

Code of practice for

Pipelines —

**Part 2: Pipelines on land: design,
construction and installation —**

Section 2.8 Steel for oil and gas

Committees responsible for this British Standard

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- Association of Consulting Engineers
- British Compressed Gases Association
- British Gas plc
- British Steel Industry
- Department of Environment (Property Services Agency)
- Federation of Civil Engineering Contractors
- Health and Safety Executive
- Institute of Petroleum
- Pipelines Industries Guild
- PSE/17 Materials and equipment for petroleum and natural gas industries
 - PSE/17/1 Linepipe

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Foreword

This Section of BS 8010 has been prepared under the direction of Technical Committee B/203. BS 8010 is a complete revision of all five Parts of CP 2010. BS 8010 is to be published in four Parts as follows.

- *Part 1: Pipelines on land: general;*
- *Part 2: Pipelines on land: design, construction and installation;*
- *Part 3: Pipelines subsea: design, construction and installation;*
- *Part 4: Pipelines on land and subsea: operations and maintenance.*

Part 1 (which supersedes CP 2010-1:1966) contains general information which is relevant to a variety of pipelines and a variety of transported materials. It deals with those aspects of pipeline development which affect the owner and occupier of land through which the pipeline passes.

Part 2 is divided into several Sections which will be published as separate documents as follows:

- *Section 2.1: Ductile iron;*
- *Section 2.3: Asbestos cement;*
- *Section 2.4: Prestressed concrete pressure pipelines;*
- *Section 2.5: Glass reinforced thermosetting plastics;*
- *Section 2.6: Thermoplastics;*
- *Section 2.7: Precast concrete;*
- *Section 2.8: Steel for oil and gas.*

Each Section will contain information on the design, construction and installation of a pipeline in the particular material. These Sections will supersede the existing Parts 2, 3, 4 and 5 of CP 2010.

Part 3 will include the general information relevant to subsea pipelines and the particular information on design, construction and installation of a pipeline in specific materials.

Part 4 will contain advice on the operation and maintenance of pipelines and will probably be in sections related to conveyed material.

This Section of BS 8010 supersedes part of CP 2010-2:1970. This Section of BS 8010 deals with oil, gas and other substances which are hazardous by nature of being explosive, flammable, toxic or reactive, generally classified as category B, category C and category D substances (see **2.2**).

The guidance given 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* IGE/TD/1:1984 *Steel pipelines for high pressure gas transmission*. The Institution's guidance is specific to 1st and 2nd family gases and can be supported by experimental data. Copies of the Recommendations are available from the Institution and should be consulted.

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 principal Acts of Parliament, which enable pipelines to be constructed and regulate procedures. These are listed in Appendix A of BS 8010-1:1989.

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.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 46, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1.1 Scope

This Section of BS 8010-2 provides guidance on the design, construction and installation of steel pipelines on land for oil, gas and toxic fluids. It is not intended to replace or duplicate hydraulic, mechanical or structural design manuals.

The extent of pipeline systems on land for conveying oil, gas and toxic fluids which are covered by this Section is shown in Figure 1.

Reference should be made to BS 8010-1:1989 for those aspects of land acquisition, routing, installation, operation, maintenance and abandonment of pipelines which affect land.

1.2 References

1.2.1 Normative references

This Section of BS 8010 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on page 44. Subsequent amendments to, or revisions of, any of these publications apply to this Section of BS 8010 only when incorporated in it by updating or revision.

1.2.2 Informative references

This Section of BS 8010 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on page 46, but reference should be made to the latest editions.

1.3 Definitions

For the purposes of this Section of BS 8010 the definitions given in BS 8010-1:1989 apply together with the following.

1.3.1

availability

the probability that a system will be in the operational state

1.3.2

coating

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

1.3.3

component

a 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.

1.3.4

design temperature

the design temperature is the maximum or minimum temperature which determines the selection of material for the duty proposed and should represent the most arduous conditions expected

1.3.5

holiday

a flaw in the coating or lining

1.3.6

holiday detector

a device for detecting flaws in the coating or lining

1.3.7

insulation joint

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

1.3.8

intermediate station

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

1.3.9

internal design pressure

the pressure selected as the maximum sustained pressure exerted by the pipeline contents for which a pipeline is to be designed

1.3.10

lining

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

1.3.11

maximum operating pressure

the sum of the static head pressure, the pressure required to overcome friction loss and any required back pressure

1.3.12

maximum allowable operating pressure (MAOP)

the MAOP is that pressure, excluding surge pressure or other variations, for which a pipeline is qualified

1.3.13

night cap

a temporary closure at the end of a section of pipeline

1.3.14**pig**

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

1.3.15**pig trap**

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

1.3.16**pipe**

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

NOTE Also known as linepipe.

1.3.17**pipeline**

a continuous line of pipes of any length without frequent branches used for transporting fluids. It does not include piping systems such as process plant piping within refineries, factories or treatment plants

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 Certain aspects of both on land and subsea Parts of BS 8010 are relevant to the shore area and should be consulted for landfalls.

1.3.18**pipeline system**

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

1.3.19**pup**

a short made-up piece of pipe

1.3.20**redundancy**

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

1.3.21**reliability**

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

1.3.22**tie-in welds**

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

1.3.23**voting systems**

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

1.4 Units

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

NOTE $1 \text{ bar} = 10^5 \text{ N/m}^2 = 10^5 \text{ Pa}$.

1.5 Application**1.5.1 General application**

The steel pipelines covered by this Section should be constructed with butt welded joints and are generally suitable for conveying oil, gas and toxic fluids. The choice of steel, components, coating and lining (if necessary) will depend on the service conditions and the particular environment. The major application of this Section will be the transmission of substances for which low alloy carbon steel pipe will 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. Environmental factors are described in BS 8010-1:1989.

Pipelines are unlikely to be required to operate outside the temperature range -25°C to $+120^\circ\text{C}$. In the event of pipelines being required to operate outside this range reference should be made to specifications such as ANSI B31.3 or BS 806 where design stresses for pipe materials at other temperatures are given.

1.5.2 Categorization of substances

Substances to be conveyed by pipelines should be placed in one of four categories according to the hazard potential of the substance. (See 2.2.)

The provisions of this Section apply to pipelines conveying category B, category C and category D substances (see 2.2).

1.6 Pipeline and plant area demarcations

This Section applies to pipeline systems connecting production plants, process plants, refineries, and storage facilities, including any section of pipeline constructed within the boundaries of such facilities for the purpose of connecting it to a pumping station or process piping.

This Section does not necessarily apply to other piping systems within such facilities and for which other British Standards are available.

Figure 1 illustrates the extent of pipeline systems to which this Section applies.

1.7 Safety

Safety considerations affecting the design, construction and installation of pipelines are covered generally in BS 8010-1:1989 and specific recommendations for the extra protective measures which may be provided for pipelines are given in appropriate clauses in this Section.

1.8 Environmental protection

Environmental factors to be considered in the design, construction and installation of steel pipelines are covered in BS 8010-1:1989.

1.9 Quality assurance

The safety and reliability of a pipeline system may be improved by the introduction of quality assurance procedures. These procedures should be used in the application of the whole of this Section including design, procurement, construction and testing.

In this respect reference should be made to BSI Handbook 22 *Quality Assurance*, BS 5750 and section 7 of this document.

NOTE Other recognized quality assurance codes may be specified and in this case section 7 should be referred to.

1.10 Statutory requirements

BS 8010-1:1989 gives recommendations for compliance with the requirements of all authorities whose duties or interests may be affected by the construction of a pipeline. Appendix A of BS 8010-1:1989 lists the principal Acts of Parliament regulating the construction of pipelines.

1.11 Documentation

BS 8010-1:1989 gives recommendations for the types and scales of plans to be used in routing surveys and construction of pipelines. In addition, the following records should be maintained by the promoter.

- a) Materials specifications and test results.
- b) Equipment manufacturers and suppliers.
- c) "As built" route alignments generally of 1 : 2 500 scale (in built-up areas 1 : 1 250 scale should be considered).
- d) Detailed larger scale drawings of crossings and installations, etc.
- e) Land drainage drawings.
- f) Pressure test records.
- g) Factory and construction inspection records.
- h) 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.

1.12 Abandonment

BS 8010-1:1989 gives recommendations for the steps to be taken on abandonment of a pipeline.

1.13 Pipeline design flowchart

The pipeline design flowchart shown in Table 1 may be used by the pipeline designer as a guide through the design process as it relates to this Section. 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 sections and clauses within this Section.

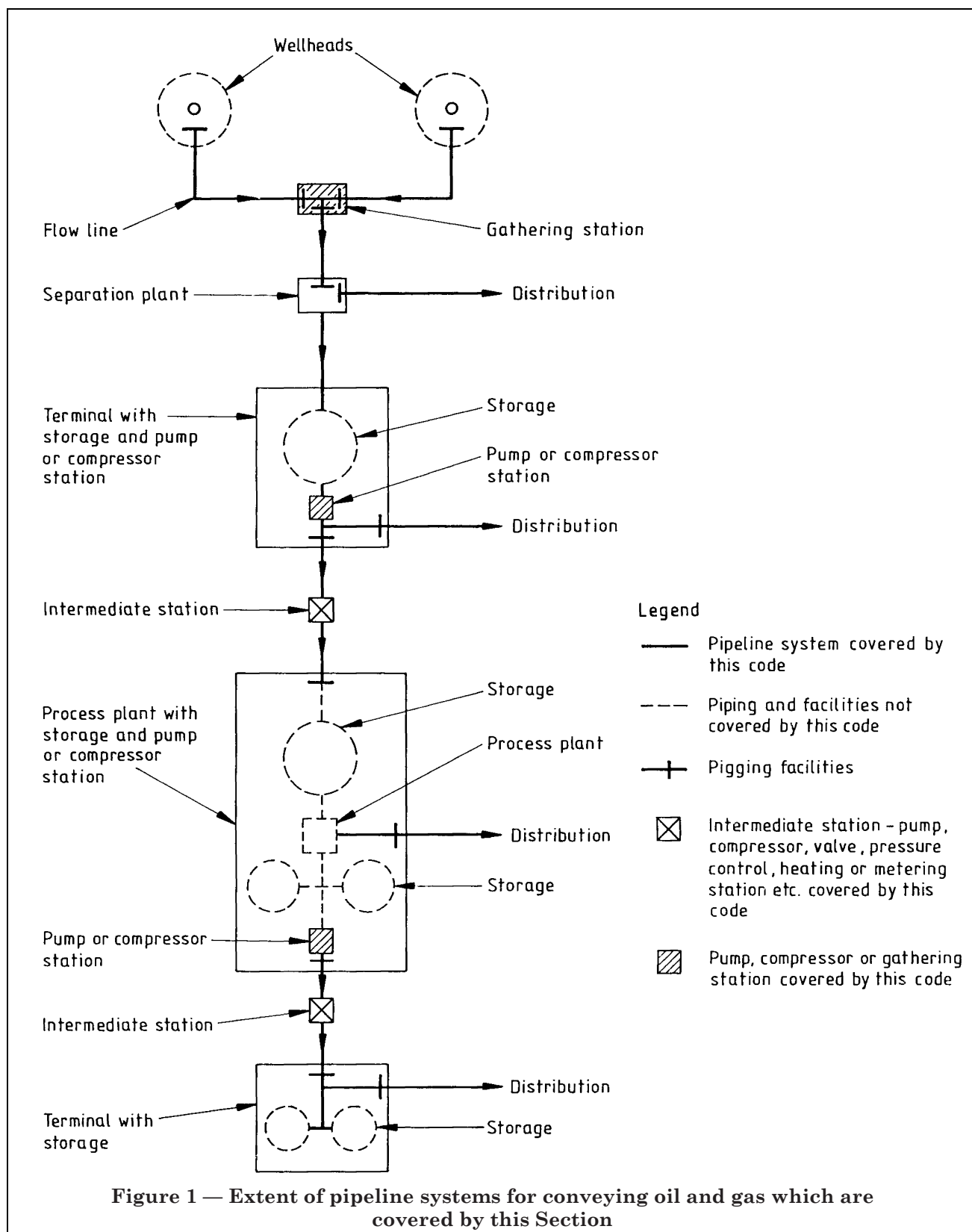
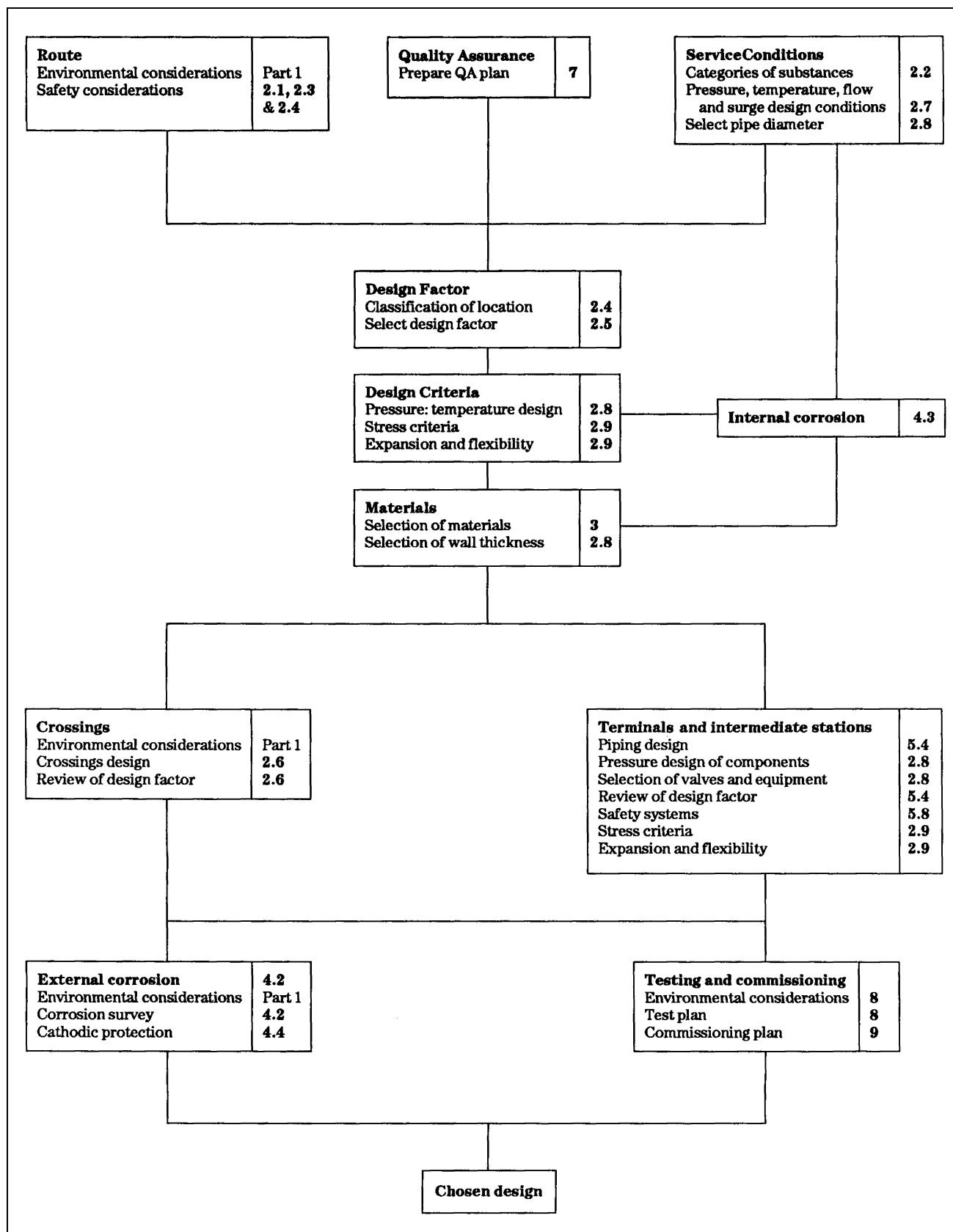


Table 1 — Pipeline design flow chart



Section 2. Design

2.1 Safety considerations

2.1.1 General

The recommendations of this Section are considered to be adequate for public safety under conditions usually encountered in pipelines including those within towns, cities, water catchments and industrial areas. The Section is not intended to be a design handbook and although it contains certain recommendations it does not replace the need for appropriate experience and competent engineering judgement. Fundamental principles should be followed throughout and materials and practices not recommended in the Section 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.

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 may be improved by the application of quality assurance procedures in design. In this respect reference should be made to section 7.

2.1.2 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.

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.

2.2 Categorization of substances

2.2.1 General

Substances to be conveyed by pipelines should be placed in one of the following four categories according to the hazard potential of the substance. If the category is not clear the more hazardous should be assumed.

Category A Typically water based fluids.

Category B Flammable and toxic substances which are liquids at ambient temperature and atmospheric pressure conditions. Typical examples would be oil, petroleum products, toxic liquids and other liquids which could have an adverse effect on the environment if released.

Category C Non-flammable substances which are gases at ambient temperature and atmospheric pressure conditions. Typical examples would be oxygen, nitrogen, carbon dioxide, argon and air.

Category D Flammable and toxic substances which are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases or liquids. Typical examples would be hydrogen, methane, ethane, ethylene, propane, butane, liquefied petroleum gas, natural gas liquids, ammonia, and chlorine.

Mixtures of gases and liquids should be placed in relation to their composition. Other gases or liquids not specifically included by name should be placed in the category containing substances most closely similar in hazard potential to those quoted (see 2.2.2). Guidance on this may be found in publications such as *A guide to the Notification of Installations Handling Hazardous Substances Regulations* 1982 [1], published by HSE and *Hazard definition: nomenclature for hazard and risk assessment in the process industries* [2] published by the Institution of Chemical Engineers.

2.2.2 Hazard potential

2.2.2.1 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 2.2.2.2 to 2.2.2.4, to assist the designer in determining the category into which hazardous substances should be placed.

2.2.2.2 Substances conveyed as a liquid

Crude oil and refined petroleum products (heavier than butane) are flammable and will be released as a liquid which 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.

2.2.2.3 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 EH40/92 *Occupational exposure limits* [3]).

Oxygen readily mixes with air, 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 may produce a vapour cloud explosion.

Methane is flammable, lighter than air, radiates heat on ignition and can form a vapour cloud which may 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 which may migrate from the point of rupture.

2.2.2.4 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 which may migrate from the point of rupture. Ethylene has the lowest critical pressure of commonly transported gases, can decompose exothermally 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 which may 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) which 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 which can migrate some distance at ground level. Ammonia will radiate heat if ignited; the gas has a toxic effect.

2.3 Safety evaluation

2.3.1 General

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

2.3.2 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.

2.4 Classification of location

2.4.1 General

The location of category C and category D 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 B substance pipelines need not be classified in relation to population density but may require extra protection or be subject to a safety evaluation.

- 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.

The measurement of population density is described in 2.4.3. 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 may be considered where the effects of a pipeline failure could be experienced by population centres outside the immediate vicinity of the pipeline.

2.4.2 Proximity to occupied buildings

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

2.4.2.2 At the pipeline feasibility study stage the initial route and population density assessment for pipelines conveying category C and category D substances (excluding methane) should be established by taking account of the proximity to occupied buildings. The minimum distance (in metres) for routing purposes between a pipeline having a design factor (see 2.5) not exceeding 0.72 and normally occupied buildings should be determined from the following formula:

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 2).

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 2 — Substance factors

Substance	Substance factor, Q
Ammonia	2.5
Ethylene	0.8
Hydrogen	0.45
LPG	1
NGL	1.25
Category C	0.3

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

The minimum distances should finally be determined by taking into account factors including the hazardous nature of the particular substance being conveyed and the pipeline inventory in conjunction with a safety evaluation of the pipeline (see 2.3).

2.4.2.3 The minimum distance between a pipeline conveying methane (a category D substance) and normally occupied buildings should be determined in accordance with Figure 2.

2.4.2.4 Pipelines designed to operate outside the range of maximum operating pressure and pipe diameters shown in Figure 2 may be acceptable provided a more detailed assessment of potential additional hazard is made in conjunction with a safety evaluation (see 2.3).

2.4.3 Population density

2.4.3.1 For category C 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 three times the minimum distance given in 2.4.2.2 for any 1.5 km length of pipeline.

2.4.3.2 For methane (a category D 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 10 times the minimum distance shown by lines A to G in Figure 2 for any 1.5 km length of pipeline.

2.4.3.3 For category D substance pipelines (excluding methane) 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 2.4.2.2 for any 1.5 km length of pipeline.

2.4.3.4 The population density is 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.

The point at which the required degree of protection changes adjacent to the boundary between class 1 and class 2 areas should be one-half of the appropriate strip width from the boundary of the higher density area.

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.

2.5 Selection of design factor

2.5.1 Design factor

The maximum design factor a to be used in the calculation of allowable stress for pipelines (see 2.10.2) should be as described in 2.5.2 and 2.5.3.

2.5.2 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 2.1.2.

2.5.3 Category C and category D substances

The design factor a should not exceed 0.72 in class 1 and 0.30 in class 2 and 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 (see 2.3.2).

Pipelines designed to convey category D 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 2.6.8 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.

2.6 General design considerations

2.6.1 Road crossings

2.6.1.1 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 substance pipelines, roads should be classified as major roads or minor roads for allocation of design factor and wall thickness. 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 of Transport and local highway authorities concerned.