

Design and installation of preinsulated bonded pipe systems for district heating

ICS 91.140.10

National foreword

This British Standard is the UK implementation of EN 13941:2003. It partially supersedes BS 7572:1992.

The UK participation in its preparation was entrusted by Technical Committee RHE/9, Thermal insulating materials, to Subcommittee RHE/9/3, Insulation of underground pipelines.

A list of organizations represented on this subcommittee 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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Design and installation of preinsulated bonded pipe systems for district heating

Conception et installation des systèmes bloqués de tuyaux
pré-isolés pour les réseaux enterrés d'eau chaude

Berechnung und Verlegung von werkmäßig gedämmten
Verbundmantelrohren für die Fernwärme

This European Standard was approved by CEN on 27 December 2002.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (EN 13941:2003) has been prepared by Technical Committee CEN/TC 107 "Prefabricated district heating pipe systems", the secretariat of which is held by DS.

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of an identical text or by endorsement, at the latest by September 2003, and conflicting national standards shall be withdrawn at the latest by September 2003.

Annex A is normative. Annexes B, C and D are informative.

This document includes a Bibliography.

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, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This standard has been prepared by JWG1, a joint working group with CEN/TC 267 "Industrial piping and pipelines"

According to the scope from CEN/TC 107

- The task of CEN/TC107/TC267/JWG1 is to specify rules for design, calculation and installation for preinsulated bonded pipe systems for underground hot water networks with pipe assemblies co-ordinated with EN 253, EN 448, EN 488 and EN 489.
- CEN/TC107/TC267/JWG1 can also specify rules for functional tests for preinsulated bonded pipe systems for underground hot water networks.
- The basic rules for design, calculation and installation should be based on functional requirements.
- The purpose of the work is to provide uniform basis for the design, construction and operation of district heating systems, to ensure that the system is reliable and efficient and safe for the surrounding area, the environment and public health.
- Joint assemblies for pipe systems dealt with should be co-ordinated with EN 489.

This standard takes account of experience acquired, of new knowledge available of the behaviour of material and of distribution of stresses and allowable deformations and also evolution in installation techniques.

When use is made of the standard, the different sections of which it is made up are interdependent and, because of this, cannot therefore be dissociated.

The standard consists of a main part and four annexes.

Depending on the character of the individual clauses, distinction is made in this standard between Principles and Application Rules.

The principles comprise:

general statements, definitions and requirements, for which there is no alternative, as well as requirements and analytical models for which no alternative is permitted unless specifically stated.

The principles are printed in normal typeface (10 point font).

The application rules are generally recognised rules, which follow the principles and satisfy their requirements.

Application rule:

The application rules and comments to principles and application rules are printed in a 8 point font. This is an application rule.

Alternative design rules can be used instead of the application rules given in this standard, provided that it is shown that the alternative rule accords with the relevant principles and it is at least equivalent with regard to the resistance, serviceability and durability achieved by the system.

Annex A is part of the standard (principles). Annexes B, C and D have status as application rules.

This standard contains a number of requirements aimed at ensuring the sound execution of distribution networks for district heating. To the extent possible, the requirements specified in this standard are functional requirements.

BS EN 13941:2003

The requirements and regulations contained in this standard should be assessed and applied in compliance with the intentions of the standard and in due consideration of the development taking place in the field it concerns. It is therefore assumed that the user of the standard has the requisite technical insight and that the user of the standard has adequate knowledge of legal and other external regulations that are of consequence to the practical application of the standard.

Special cases can occur within the scope of this standard in which its contents do not cover. An evaluation whether the contents cover should be made in any specific case where the standard is used.

Presently CEN/TC 107 "Pre-fabricated district heating pipe systems" is preparing standards for preinsulated flexible pipes and surveillance systems.

1 Scope

This European Standard specifies rules for design, calculation and installation for preinsulated bonded pipe systems for buried hot water distribution and transmission networks, see. Figure 2, with pipe assemblies in accordance with EN 253, for continuous operation with hot water at various temperatures up to 120 °C and occasionally with peak temperatures up to 140 °C and maximum internal pressure 25 bar (overpressure).

Application rule:

For larger pipe dimensions and pressures below 25 bar wall thickness bigger than specified in EN 253 can be required for straight pipes, bends and tees.

The principles of the standard can be applied to preinsulated pipe systems with pressures higher than 25 bar, provided that special attention is paid to the effects of pressure. Adjacent pipes belonging to the network (e.g. pipes in ducts, valve chambers, road crossings above ground etc.) can be designed and installed according to this standard.

The standard assumes use of treated water, which by softening, demineralisation, deaeration, adding of chemicals, or otherwise has been treated to prevent internal corrosion and deposits in the pipes.

This standard is not applicable for such units as

- pumps,
- exchangers,
- boiler installations, tank installations,
- consumer installations.

However, the full functional ability and durability of such units should be ensured in consideration of the impacts from the district heating system and other impacts occurring from the conditions under which they have been installed.

Guidelines for product quality inspection and in situ tests of joints are given in annex A of EN 448:2003, annex D of EN 253:2003, annex A of EN 488:2003 and annex B of EN 489:2003.

Guidelines for welding of polyethylene casing are given in annex B of EN 448:2003.

The estimation of expected life with continuous operation at various temperatures is outlined in annex B of EN 253:2003

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 (including amendments).

EN 253	2003	<i>District heating pipes – Preinsulated bonded pipe systems for directly buried hot water networks – Pipe assembly of steel service pipe, polyurethane thermal insulation and outer casing of polyethylene.</i>
EN 287-1		<i>Approval testing of welders – Fusion welding – Part 1: Steels.</i>
EN 288-1	1992	<i>Specification and qualification of welding procedures for metallic materials – Part 1: General rules for fusion welding.</i>
EN 288-2		<i>Specification and approval of welding procedures for metallic materials – Part 2: Welding procedure specification for arc welding.</i>
EN 288-3		<i>Specification and approval of welding procedures for metallic materials – Part 3: Welding procedure tests for the arc welding of steels.</i>
EN 444		<i>Non-destructive testing - General principles for radiographic examination of metallic materials by X- and gamma-rays.</i>

EN 448	2003	<i>District heating pipes – Preinsulated bonded pipe systems for directly buried hot water networks – Fitting assemblies of steel service pipes, polyurethane thermal insulation and outer casing of polyethylene.</i>
EN 488	2003	<i>District heating pipes – Preinsulated bonded pipe systems for directly buried hot water networks – Steel valve assembly for steel service pipes, polyurethane thermal insulation and outer casing of polyethylene.</i>
EN 489	2003	<i>District heating pipes – Preinsulated bonded pipe systems for directly buried hot water networks – Joint assembly for steel service pipes, polyurethane thermal insulation and outer casing of polyethylene.</i>
EN 571-1		<i>Non destructive testing - Penetrant testing - Part 1: General principles.</i>
EN 583-1		<i>Non-destructive testing - Ultrasonic examination - Part 1: General principles.</i>
EN 719	1994	<i>Welding coordination – Tasks and responsibilities.</i>
EN 729-1		<i>Quality requirements for welding – Fusion welding of metallic materials – Part 1: Guidelines for selection and use.</i>
EN 729-2		<i>Quality requirements for welding – Fusion welding of metallic materials – Part 2: Comprehensive quality requirements.</i>
EN 729-3		<i>Quality requirements for welding – Fusion welding of metallic materials – Part 3: Standard quality requirements.</i>
EN 729-4		<i>Quality requirements for welding - Fusion welding of metallic materials - Part 4: Elementary quality requirements.</i>
EN 970		<i>Non-destructive examination of fusion welds - Visual examination.</i>
EN 1289		<i>Non-destructive examination of welds - Penetrant testing of welds - Acceptance levels.</i>
EN 1290		<i>Non-destructive examination of welds - Magnetic particle examination of welds.</i>
EN 1291		<i>Non-destructive examination of welds - Magnetic particle testing of welds - Acceptance levels.</i>
EN 1418		<i>Welding personnel - Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials.</i>
EN 1435		<i>Non-destructive examination of welds - Radiographic examination of welded joints.</i>
EN 1594		<i>Gas supply systems - Pipelines for maximum operating pressure over 16 bar – Functional requirements.</i>
EN 1712		<i>Non-destructive examination of welds - Ultrasonic examination of welded joints - Acceptance levels.</i>
EN 1714		<i>Non-destructive examination of welds - Ultrasonic examination of welded joints.</i>
EN 10204		<i>Metallic products – Types of inspection documents.</i>
EN 10216-2		<i>Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties.</i>

EN 10217-2		<i>Welded steel tubes for pressure purposes - Technical delivery conditions – Part 2: Electric welded non-alloy and alloy steel tubes with specified elevated temperature properties.</i>
EN 10217-5		<i>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.</i>
EN 13018		<i>Non-destructive testing - Visual testing - General principles.</i>
EN 25817		<i>Arc-welded joints in steel – Guidance on quality levels for imperfections (ISO 5817:1992).</i>
EN 29692		<i>Metal-arc welding with covered electrode, gas-shielded metal-arc welding and gas welding – Joint preparations for steel (ISO 9692:1992).</i>
ISO 1000		<i>SI units and recommendations for the use of their multiples and of certain other units.</i>
ISO 3419		<i>Non-alloy and alloy steel butt-welding fittings.</i>
ISO/TR 15608	2000	<i>Welding - Guidelines for a metallic material grouping system (ISO/TR 15608:2000).</i>

3 Units and symbols

3.1 Units

The unit system applied in this standard is the SI system (Système International d'Unités), see ISO 1000 and others.

The following units and their multiples are used:

Length	m	(metre)
	mm	(millimetre)
Mass	kg	(kilogram)
Force	N	(Newton)
Stress	N/mm ²	(Newton per square millimetre)
Pressure	Pa	(Pascal = Newton per square metre)

Other units applied:

Temperature	°C	(degree centigrade)
Pressure	bar	(1 bar = 10 ⁵ Pa = 0,1 N/mm ²)

3.2 Symbol

<i>A</i>	Area
<i>c</i>	Cohesion of the soil, fabrication tolerance
<i>D</i>	Diameter of casing
<i>d</i>	Diameter of service pipe
<i>E</i>	Modulus of elasticity
<i>F</i>	Friction force
<i>f</i>	Design stress, friction force per area unit, deflection
<i>G</i>	Selfweight
<i>I</i>	Momentum of inertia
<i>i</i>	Stress intensification factor
<i>L</i>	Friction length
<i>l</i>	Length
<i>M</i>	Bending moment
<i>N</i>	Normal force, number of full action cycles
<i>n</i>	Number
<i>p</i>	Internal pressure
<i>R_e</i>	Specified minimum upper yield strength
<i>R_m</i>	Tensile strength
<i>R</i>	Bend radius
<i>r</i>	Pipe radius
<i>T</i>	Temperature
<i>t</i>	Pipe wall thickness
<i>W</i>	Section modulus
<i>Z</i>	Depth of burial (measured to centreline of pipe)
	Coefficient of thermal expansion
	Specific gravity, partial safety coefficient
	Friction angle between pipe and soil, displacement from thermal expansion
	Strain
	Angle
	Coefficient of thermal conductivity
	Coefficient of friction between pipe and soil
	Density
	Normal stress
	Shear stress

Poisson's ratio

Internal friction angle of soil

Indices

<i>a</i>	Action
<i>b</i>	Branch pipe (at tee connections)
<i>c</i>	Casing
<i>d</i>	Design
<i>fat</i>	Fatigue
<i>i</i>	Inner, inside
<i>j</i>	Reference
<i>m</i>	Mean, membrane, material
<i>min</i>	Minimum
<i>n</i>	Nominal, number (of fatigue cycles)
<i>o</i>	Outer, outside
<i>r</i>	Run pipe (at tees)
<i>res</i>	Resulting
<i>u</i>	Fracture
<i>v</i>	Vertical

Separate symbol lists are found in annex A, B and C.

4 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 253:2003 and the following apply.

4.1

action

set of concentrated or distributed forces acting on the pipe system (force-controlled action), or the cause of imposed or constrained deformations in the system (displacement-controlled action). Actions are often referred to as "loads"

4.2

action cycle

one action cycle is one impact with a given stress range. An action cycle comprises one full action course (which is twice the action amplitude calculated from an average value)

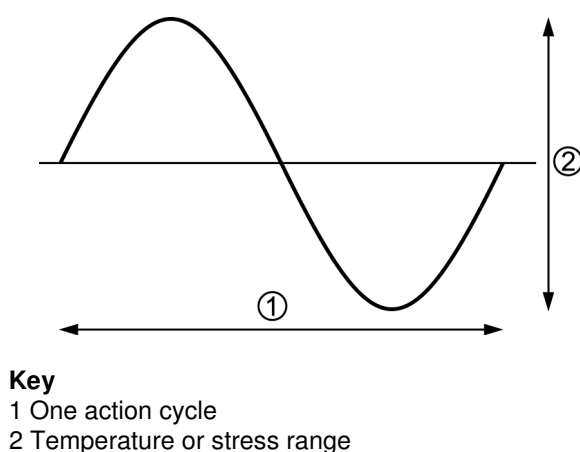


Figure 1 - Action cycle

4.3

bonded system

consisting of a service pipe, insulating material and casing, which are bonded by the insulating material

4.4

cold installed preinsulated bonded pipes

district heating systems where the pipes are installed and taken into operation without prior pre-stressing by pre-heating

4.5

creep

slow progressive strain under the influence of stresses

4.6

design pressure

internal pressure equal to or greater than the maximum operating pressure at any point of the pipeline acting in a component or pipe section multiplied by a partial safety factor

4.7

design temperature

maximum temperature used for the design of a component or pipe section

4.8

displacement-controlled action

action called forth by enforced deformation or movement, e.g. thermal expansion or settling

4.9

distribution pipeline

pipeline leading from place of production or transmission line to heating installations. Distribution mains are primarily main pipelines or house service connections, see Figure 2.

4.10

ductile materials

materials, which with good approximation are linearly elastic up to the yield stress or to the 0,2% proof stress, and which have a minimum elongation at rupture of 14 %

4.11

extruded tees

are manufactured by drawing a collar on which the branch pipe is welded. The collar is welded onto a transitional piece with increased wall thickness, so that the local stress intensification for the tee is reduced before the straight pipe with normal wall thickness.

4.12

fabricated tees

are manufactured by welding a branch pipe directly onto a run pipe

4.13

fatigue strength

stress range of constant magnitude which, under given circumstances, just causes fatigue failure

4.14

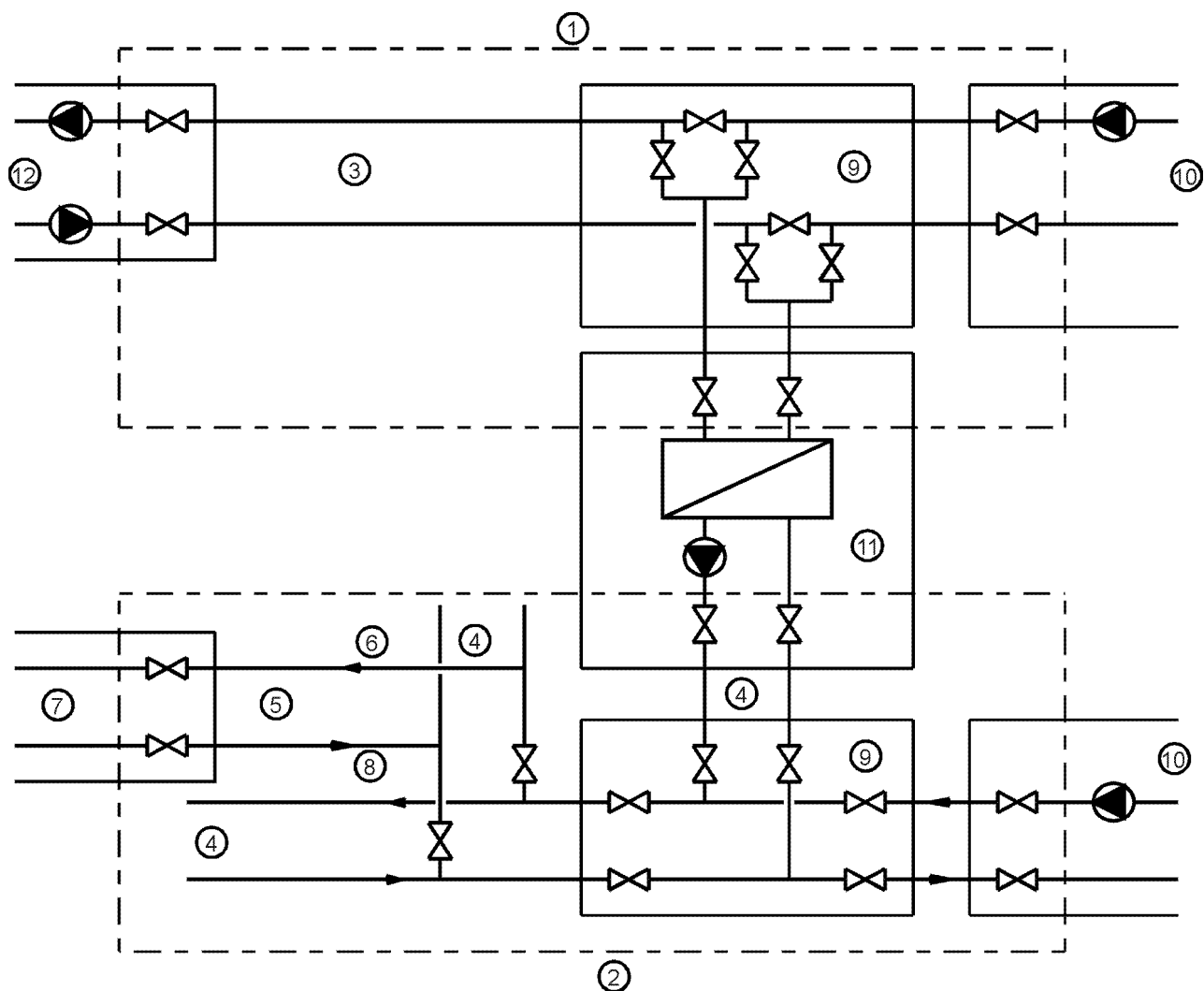
force-controlled action

action, which maintains its size irrespectively of the deformation of the structure, e.g. pressure and weight

4.15

house service connection

pipeline leading from main pipeline to one consumer installation, see Figure 2.



Key

- | | |
|----|--------------------------|
| 1 | TRANSMISSION SYSTEM |
| 2 | DISTRIBUTION SYSTEM |
| 3 | TRANSMISSION PIPE |
| 4 | MAIN PIPE |
| 5 | HOUSE SERVICE CONNECTION |
| 6 | SUPPLY PIPE |
| 7 | CONSUMER |
| 8 | RETURN PIPE |
| 9 | VALVE CHAMBER |
| 10 | HEAT PRODUCTION |
| 11 | HEAT EXCHANGER STATION |
| 12 | PUMP STATION |

Figure 2 - Distribution and transmission systems

4.16

installation temperature

temperature arising from the ambient conditions during laying or installation, prevalent at the time when action is taken

4.17

main pipeline

pipeline supplying several heating installations. See Figure 2.

4.18

number of equivalent full action cycles

number of action cycles with constant full action range calculated from a known or presupposed temperature history using Palmgren-Miner's formula and the respective SN-curve

4.19

operating pressure

maximum internal pressure acting against the pipe wall at any point or in any section of the pipeline at a given operating temperature

Application rule:

This is generally the internal pressure needed to take account of the static head, friction losses and required outlet pressure.

4.20

operating temperature

water temperature in a component or pipe section during specified operating conditions

4.21

pre-heated system

system, which after being assembled, but before backfilling, is heated to a pre-heating temperature allowing the system to expand without introducing additional stresses

4.22

preinsulated systems

systems assembled at site consisting of prefabricated pipe elements and components with integrated protective casing, insulation and service pipe

4.23

pressure

over-pressure or sub-pressure as compared to normal atmospheric pressure. Unless otherwise indicated, pressure refers to gauge pressure.

4.24

pre-stressing temperature

temperature applied during pre-stressing of a pre-heated system

Application rule:

The pre-heating temperature is chosen such as approximately average axial stress is obtained, compared to the axial stress levels at ambient temperature and maximum operating temperature.

4.25

reference stress

is calculated (with sign) from the membrane or resulting stresses by Tresca or by von Mises' formula

Application rule:

The formulae are presented in 7.4.3

4.26

resulting stresses

all stress occurring in one point, i.e. membrane stresses plus stresses varying over the wall thickness

4.27

service life

span of time during which the network is expected to function without major replacements, given normal maintenance and operation conditions as described in the project

4.28

service pipe

steel pipe that contains the water

4.29**single action compensator**

functioning during pre-heating. After pre-heating the compensator is locked

4.30**strain**

unit deformation, e.g. elongation or reduction per unit of length

4.31**stress range**

difference between maximum stress and minimum stress for one single load cycle, the stress being computed with preceding sign, see Figure 1

4.32**surge pressure (water hammer)**

variation of pressure for relatively short period, resulting from a change in velocity of the circulating water. Such a change can be a consequence of valve closing, pump failure, boil over, impacts from non-return valves, blockage, fractures in the pipeline, etc.

4.33**system**

complete pipeline installation including joints, branches, accessories, etc. and adjacent pipelines

4.34**temperature range**

absolute value of the difference between the two extremes of temperature occurring during a cycle, taking account of operational and environmental influences, see Figure 1

4.35**test pressure**

internal pressure occurring within the pipeline or a part of the pipeline during strength testing (strength test pressure) or leak tightness testing (leak tightness test pressure)

4.36**transmission pipelines**

major pipelines leading from place of production to distribution pipelines, see Figure 2

4.37**valves and accessories**

surveillance, operating and safety equipment directly fitted to a district heating pipeline

4.38**weld-in tees**

are e.g. made by forging and are usually seamless

5 General considerations for system design

5.1 General requirements

Design and installation of district heating pipe systems shall ensure that the system is given

sufficient durability, robustness and reliability in relation to the internal and external loads and impacts, to which it is likely to be subjected in normal operation.

sufficient safety that unusual operating conditions or accidents do not jeopardise persons or the environment,
good energy economy,
good operating properties,
safety of supply.

Application rule:

Installation expenses, maintenance expenses and operating expenses arising throughout the service life of the system should be included in the assessment of the system.

The assessment of operating properties should pay regard to the possibilities of inspection and maintenance.

5.2 Service life

When a system, designed according to this standard, is subject to temperatures exceeding 120 °C, for periods such that the requirement for a service life of 30 years at continuous operation at 120 °C, calculated in accordance with annex B of EN 253:2003, is exceeded, the service life of components subject to ageing shall be assessed.

Application rule:

The minimum requirements for the type test of EN 253 (based on the shear strength between PUR foam and steel pipe) is a service life of 30 years for continuous operation at 120 °C.

If the cumulative ageing requires a lifetime exceeding the equivalence of 30 years at 120 °C special documentation for the ageing properties are required.

5.3 Preliminary investigations

Preliminary investigations comprising an assessment of all conditions of importance to a district heating project shall be carried out.

These preliminary investigations shall elucidate matters in the planning, design, execution and operating stages as well as consequences of any kind of failure of the system.

The principal basis of the preliminary investigation is the main data for the current system, e.g.

- function,
- pressure and temperature,
- dimensions,
- depth of burial,
- materials,
- distances and heat transfer to other utility networks, buildings and trees,
- geotechnical and groundwater parameters, etc.

Application rule:

The preliminary investigations may include elucidation of the following matters:

- pipeline route,
- operating conditions of the system, e.g. variations in pressure and temperature and requirements for safety of supply,
- function mode of the system during operating and maintenance stage as well as resistance to relevant impacts such as:
 - loads due to installation and operation,
 - internal and external loads and deformations,
- consequences of possible kinds of failure of the system,
- authorities' requirements, environment and third party aspects,
- methods of execution.

5.4 Determination of project class

5.4.1 Risk assessment

Possible coincidences involving a risk of personal damage or consequences to the society or environment, shall be assessed.

Application rule:

When evaluating possible risk both the probability of a failure and the effects of a failure should be taken into account.

The **effect of failure** of a district heating pipeline system to its environment is related to temperature, pressure and diameter of the pipeline.

The **probability of a failure** is based on internal and external factors and the quality of design, installation and operation.

Possible risks are:

- escape of hot water due to bursting or leakage, involving a risk of scalding, flooding, tunnelling, etc.,
- damage to the installation, involving interruption of the heat supply,
- damage to the installation, involving a risk of further spread of the damage in the installation,
- loss of safety of supply.

The consequences of failure may be related to the entire system or to a section only.

The project class determines the level for design and installation of the pipeline system.

5.4.2 Project classes

The choice of project class is related to the level of safety and complexity of execution expressed as requirements with respect to design procedures and construction.

Based on preliminary investigations and risk assessment the pipeline system shall be classified in one of the following classes:

Table 1 - Project classes

Project class A	Small and medium diameter pipes with low axial stresses pipes with low risk of personal damage or damage to the surroundings pipes with low risk of economic losses
Project class B	High axial stresses, small and medium diameter pipes
Project class C	Large diameters pipes and/or high pressures pipes with higher risk of personal damage or damage to the surroundings special or complex constructions

Application rule:

Special or complex constructions can be crossings with railways, major roads and waterways, which are normally designed in consultation with the owners and/or authorities. For crossings with dykes and flood defences extra measures may be required to prevent flooding of the hinterland.

System parts, which are not directly pressurised, but in which a failure may involve fracture or leakage in a pressurised section are referred to the same project class as the pressurised section.

Pipelines, which are accessible during operation shall, as a minimum, be classified in project class B.

Based on the expected effects the project classes A, B and C are determined by Figure 3.

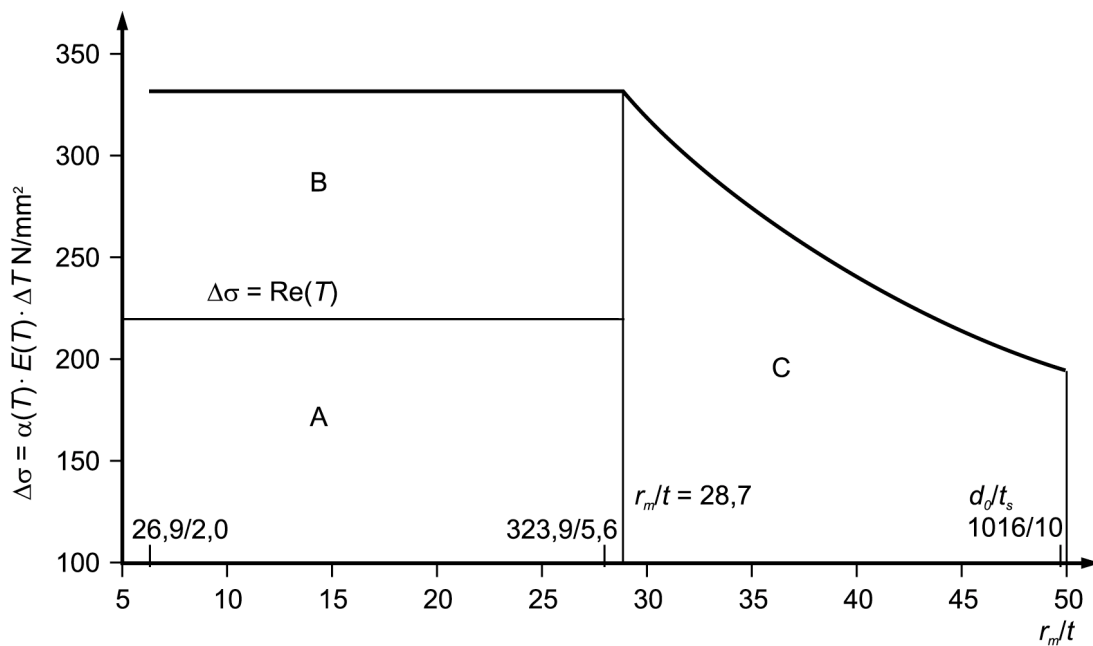


Figure 3 - Definition of project classes for a steel with a specified minimum yield strength, $R_e(23\text{ °C}) = 235\text{ N/mm}^2$

Table 2 - Requirements for project classes

Project class	Welding control	Fatigue analysis	Documentation
Figure 3	8.5.8	7.4.2	
A	5%	$fat = 5$	Generalised documentation, 7.2
B	10%	$fat = 6,67$	Generalised documentation, 7.2
C	20%	$fat = 10$	Specific documentation required

Application rule:

In relation to project class the following has to be considered:

- requirements for documentation,
- determination of fat in Palmgren-Miner's formula,
- requirements for welding,
- scope of inspection of weld seams,
- quality management and scope of inspection.

An installation can always be classified in a higher project class than stated in Figure 3.

Application rule:

Following conditions can result in the choice of a higher project class:

- system design and complexity,
- soil and groundwater conditions,
- traffic conditions,
- position in relation to other structures and utility networks,
- experience with corresponding installations,
- new methods,
- location of the pipeline and possibilities for maintenance and replacement.

5.5 Design documentation

5.5.1 General

Any pipe installation shall be made on basis of design documentation that is sufficiently detailed to ensure execution of the project presupposed quality.

If the installation is changed during execution the design documentation shall be changed accordingly.

General design documentation in all project classes shall comprise :

- general operational data,
- data related to the pipeline,
- specifications for quality control.

5.5.2 Operational data

Operational data:

- design life, design pressure and design temperature,
- number of operating temperature and pressure cycles and their duration occurring during the life of the pipelines (estimated pipeline operating pattern over its life).

Application rule:

The relevant values for both summer and winter conditions as well as the expected number of full cycles should be specified.

5.5.3 Data related to the pipeline

Data on pipeline location, materials and special provisions.

- a) Data on the pipeline route.

Drawings shall contain all information required for a safe and reliable design, such as:

- map of the planned route,
- the longitudinal profile,
- the location of the pipeline with respect to other structures, including intersecting or parallel pipelines or cables, buildings and other obstacles,
- locations of horizontal and vertical bends, tees and reducers, casings, fixpoints, concrete ducts, etc.,
- information on civil engineering works and special constructions.

Application rule:

Above data may be presented in the form of:

- a geographical map with, where applicable, an indication of the area covered by the individual route maps,
- route maps or similar drawings,
- detailed maps and drawings standard structures, indicating the route map(s) to which they apply and providing all information needed for assessment of the design and installation.

The following drawings can be required:

- drawings of pipeline elements, fixed points, casings, etc.,
- isometric calculation drawings for special structures,
- distances between the pipeline and buildings (survey distance) and project class, on a separate list or route map,
- drawings of sheet-piling structures (pile driving plan).

b) Data related to pipeline dimensions:

- outside diameters and tolerances,
- nominal wall thickness and tolerances,
- relevant data on fittings, including bend radii or other information relating to the pipeline element (reducers, tees, etc.),
- corrosion allowances if applied,
- data on abutting structures and supports which affect the distribution of forces acting on the medium-carrying pipeline.

c) Material data:

- material specifications and certificates.

d) Installation data.

Information may be required on the following aspects, among others:

- any pre-stressing applied to the pipeline, and the point at which and methods by which this pre-stressing is applied,
- small angular deviations and permitted elastic bending radii applied to the pipeline, both permanent and temporary,
- test pressure,
- installation temperature.

e) As built drawings:

- registration of location.

Application rule:

An installation plan should include the items a to d.

5.5.4 Specifications for quality control

Application rule:

A plan for quality control should be elaborated for each project.

Quality control can e.g. be divided into five stages:

- procurement,
- design,
- installation and approval
- setting into operation
- operation phase.

Quality control should be ensured for each stage covering the following domains:

- management and organisation of the quality control ,
- management and organisation of the inspection.

It is recommended to

- compare the draft project with the specified objectives and the conditions of the intended operation,
- check the design,
- check the preinsulated components,
- check each stage of the execution, paying special attention to the construction details,
- require the inspections, tests and certificates specified in the quality control plan for applied materials prior to setting into operation.

During each stage of execution the supplier, the manufacturer and the owner should keep the complete documentation updated:

- description of materials,
- quality control plan,
- design report,
- report on setting into operation,
- maintenance records,
- inspection certificates for the materials, works certificates, welding, tests etc. as specified in the quality control plan, report on transfer to the user.

6 Components and materials

6.1 Basic requirements

6.1.1 General

Preinsulated bonded pipe systems for district heating having a pipe assembly of steel service pipe, polyurethane thermal insulation and an outer casing of high density polyethylene shall as a minimum comply with the basic material requirements in EN 253, EN 448, EN 488 and EN 489.

All materials significant to the proper functioning of the system shall possess stable properties during the service life of the system, considering the temperatures and other actions to which the materials will be exposed. Fatigue, creep and ageing shall be considered in this context.

When designing the system the properties of the components shall be calculated in values, which are valid throughout the entire service life of the system.

Application rule:

Properties, which are not directly influencing the service life of the system such as thermal conductivity, should be calculated with weighted average values.

6.1.2 Non standardised components

To the extent to which preinsulated pipes, fittings and joints, not covered by the aforementioned standards, are used for the circulation of district heating water the necessary requirements for material properties, strength and durability shall be substantiated on basis of relevant European Standards, or it shall be otherwise documented that properties and system design comply with the functional requirements of this standard throughout the service life of the system.

Non standardised components shall fulfil the requirements for standardised components whenever applicable.

6.2 Steel pipe components

6.2.1 General

Steel pipe components under the scope of this standard are:

- straight pipe,
- bends,
- tees and branch connections,
- reducers and extensions,
- other steel components like wall penetrations and single action compensators.

6.2.2 Documentation

All steel pipes and components used for fabrication of pipe systems under the scope of this standard shall as a minimum be delivered with a 3.1.B certificate according to EN 10204.

The manufacturer shall keep documentation of the certificates.

6.2.3 Characteristic values for steel

6.2.3.1 General

Materials for steel service pipe shall be either welded pipe according to EN 10217-2 or EN 10217-5 or seamless pipe according to EN 10216-2 with diameter tolerances according to EN 253.

Application rule:

EN 253 specifies stricter tolerances on diameter than specified in the above mentioned steel standards.

As an alternative, equivalent European or national standards may be used.

6.2.3.2 Steels with specified elevated temperature properties

Values for the yield strength at design temperature shall be derived from the specified minimum yield strength or 0,2 %-proof stress at elevated temperature given by the relevant material standards. These specified minimum values guaranteed for the delivery condition can be used for design purposes, unless heat treatment is known leading to lower values. In such cases the values to be used shall be agreed upon by the parties involved.

In case steel pipe or pipe components are delivered without the required certificate according to 6.2.2 the specified minimum yield strength shall be divided by an extra safety factor $m_{\text{yield}} = 1,2$. (This factor is to be multiplied by the partial factor for yielding of base material, according to 7.4.2)

Application rule:

Tests performed by the steel pipe manufacturer at elevated temperatures to determine the yield strength values for a specific material delivery may lead to acceptance of a higher yield strength value at elevated temperatures compared with the values specified in the relevant standard.

6.2.3.3 Steels without specified elevated temperature properties

In those cases where the material standards for unalloyed and low alloy steels show no specified value for the yield strength at elevated temperatures, the following formula shall be used:

$$R_{p0.2} = R_m \frac{720 - T}{1.400} \quad \text{for } 50^\circ\text{C} \leq T \leq 140^\circ\text{C}$$

6.2.3.4 Elasticity modulus (E) and linear thermal expansion coefficient (α) at elevated temperatures

Application rule:

The following formulas should be used for non alloy or low alloy steel with temperatures up to 140 °C:

$$E = 214 - \frac{T}{175} \times 10^4 \quad (\text{N/mm}^2)$$

$$\alpha = 11,4 + \frac{T}{129} \times 10^{-6} \quad (1/K)$$

For simple design and temperatures up to 100 °C the value of the product $E \cdot \alpha$ may be valued equal to 2,52 N/mm²/K.

6.2.4 Specific requirements for bends and tees

The use of mitred bends made from straight pipe sections for the service pipe is normally not allowed.

Bends and tees shall normally be made of steel with the same (or higher) specified minimum yield strength than the adjacent straight pipes.

When installing a bend or a tee in a pipe system, the nominal wall thickness of the bend or tee at the welding ends shall normally not be less than the nominal wall thickness of the adjacent straight pipes.

Only set-on branches shall be used. The use of branches welded into the run pipe is not permitted.

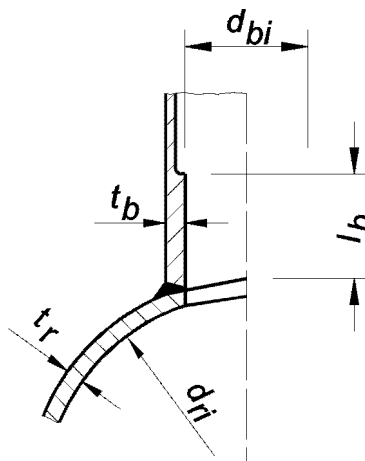


Figure 4 - Set-on branch

Tees may be reinforced by increasing the wall thickness of the run pipe and/or the branch pipe or by compensating plates to withstand the internal pressure, bending moments and axial compressive forces according to the requirements of annex A and C.

Application rule:

For extruded tees for project class C the nominal design stress should be generally reduced to 90 % of σ_d given in 6.2.3.

6.2.4.1 Compensating plates

Reinforcement of tees by compensating plates in project class C is limited to a diameter ratio of $d_{ob}/d_{or} \leq 0,8$ where d_{ob} and d_{or} are the outer diameter of the branch and the run pipe respectively.

6.2.5 Specific requirements for reducers and extensions

Reducer material shall have the same or higher yield strength as the adjacent straight pipes.

Annex A specifies additional requirements for non standardised components.

Application rule:

As an alternative to ISO 3419 an equivalent European or national standard may be used. See 4.1.5 of EN 448:2003.

6.2.6 Specific requirements for other components

Other components like wall penetrations and single action compensators shall be considered as non-standardised components for which the conditions of 6.1.2 apply.

6.3 Polyurethane foam insulation

The thermal insulation shall comply with the requirements of EN 253.

Application rule:

Characteristic values for PUR foam:

Elasticity modulus: $E_{PUR} = 6,5 \text{ MPa}$ (long term at 140 °C)

$E_{PUR} = 10,0 \text{ MPa}$ (at 23 °C)

Concerning insulation thickness, see annex D.

6.4 PE casing

The PE casing and welding of PE casing shall comply with the requirements EN 253, EN 448 and EN 489.

6.5 Expansion cushions

Materials selected for use in expansion cushions shall provide the required flexibility, be chemically stable and possess the required strength, during the entire service life of the pipe system, at the design range of temperatures.

The thickness of the cushion shall be selected so that the surface temperature at the PE casing pipe is not exceeding 50 °C.

Elasticity modulus as a function of the percentage of compression (secant modulus) shall be specified by the manufacturer based on tests.

Application rule:

Expansion cushions should be closed cell and of a type preventing the progressive compaction caused by sand backfill of the soil cavity occurring after pipe displacement.

When load-deformation curves made up from uni-axial tests are used it should be observed that the cushions in practice will be approximately twice as rigid due to Poisson's ratio.

6.6 Valves and accessories

6.6.1 General requirements

Preinsulated valves shall comply with EN 488.

The applied materials and the fabrication methods shall be such that the design conditions can be fulfilled throughout the entire service life.

Valves and accessories shall be dimensioned to withstand operational conditions and external actions in accordance with the relevant chapters and annexes of this standard. Special attention shall be paid to ensure that high axial compressive forces in restrained pipelines parts can be taken up.

Preinsulated valves for buried installation shall be designed in such a way that they require a minimum of maintenance.

Any preinsulated component shall be fully welded.

6.6.2 Marking and documentation

Valves and accessories shall be clearly and durably marked allowing identification of manufacturer, pressure class (if applicable), design temperature, etc.

The manufacturer shall keep documentation that the components have been designed according to this standard.

Application rule:

Each prefabricated component which is a part of a district heating pipe system, should by labelling be furnished with a declaration stating the conditions the component has been designed and manufactured for.

The declaration shall specify following design data:

- material and grade,
- max. operating pressure,
- max. axial stress for straight pipe parts or maximum axial force,
- max. bending moment (for valves, one time compensators),
- installation method:
 - A: Conventional installation methods (e.g. pre-heating, single action compensators).
 - B: Cold installation.

7 Actions and limit states

7.1 General

Design and calculation shall be performed in such a way that sufficient documentation is provided that the pipe system will be able to withstand all relevant actions and fulfil the safety and functional requirements during its entire service life.

Application rule:

For a given pipeline system the design and calculation procedure, as presented in Figure 5, can be followed. It includes the following steps:

- I. Assessment of design data.
- II. Classification of actions.
- III. Sub-division of the pipeline, along the proposed route into sections for stress analysis.
- IV. Determination of project class and options for simplified analysis.
- V. Selection of the combinations of actions to be considered.
- VI. Limit state design (and the safety factors to be applied).
- VII. Determination of cross sectional forces and displacements due to the action combinations calculated.

- VIII. Calculation of the stresses (and/or strains).
- IX. Selection of assessment criteria (limit states and associated limit values).
- X. Checking of the calculated stresses, strains and deformations with the limit values.

The depth of analysis for each of these steps depends on

complexity of the pipe system in the section considered,
physical pipe parameters,
project class.

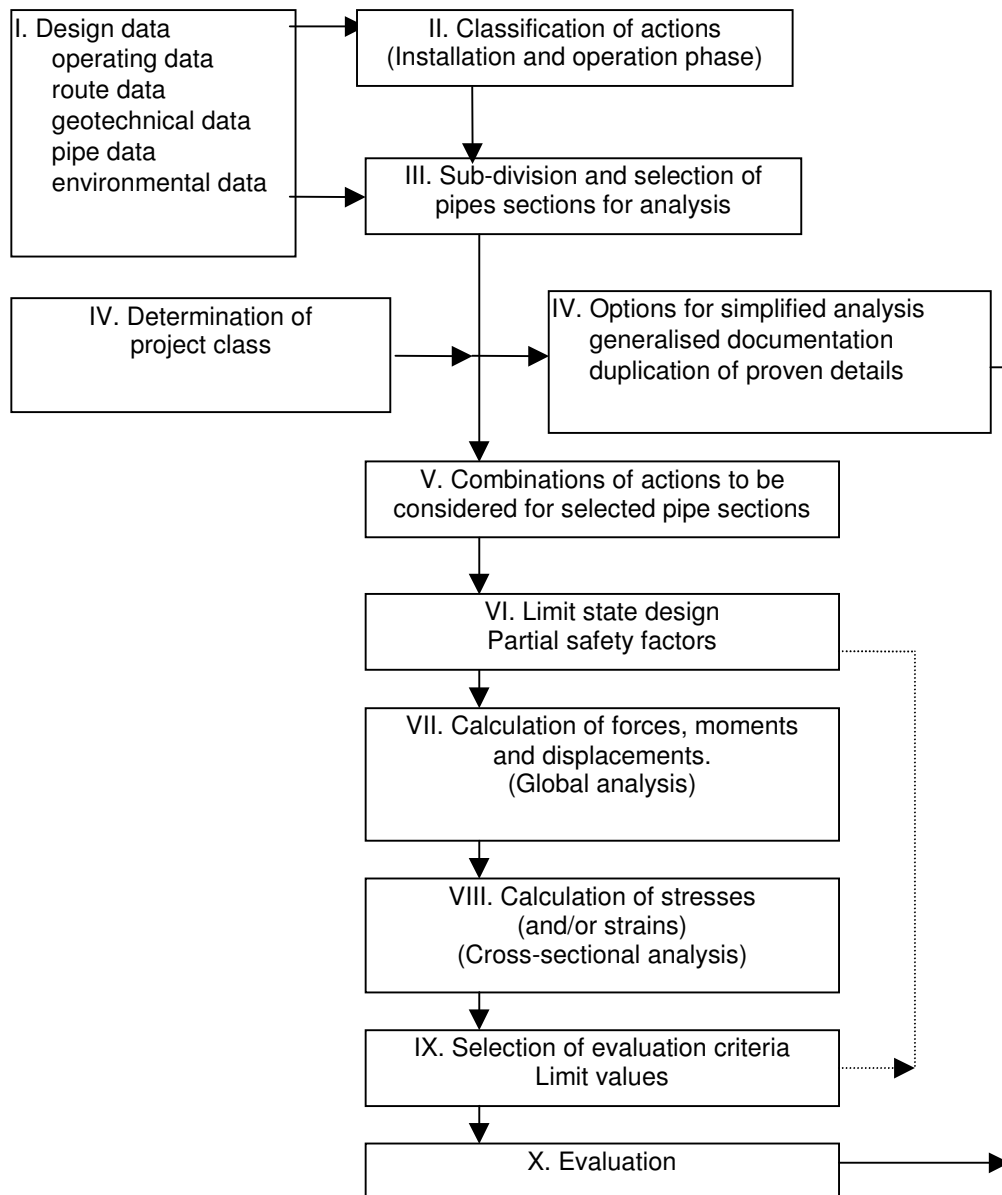


Figure 5 - Flow chart for the design of district heating systems

7.2 Simplified analysis procedure

In project classes A and B design and installation can be performed on the basis of generalised documentation, provided it is in compliance with the requirements of this standard and fulfil the prerequisites (pressure, temperature, traffic actions, etc.) corresponding to local conditions.

Application rule:

Generalised documentation can be e.g. company standards or manufacturers' manuals, provided that the company or manufacturer keeps documentation that the company standards or manufacturer's manuals are in compliance with this standard.

Proven construction details can be installed on the basis of available experience provided that the new construction is not subject to more severe actions.

Application rule:

Fatigue life should always be checked, by estimation of the equivalent number of full temperature cycles, for the pipe system considered, see C.5.2. The number of cycles shall be lower than the number of full temperature cycles presupposed in the generalised documentation (minimum values, see Table 4).

7.3 Actions

7.3.1 General

Actions shall be determined in such a way that the calculation models used provide sufficient documentation that the installation complies with given functional requirements.

Application rule:

The characteristic value of a stochastic variable action is in principle defined as the action value which, at a probability of 95%, will not be exceeded.

Selfweight may, in most cases, be calculated on the basis of the nominal dimensions and mean unit masses.

For the assessment of actions and possible combinations, installation phase and operating phase and any foreseen modification in the use of the current installation and areas shall be taken into consideration.

Application rule:

The installation phase includes transport, handling, welding, laying, backfilling, testing, commissioning (note that actions arising during the installation phase may persist during the operating phase, e.g. pre-stressing).

The operating phase includes the situation after completion of installation, whether the pipeline is in service or not.

Design actions are obtained by multiplying (or dividing) the characteristic values by partial safety factors, γ_a .

7.3.2 Classification of actions

The actions and partial safety factors that shall be taken into account in the design are presented in Table 3.

Actions can be divided into

- force-controlled actions and
- displacement-controlled actions.

Table 3 - Classification of actions and partial safety coefficients

FORCE-CONTROLLED ACTIONS	PARTIAL SAFETY FACTORS ^a
PRESSURE - operating pressure - pressure surges. Note 1 - external pressure - internal vacuum. Note 2 - test pressure	1,2 1,2 1,05 1,2 1,0
PERMANENT ACTIONS Selfweight - pipe assembly - water - accessories (valves, etc.) - buoyancy - neutral/passive soil pressure (see NOTE 4) - settlements. Note 3	1,0 1,0 1,0 1,2 1,0 - 1,5 1,2
VARIABLE ACTIONS (see NOTE 4) - traffic - wind - snow	1,0 - 1,5
DISPLACEMENT-CONTROLLED ACTIONS	
TEMPERATURE VARIATIONS - variations during operation - start-up/shut-down cycles - lateral soil reactions - soil/pipe friction	1,0
PERMANENT ACTIONS - pre-stressing thermal, electrical, mechanical - settlements. Note 4 - differential settlements - deformations during installation	1,0 1,5 1,0 1,2 1,0

NOTE 1 Application rule:

Steps in design and operation should be taken to reduce the risk of harmful pressure surges. In project class C the possibility and consequences of pressure surges should be analysed.

NOTE 2 The design pressure for vacuum -1 bar.

NOTE 3 If it is not acceptable that the pipe follows soil settlement the weight of soil should be treated as a force-controlled action.

NOTE 4 Depending on the standard used for actions.

7.4 Limit states

7.4.1 General

Pipelines for district heating systems shall be designed and constructed such that the probability of an ultimate limit state or serviceability limit state being exceeded during the planned service life is sufficiently low.

Application rule:

The methodology described below is one method to prove that the functional requirement above is fulfilled.

The effect of the design actions in terms of stress, strain and deformation calculated shall not exceed the associated limit states for the pipe materials.

The required safety margin between 'service' condition of the pipeline and the limit state is expressed by the terms 'characteristic value', 'partial safety factor' and 'design action'.

Application rule:

The (residual) uncertainties for which partial safety factors are intended to compensate include:

- the possibility of the action being greater than the characteristic value,
- the possibility of the actual values for the strength of the pipeline being lower than the characteristic values employed,
- deviations from the physical reality, due to the calculation model used in the analysis process.

Ultimate limit states are those associated with collapse or other forms of structural failure:

- failure caused by plastic deformation (limit state A),
- rupture caused by (high and low cycle) fatigue (limit state B),
- instability of the pipeline system or part of it (limit state C),
- leakage (by other causes, e.g. corrosion or third party damage), which may affect safety.

Serviceability limit states corresponds to states beyond which specified service criteria are no longer met:

- deformations or deflections which adversely affect the effective use or maintenance of the pipeline system or cause damage to finishes or structural elements, not being part of the pipeline system, such as installed equipment and/or abutting structures (limit state D).

7.4.2 Limit states for service pipes of steel

7.4.2.1 General

For steel pipes the following limit states are derived from the ultimate and serviceability limit states.

7.4.2.2 Limit state A: Failure caused by plastic deformation

Limit state A1: Ultimate limit state reached by one severe action (load bearing capacity)

Limit state A2: Ultimate limit state reached by few actions (stepwise plastic deformation)

For actions, the partial safety factors γ_a are applied according to Table 3.

Limit state A1: Ultimate limit state reached by one severe action (load bearing capacity)

An equilibrium stress field is any stress field, which is necessary to satisfy the equilibrium equation for force-controlled actions.

The corresponding stress at each point of the structure is not to be greater than the characteristic material parameter divided by the partial safety factor.

The installation, inclusive of valves and accessories, is to be examined for one single elevated effect of the most unfavourable combination of force-controlled actions.

Application rule:

The action combinations comprise operating condition as well as condition during pressure testing.

In some special cases the axial membrane forces from displacement-controlled actions shall be included when calculating the equilibrium stress field (e.g. free spanning pipes with high axial forces from pre-stressing or heating).

For the design an elasto-plastic material model is used. In the calculations a purely linear elastic stress-strain relation is used, also for stresses exceeding the yield strength.

The design of solid component walls with membrane and bending stresses shall verify that the following is observed for the principal stresses, and in the case of composite stress conditions also for the reference stress:

$$\begin{aligned} \sigma_{j,m} &= \frac{R_e(T)}{\gamma_m} \\ \sigma_{res} &\leq \begin{cases} 1,5 \times \sigma_d & \text{for } \sigma_m \leq 0,67 \times \sigma_d \\ 2,5 \times \sigma_d + 1,5 \times \sigma_m & \text{for } \sigma_m > 0,67 \times \sigma_d \end{cases} \\ \sigma_{j,res} &\leq \begin{cases} 1,5 \times \sigma_d & \text{for } \sigma_{j,m} \leq 0,67 \times \sigma_d \\ 2,5 \times \sigma_d + 1,5 \times \sigma_{j,m} & \text{for } \sigma_{j,m} > 0,67 \times \sigma_d \end{cases} \end{aligned}$$

where

- σ_d is the design stress
- σ_m is the design membrane stress
- $\sigma_{j,m}$ is the design reference stress for the membrane stresses
- σ_{res} is the design total stress of membrane stress and bending stress
- $\sigma_{j,res}$ is the design reference stress for the total stresses of membrane stresses and bending stresses
- γ_m is the partial safety factor for material

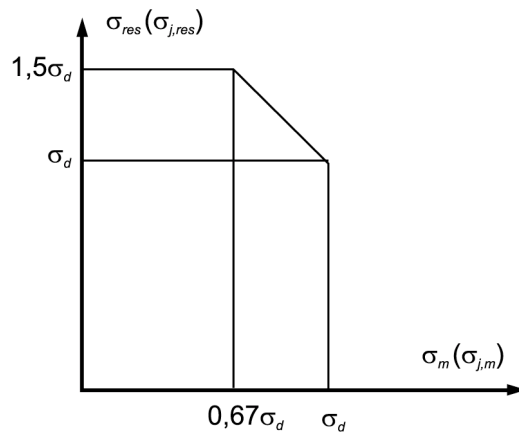


Figure 6 - Range for limit state A1

Application rule:

The requirements for σ_{res} and $\sigma_{j,res}$ will always be fulfilled if $\sigma_{j,res} \leq R_e(T)/\gamma_m$. However, the requirements above will allow higher ovalising stresses.

For straight pipes with $T \leq 140^\circ\text{C}$, the hoop stress from internal pressure shall be calculated from

$$\sigma_{pd} = \frac{p_d \cdot d_o}{2 \cdot t_{min} \cdot \gamma_z}$$

where

σ_{pd} is the design hoop stress

γ_z is the weld factor for longitudinal welds (normally = 1 for welds made by the steel pipe manufacturer)

t_{min} is the nominal wall thickness minus thickness allowance and possible allowance for corrosion.

Application rule:

Limit state A1 concerns safety against failure from force-controlled action. Limit state A1 can be decisive for high pressures and in case of large moments from force-controlled action (e.g. selfweight on free spanning pipes) or ovalising stresses (e.g. traffic actions and selfweight of soil).

Partial safety factors for steel where the material standards for unalloyed and low alloyed steels show values for yield strength at elevated temperatures:

Yielding of base material, yielding of weld seam, $\gamma_m = 1,25$.

Partial safety factors for actions, see Table 3.

Application rule:

With the partial factor of 1,2 on pressure this gives a safety factor $1,2 \cdot 1,25 = 1,5$ on force-controlled actions.

Limit state A2: Ultimate limit state reached by few actions (stepwise plastic deformation)

Application rule:

Limit state A2 concerns incremental collapse and stress ratcheting.

Fracture resulting from repeated yielding or gradually increasing plastic deformation shall be prevented.