

Gas supply systems — Pipelines for maximum operating pressure over 16 bar — Functional requirements

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National foreword

This British Standard is the official English language version of EN 1594:2000.

EN 1594 recognises the need for more detailed national standards and codes of practice in the CEN member countries. For the UK additional guidance of this nature can be found in BS 8010-1 and BS 8010-2-2.8. In due course BS 8010-2-2.8 will be revised and reissued.

The UK participation in its preparation was entrusted by Technical Committee GSE/33, Gas Supply, to Subcommittee GSE/33/3, Gas Supply: Transmission, which has the responsibility to:

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

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

Cross-references

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Summary of pages

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This European Standard was approved by CEN on 21 October 1999.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 234, Gas supply, the Secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2000, and conflicting national standards shall be withdrawn at the latest by September 2000.

There is a complete suite of functional standards prepared by CEN/TC 234, Gas supply, to cover all parts of the gas supply system from the input of gas to the transmission system up to the inlet connection of the gas appliances, whether for domestic, commercial or industrial purposes.

A list of the relevant functional standards prepared by CEN/TC 234 is included in clause 2 and Annex A to this document.

CEN/TC 234 will continue its work updating this standard to the latest developments at regular intervals.

In preparing this standard a basic understanding of gas supply by the user has been assumed.

Gas supply systems are complex and the importance on safety of their construction and use has led to the development of very detailed codes of practice and operating manuals in the member countries. These detailed statements embrace recognized standards of gas engineering and the specific requirements imposed by the legal structures of the member countries.

This European Standard has been prepared under mandate M/017 given to CEN by the Commission of the European Communities and the European Free Trade Association.

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

Introduction

This European Standard describes the general functional requirements for gas supply through pipe systems and covers the pressure range greater than 16 bar maximum operating pressure (MOP) for steel systems. It gives normative and informative references for safe and secure gas supply systems. It applies to their design, construction, operation and the related aspects of safety, environment and public health, all in order to provide a safe and secure supply of gas.

The requirements of this standard are based on safe gas engineering practice under conditions normally encountered in the gas industry. Requirements for all unusual conditions cannot be specifically provided for, nor are all engineering and construction details prescribed.

Existing industrial safety regulations applying to work areas, safety devices, and safe work practices are not intended to be supplanted by this standard.

Managers with responsibilities for the design, construction and operation of gas supply systems should have regard to the guidance given in this document and to other relevant standards. It is the responsibility of these managers and engineers to apply these functional requirements, supplemented with other proven good practice to the particular circumstances of each gas supply system.

The designer, constructor or operator of pipeline systems is cautioned that this standard is not a design handbook or code of practice. Additional national or company standards describing the details are needed. These detailed standards should be in line with the basic principles of this standard.

In preparing the standard it was recognized that the suite of relevant European standards is incomplete. Reference may be made where appropriate to international, national or other standards until relevant European Standards are available.

1 Scope

This European Standard is applicable to pipelines with a maximum operating pressure (MOP) over 16 bar for the carriage of processed, non-toxic and non-corrosive natural gas according to ISO 13686 in onland gas supply systems, where:

- the pipeline elements are made of unalloyed or low-alloyed carbon steel;
- the pipeline elements are joined by welds, flanges or mechanical couplings;
- the pipeline is not located within commercial or industrial premises as an integral part of the industrial process on these premises except for any pipelines and facilities supplying such premises;
- the design temperature of the system is between -40 °C and 120 °C inclusive.

This European Standard does not apply to existing pipelines, in use prior to the publication of this standard, nor to modifications to existing pipelines.

Gas supply systems covered by this standard begin after the gas producer's metering station. The functional demarcation of the pipeline system within a plant area will be determined from case to case. Generally speaking, this will be directly after the first isolating valve of the installation.

This standard also describes the mechanical requirements for pipework in stations with a maximum operating pressure greater than 16 bar. Welding requirements are described in a special application standard on welding for gas supply systems, EN 12732. Functional requirements for stations are given in:

- | | |
|------------|--|
| EN 1776, | <i>Gas supply systems - Natural gas measuring stations - Functional requirements</i> |
| EN 1918-5, | <i>Gas supply systems - Underground gas storage - Part 5: Functional recommendations for surface facilities</i> |
| EN 12186, | <i>Gas supply systems - Gas pressure regulating stations for transmission and distribution - Functional requirements</i> |
| EN 12583, | <i>Gas supply systems - Compressor stations - Functional requirements.</i> |

This European Standard specifies common basic principles for gas supply systems. Users of this European Standard should be aware that there may exist more detailed national standards and codes of practice in the CEN member countries.

This European Standard is intended to be applied in association with these national standards and/or codes of practice setting out the above mentioned principles.

In the event of conflicts in terms of more restrictive requirements in the national legislation/regulation with the requirements of this standard, the national legislation/regulation shall take precedence.

Reference is made in this standard to relevant European and other recognized standards for products used to construct and operate gas supply systems.

A schematic representation of pipelines for gas transmission is given in Figure 1.

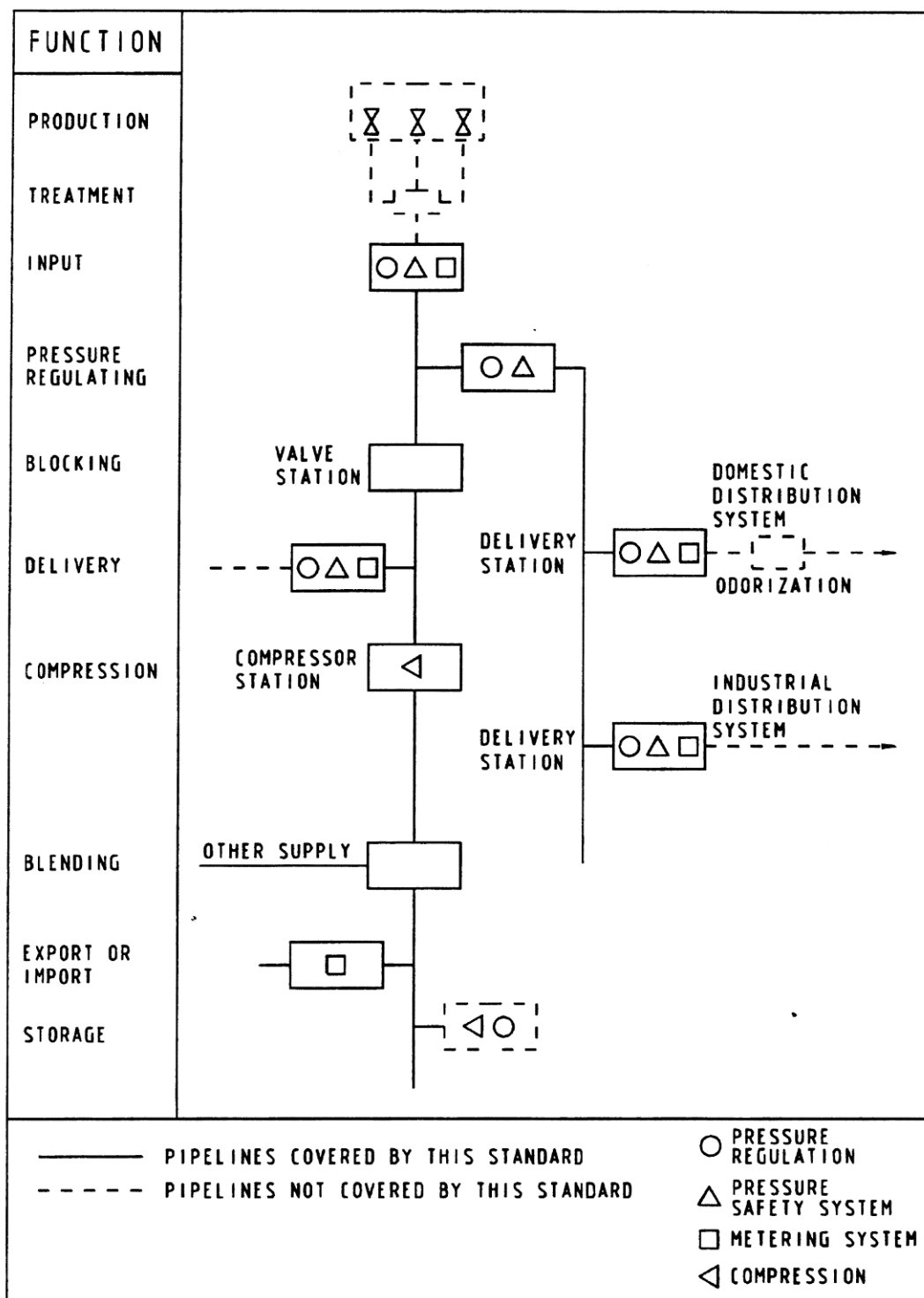


Figure 1 - Schematic representation of pipelines for gas supply over 16 bar

2 Normative references

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

- EN 10002-1, *Metallic materials - Tensile testing - Part 1: Method of test*
- EN 10204, *Metallic products - Types of inspection documents*
- EN 10208-2, *Steel pipes for pipelines for combustible fluids - Technical delivery conditions - Part 2: Pipes of requirement class B*
- prEN 10216-1, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties*
- prEN 10216-2, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties*
- prEN 10216-3, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 3: Non-alloy and alloy fine grain steel tubes*
- prEN 10216-4, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 4: Non-alloy and alloy steel tubes with specified low temperature properties*
- prEN 10217-1, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties*
- prEN 10217-2, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 2: Electric welded non-alloy and alloy steel tubes with specified elevated temperature properties*
- prEN 10217-3, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 3: Non-alloy and alloy fine grain steel tubes*
- prEN 10217-4, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 4: Electric welded non-alloy and alloy steel tubes with specified low temperature properties*
- prEN 10217-5, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 5: Submerged arc welded non-alloy and alloy steel tubes with specified elevated temperature properties*
- prEN 10217-6, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 6: Submerged arc non-alloy and alloy steel tubes with specified low temperature properties*
- prEN 10285, *Steel tubes and fittings for on and offshore pipelines - External three layer extruded polyethylene based coatings*
- prEN 10286, *Steel tubes and fittings for on and offshore pipelines - External three layer extruded polypropylene based coatings*
- prEN 10287, *Steel tubes and fittings for on and offshore pipelines - External fused polyethylene based coatings*
- prEN 10288, *Steel tubes and fittings for on and offshore pipelines - External two layer extruded polyethylene based coatings*
- prEN 10289, *Steel tubes and fittings for on and offshore pipelines - External liquid applied epoxy and epoxy-modified coatings*
- prEN 10290, *Steel tubes and fittings for on and offshore pipelines - External liquid applied polyurethane and polyurethane-modified coatings*
- EN 12007-1, *Gas supply systems - Pipelines for maximum operating pressure up to and including 16 bar - Part 1: General functional recommendations*
- EN 12007-3, *Gas supply systems - Pipelines for maximum operating pressure up to and including 16 bar - Part 3: Specific functional recommendations for steel*
- EN 12068, *Cathodic protection - External organic coatings for the corrosion protection of buried or immersed steel pipelines used in conjunction with cathodic protection - Tapes and shrinkable materials*
- EN 12186, *Gas pressure regulating stations for transmission and distribution*
- EN 12327, *Pressure testing, commissioning and decommissioning procedures for gas supply systems*

- EN 12583, *Gas supply systems - Compressor stations - Functional requirements*
- prEN 12560-1, *Flanges and their joints - Dimensions of gaskets for Class-designated flanges - Part 1: Non-metallic flat gaskets with or without inserts*
- prEN 12560-2, *Flanges and their joints - Dimensions of gaskets for Class-designated flanges - Part 2: Spiral wound gaskets for use with steel flanges*
- prEN 12560-3, *Flanges and their joints - Dimensions of gaskets for Class-designated flanges - Part 3: Non-metallic PTFE envelope gaskets*
- prEN 12560-4, *Flanges and their joints - Dimensions of gaskets for Class-designated flanges - Part 4: Corrugated flat or grooved metallic and filled metallic gaskets for use with steel flanges*
- EN 12732, *Gas supply systems - Welding steel pipework - Functional requirements*
- EN 45004, *General criteria for the operation of various types of bodies performing inspection*
- EN 45011, *General requirements for bodies operating product certification systems (ISO/IEC Guide 65:1996).*

3 Definitions, symbols and abbreviations

For the purposes of this standard, the following definitions apply. Symbols used in formulae are defined where they occur.

3.1 commissioning

the activities required to pressurize pipework, stations, equipment and assemblies with gas and to put them into operation

3.2 control zone

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

3.3 decommissioning

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

3.4 design factor

f_o
a factor applied when calculating the wall thickness or pressure

3.5 design pressure DP

the pressure on which design calculations are based

3.6 design temperature

the temperature on which design calculations are based

3.7 emergency

a situation which could affect the safe operation of the gas supply system and/or the safety of the surrounding area, requiring urgent action

3.8 gas

the gaseous fuel which is in gaseous state at a temperature of 15 °C under atmospheric pressure (1,013 25 bar absolute)

3.9

gas distribution system

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

3.10

gas distributor

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

3.11

gas transmission

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

3.12

incident

an unexpected occurrence, which could lead to an emergency situation.

This includes a leakage of gas or plant failure

3.13

incidental pressure

IP

the pressure which occurs incidentally within a system at which a safety device becomes operative

3.14

inspection

the 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

3.15

installation

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

3.16

installation temperature

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

3.17

maintenance

the 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

3.18

maximum incidental pressure

MIP

the maximum pressure which a gas system can experience during a short time, limited by the safety devices

3.19

maximum operating pressure

MOP

the maximum pressure at which a system can be operated continuously under normal conditions

NOTE Normal conditions are: no fault in any device or stream.

3.20

national requirements

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

3.21

onshore pipeline

a buried and/or above ground pipeline including those sections laid in or across inland lakes or water courses

3.22

operating pressure

OP

the pressure which occurs within a system under normal operating conditions

3.23

operating temperature

OT

the temperature which occurs within a system under normal operating conditions

3.24

pig

a device which is driven through a pipeline by the flow of fluid, for performing various internal activities (depending on pig type), such as separating fluids, cleaning or inspecting the pipeline

3.25

pipeline

a system of pipework with all associated equipment and stations up to the point of delivery. This pipework is mainly below ground but also includes above ground parts

3.26

pipeline components

the elements from which the pipeline is constructed. The following are distinct pipeline elements:

- pipe including cold-formed bends;
- fittings;

EXAMPLE 1 Reducers, tees, factory-made elbows and bends, flanges, caps, welding stubs, mechanical joints.

- fabrications, manufactured from the elements referred to above;

EXAMPLE 2 Manifolds, slug catchers, pig launching/receiving stations, metering and control runs.

- equipment;

EXAMPLE 3 Valves, expansion joints, insulation joints, pressure regulators, pumps, compressors.

- pressure vessels

3.27

pipeline operator

the private or public organization authorized to design, construct and/or operate and maintain the gas supply system.

3.28

pipework

an assembly of pipes and fittings

3.29

point of delivery

the point of transfer of ownership of gas from supplier to the customer

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

3.30

precommissioning

a series of activities, including cleaning and possible drying, executed prior to pipeline commissioning

3.31

pressure

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

3.32

pressure control system

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

3.33

pressure regulating system

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

3.34

pressure safety system

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

3.35

recommissioning

the activities required to put a decommissioned pipeline, associated stations and equipment into service again

3.36

special crossing

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

EXAMPLE Major road, railway, river, canal, dyke.

3.37

station

a plant or facility for the operation and/or processing of gas supply systems

3.38

strength test

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

3.39

strength test pressure

STP

the pressure applied to a system during strength testing

3.40

test pressure

TP

the pressure to which the gas supply system is subjected to ensure that it can operate safely

3.41

tightness test

a specific procedure to verify that the pipework and/or station meets the requirements for leak tightness

3.42

tightness test pressure

The pressure applied to a system during tightness testing

3.43

volume under normal conditions

a quantity of gas which in the dry state occupies a volume of 1 m³ at atmospheric pressure (1,013 25 bar absolute) at a temperature of 0 °C

3.44

volume under standard conditions

a quantity of gas which in the dry state occupies a volume of 1 m³ at atmospheric pressure (1,013 25 bar absolute) at a temperature of 15 °C

4 Quality system

The life of a pipeline for transmission of gas can be divided into three phases:

- the design;
- the construction and testing;
- the operation and maintenance.

A quality system should be applied to the design, construction, testing, operation and maintenance activities in accordance with this standard.

Reference may be made to the EN ISO 9000 series of standards or to equivalent quality assurance systems.

After the pipeline has been commissioned, the integrity should be maintained by a precisely defined programme of operation, maintenance and condition monitoring (a pipeline integrity management system).

Competent personnel capable of assessing the quality of the work within the scope of this standard shall be employed in all activities in the design, construction, testing and operating phases.

5 Safety and the environment

5.1 Introduction

Various safety measures are required to ensure a safe pipeline. Measures that are appropriate to the specific circumstances shall be adopted.

5.2 Appropriate safety measures

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 the measures on each occasion.

When selecting measures, consideration shall be given to the safety and environmental conditions existing at the time of construction for which firm details are known:

- A control zone should be established to control all third-party activities in order to safeguard the pipeline against interference.
- If a system of area classification is used, design factors should be chosen relevant to the classification levels.

This design factor may be increased if additional measures are taken against third-party interference (for limitation on the design factor reference is made to 7.2).
- The route of the pipeline should be at an appropriate distance from buildings. The distance should be fixed by the particular parameters and/or national requirements.
- For high-strength pipe steels, appropriate toughness properties for fracture-arrest capability should be selected.
- The minimum depth for the pipeline shall 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 7.7 is adopted.
- Additional forms of mechanical protection can reduce interference by third-party activity. Designers shall carefully select the forms of the additional protection to minimize 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.
- Pipeline safety can further be increased by ensuring an adequate frequency of surveillance.

5.3 Routing considerations

5.3.1 Introduction

Safety, environmental and technical considerations are the primary factors governing the pipeline route.

The shortest route need not to be the most suitable. Physical and environmental obstacles, high voltage cables and installations and other factors shall be considered.

The factors can be broadly separated into above-ground (topographical) and below-ground (subterranean) factors. It is usually convenient to consider both natural and man-made features under these two headings.

5.3.2 Surveys

An essential prelude to pipeline projects is to acquire from records, maps and physical survey a set of data that is relevant for the design, construction and safe and reliable operation of the pipeline. The adoption of a preliminary route shall be preceded by a desk study, making use of all available information.

Before a route is finally adopted for construction, a physical survey shall be made, aided as necessary by aerial photography, soil surveys, underwater observation and a review of geographical, geotechnical, topographical and environmental features, as well as safety-related aspects in connection with other activities along the pipeline route. The route survey shall cover a sufficient width and be sufficiently accurate to identify features that could adversely influence the installation and operation of the pipeline.

5.3.3 Environmental impact

The planning of any proposed pipeline route shall be approached systematically to identify and record environmental issues which could be affected. Detailed assessments may need to be undertaken to ascertain the impact of the pipeline on environmentally sensitive areas. Among environmental factors to be considered in selecting route and station locations, care shall be taken to identify the possible effects on the following:

- areas of outstanding natural beauty;
- ancient monuments, archaeological and ornamental sites;
- natural resources, such as water catchment areas, forestry;
- flora and fauna.

Also the following aspects shall be considered:

- the reduction of noise and vibration;
- the avoidance of odour and dust and deterioration of air quality.

Other considerations applying to pipelines laid under inland water courses include:

- the underwater environment;
- underwater development;
- bed conditions.

5.3.4 Ground conditions

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

- areas of geotechnical instability, including faults and fissuring;
- soft or waterlogged ground;
- corrosive nature of the soil;
- rock and hard ground;
- flood plains;
- areas with high seismic risk;
- mountainous areas;
- existing or potential areas of land slippage, subsidence and differential settlement;

- mining areas and quarrying;
- infill land and waste disposal sites, including those contaminated by disease or radioactivity.

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

5.4 Linevalve spacing

Pipeline systems should be sectionalized using linevalves.

In determining the spacing of linevalves, consideration should be given to operating pressure, pipeline diameter, time taken to arrive at the valve site, the need for linevalves for operational purposes, the position of the nearest offtakes and other existing valves.

6 Pressure safety

6.1 Pressure levels

Stress and strain calculations on the pipeline during the design phase shall be based on the design pressure (DP) of the pipeline.

The pipeline shall be pressure-tested after construction and prior to operation. The test pressure (TP) shall be chosen in accordance with 9.5.

The maximum operating pressure (MOP) shall not exceed the design pressure (DP).

6.2 Normal operation

A pressure control system shall be provided to ensure that, during normal operation, the sustained operating pressure does not exceed the maximum operating pressure (MOP) at any point in the pipeline. The pressure regulators shall be sized for the normal operating conditions expected.

The sustained operating pressure is the maximum set pressure for the pressure regulation devices. However, when operating at or near the maximum operating pressure, this pressure may be exceeded by no more than +2,5 % of its value due to the variations of pressure regulation devices.

6.3 Requirements for installation of pressure safety devices

Throughout a gas supply system, pressure can be reduced or increased at one or more stations.

Apart from pressure regulation devices, consideration shall be given to safety devices which protect the downstream pipeline section against failure of the pressure regulation system. If installed, the safety device shall operate independently of the active pressure regulation device.

An incidental pressure rise is acceptable provided systems exist to automatically limit the extent of the excess to 15 % above the maximum operating pressure (a lower value may be selected for this pressure, which is the maximum incidental pressure or MIP). The maximum operating pressure shall not be exceeded for longer than is strictly necessary to check the malfunction and to reset the normal operating conditions. The safety device(s) shall be set such that the maximum incidental pressure is not exceeded (see Figure 2).

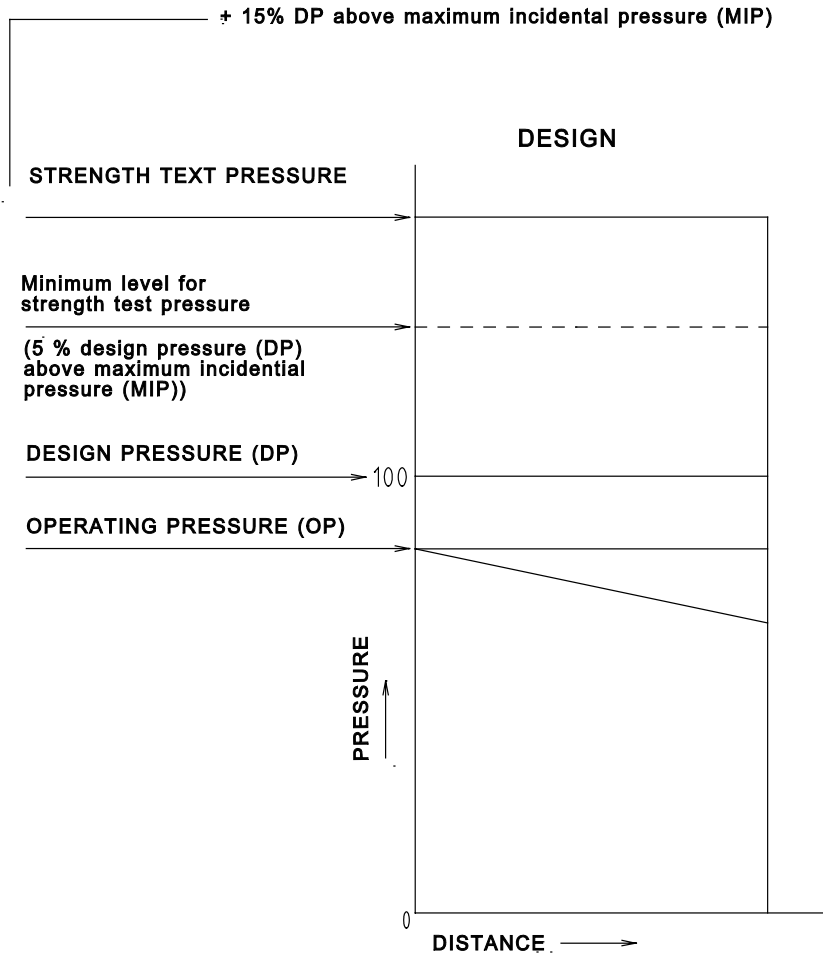
The installation of pressure safety devices for pressure regulating systems shall be in accordance with EN 12186 and for compressor stations in accordance with EN 12583.

6.4 Pipeline with DP equal to or less than 40 bar and hoop stress equal to or less than $0,45R_{f0,5}$

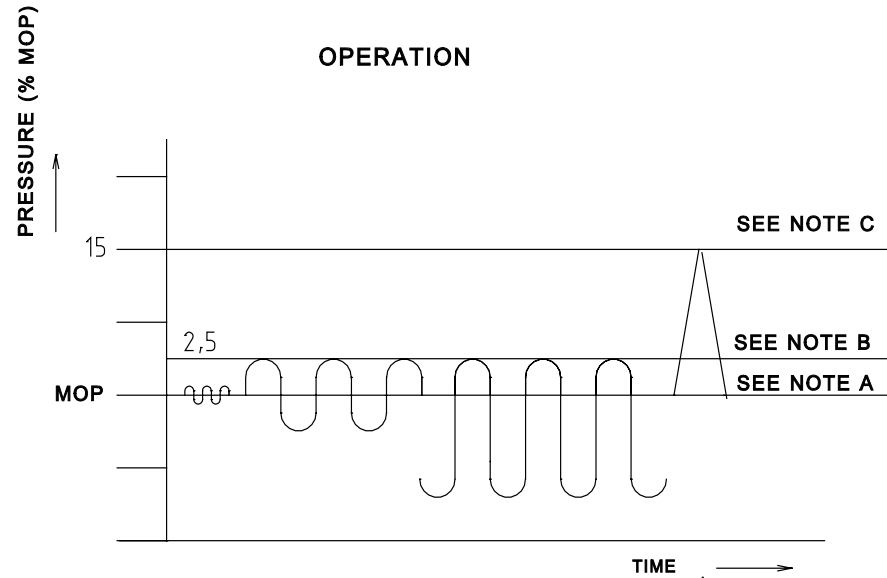
For pipelines with a design pressure equal to or less than 40 bar and a hoop stress level at the design pressure, calculated according to the formula in 7.2, equal to or less than 0,45 specified minimum yield strength ($R_{f0,5}$), the incidental pressure rise referred to in 6.3 may be increased to +20 % above the maximum operating pressure.

6.5 Pipeline with DP equal to or less than 24 bar and hoop stress equal to or less than $0,30R_{t0,5}$

Pipelines with a design pressure equal to or less than 24 bar and a hoop stress level at the design pressure, calculated according to the formula in 7.2, equal to or less than 0,30 specified minimum yield strength ($R_{t0,5}$), may be designed and operated in accordance with EN 12007-1 and EN 12007-3. However, construction and testing shall be carried out in accordance with this standard.



Pressure is expressed as a percentage of the design pressure.



Pressure is expressed as a percentage of maximum operating pressure (MOP).

NOTE A Normally equal to design pressure, but can be lower.

NOTE B Normal acceptable operational control level.

NOTE C Maximum incidental pressure (MIP) (may be increased for pipelines with design pressure (DP) 40 bar and hoop stress level 0,45 $R_{t0,5}$)

Figure 2 - Guide to pressure limiting systems

7 Design

7.1 General

7.1.1 Design principles

The design of the pipeline shall lead to a safe system for transmission of gas.

The design shall consider all technical issues together with the environmental and safety aspects.

The design shall take into account the controlled release of gas or other materials during construction, operation or maintenance of the pipeline.

The design principles shall be documented together with procedures in the design report (see 7.5).

7.1.2 Basis of design

7.1.2.1 Pipeline

The pipeline shall be leak-tight and shall have the necessary resistance to safely withstand all the forces to which it is expected to be exposed during construction, testing and operation.

The pipeline consists of pipeline sections (see example 1) and stations (see example 2). During the design phase these parts of the pipeline can be considered separately, as long as the interaction of forces between the connected parts is also considered.

EXAMPLES 1 Buried, submerged, above ground, trenchless.

EXAMPLES 2 Compression, pressure regulating, metering.

Crossings with railways, major roads and waterways shall be designed in consultation with the owners and/or authorities.

For crossings with dykes and flood defences extra measures can be required to prevent possible flooding of the hinterland.

7.1.2.2 Pipeline sections

Pipeline sections shall be supported, anchored or buried such that, during its lifetime, the pipeline section will not move with respect to its installed position, except for permitted displacement due to pressure loads, thermal loads and displacements expected after installation.

If a submerged pipeline section is not buried, covered or anchored, the pipework's own weight under all conditions, whether empty, filled with medium or filled with test medium, shall be such as to guarantee horizontal and vertical stability during both the construction and operating phases.

NOTE The design pressure and diameter required for a pipeline are determined by gasflow requirements and economics and this determination falls outside the scope of this standard.

Initial design to determine the wall thickness of the pipeline section is based on internal pressure and a design factor. Additional measures can be required to provide protection against third-party interference as referred to in 5.2.

Where a section of the pipeline passes through areas which can impose significant external loads, it is necessary for a more comprehensive design process to be followed as set out in 7.3. To decide whether these additional requirements are necessary, an analysis of all expected forces shall be undertaken or reference made to a previous analysis undertaken for a similar pipeline.

7.1.2.3 Station pipework

The pressure strength of station pipework should be achieved by selecting suitable pipe and components from a limited range of pressure ratings.

Because station pipework, either buried or above ground, is often subject to greater external forces due to temperature, vibration and restraint forces than the transmission pipeline, it can be necessary to impose additional requirements.

7.2 Wall thickness determination

If no additional requirements are imposed, for straight pipe the minimum wall thickness to withstand the internal pressure is calculated as follows:

$$T_{\min} = \frac{DP \times D}{20\sigma_p}$$

with the requirement:

$$\sigma_p \leq f_o R_{t0,5}(\theta)$$

where:

$T_{\min}$	is the calculated minimum wall thickness, in millimetres (mm);	
DP	is the design pressure, in bar;	
D	is the outside diameter of the pipe in accordance with EN 10208-2, in millimetres (mm). If D_i is preset, D shall equal $D_i + 2T_{\min}$, D_i being the inside diameter in millimetres (mm);	
σ_p	is the hoop stress, in newtons per square millimetre (N/mm ²);	
f_o	is the design factor;	
$R_{t0,5}(\theta)$	is the specified minimum yield strength at the design temperature, in newtons per square millimetre (N/mm ²); Temperature less than or equal to 60 °C $R_{t0,5}(\theta) = R_{t0,5}$ Temperature over 60 °C the value of the specified minimum yield strength has to be corrected for the temperature	
$R_{t0,5}$	is the specified minimum yield strength at ambient temperature, in newtons per square millimetre (N/mm ²) (ref. EN 10002-1).	

The maximum design factor (f_o) for internal pressure to be used for the pipeline section in question is as follows:

–	underground sections, except stations	$\leq 0,72$
–	pipelines in tunnels continuously supported	$\leq 0,72$
–	stations	$\leq 0,67^a$
	^a with the further wall thickness requirements in 7.9.2	

NOTE The wall thickness to be specified according to EN 10208-2 is the calculated minimum wall thickness plus the specified under wall thickness tolerance.

For bends and elbows the minimum wall thickness to withstand the internal pressure is calculated according to 7.10.2.

7.3 Additional design requirements

7.3.1 Forces

A pipeline shall be designed so that it can withstand the effects of the predictable forces on it resulting from:

- internal pressure;
- the anchoring or backfilling of the pipeline, road and rail traffic and loads necessary for the installation and pressure testing of the pipeline;
- the weight loading imposed during hydrostatic testing;
- the attachment of branch connections;
- the attachment of non-pressure containing components;

- the attachment of non-pressure containing components;
- buoyancy;
- any other buried structure such as a pipeline, gas main or service pipework;
- environmental loads such as flooding, ice, snow, wind;
- settlement;
- mining subsidence;
- frost heave;
- landslide;
- areas with high seismic risk;
- areas of future planned increases in soil cover, local embankments, etc.;
- soil erosion;
- above-ground sections.

The designer shall take into account all other circumstances that can require calculations to be carried out for the pipeline section or the station pipework, such as:

- higher pipe temperature and/or large temperature differences in relation to special pipe configurations;
- any circumstances that can lead to excessive construction settlement differences as a result of the construction techniques employed;
- above-ground pipeline sections locally supported.

The calculations comprise of an analysis of the loads and displacements and an analysis of the stresses and strains which can occur. The degree to which each of these stages is involved in the analysis depends on the complexity of the design and the physical parameters of the pipeline section.

Where the assessment shows that additional design requirements should be imposed on the section under consideration, an established method of analysis shall be used to determine the stresses and strains and effects of all loadings on the pipeline section.

7.3.2 Soil engineering data required

If sufficient information is available on the nature of the soil, the analysis for certain pipeline sections can be based on typical soil parameters, where necessary in combination with additional soil mechanical investigation, such as soil sampling or cone penetration tests.

In the case of special structures and/or widely varying soil properties or in situations where substantial permanent soil displacements are expected, these parameters shall be established on the basis of a soil analysis.

7.3.3 Structural models for pipeline sections

Three different models can be used to analyze both supported (above-ground) pipeline sections subjected to typical operating loads and buried pipeline sections in the context of pipe/soil interaction problems:

- a) **pipe considered as a ring:** This model is used for calculating the circumferential stresses and strains in the cross-section of the pipe.
- b) **pipe considered as a beam:** This model is used for calculating the longitudinal stresses and strains in the pipeline sections. Using this model, the reaction forces perpendicular to the pipe can be used in the calculation of stress and strain in the cross-section of the pipe.
- c) **pipe considered as a shell:** Pipe behaviour can be modelled precisely using shell elements in finite element analysis. This model can be used to solve problems of stress concentration to components, such as tees, bends, nozzles, supports, or local behaviour of the pipe wall (wrinkling, ovality, etc.)
For buried pipeline sections, the pipe/soil interaction can be modelled either by finite elements or by simplified methods.

7.4 Analysis of stress and strain

7.4.1 Elastic and extended elastic design

7.4.1.1 General

The calculation method is based on determination of stresses caused by loads during the construction and operation phases. The stresses are combined to resultant stresses (σ_v). No resultant stress shall exceed the relevant allowable stress.

7.4.1.2 Resultant stress (σ_v)

The state of stress at any point is completely described by the normal stresses σ_x , σ_y and σ_z and the shear stresses τ_x , τ_y and τ_z in a tri-axial system with mutually perpendicular axes x , y and z or by the principal stresses σ_1 , σ_2 and σ_3 and their directions.

The resultant stress is a parameter which is considered to be characteristic of the state of stress at a point. The resultant stress can be calculated either by the shear stress hypothesis or the yield criterion.

According to the shear stress hypothesis, this is: $\sigma_v = \sigma_{\max} - \sigma_{\min}$
where:

$\sigma_{\max}$	is the maximum principal stress in one of the three directions;
$\sigma_{\min}$	is the minimum principal stress in one of the other two directions.

According to the Von Mises/Huber Hencky yield criterion, the resultant stress is given by:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x \sigma_y - \sigma_z \sigma_x - \sigma_y \sigma_z + 3(\tau_x^2 + \tau_y^2 + \tau_z^2)}$$

In a bi-axial system:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

Here, either $\sigma_z = 0$ or may be disregarded in terms of absolute value compared with σ_x and σ_y .

This also applies to the two shear stresses compared with the shear stress under consideration.

A bi-axial state of stress can be assumed in pipeline sections which contain no ancillaries, branches, etc.

7.4.1.3 Allowable stress

Under loading conditions where all stresses are considered as primary stresses and the calculation is carried out with characteristic values for the loads, the maximum resultant stress shall not exceed the allowable stress.

The allowable stress is $0,72R_{t0,5}(\theta)$

Temperature less than or equal to 60 °C

Temperature over 60 °C

$R_{t0,5}(\theta) = R_{t0,5}$

the value of the specified minimum yield strength has to be corrected for the temperature.

A higher allowable stress can be used where the stresses are divided into primary (e.g. direct equilibrium) and secondary (e.g. displacement controlled).

An example of this method ("extended elastic design") is given in Annex G, but other established methods may be used.

7.4.2 Limit state design

7.4.2.1 General

The calculation procedure is based on the method of (partial) load factors and calculation loads. The calculation loads are obtained by multiplying the relevant (characteristic) loads arising during the construction and operating phases by the relevant load factor.

The load factor takes account of uncertainty as to the magnitude of the loads, the strength of the material and the construction.

The effect of the calculation loads shall not exceed the limit value associated with the relevant limit state.

In the limit state design, a clear distinction shall be made between load-controlled strains and deformation-controlled strains.

7.4.2.2 Relevant limit states

The relevant limit states are:

a) **stress:** The limit state in which the limit stress is exceeded.

b) **strain:** The limit state in which the limit strain is exceeded.

In evaluating this limit strain, the presence of imperfections in the pipe material and the joints shall be taken into account.

c) **alternating yield:** The limit state in which the variations in the strains due to cyclic loads are so great that plastic deformation occurs on each load reversal (plastic fatigue).

d) **fatigue:** The limit state for failure due to cyclic loading over time.

e) **resonance and vortex shedding:** The limit state for excessive excursions by the pipeline or its component parts.

These excursions arise when the frequency of excitation coincides with the pipeline's natural frequency.

For pipeline sections which are locally unsupported by soil and exposed to waves and currents, a study should be made of the possibilities of vibration due to vortex shedding and other instability phenomena.

f) **deformation:** The limit state for excessive deformation, taking the form for example of excessive ovality, local buckling, implosion or overall flexural buckling of the pipeline.

Generally speaking, excessive deformations of this kind will occur in the plastic range and therefore consist chiefly of plastic deformations. Situations can arise, however, in which excessive elastic deformations occur that have a deleterious effect on safety.

EXAMPLE Include seizure of close-tolerance moving parts (valves) and distortion of flanges which impairs their integrity.

g) **Displacement/lateral stability.**

7.5 Design report

On completion of the design, a comprehensive design report shall be produced containing the following information:

a) a description of the pipeline:

- 1) general data relating to the project, description of the pressure containment system, demarcation of the boundaries of the transmission pipeline, safety devices;
- 2) data relating to the gas and design conditions, the design pressure and design temperature, the values at critical design conditions of:
 - mass flow rate;
 - density;
 - viscosity (dynamic).

b) drawings:

- 1) geographical maps with, where applicable, an indication of the area covered by the individual route maps;
- 2) route maps or similar drawings;
- 3) detail and standard maps, indicating the route maps to which they apply and providing all information needed for evaluation of the design and construction.

c) data of pipeline components and structures:

- 1) outside or inside diameter(s);
- 2) wall thickness(es);
- 3) wall thickness tolerances;
- 4) relevant data on fittings, including bend radii or other information relating to the pipeline elements;
EXAMPLE Reducers, tees.
- 5) data on abutting structures and supports which affect the forces and moments acting on the carrier pipework;
- 6) steel grade and specification;
- 7) thickness and type of coating;
- 8) thickness and density of weight coating, if required.

d) construction information, if required:

- 1) elastic bending radii to be applied to the pipeline section, both permanent and temporary;
- 2) test pressure, including the nature and weight of the test medium;
- 3) installation temperature;
- 4) specification of procedures to be employed in the installation of the pipeline sections, together with relevant data, design details and construction specifications;

EXAMPLE 1

- Installation specifications for pipeline sections: open trench (dry/wet), jacking, boring, horizontal directional drilling, tunnelling;
 - data, design details and construction specifications: preparation of the trench bottom, method of backfilling and compacting the trench.
- 5) land management and soil engineering data.

EXAMPLE 2

- Soil handling, wellpoint drainage, surface reinstatement.

7.6 Land management and geotechnical studies

The purpose of the land management study is to gather data needed for reporting on land and water management and agricultural/horticultural aspects of the pipeline route.

These data are used to provide appropriate support in land management and agricultural/horticultural matters relating to the construction of the pipeline and to limit damage.

The purpose of the geotechnical study is to gather data for a report on geohydrological water management and geomechanical aspects relating to the pipeline route. (See also 5.3.4.)

7.7 Depth of cover

Buried pipework and casings shall in general have a minimum depth of cover of 0,80 m. A reduced depth of cover may be applied. Examples of cases of reduced depth are:

- rocky terrain;
- where the pipe crosses ditches or water courses.

NOTE Appropriate protective measures can be required.

An increased depth of cover shall be applied in the following cases:

- situations where frost heave can occur;
- areas where agricultural or horticultural practices require a greater depth;
- areas which can be subject to erosion;
- waterways. The lowest expected bed profile of the crossing should be determined. If the waterway is navigable, consideration shall be given to protection of the pipeline against damage from ships' anchors.

7.8 Casing pipes

The use of cased crossings should be minimized as they can cause adverse effects on cathodic protection systems.

When casings are used, they shall be designed such that:

- they are capable of withstanding all external loads;
- the carrier pipe is easily installed;
- cathodic protection of the carrier pipe can be provided if necessary;
- they can be sealed effectively or can be filled with a suitable material to minimize water circulation and thus reduce the oxygen supply to a minimum;
- the carrier pipe is provided with an adequate number of suitable supports at regular intervals and provision is made, especially at the extremities of the casing, to avoid the possibility of contact between the carrier pipe and the casing;
- the support rings are spaced and calculated on the basis of the weight of the pipe filled with water and additional cross-sectional forces caused by construction settlement at the extremities which mark a transition between two methods of installation.

7.9 Station design

7.9.1 Layout

The point of demarcation between the pipeline section and the station should be immediately upstream of the first inlet valve and immediately downstream of the last outlet valve. Alternatively, the station fence or the isolating valves can be taken as the point of demarcation.

The requirements applicable to the layout of the station depend on the surrounding area and the type of station.

However, each station shall be designed such that:

- the station or parts of the station can be taken out of service by operating a number of valves. This is not required for valve stations;
- efficient long-term operation is guaranteed under all weather conditions;
- the station suffers no adverse effects due to subsidence, settlement, corrosion or any other cause;
- maintenance can be carried out without interrupting the gas flow;
- unauthorized operation of components is prevented.

Within stations, certain requirements shall be imposed with respect to the minimum spacing between components, for example to facilitate maintenance and firefighting.

If circumstances require, stations shall be fenced to prevent unauthorized entry. Consideration shall be given to provisions to facilitate the evacuation of personnel from the station in case of emergency.

Depending on the size of the station, gates shall be dimensioned and constructed to permit easy access to firefighting equipment and ambulances.

If the station is installed in a building, the building shall be subject to the evacuation requirements.

The electrical installation shall be in accordance with the requirements of the relevant EN standards.

The electric lighting system, where fitted, shall be designed so that exits and critical areas inside and outside the station are clearly visible at night and in fog.

The construction of electrical installations in areas where there are potential gas atmospheres shall comply with the relevant EN standards.

Consideration shall be given to measures for the protection against lightning strikes. These measures shall satisfy relevant standards.

For pressure regulating systems the station layout shall be in accordance with EN 12186 and for compressor stations in accordance with EN 12583.

7.9.2 Components

Each individual component of a station shall be capable of performing the function required of it and shall satisfy the standards to which the component in question has been designed.

These include mechanical components (see example 1), electrical components (see example 2), and pipework and pipeline components (see example 3). The requirements relating to flanges, gaskets, bolts, nuts, valves and other fittings are specified in 7.10 and clause 8.

EXAMPLE 1 Compressors and pumps.

EXAMPLE 2 Generators, batteries.

EXAMPLE 3 Fittings, flanges, gaskets, valves.

The specified wall thickness T of pipework shall not be less than the values stated in Table 1 and shall be sufficient for the loads imposed, including internal pressure with a design factor $f_0 \leq 0,67$.

Table 1 - Smallest wall thickness to be specified

D (mm)	$\leq 114,3$	168,3	219,1	273	323,9	355,6	406,4	508	610	> 610
T (mm)	3,2	4,0	4,5	5,0	5,6	5,6	6,3	6,3	6,3	1 % D

Components within stations are generally connected by pipework, including oil, gas, compressed air and water piping and instrumentation, control, power gas and sampling pipework. This pipework and the associated valves, flanges, reducers, bends and other components shall be made of suitable material and shall be capable of withstanding the maximum and minimum pressures and temperatures.

The installation as a whole shall satisfy safety and reliability requirements for the station in question.

7.9.3 Interaction with onland pipeline section

In the design of the connections between the onland section of the pipeline and the station, due account shall be taken of their interaction.

An expansion calculation is required for outlet lines from compressor stations laid in soft peat or clay soils.

Due account shall be taken of pulsations.

EXAMPLE Flow-induced pulsations.

Expansion and contraction of the pipeline due to temperature and pressure changes shall be taken into account in the design of the station. If necessary, the pipeline shall be anchored or suitably configured so that temperature and pressure variations do not give rise to stresses within components which exceed permitted levels.

Components of stations and adjacent pipeline sections shall be designed such that stresses due to non-uniform settlement remain within acceptable limits.

7.10 Pipeline components

7.10.1 General

Rules relating to the design of pipeline components are set out in 7.10.2 to 7.10.8 inclusive. Specifications for the material of the pipeline components are given in clause 8.

Components shall be of the same or equivalent material as required for the pipes.

7.10.2 Bends and elbows

Changes in pipeline direction can be achieved either by bending the pipe (see 9.2.8) or by installing a factory-made bend or elbow in the pipeline.

In the case of bends with a bend radius smaller than $20D$, the maximum hoop stress requirement in accordance with 7.2 shall become:

Inside of the bend:

$$\frac{2R - 0,5D}{2R - D} \sigma_p \leq f_o R_{t0,5}(\theta)$$

Outside of the bend:

$$\frac{2R + 0,5D}{2R + D} \sigma_p \leq f_o R_{t0,5}(\theta)$$

where:

R	is the bend radius along the centreline of bend, in millimetres (mm);
D	is the outside diameter, in millimetres (mm);
σ_p	is the hoop stress, in newtons per square millimetre (N/mm ²) ^a ;
$R_{t0,5}(\theta)$	is the specified minimum yield strength at the design temperature, in newtons per square millimetre (N/mm ²). Temperature less than or equal to 60 °C $R_{t0,5}(\theta) = R_{t0,5}$ Temperature over 60 °C the value of the specified minimum yield strength has to be corrected for the temperature
$R_{t0,5}$	is the specified minimum yield strength at ambient temperature, in newtons per square millimetre (N/mm ²) (ref. EN 10002-1).
f_o	is the design factor.
^a	in the calculation of the hoop stress, the minimum wall thickness after bending shall be considered.

7.10.3 Tees

Tees shall have sufficient strength against internal pressure. An example of a wall thickness calculation method is described in Annex L. Equivalent calculation methods may be used.

7.10.4 Flanges

Flanges shall be designed to accommodate the operating and climatic conditions and the associated permissible operating pressures. The dimensions and drilling pattern for all flanges shall satisfy the requirements of the applicable standards.

7.10.5 Caps

Caps shall have sufficient strength against internal pressure. An example of a wall thickness calculation method is described in Annex M. Equivalent calculation methods may be used.

7.10.6 Bolts and nuts

Bolts and nuts shall be designed in accordance with the relevant standard. Nuts shall be tightened onto bolts or studs sufficiently for the thread to project above the nut.

At points where vibration can occur, the nuts shall be effectively secured.

7.10.7 Gaskets

Gaskets shall be made of a material which is compatible with the gas conveyed by the pipeline and shall be capable of withstanding the operating temperature and pressure. Gaskets shall be designed in conjunction with the design of the flange and in accordance with the relevant part of prEN 12560. Gaskets containing asbestos shall not be used.

7.10.8 Other fittings

Other fittings shall be designed in accordance with the relevant standard. The level of stress at fittings shall be lower than or equal to that of the adjacent pipes at the same pressure and temperature.

EXAMPLE Other fittings can be reducers, insulating joints.

Insulating couplings are considered preferable to insulating flanges.

7.11 Pigging suitability

A pipeline should be designed to allow for initial and periodic pigging. Consideration shall be given to the maximum allowable variation of the pipe inside diameter, permitted ovality, minimum bend radius and the selection of bends, tees (with guide bars fitted, if necessary) and other components to permit safe and effective pigging. Pig launch and receiving stations are required at intervals with the appropriate equipment for loading, unloading, dust catching and collection of water or condensate (see also Figure 3).

7.12 Arrangements for venting

To permit depressurization of a pipeline section, facilities shall be provided for removing the gas from the section. An example of a pipeline with the appropriate facilities is given in Figure 3.

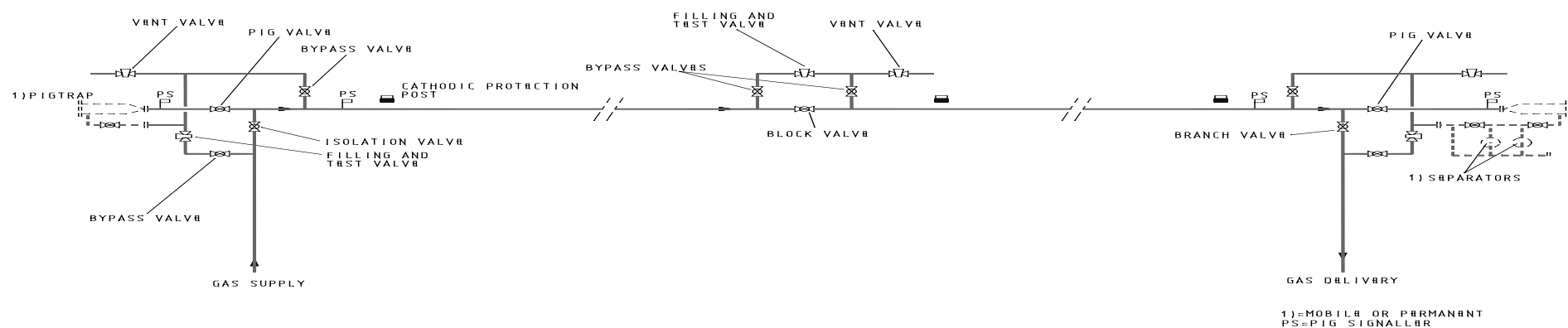


Figure 3 – Example of a valve station layout in piggable pipeline