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

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National foreword

This British Standard is the UK implementation of EN 1594:2013. It supersedes BS EN 1594:2009 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GSE/33, Gas supply.

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

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

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English Version

Gas infrastructure - Pipelines for maximum operating pressure over 16 bar - Functional requirements

Infrastructures gazières - Canalisation pour pression
maximale de service supérieure à 16 bar - Prescriptions
fonctionnelles

Gasinfrastruktur - Rohrleitungen für einen maximal
zulässigen Betriebsdruck über 16 bar - Funktionale
Anforderungen

This European Standard was approved by CEN on 18 July 2013.

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 CEN-CENELEC Management Centre 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 CEN-CENELEC Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 1594:2013) has been prepared by Technical Committee CEN/TC 234 “Gas infrastructure”, 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of an identical text or by endorsement, at the latest by March 2014, and conflicting national standards shall be withdrawn at the latest by March 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1594:2009.

Annex J provides details of significant technical changes between this European Standard and the previous edition.

There is a complete suite of functional standards prepared by CEN/TC 234 “Gas infrastructure” to cover all parts of the gas infrastructure 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.

Compliance to this standard ensures the interoperability, safety and reliability requirements of pipeline systems.

Directive 2009/73/EC concerning common rules for the internal market in natural gas and the related Regulation (EC) No 715/2009 on conditions for access to the natural gas transmission networks also aim at technical safety (security) including technical reliability of the European gas system. These aspects are also in the scope of CEN/TC 234 standardization. In this respect, CEN/TC 234 evaluated the indicated EU legislation and amended this technical standard accordingly, where required and appropriate.

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

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

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

Gas infrastructure is 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 member countries. These detailed statements embrace recognised standards of gas engineering and specific requirements imposed by legal structures of these member countries.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

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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 infrastructure. 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 European 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 European Standard.

Managers with responsibilities for the design, construction and operation of gas infrastructure will have regard to the guidance given in this European Standard 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 all gas infrastructures.

The designer, constructor or operator of pipeline systems is cautioned that this European 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 European Standard.

In preparing this European Standard it was recognised 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 EN ISO 13686 in onland gas infrastructure.

This European Standard is also applicable to pipelines with a maximum operating pressure (MOP) over 16 bar for the carriage of non-conventional gases such as injected biomethane, complying with EN ISO 13686 and for which a detailed technical evaluation of the functional requirements is performed ensuring there are no other constituents or properties of the gases that can affect the integrity of the pipeline.

Onland gas infrastructure is where:

- pipeline elements are made of unalloyed or low-alloyed carbon steel;
- 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 $-40\text{ }^{\circ}\text{C}$ and $120\text{ }^{\circ}\text{C}$ inclusive.

This European Standard applies to onshore pipeline systems from the point where the pipeline first crosses what is normally accepted as battery limit between on and offshore, e.g.:

- first isolation valve;
- the base of steep sea shelf;
- above the high water/low water mark onto mainland;
- an island.

This European Standard also applies to a pipeline system with a starting point onshore, also when parts of the pipeline system on the mainland subsequently cross fjords, lakes etc.

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

Gas infrastructures covered by this European 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 European 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 infrastructures EN 12732. Functional requirements for stations are given in:

- EN 1776, *Gas supply systems — Natural gas measuring stations — Functional requirements*
- EN 1918-5, *Gas supply systems — Underground gas storage — Part 5: Functional recommendations for surface facilities*
- EN 12186, *Gas supply systems — Gas pressure regulating stations for transmission and distribution — Functional requirements*
- EN 12583, *Gas supply systems — Compressor stations — Functional requirements*

This European Standard specifies common basic principles for gas infrastructures. 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.

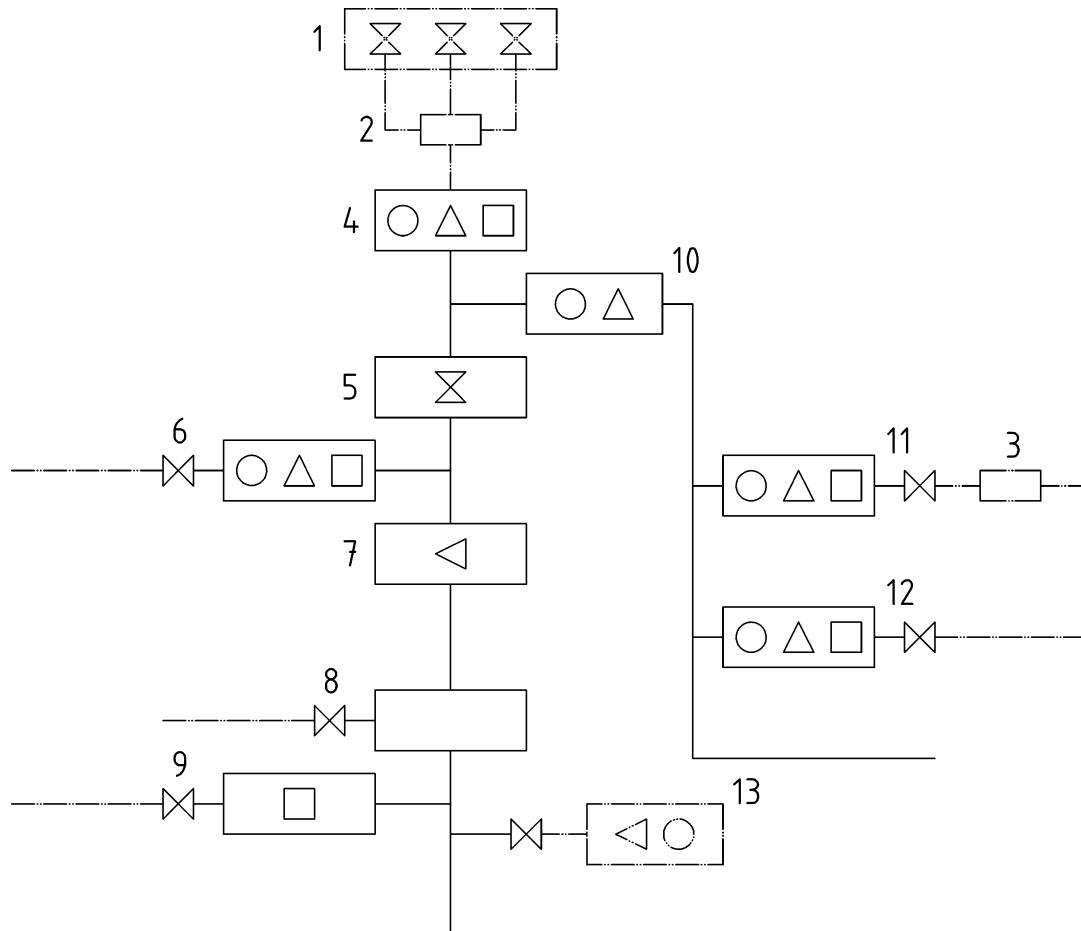
In the event of conflicts in terms of more restrictive requirements in the national legislation/regulation with the requirements of this European Standard, the national legislation/regulation takes precedence as illustrated in CEN/TR 13737 (all parts).

NOTE CEN/TR 13737 (all parts) contains:

- clarification of relevant legislation/regulations applicable in a country;
- if appropriate, more restrictive national requirements;
- national contact point for the latest information.

Reference is made in this European Standard to relevant European and other recognised standards for products used to construct and operate gas infrastructures.

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



Key

Symbols	Stations
— pipelines covered by this standard	1 P – well, production
- - - pipelines not covered by this standard	2 T – treatment
○ pressure regulation	3 D – odourisation
△ pressure safety system	4 S 1 – gas receiving
□ metering system	5 S 2 – valve station
◁ compression	6 S 3 – delivery station
⋈ valve	7 S 4 – compressor station
⊠ isolation device	8 S 5 – other supply (e.g. for blending)
	9 S 6 – export or import
	10 S 7 – pressure regulating
	11 S 8 – domestic distribution
	12 S 9 – industrial distribution
	13 S 10 – storage

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

2 Normative references

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

EN 1515-3, *Flanges and their joints — Bolting — Part 3: Classification of bolt materials for steel flanges, class designated*

EN 1759-1, *Flanges and their joint — Circular flanges for pipes, valves, fittings and accessories, Class designated — Part 1: Steel flanges, NPS 1/2 to 24*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1)*

EN 10204, *Metallic products — Types of inspection documents*

EN ISO 3183, *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems (ISO 3183)*

EN 10288, *Steel tubes and fittings for onshore and offshore pipelines — External two layer extruded polyethylene based coatings*

EN 10289, *Steel tubes and fittings for onshore and offshore pipelines — External liquid applied epoxy and epoxy-modified coatings*

EN 10290, *Steel tubes and fittings for onshore and offshore pipelines — External liquid applied polyurethane and polyurethane-modified coatings*

EN 10301, *Steel tubes and fittings for on and offshore pipelines — Internal coating for the reduction of friction for conveyance of non corrosive gas*

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 supply systems — Gas pressure regulating stations for transmission and distribution — Functional requirements*

EN 12327, *Gas infrastructure — Pressure testing, commissioning and decommissioning procedures — Functional requirements*

EN 12560-1, *Flanges and their joints — Gaskets for Class-designated flanges — Part 1: Non-metallic flat gaskets with or without inserts*

EN 12560-2, *Flanges and their joints — Gaskets for Class-designated flanges — Part 2: Spiral wound gaskets for use with steel flanges*

EN 12560-3, *Flanges and their joints — Gaskets for Class-designated flanges — Part 3: Non-metallic PTFE envelope gaskets*

EN 12560-4, *Flanges and their joints — Gaskets for Class-designated flanges — Part 4: Corrugated, flat or grooved metallic and filled metallic gaskets for use with steel flanges*

EN 12583, *Gas infrastructure — Compressor stations — Functional requirements*

EN 12732, *Gas infrastructure — Welding steel pipework — Functional requirements*

EN 12954, *Cathodic protection of buried or immersed metallic structures — General principles and application for pipelines*

EN 14141, *Valves for natural gas transportation in pipelines — Performance requirements and tests*

EN 16348, *Gas infrastructure — Safety Management System (SMS) for gas transmission infrastructure and Pipeline Integrity Management System (PIMS) for gas transmission pipelines — Functional requirements*

3 Terms, definitions, symbols and abbreviations

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

3.1

abandonment

permanent decommissioning where a pipeline or a pipeline section is physically isolated from the gas pipeline system

3.2

casing

protection by means of a construction around the pipeline in order to prevent external loads, or third party interference

3.3

commissioning

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

3.4

control zone

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

3.5

decommissioning

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

3.6

design factor

f_o
factor applied when calculating the wall thickness or pressure

3.7

design pressure

DP
pressure on which design calculations are based

3.8

design temperature

temperature on which design calculations are based

3.9

emergency

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

3.10

gas

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

3.11

gas distribution system

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

3.12

gas distributor

private or public organisation authorised to distribute gas to consumers through a gas distribution system

3.13

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

3.14

gas transportation system

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

3.15

golden weld

weld on which a strength test is not performed

EXAMPLE The test sections tie-in welds and the test section-station tie-in welds are considered “golden welds”.

3.16

incident

unexpected occurrence, which could lead to an emergency situation

Note 1 to entry: This includes a leakage of gas or plant failure.

3.17

incidental pressure

IP

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

3.18

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

3.19

installation

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

3.20

installation temperature

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

3.21

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

3.22

maximum incidental pressure

MIP

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

3.23

maximum operating pressure

MOP

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

Note 1 to entry: Normal conditions are: no fault in any device or stream.

3.24

national requirements

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

3.25

onshore pipeline

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

3.26

operating pressure

OP

pressure which occurs within a system under normal operating conditions

3.27

operating temperature

OT

temperature which occurs within a system under normal operating conditions

3.28

pig

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

3.29

pipeline

system of pipework with all associated equipment and stations up to the point of delivery

Note 1 to entry: This pipework is mainly below ground but also includes above ground parts.

3.30

pipeline components

elements from which the pipeline is constructed; these are:

a) specially designed and manufactured elements:

- 1) pipe including cold-formed bends;
- 2) fittings;

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

- 3) factory made bends;
- 4) fabrications, manufactured from the elements referred to above;

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

- 5) equipment;

EXAMPLE 3 Valves, expansion joints, insulation joints, compressors.

- 6) pressure vessels;
- b) standard pressure equipment:
- 1) pressure equipment at pipelines, pressure reduction stations or compression stations not specially designed and manufactured for the pipeline.

EXAMPLE 4 Measuring devices, valves, pressure regulators, safety valves, filters, heat exchangers, vessels.

3.31

pipeline operator

private or public organisation authorised to design, construct and/or operate and maintain the gas infrastructure

Note 1 to entry: Synonyms are: network operator, grid operator.

3.32

pipework

assembly of pipes and fittings

3.33

point of delivery

point where the gas is transferred to the user

Note 1 to entry: This can be at a means of isolation or at a meter connection.

3.34

precommissioning

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

3.35

pressure

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

3.36

pressure control system

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

3.37

pressure regulating system

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

3.38

pressure safety system

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

3.39

**raise boring
(back reaming)**

method of vertical drilling in solid rock where a reamer head is pulled back upwards through the small pilot hole

3.40

recommissioning

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

3.41

small components

instrument pipework, instruments, weld fittings, and similar components produced as bulk material with a diameter < 25 mm

3.42

special crossing

point at which the pipeline has to pass a special feature

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

3.43

station

plant or facility for the operation and/or processing of gas infrastructures

3.44

strength test

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

3.45

strength test pressure

STP

pressure applied to a system during strength testing

3.46

test pressure

TP

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

3.47

tightness test

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

3.48

tightness test pressure

pressure applied to a system during tightness testing

3.49

volume under normal conditions

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

3.50

volume under standard conditions

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 and management systems

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

- a) design;
- b) construction and testing;
- c) operation and maintenance.

Quality and safety management systems should be applied to these three phases in accordance with this European Standard.

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 European Standard shall be employed in all activities in the design, construction, testing and operating phases.

Reference is made to EN 16348.

5 Safety and the environment

5.1 General

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

The pipeline operator shall consider energy efficiency with regards to design, construction, testing, operation and maintenance. Reference can be made to EN ISO 50001.

In order to minimise the impact on the environment the pipeline operator shall consider environmental issues with regards to design, construction, testing, operation and maintenance and shall comply with relevant legislation.

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) A control zone shall be established to control all third-party activities in order to safeguard the pipeline against interference.
- b) If a system of area classification is used, design factors shall be chosen relevant to the classification levels.
- c) 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).
- d) The route of the pipeline shall be at an appropriate distance from buildings. The distance should be determined by the particular parameters and/or national requirements.

- e) For high-strength pipe steels, appropriate toughness properties for fracture-arrest capability should be selected.
- f) 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.
- g) Additional forms of mechanical protection can reduce interference by third-party activity. Designers shall carefully select the forms of the additional protection to minimise any adverse effects on the efficiency of the cathodic protection.
- h) 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 General

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. Amongst environmental factors to be considered in selecting route and station locations, care shall be taken to identify the possible effects on the following:

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

The following aspects shall also be considered:

- e) the reduction of noise and vibration;

- f) the avoidance of odour and dust and deterioration of air quality.

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

- g) the underwater environment;
- h) underwater development;
- i) bed conditions.

5.3.4 Ground conditions

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

- a) areas of geotechnical instability, including faults and fissuring;
- b) soft or waterlogged ground;
- c) corrosive nature of the soil;
- d) rock and hard ground;
- e) flood plains;
- f) areas with high seismic risk;
- g) mountainous areas;
- h) existing or potential areas of land slippage, subsidence and differential settlement;
- i) mining areas and quarrying;
- j) 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 Line valve spacing

Pipeline systems should be sectionalised using line valves.

In determining the spacing of line valves, consideration should be given to operating pressure, pipeline diameter, time taken to arrive at the valve site, the need for line valves for operational purposes, the position of the nearest off-takes 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 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 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 infrastructure, 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 (MIP) or. 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).

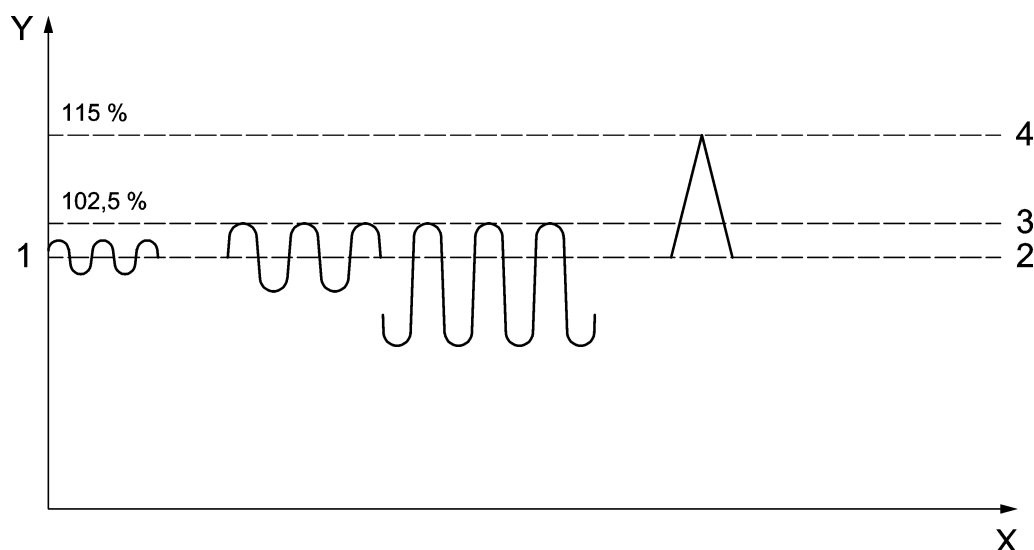
The installation of pressure safety devices for pressure regulating systems shall be in accordance with EN 12186 and for compressor stations in accordance with EN 12583.

6.4 Pipeline with DP equal to or less than 40 bar and hoop stress equal to or less than $0,45 R_{t0,5}$

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 ($R_{t0,5}$), 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 $0,30 R_{t0,5}$

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 European Standard.



Key

PRESSURE IS EXPRESSED AS A PERCENTAGE OF MOP:			
Y	P - pressure	2	Level A - normally equal to design pressure, but can be lower
X	T - time	3	Level B - normal acceptable operational control level
1	MOP	4	Level C - MIP, (may be increased for pipelines with DP ≤ 40 bar and hoop stress ≤ 0,45 R _{10,5})

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.

EXAMPLE 1 Buried, submerged, above ground, trenchless.

EXAMPLE 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 pipeline'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 gas-flow requirements and economics and this determination falls outside the scope of this European 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.

7.2 Wall thickness determination

7.2.1 Straight pipe

For normal load conditions the minimum wall thickness for straight pipe is calculated as follows:

$$T_{\min} = \frac{DP \times D}{20 \times f_o \times R_{t0,5}(\theta)} \quad (1)$$

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 millimetres (mm).

If D_i is preset, D shall equal $D_i + 2 T_{\min}$, D_i being the inside diameter in millimetres (mm);

f_o is the design factor;

$R_{t0,5}(\theta)$ is the specified minimum yield strength at the design temperature, in Newton per square millimetre (N/mm²).

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 Newton per square millimetre (N/mm²) (see EN ISO 6892-1).

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 $\leq 0,67$, with the further wall thickness requirements in 7.9.2.

NOTE The wall thickness to be specified according to EN ISO 3183 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 7.2.2.

7.2.2 Bends and elbows

For normal load conditions, the minimum wall thickness of bends $< 20 D$ is calculated as follows:

inside of the bend:

$$T_{\min} = \frac{2R - 0,5 D}{2R - D} \times \frac{DP \times D}{20 \times f_o \times R_{t0,5}(\theta)} \quad (2)$$

outside of the bend:

$$T_{\min} = \frac{2R + 0,5 D}{2R + D} \times \frac{DP \times D}{20 \times f_o \times R_{t0,5}(\theta)} \quad (3)$$

where

R is the bend radius along the centreline of bend, in millimetres (mm).

The minimum wall thickness after bending shall be considered.

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:

- a) internal pressure;
- b) elastic bending;
- c) external loads;
- d) temperature variations;

- e) the anchoring or backfilling of the pipeline, road and rail traffic and loads necessary for the installation and pressure testing of the pipeline;
- f) the weight loading imposed during hydrostatic testing;
- g) the attachment of branch connections;
- h) the attachment of non-pressure containing components;
- i) buoyancy;
- j) any other buried structure such as a pipeline, gas main or service pipework;
- k) environmental loads such as flooding, ice, snow, wind;
- l) settlement;
- m) mining subsidence;
- n) frost heave;
- o) landslide;
- p) areas with high seismic risk;
- q) areas of future planned increases in soil cover, local embankments etc.;
- r) soil erosion;
- s) 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:

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

The calculations are comprised 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 analyse 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, ovalisation, 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:

$$\sigma_v = \sigma_{\max} - \sigma_{\min} \quad (4)$$

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:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_z\sigma_x - \sigma_y\sigma_z + 3(\tau_x^2 + \tau_y^2 + \tau_z^2)} \quad (5)$$

In a bi-axial stress state:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2} \quad (6)$$

Here, either σ_z is zero 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 resultant 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 resultant stress.

The allowable resultant stress is: $1,0 \times R_{t0,5}(\theta)$

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.

A higher allowable stress can be used where the stresses are divided into primary (e.g. direct equilibrium) and secondary (e.g. displacement controlled). This method is called “extended elastic design”.

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 ovalisation, 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) **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:
 - i) mass flow rate;
 - ii) density;
 - iii) 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 1 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 2

— 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 3 Soil handling, well-point 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 geo-hydrological water management and geo-mechanical 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 might be required.

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

- 1) situations where frost heave can occur;
- 2) areas where agricultural or horticultural practices require a greater depth;
- 3) areas which can be subject to erosion;
- 4) 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 minimised as they can cause adverse effects on cathodic protection systems.

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

- a) they are capable of withstanding all external loads;
- b) the carrier pipe is easily installed;
- c) cathodic protection of the carrier pipe can be provided if necessary;
- d) they can be sealed effectively or can be filled with a suitable material to minimise water circulation and thus reduce the oxygen supply to a minimum;
- e) 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;
- f) 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:

- a) 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;
- b) efficient long-term operation is ensured under all weather conditions;
- c) the station suffers no adverse effects due to subsidence, settlement, corrosion or any other cause;
- d) maintenance can be carried out without interrupting the gas flow;
- e) unauthorised operation of components is prevented.