construction and the safe and reliable operation of the pipeline should be compiled from records, maps and physical surveys. The selected route should be recorded on alignment sheets of an appropriate scale. The co-ordinates 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 consideration should be given to the need for a vertical profile of the route.

C.4 Operating conditions and hazards

The main operating conditions in pipelines that can affect route selection are:

a) the nature of the contents;

b) the maximum working pressure;

c) the peak flow rate;

d) the pipeline material and diameter.

For a given pipeline material, diameter and content, consideration should be given to:

a) the probability of fracture and its consequences;

b) the maximum possible size of fracture;

c) the consequent maximum rate of release of contents;

d) any change of state of the contents under atmospheric conditions;

e) the total volume that can escape under emergency conditions.

Where pipelines convey flammable or toxic substances or those liable to cause contamination, the routes selected should, wherever reasonably practicable, avoid built-up areas. Consideration should be given to routing that will minimize the possibility of external damage, which could lead to incidents and attendant damage to third parties. A safety evaluation may be requested by the approving authority, and this requirement should be checked before a preliminary route is put forward.

Fire authorities should be consulted in appropriate cases in order that they may take into account the risk categories of the areas being traversed, to determine measures required to deal with accidents.

C.5 Terrain and subterranean conditions

An important consideration in pipeline routing is the geography of the terrain traversed. On land, this can be broadly separated into surface topography and subterranean geology, and it is usually convenient to consider both natural and man-made geographical features under these two headings.

The principal geographical features which are likely to be encountered and should be considered, include the following.

Land surface

Agricultural:	crops, livestock, woodlands

Heritage:	natural beauty, archaeological, ornamental
Natural barriers:	rivers, mountains
Natural resources:	water catchment areas, forestry
Occupation:	population, communications, services
Physical:	contouring, soil or rock type, water, soil corrosivity

Subterranean

Earthquake zone category
Geological features
Land infill
Mining and quarrying
Old mine and quarry workings
Pipelines and underground services
Possible land slippage
Tunnels
Water table limits

C.6 Adverse ground conditions

The following adverse ground conditions should be considered during the route planning stage:

a) the proximity of past, present and future mineral extractions, including uncharted workings;

b) areas of geological instability including faults and fissuring;

c) soft or waterlogged ground;

d) soil corrosivity;

e) rock and hard ground;

f) flood plains;

g) earthquake zones;

h) existing or potential areas of land slippage and subsidence;

i) infilled land and waste disposal sites including those contaminated by disease or radioactivity.

British Coal, private mine owners and the owners of mineral rights should be consulted to determine the extent of present and possible future mining operations and the existence of tips and old workings. These bodies should be consulted on possible projected subsidence.

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 pipelines, observations leading to their detection should be incorporated in the regular surveillance procedures adopted. This will include measurement of local ground movement and of indicative changes in pipeline stresses.

C.6.1 ***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 In exceptional circumstances it may be advantageous to override normal design limitations, and provide alternative installation methods or additional protective measures giving the same degree of reliability and safety.

Areas designated for future development require careful consideration, to reduce the incidence of expensive diversions or alternative works at a later date.

The routes of pipelines conveying substances that may cause contamination of water supplies should, wherever reasonably practicable, avoid crossing exposed aquifers or land immediately upstream of waterworks intakes or impounding reservoirs. Where avoidance is not possible, statutory water undertakers and private abstractors may 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 may 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 flood water. Where pipelines cross or are laid adjacent to any such embankments, it is essential that the agreement of the relevant water authority be sought.

Consideration should be given to the availability and suitability of water for hydrostatic test purposes and its subsequent discharge.

C.6.2 ***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 routing is being negotiated with landowners and occupiers. Access may 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.

C.6.3 ***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. It is essential that pipeline routes accommodate the special conditions imposed by the authorities concerned.

Normally pipelines should be routed to minimize disruption to existing facilities and services. However, at locations where this is not possible, the most appropriate solution may 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 may arrange to excavate exploratory trial holes, or will 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. Pipelines laid in highways are subject to legislation related to public utilities street works.

C.6.4 *Agricultural practice*

Pipelines should be located to produce minimum disturbance to established agricultural practice.

Permanent above ground apparatus, located on or adjacent to the line of pipelines, should be sited with the agreement of the land owners and occupiers concerned to minimize future obstruction.

Consideration should be given to terminating sewer manholes below the surface of agricultural land. Chambers which terminate at ground level should be sited at field boundaries.

C.6.5 *Environmental impact*

Among environmental factors to be considered should be the possible effects on the following:

a) sites of special scientific interest;

b) national parks and country parks;

c) areas of outstanding natural beauty;

d) ancient monuments and archeological sites;

e) tree preservation orders;

f) noise and vibration;

g) odour and dust.

Early reference should be made to the relevant planning authorities to determine whether an Environmental Impact Assessment (EIA) will be required for a pipeline and its associated above ground installations. If required, an EIA should cover the effect of pipeline works on local amenities and future developments. Pipeline promoters should also ascertain at the planning stage whether they are or are likely to be subject to Directives of the European Communities.

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 a prior noise assessment can be made.

NOTE Particulars of previous noise complaints may be obtained from relevant local authorities.

Annex D (normative)
Planning and legal

D.1 Planning permission

D.1.1 *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 should be carried out to determine if other construction related areas (e.g. construction camp and pipe storage areas) require planning permission.

D.1.2 *Consultations with other parties*

D.1.2.1 *General*

A pipeline will usually cross the routes of roads, railways, canals and water courses. 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 should be submitted to each appropriate authority in sufficient detail to enable proper consideration 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.

D.1.2.2 *Land easement details*

At the easement negotiation stage, the boundary of each ownership/tenancy should be established. Consideration should be given to utilizing 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 at a suitable scale should be marked up giving a reference number for each ownership (plot) and tenancy (parcel).

The appropriate information should form a book of reference which ties the land owner/occupiers back to the given reference numbers recorded on the maps/images.

D.1.2.3 *Railways*

When pipelines are to be laid across or adjacent to tracks, the appropriate railway authority should be consulted well in advance. In the case of main lines a year or more notice of works may be necessary. A complete closure of all tracks for a 24 h period is unlikely to be available. Appropriate administrative and operational costs should be paid by the promoter.

British Rail has produced a handbook, entitled "Engineering recommendations for pipelines constructed on or adjacent to railway property" to which reference should be made.

D.1.2.4 *Rivers, canals and foreshores*

Special methods of construction may be required when pipelines cross canals, roads and railways. Consideration should be given to the use of pre-tested pipe in crossings.

Where the proposed route crosses rivers canals or foreshores it is advisable to consult with the relevant owners/authority prior to finalizing the overall route. Restrictions which were not apparent during the desk top study may exist. These may include environmental restrictions or fishing/riparian rights.

Discussions regarding water abstraction and disposal should take place at an early stage in the project. Restrictions may apply to, quantities of water available, timing of abstraction and disposal or other aspects affecting location of the crossing or abstraction point.

D.1.2.5 *Pipe laying across country*

Consultation should be carried out to determine aspects that could possibly affect design, construction and operations. The following list, which is not exhaustive, identifies some of the groups that have an interest in cross-country projects:

— Planning officers of County and District & Parish Councils, Local Unitary Authorities and, in Scotland, Regional Councils;

— English Nature, Countryside Agency (England), and Countryside Council for Wales and Scottish Natural Heritage;

— EA (England and Wales) and SEPA (Scotland);

— Department of the Environment Transport and The Regions;

— English Heritage and Historic Scotland;

— Department of Trade and Industry (DTI);

— Crown Estates;

— Ministry of Defence;

— MAFF;

— HSE;

— Country Landowners' Association or the Scottish Landowners Federation;

— National Farmers Union or the National Farmers Union of Scotland;

— The Coal Authority;

— Utilities -electricity, water, telephone and gas companies; etc.;

— British Geological Society;

— British Pipeline Agency;

— Railtrack and other statutory railways boards;

— British Waterways;

— Scottish River Purification Board;
— Civil Aviation Authority;
— Council for Preservation of Rural England;
— Scottish Woodland Owners Association;
— Independent pipeline operators;
— Independent developers of mineral rights;
— Internal Drainage Boards;
— Landowners and occupiers;
— Local trusts for nature conservation and archaeology;
— National Park Authorities.

D.2 Legal

D.2.1 ***General***

It is essential to consider the legal requirements necessary when planning a pipeline project. Reference should be made to national and local requirements with regard to type of consent, license and permits necessary at each stage of the project.

D.2.2 ***Types of rights***

D.2.2.1 *Land rights*

The practical considerations and aims of this subclause apply, irrespective of whether the land is acquired by private treaty or by statutory powers.

The responsibility for acquiring the necessary land, easements and ancillary rights for the pipeline rests with the promoter. These should be obtained wherever possible by private negotiation. If statutory powers are necessary, the procedure to be followed has been established by legislation.

The easement agreed with the landowner/occupier will need to satisfy the interests of the promoter and the owner/occupier.

The promoter will need to include the right to construct, use and maintain the pipeline for the expected life of the project.

Promoters should, at the earliest stage, consult the owners and occupiers concerned, as well as statutory organizations, and other representative associations such as the Country Landowners' Association and National Farmers' Union or their equivalent counterparts in Scotland, Wales and Northern Ireland.

During negotiations, land owners/occupiers should be informed as to the method and type of construction that is anticipated. This should include 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.

Promoters should make full use of other advice from land agents, surveyors and engineers in all negotiations with owners and occupiers. Promoters should make full use of legal advice although this may not be necessary in the case of way leave orders acquired by statute.

The landowner/occupier should be assured that, on completion of construction and commissioning, the land will be reinstated to the owner/occupiers satisfaction. This should include reinstatement of, land drainage, access ways, replacement of hedgerows and fencing etc.

D.2.2.2 *Survey access*

Although much can be done from plans and geological and aerial surveys, route selection requires access to the land, and may often necessitate on site ground investigations. The consent of owners and occupiers should be sought individually for any such access.

The promoter will normally obtain temporary rights which will lapse after the survey is completed. A prior undertaking should be given to landowners and occupiers to make good damage done or loss sustained during the survey and to pay compensation for any damage not made good.

Prior consultation with planning and other local authorities, as described above can avoid an unnecessarily large number of entries on to land.

D.2.2.3 *Rights granted directly by Acts of Parliament*

Statutory authorities and government bodies have powers under Acts of Parliament to lay, use and maintain pipelines. Reference should be made to the acts or orders which grants those powers, as to the procedure to be adopted by the authority concerned.

D.2.2.4 *Rights granted by agreement between landowner and promoter*

Where a promoter is not granted rights directly by Acts of Parliament, he will require the agreement of the landowner, conferring some interest in or over the land concerned, to lay and maintain a pipeline. The agreement may take any of a variety of names (such as easement or lease) but legally the interests which may be conferred, and the associated degrees of security to the promoter, are, in the 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 his 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 will require are as follows.

a) **Freeholds**. Generally, the only freeholds which need to be purchased outright will be 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 may sometimes be set back from a public highway, specific provision for permanent rights of access to and from the plots should be made.
b) **Easements and leases**. It will not usually be appropriate to purchase land for laying the pipeline itself and, where possible, easements or leases should be obtained.

If it is the promoter's own land which will be served by the pipeline (i.e. a dominant tenement, such as a refinery at one or other end of the pipeline) easements may be acquired. These may be for a term of years or in perpetuity and, as they run with the land, they will not be extinguished by a change of ownership; thus, if the landowner dies or sells his land or if the pipeline changes hands, the pipeline easement will continue automatically, provided 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) will need to be acquired. Leases of subterranean strips are subject to the provisions of the Land Registration Acts as to registration of leases.

An easement or a lease will cover pipeline works (including surface obstructions) and, where necessary, rights of way, cathodic protection beds and other apparatus. The document will specify 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 should 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 **13**).

The restrictions on the grantor in respect of the protection of the pipeline should also be included.

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, should 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) should be registered.

a) **Way leaves**. The way leave will confer no interest in the land as such, the contractual rights being binding only on the original contracting parties, and will thus confer no security on the promoter if the original landowner sells his land. Care should therefore be taken by the promoter not to obtain only a way leave when a greater interest in land is required.

b) **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 may be required for works not covered by the grant for the pipeline.

c) **Mineral rights**. It should be ascertained if any mineral rights are owned or leased separately from the surface ownership. Suitable arrangements will generally need to be made to safeguard rights of support and to negotiate compensation to mineral owners and operators. An adaptation of one of the statutory mining codes may 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 will be acquired under the appropriate Scottish statutes, although rights may be acquired through agreement with the landowner by the following:

1) acquisition of the dominium utile (similar to freehold purchase in England);

2) leasehold;

3) Deed of Servitude (similar to easement in England);

4) way leave.

D.2.2.5 *Rights granted indirectly by Acts of Parliament*

A promoter wishing to lay and maintain a pipeline over land may fail to obtain the agreement of a landowner. The promoter may then have to seek the right compulsorily under appropriate legislation.

D.2.3 ***Financial consideration and compensation***

D.2.3.1 *Payments to owners*

Owners are generally entitled to receive payment for granting an easement or lease, or sale of freehold interest, or where rights are acquired by statute.

D.2.3.2 *Compensation for damage and loss*

Owners or occupiers or both are entitled to compensation for any land which cannot be fully reinstated.

Compensation is therefore payable for damage to crops, loss of profits, loss of residual manurial value, loss of or damage to sporting rights. Negotiations over compensation for land covered by rights described above are the responsibility of the promoter.

Landowners and occupiers should be made aware that occupation of land by a contractor is permitted only within the designated working area.

Landowners and occupiers concerned should avoid entering into independent negotiations with the contractor executing the work.

In cases where the promoter is exercising statutory powers, owners and occupiers have a duty to mitigate any losses which may arise.

Shooting and fishing rights are often sub-let but may still be subject to compensation for loss. Before construction it should be determined to whom compensation should be paid.

Delay in payment of compensation should be avoided and, where appropriate, payment on account should be made for matters not in dispute.

D.2.3.3 *Professional costs*

The professional fees reasonably incurred by the owners and/or occupiers of any interest in land through which the pipeline may be routed should normally be reimbursed by the promoter. Costs may be based on the Ryde's scale of Professional Charges as appropriate for pipeline work.

D.2.4 ***Trees and hedgerows***

The route of the pipeline selected should minimise the amount of trees to be removed. In some instances a license will be required from the Forestry Commission to authorise the felling of trees. Liaison should take place with the local authority to ascertain which trees are protected by a tree preservation order (TPO). Where a TPO exists special arrangements shall be made for protection of trees from damage.

Local authorities should be contacted for permission to remove hedgerows.

D.2.5 ***Transmittable diseases***

The Ministry of Agriculture Fisheries and Food (MAFF) will make available on request, details of any restrictions in force regarding transmittable diseases, in the areas concerned. This will include notification in areas adjacent to those concerned. MAFF will also specify any necessary precautions to be taken in respect to the diseases encountered. It is recommended that the local officer is contacted prior to commencement of construction.

D.2.6 ***Deposits of waste***

EC, national and local regulations exist concerning waste deposits. Due care and recognition should be given to licensing requirements regarding the disposal of waste.

D.2.7 ***Control of noise***

The subject of noise should be addressed during the design phase of the project. Due regard should be given to noise generated by, construction plant and equipment, and fixed plant employed for operation of the pipeline, i.e. compressors and pumps etc.

The local authority have the right to serve an abatement notice on the promoter, which could reduce the efficiency of the construction activities or curtail operation of the pipeline.

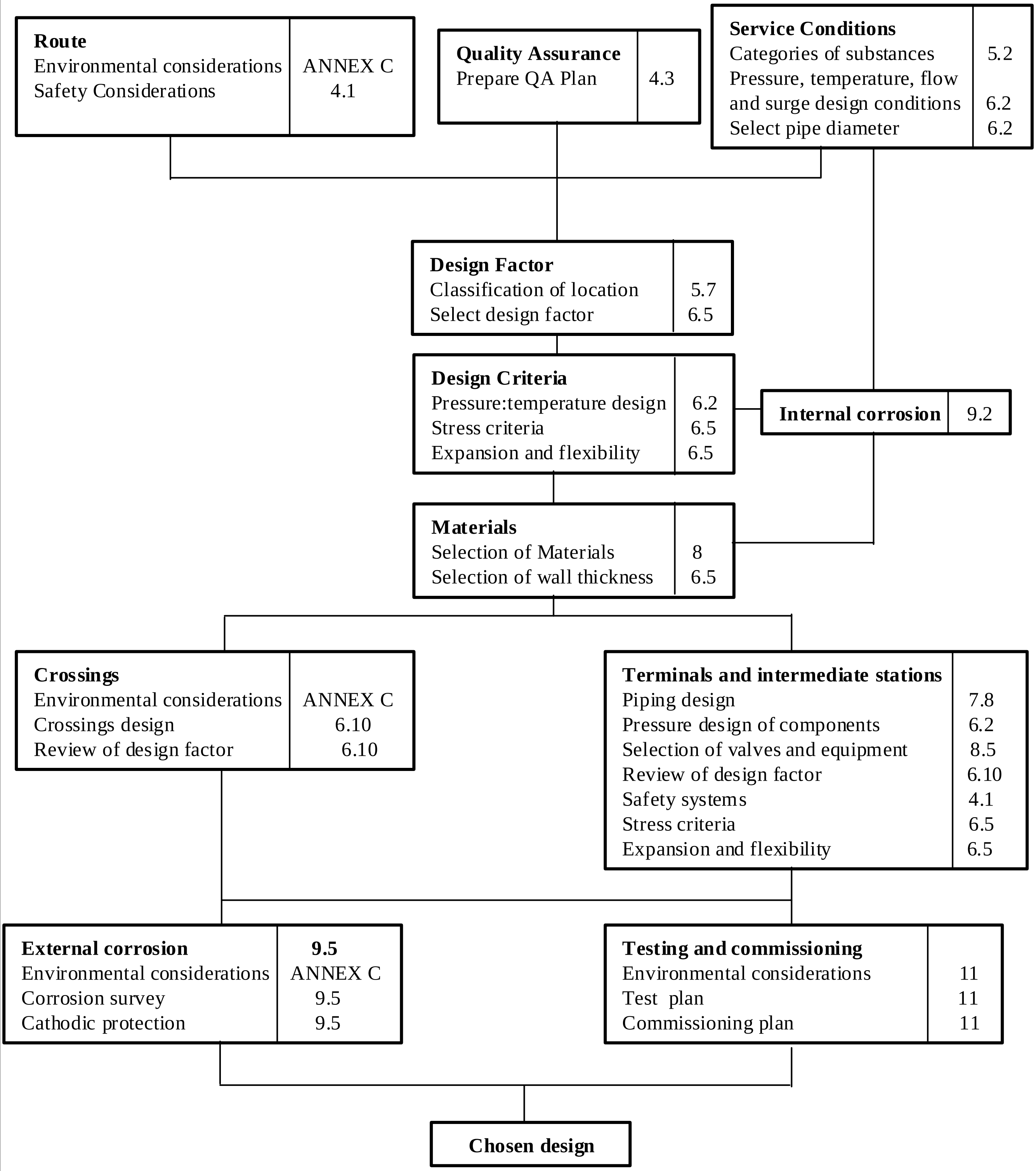
Codes of practice for construction and operation are available from the regulating authorities and should be incorporated into the construction contract and equipment specifications.

D.2.8 ***Environmental protection***

An EIA is mandatory for certain pipeline projects, dependent on diameter and length. An EIA may still be required where the pipeline route traverses through sensitive areas. Such pipelines are subject to the approval of the Secretary of State at the Department of Trade and Industry. It is important to decide on the requirement to provide an EIA early in the project, averting possible delay in completion or creating unnecessary re-route work.

Annex E
Design flowchart

Annex E. Pipeline design flowchart



Bibliography

BS 2654, *Specification for manufacture of vertical steel welded non-refrigerated storage tanks with butt-welded shells for the petroleum industry*.
BS 5555, *Specification for SI units and recommendations for the use of their multiples and of certain other units*.
BS 5607, *Code of practice for the safe use of explosives in the construction industry*.
BS 6031, *Code of practice for earthworks*.
BS 7910, *Guide on methods for assessing the acceptability of flaws in metallic structures*.
BS EN 12007 (all parts), *Gas supply systems — Pipelines for maximum operating pressure up to and including 16 bar.*
BS EN 13480 (all parts), Metallic industrial piping
BS EN ISO 9000, *Quality management and quality assurance standards.*
API 5L, *Specification for line pipe.*[6)]
API RP 5L1, *Railroad transportation of line pipe.*
API RP 5LW, *Transportation of line pipe on barges and marine vessels.*
IGE/TD3, *Distribution mains, edition 3.*[7)]
ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*.

[1] GREAT BRITAIN Health and Safety at Work etc. Act (1974). London: HMSO.
[2] GREAT BRITAIN Pipelines Act (1962). London: HMSO.
[3] GREAT BRITAIN Pressure Systems Safety Regulations 2000: HMSO
[4] GREAT BRITAIN Pressure Equipment Regulations 1999: HMSO
[5] GREAT BRITAIN SI 1990/No. 442 Electricity and Pipelines Works (Assessment of Environmental Effects) Regulations. London: HMSO.
[6] TIMOSHENKO and GERE Theory of elastic stability 2nd edition 1981. London: HMSO.
[7] EEMUA 166 Engineering Equipment and Material Users Association — publication 166. London: HMSO 1992.
[8] SMITH and De WAARD Section criteria for materials in oil and gas processing plants. Brighton, UK Corrosion, Conference Proceedings, Brighton, October 1987.
[9] SMITH, De WAARD, SIMON and THOMAS Controlling factors in the rate of CO2 corrosion. Brighton, UK Corrosion Conference Proceedings, October 1987.
[10] MILLIAMS Corrosion of oil and gas pipelines — "State of the art", Amsterdam, Offshore Oil and Gas Pipeline Technology Conference Proceedings, January 1985.
[12] De WAARD and MILLIAMS Prediction of carbonic acid corrosion in natural gas pipelines, Durham, First International Conference on the Internal and External Protection of Pipes, September 1975.
[13] MILLIAMS and KROESE Aqueous corrosion of steel by H2S and H2S/CO2 mixtures, London, Third International Conference on the Internal and External Protection of Pipes, September 1979.
[14] Van GELDER Hydrogen induced cracking: Determination of maximum allowed H2S partial pressure, Massachusetts: Corrosion 85.

6) American Petroleum Institute (API) standards are available from BSI Customer Services, Tel: +44 (0)20 8996 9001.
7) Institution of Gas Engineers (IGE) standards are available from the Institution of Gas Engineers, 21 Portland Place, London, W1B 1PY, UK. Tel: +44 (0)20 7636 6603. Fax: +44 (0)20 7636 6602.

[15] ENGINEERING SERVICES DATA UNIT (ESDU) A cross-flow response due to vortex shedding: isolated, circular, cylindrical structures in wind or gas flow. No. 78006, 1978.
[16] RANDKIVI A.J. Loose boundary hydraulics. Pergamon Press, 1976.
[17] GRAVESON and FREDSOE Modelling of liquefaction scour and natural backfilling process in relation to marine pipelines. Copenhagen, Seminar of Offshore Oil and Gas Pipeline Technology. 1983.
[18] MURPHY and LANGER. Ultimate pipe strength under bending 1985.