



BSI Standards Publication

District heating pipes — Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks

Part 1: Design

National foreword

This British Standard is the UK implementation of EN 13941-1:2019+A1:2021. It supersedes BS EN 13941-1:2019, which is withdrawn.

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English Version

District heating pipes - Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks - Part 1: Design

Tuyaux de chauffage urbain - Conception et installation des systèmes bloqués de monotubes ou bitubes isolés thermiquement pour les réseaux d'eau chaude enterrés directement - Partie 1 : Conception

Fernwärmerohre - Auslegung und Installation von gedämmten Einzel- und Doppelrohr-Verbundsystemen für direkt erdverlegte Heißwasser-Fernwärmenetze - Teil 1: Auslegung

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European foreword

This document (EN 13941-1:2019+A1:2021) has been prepared by Technical Committee CEN/TC 107 “Prefabricated district heating and district cooling pipe system”, 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of an identical text or by endorsement, at the latest by June 2022, and conflicting national standards shall be withdrawn at the latest by June 2022.

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

This document supersedes A1 EN 13941:2019 A1.

This document includes Amendment 1 approved by CEN on 15 October 2021.

The start and finish of text introduced or altered by amendment is indicated in the text by tags A1 A1.

EN 13941, *District heating pipes — Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks* consists of the following parts:

- *Part 1: Design;*
- *Part 2: Installation.*

In comparison to EN 13941:2009+A1:2010, the following changes have been made:

- a) EN 13941 is considered to be the “system standard”, including all requirements for materials and components and where necessary referring to the related product standards;
- b) chapters related to installation are moved to EN 13941-2;
- c) terms and definitions are moved to EN 17248;
- d) the document structure is improved, giving a better balance between standard text and annexes;
- e) twin pipes are included in a new Annex E;
- f) Annex H: “Scope of EN 13941 in relation to Pressure Equipment Directive (PED)” was added;
- g) requirements for horizontal and vertical stability and for parallel excavations are made more explicit;
- h) minimum free distances between parallel pipes are introduced as well as a warning to be aware of works of third parties that might endanger the integrity or the required design conditions of the district heating pipes;
- i) requirements for horizontal directional drillings are included (also in EN 13941-2);
- j) required properties and testing methods for expansion cushions are included;
- k) a design fatigue curve for fillet welds (e. g. in single use compensators) is included;

- l) the use of stress concentration factors for butt welds in district heating pipes is, in line with present international pipeline codes, not considered necessary anymore;
- m) a great number of smaller adjustments and editorial improvements.

■^{A1} In comparison to EN 13941-1:2019, the following changes have been made:

- a) minor corrections throughout the document. ■^{A1}

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document has been prepared by CEN/TC 107/WG 13 “Prefabricated district heating and district cooling pipe system”.

According to the scope of CEN/TC 107:

- the task of CEN/TC 107/WG 13 is to specify rules for design, calculation and installation for factory made thermal insulated bonded single and twin pipe systems for directly buried hot water networks;
- CEN/TC 107/WG 13 also contributes to rules for functional tests for thermal-insulated bonded pipe systems for underground hot water networks;

When use is made of the standard, the different sections of which it is made up is to be interpreted as being interdependent and, because of this, cannot be dissociated.

The revision of EN 13941:2009+A1:2010 involves the subdivision of the document in two separate documents:

- EN 13941-1, *District heating pipes — Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks — Part 1: Design*;
- EN 13941-2, *District heating pipes — Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks — Part 2: Installation*.

This volume (Part 1) consists of a main part and eight annexes.

Annexes A, and F are normative. Annexes B, C, D, E, G, H, I, J and K are informative.

This document contains a number of requirements aimed at ensuring the sound execution of distribution networks and transportation pipelines for district heating.

The requirements and regulations contained in this document 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.

NOTE Some paragraphs of this standard are possibly covered by national regulations in some countries which naturally apply instead of this standard.

1 Scope

This document specifies requirements for design, calculation and installation of factory made thermal insulated bonded single and twin pipe systems for buried hot water networks for continuous operation with treated water at various temperatures up to 120 °C and occasionally peak temperatures up to 140 °C for maximum 300 h/a, and maximum internal pressure 2,5 MPa.

Flexible pipe systems according to the EN 15632 series are not under the scope of this standard.

The standard EN 13941, *Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks* consists of two parts:

- a) EN 13941-1: *Design*;
- b) EN 13941-2: *Installation*.

The requirements in this part, EN 13941-1, form a unity with those of EN 13941-2.

The principles of the standard may be applied to thermal insulated pipe systems with pressures higher than 2,5 MPa, provided that special attention is paid to the effects of pressure.

Adjacent pipes, not buried, but belonging to the network (e.g. pipes in ducts, valve chambers, road crossings above ground etc.) may be designed and installed according to this standard.

This document presupposes the use of treated water, which by softening, demineralization, de-aeration, adding of chemicals, or otherwise has been treated to effectively prevent internal corrosion and deposits in the pipes.

NOTE For further information on water qualities to be used in district heating pipe systems see also bibliographic entry [2].

This standard is not applicable for such units as:

- a) pumps;
- b) heat exchangers;
- c) boilers, tanks;
- d) systems behind domestic substations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 253, *District heating pipes — Bonded single pipe systems for directly buried hot water networks — Factory made pipe assembly of steel service pipe, polyurethane thermal insulation and outer casing of polyethylene*

EN 448, *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*

EN 488, *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*

EN 489-1, *District heating pipes — Bonded single and twin pipe systems for directly buried hot water networks — Casing joint assemblies and thermal insulation for hot water networks in accordance with EN 13941-1*

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

EN 10216-2, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties*

EN 10217-2, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 2: Electric welded non-alloy and alloy steel tubes with specified elevated temperature properties*

EN 10217-5, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 5: Submerged arc welded non-alloy and alloy steel tubes with specified elevated temperature properties*

EN 10253-2, *Butt-welding pipe fittings — Part 2: Non alloy and ferritic alloy steels with specific inspection requirements*

EN 13480-3, *Metallic industrial piping — Part 3: Design and calculation*

EN 13941-2, *District heating pipes — Design and installation of thermal insulated bonded single and twin pipe systems for directly buried hot water networks — Part 2: Installation*

EN 14419, *District heating pipes — Preinsulated bonded pipe systems for directly buried hot water networks — Surveillance systems*

EN 15698 (all parts), *District heating pipes — Bonded twin pipe systems for directly buried hot water networks*

EN 17248,  deleted text  District heating and district cooling pipe systems — Terms and definitions

EN ISO 1856, *Flexible cellular polymeric materials — Determination of compression set (ISO 1856)*

3 Terms and definitions, units and symbols

3.1 Terms and definitions

For the purpose of this document, the terms and definitions given in prEN 17248 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1 Symbols

Table 1 — Symbols

Symbol	Name	Unit
A	Area	mm^2
A, A_S	Cross sectional area of the steel service pipe	mm^2
A_p	Internal pipe area, where the pressure is acting on.	mm^2
A_m	Cross sectional metal area effective for compensation of over-pressure	mm^2
A_{MS}	Cross sectional area of the run pipe, effective for reinforcement.	mm^2
A_{MP}	Cross sectional areas of the compensating plate effective for reinforcement.	mm^2
C	Distance between the centre lines of two pipes.	mm
c	Cohesion of the soil,	kN/m^2
c'	Effective cohesion of the soil	kN/m^2
c_1	Correction to wall thickness for fabrication tolerance;	mm
c_2	Correction to wall thickness for corrosion allowance	mm
D	'Deflection Lag' (creep) factor, related to lateral consolidation.)for calculation of ovalisation of top load'	—
D_C/D_i	Outer diameter/inner diameter of casing	mm A1 deleted text A1
D_{CU}	Equivalent outside diameter of the expansion cushions	mm
DN	Nominal diameter	—
D_{PUR}	Diameter of the insulation material;	mm
d	Diameter of (steel) service pipe	mm
d_i	Inside diameter of the steel service pipe.	mm
d_o	Outside diameter of the steel service pipe	mm
$d_{bo}/d_{bi}/d_{bm}$	Outside/inside/mean diameter of branch in T-piece	mm
$d_{ro}/d_{ri}/d_{rm}$	Outside/inside/mean diameter of run pipe in T-piece	mm
d_m	Mean diameter of service pipe	mm
$d_{min.}/d_{omax}$	Minimum/maximum mean diameter of service pipe	mm
$d_{o_{min.}}/d_{o_{max}}$	Outside diameter of smallest/largest pipe	mm
d_{oc}	Outer diameter at any point along the cone (of a reducer);	mm
d_w	Average diameter of the (expansion) bellow	mm
E	Modulus of elasticity	MPa
E_{cu}	Elasticity modulus of expansion cushions, see 6.5	MPa

Symbol	Name	Unit
E_1, E_2, E_n	Elasticity modulus of the road foundation layer to be converted	MPa
E_g	Modulus of elasticity of the subsoil	MPa
F	Friction force per unit length of pipe	kN/m
f_u	Ultimate axial soil resistance	kN/m ²
f	Axial soil restraint	kN/m ²
f	Deflection	mm
f_{rr}	Rerounding factor caused by internal pressure	—
G	Effective self-weight of the factory made pipe assembly (including pipe fill) per metre of pipe length	kN/m
G_w	Effective weight of soil stratum over the pipe per metre of pipe length	kN/m
H	Soil cover above pipe	m
H_w	Depth of ground water table below grade	m
HH_n	Thickness of the road foundation layer to be converted	m
h_a	heat loss factors antisymmetrical; heat exchange between flow and return of twin pipes	—
h_i	Is inside height of ellipsoidal end	mm
h_s	heat loss factors symmetrical; twin pipe heat loss to the surrounding of the pipe	—
I	Moment of inertia of pipe cross section (single pipe)	mm ⁴
I_b	Moment of inertia of branch cross section (T-piece calculation)	mm ⁴
I_w	Moment of inertia of pipe wall	mm ⁴
i	Stress concentration factor	—
i_{a1}	Stress concentration factor for axial stresses from normal force	—
i_{a2}	Stress concentration factor for axial stresses from bending moments	—
i_{a3}	Stress concentration factor for shear stresses from torsion	—
i_{a4}	Stress concentration factor for shear stresses from shear forces	—
i_{ap}	Stress concentration factor for hoop stresses from pressure	—
K_o	Coefficient of horizontal soil pressure at rest	—
K	Moment coefficient, as a function of the vertical loading angle (α), support angle (β) and position on the pipe circumference	—
K_c	Soil pressure coefficient acc. to Brinch Hansen, depending on φ and Z/D_c [A1] for cohesive soil and mixed soils [A1]	—
K_q	Soil pressure coefficient acc. to Brinch Hansen, depending on φ and Z/D_c [A1] for granular soil and mixed soils [A1]	—
k	Line bedding constant	N/mm ²

Symbol	Name	Unit
k_b	Flexibility factor for bending	—
k_h	Coefficient of horizontal soil reaction, plate bedding constant	N/mm ³
k, k_1, k_2	Valuation constants for the calculation of stress concentration factors	—
K_y	Deflection factor	—
L	Friction length	m
$\overline{A_1} L_{all}$	allowable length between the single use compensators	m $\overline{A_1}$
L_p	distance between service pipes	m
l	Length	m
l	Reinforcing length (calculation of T-pieces), as shown by the index	mm
l_b, l_r	Extent of increased wall thickness for branch and run pipe	mm
M, M_z	Bending moment	kNm
M_{tot}	Tangential bending moment in the pipe wall, due to Q_{tot}	kNm
M_x	Torsional moment	kNm
m	Constant in the SN curve	—
N	number of full action cycles	—
N_{cr}	critical axial compressive force in the single pipe;	N
N_i	number of cycles of stress range ΔS_i $\Delta \sigma_i$ to cause failure	—
N_x	Axial force (positive for tension), (pressure, temperature and soil reaction)	N
N_p	Axial force from pressure at expansion;	N
N_R	Axial force from lateral soil reaction at expansion (N_R is normally negative).	N
n_i	Number of cycles with temperature range ΔT_i ;	—
p	Internal pressure	MPa
p_d	Design pressure	MPa
p	Horizontal soil pressure	kN/m ²
p_u	Ultimate horizontal soil resistance	kN/m ²
P	Horizontal soil reaction per unit length of pipe, calculated based on D_c	kN/m ²
P_v	Traffic load at pipe top level, caused by the axle load system	kN/m ²
q	Vertical soil pressure	kN/m ²
$\overline{A_1} q_f$	Flow line	W/m
q_r	Return line	W/m $\overline{A_1}$
q_u	Ultimate vertical soil resistance	kN/m ²

Symbol	Name	Unit
Q	Vertical soil reaction per unit length of pipe	kN/m
Q_v	Traffic load, in kN/m, at pipe top level	kN/m
Q_{tot}	Total vertical load at pipe top level	kN/m
Q_{up}	Upward force from buoyancy	kN/m
Q_s	Effective vertical soil load at pipe top level	kN/m
R	Inside radius of curvature of central part of ellipsoidal end	mm
R	Bend radius	mm
R_e	Specified minimum upper yield strength	MPa
R_{eT}	Specific minimum yield strength at design temperature	MPa
R_m	Tensile strength	MPa
R_a	Specific antisymmetrical insulation resistance of the soil	m ² K/W
R_s	Specific symmetrical insulation resistance of the soil	m ² K/W
R_j	Specific insulation resistance of the insulating material	m ² K/W
R_h	Specific insulation resistance of the heat exchange between flow and return	m ² K/W
r	Pipe radius	mm
r_g	Average pipe radius	mm
r, r_1, r_x	Radii of curvature	mm
r_b, r_m	Stress reduction factors for branch and run pipe (T-piece calculation)	—
S	Stress range	MPa
S_F	Shear force, which can result from the soil pressure at rest	kN/m
S_{Rd}	Allowable welding stress (for fixing bars in twin pipe systems)	MPa
T	Temperature	°C
ΔT	Temperature difference	K
T_1, T_2, T_3	Pulling forces during installation of horizontal directional drillings (HDD)	
t	Pipe wall thickness	mm
t_{cf}/t_{cr}	casing wall thickness of flow and return pipe	mm
t_{min}	Minimum pipe wall thickness = $t_n - c_1 - c_2$	mm
t_b	Nominal wall thickness of branch pipe (T-piece calculation).	mm
t_{cu}	Equivalent thickness of expansion cushions	mm
t_n	Nominal wall thickness of service pipe	mm
$\boxed{A_1} T_g \boxed{A_1}$	Minimum thickness of end to limit membranes stress in centre of reducer, see Annex A	mm

Symbol	Name	Unit
T_f	Temperature in the flow pipe (heat loss calculation)	°C
T_r	Temperature in the return pipe (heat loss calculation)	°C
t_r	Nominal wall thickness of run pipe (T-piece calculation)	mm
t_s	Undisturbed soil temperature at depth Z	°C
t_o	steel service pipe wall thickness	mm
u	Axial displacement of pipe	mm
U_1 and U_2	Coefficients of heat loss	—
V_y, V_z	Shear force	N
v	Horizontal (lateral) displacement pipe	mm
v_u	Horizontal displacement of pipe at reaching ultimate horizontal soil resistance	
w	Vertical displacement of pipe	mm
W	Section modulus	mm ³
Z	Depth of burial (measured to centreline of pipe assembly)	m
Z_c	Corrected value of depth Z	$\boxed{A_1}$ mm $\boxed{A_1}$
z	Joint efficiency factor	—
α	Coefficient of thermal expansion of steel service pipe	1/K
α	semi angle of reducer at apex	°
α, θ	Angle	°
β	dimensionless thermal resistance parameter	—
γ_a	Partial load factor	—
γ_{fat}	Safety factor for fatigue fracture	—
γ_m	Partial factor for strength of material	—
γ_s	Effective weight of soil above ground water table	kN/m ³
γ_{sw}	Effective weight of soil below ground water table = $\gamma'_{sw} - \gamma_w$;	kN/m ³
γ'_{sw}	Effective weight of saturated soil below ground water table	kN/m ³
γ_w	Effective weight of water	kN/m ³
δ	Angle of interface friction between soil and (casing) pipe	°
δ	Displacement from thermal expansion	mm
δ_y	Vertical deflection of the pipe cross section	mm
ε	Strain	—
λ	Coefficient of thermal conductivity	W/(mK)
λ_i	Coefficient of thermal conductivity for the PUR;	W/(mK)

Symbol	Name	Unit
λ_s	Coefficient of thermal conductivity of soil	W/(mK)
λ_n	Coefficient of neutral horizontal earth pressure ($\lambda_n = 1 - \sin \varphi$).	—
μ	Coefficient of interface friction between pipe (casing) and soil	—
ρ	Density	kg/m ³
σ	Normal stress (positive at tension)	MPa
$\sigma_a, \sigma_x, \sigma_{ax}$	Axial (normal) stress	MPa
σ_{all}	Allowable stress	MPa
$\sigma_{t,all}$	Allowable tensile stress	MPa
$\sigma_{c,all}$	Allowable compressive stress	MPa
σ_d	Design stress ($R_e(T) / \gamma_m$)	MPa
σ_{dp}	Design stress (allowable) of the compensating plate material	MPa
σ_{pd}	Calculated hoop stress from internal (design) pressure	MPa $\langle A_1 \rangle$
	$\langle A_1 \rangle$ deleted text $\langle A_1 \rangle$	
σ_{PUR}	Compressive stress in the PUR, calculated as a formal stress	MPa
σ_t	Tangential stress	MPa
σ_m	Membrane stress	MPa
$\sigma_{j,m}$	Equivalent stress for membrane stresses	MPa
σ_{res}	Resulting stress of membrane stress and bending stress	MPa
$\sigma_{j,res}$	Equivalent stress for resulting stresses of membrane stresses and bending stresses	MPa
σ_n	Effective normal stress along the periphery of the casing.	MPa
σ_v	Effective (normal) intergranular soil stress at pipe centre level.	MPa
σ_q	Ovalisation stress from soil pressure, traffic, etc.	MPa
τ	Shear stress	MPa
ν	Poisson's ratio	—
φ'	effective angle of Internal friction of soil	°

Table 2 — Indices

a	: Action	min	: Minimum
b	: Branch pipe (at T-piece connections)	n	: Nominal, number (of fatigue cycles)
c	: Casing	o	: Outer, outside
d	: Design	p	: Compensating plate, pressure
fat	: Fatigue	r	: Run pipe (at T-pieces)
i	: Inner, inside	res	: Resulting

a	: Action	min	: Minimum
j	: Reference	u	: Fracture
m	: Mean, membrane, material, metal	v	: Vertical

3.1.2 Abbreviations

LC Load Combination
 SUC Single Use Compensator
 NFP Natural Fixed Point
 PED Pressure Equipment Directive

4 General requirements

4.1 Functional requirements

Design 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 not to endanger persons or the environment;
- good energy economy;
- good overall economy (total life-cycle costs);
- good operating properties;
- safety of supply;
- good possibilities of inspection and maintenance.

The full functional ability and durability of units connected to the district heating system, such as pumps, heat exchangers, boilers, tanks, and systems behind domestic substations shall be ensured and verified, in consideration of the interaction between these units and the district heating pipeline system including possible imperfections from the conditions under which they have been installed.

It is permissible to use alternative design rules to this standard, provided that it is demonstrated 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.

For the scope of EN 13941 in relation to Pressure Equipment Directive (PED), see also Annex H.

4.2 Service life

New pipe systems for district heating shall be designed for a service life of minimum 30 years for continuous operation with hot water at various temperatures up to 120 °C and at individual time intervals with a peak temperature up to 140 °C. The sum of these individual time intervals shall, in average, not exceed 300 hours a year.

NOTE 1 The service life as defined above is determined by the aging of the thermal insulation and the casing, potentially leading to deterioration of important mechanical properties of the foam (e.g. the adhesion between service pipe and foam) and the casing.

NOTE 2 There are other time-dependant mechanisms that influence the service life such as fatigue of steel components and water qualities.

4.3 Preliminary investigations

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

These preliminary investigations should elucidate matters in the planning, design, execution and operating phases 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;
- soil cover above pipe (See Figure 5);
- materials;
- distances and heat transfer to other utility networks, buildings and trees;
- geotechnical and groundwater parameters, etc.

A preliminary investigation should include the following steps:

- operating conditions of the system, including expected variations in temperature and pressure during the service life of the system;
- requirements for safety of supply;
- investigation of possible pipeline routes;
- preliminary soils investigation (see Annex B);
- resistance to relevant impacts, such as:
 - a) loads due to installation and operation;
 - b) internal and external loads and deformations;
- consequences of possible modes of failure of the system;
- identifying of authorities' requirements, including environmental and third party aspects;
- possible methods of construction and pipe installation.

NOTE The more of these steps are being performed in a preliminary investigation, the better is the technical and economical result.

In certain cases, the regular side by side installation may change into an installation where one pipe is on top of the other.

4.4 Determination of project class

4.4.1 Risk assessment

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

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

NOTE 1 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.

NOTE 2 Possible risks are:

- a) escape of hot water due to bursting or leakage, involving a risk of scalding, flooding, tunnelling, etc.;
- b) damage to the pipeline system, involving interruption of the heat supply;
- c) damage to the pipeline system, involving a risk of further spread of the damage in the pipeline system;
- d) loss of safety of supply to important consumers (hospitals, etc.).

The consequences of failure can be related to the entire system or to a section only. The project class determines the level for design, installation and documentation of the pipeline system.

4.4.2 Project classes

The choice of project class is related to the level of safety and complexity of design construction and installation 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 classes given in Table 3.

Table 3 — Project classes

Project class	Characteristic
A	<ul style="list-style-type: none"> — Small and medium diameter pipes with low axial stresses; — pipes with low risk of personal damage or damage to the environment, and/or surrounding buildings; — pipes with low risk of economic losses.
B	<ul style="list-style-type: none"> — small and medium diameter pipes with high axial compressive stresses; — pipes with low risk of personal damage or damage to the environment and/or surrounding buildings; — pipes with low risk of economic loss.

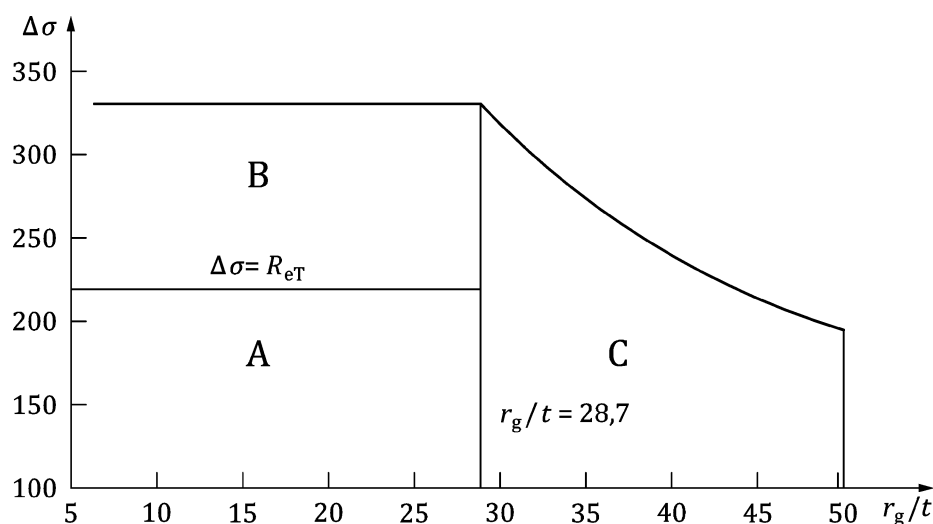
Project class	Characteristic
C	<ul style="list-style-type: none"> — Large diameters pipes and/or high pressures; — pipes with higher risk of personal damage or damage to the environment and/or surrounding buildings; — special or complex constructions.

Special or complex constructions can be crossings with railways, major roads and waterways, which 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 flooding of the hinterland.

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

NOTE 1 Pipeline sections that are accessible during operation, (e.g. in tunnels or ducts under roads, in valve chambers, above ground sections, etc) can result in increased risk of personal damage

Based on the expected effects the project classes A, B and C are determined by Figure 1.



Key

- A project class A (low)
- B project class B (medium)
- C project class C (high)
- $\Delta\sigma$ axial stress range from the temperature difference

Figure 1 — Definition of project classes for a steel with a specified minimum yield strength, $R_e(23\text{ °C}) = 235\text{ MPa}$

$\Delta\sigma$ is calculated as follows:

$$\Delta\sigma = E \cdot \alpha \cdot \Delta T \quad (\text{MPa})$$

where

ΔT is the temperature difference between operation temperature and installation temperature

In relation to the project class, the following shall be considered:

- requirements for documentation, see 4.5 and Table 4;
- determination of γ_{fat} in Palmgren-Miner's equation, see 6.7;
- requirements for welding, and scope of inspection of weld seams, see EN 13941-2;
- quality management and scope of inspection, see 4.10.

A pipeline system may always be classified in a higher project class than stated in Figure 1.

NOTE 2 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 similar pipeline systems;
- new production, design or construction methods;
- location of the pipeline and possibilities for inspection, maintenance and replacement.

4.5 Design documentation

4.5.1 General

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

The requirements for project classes are written in Table 4.

Table 4 — Determination requirements for project classes

Project class Figure 1	Documentation
A	Generalized documentation ^a
B	Generalized documentation
C	Specific project documentation required
^a Compliance of the generalized documentation with the requirements of this standard shall be documented	

Changes which have become necessary during the installation phase shall be included in the design documentation.

General design documentation in all project classes shall comprise:

- a) general operational data;
- b) data related to the pipeline;
- c) specifications for quality control.

4.5.2 Operational data

Operational data:

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

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

4.5.3 Data related to the pipe system

Data on pipeline location, materials and special provisions.

- a) data on the pipeline route;

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

- 1) map of the planned route;

The use of GIS based systems is recommended;

- 2) the soil cover of the pipeline system at all relevant locations;
- 3) the horizontal and vertical position of the pipeline with respect to other structures, including intersecting or parallel pipelines or cables, buildings and other obstacles, as required by national standards and/or regulations;
- 4) locations and relevant technical data of horizontal and vertical bends, T-pieces and reducers, casings, fixed points, single use compensators (SUC's), concrete ducts, etc.;
- 5) information on civil engineering works and special constructions that are necessary for safe and effective construction and installation;
- 6) relevant geotechnical data;
- 7) location, length and thickness of expansion cushions;
- 8) protection against delamination and sliding of expansion cushions from the pipe;
- 9) type and mechanical properties of expansion cushions;
- 10) location of crossings with civil infrastructure, begin and end points, (soil cover) of protection pipes, horizontal drillings, etc.;
- 11) All other information, required for proper executions of the works.

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;
- detail maps and drawings standard structures, indicating the route map 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 pipe and pipe component dimensions:

- 1) outside diameters, of both steel service pipe and casing;
- 2) nominal wall thickness, of both steel service pipe and casing;
- 3) relevant data on fittings, including bend radii or other information relating to the pipeline element (reducers, T-pieces, SUC's, etc.);
- 4) corrosion allowances if applied;
- 5) insulation classes;
- 6) data on abutting structures and supports which affect the distribution of forces acting on the medium-carrying pipeline.

c) Material data:

- 1) material specifications and certificates (steel service pipe, PUR and casing).
- 2) the technical information which is required by the product standards of the pipe elements (e.g. EN 253, EN 448, EN 488, EN 489-1, EN 14419, the EN 15698 series)

d) Installation data;

Information is required as a minimum on the following aspects:

- 1) any pre-stressing applied to the pipeline, and the point at which and methods by which this pre-stressing is applied;
- 2) Methods for measurement and control of the desired elongation, in case of pre-stressing;
- 3) Applied small angular deviations at the weld and permitted elastic bending radius applied to the pipeline, both permanent and temporary;
- 4) test pressure;
- 5) installation temperature.

For further required information, reference is made to EN 13941-2.

e) Data related to underground structures;

Drawings and calculations of underground structures that might be affected by forces from district heating pipelines:

- f) As built drawings. Reference is made to EN 13941-2.
- g) Maintenance instructions for the system, specifically for valves and surveillance systems.

4.6 Route selection and positioning of the pipes

4.6.1 Minimum distances between parallel pipes

In the design phase a suitable minimum distance between two parallel district heating pipes shall be selected, dependant on trench type and outer diameter of the casing and taking into account all relevant influences, such as:

- required space for compaction to obtain the required interface friction between casing and surrounding soil;
- required space to obtain extra compaction under roads, to limit construction settlements;
- required space with regard to suitable working circumstances for welding and joint installation (e.g. man excess holes);
- required minimum distance to ducts and/or cables of third parties;
- required space for personal safety;
- required space for casings under on-site conditions;
- required space for expansion cushions: The minimum distance between the outer sides of the expansion cushions shall be at least 100 mm.

As a minimum for accessible and non-accessible trenches, the distances according to Table 5 shall be maintained.

The requirements for minimum distances within accessible trenches are given in EN 13941-2.

The required space for welding and joint installation can be provided over man excess holes.

Table 5 — Minimum distances between parallel pipes regarding technical aspects (e.g. compaction)

Outside diameter of casing D_c mm	Minimum distance in between two parallel casings mm	Minimum distance between casing and trench wall of non- accessible trenches ^a mm
$D_c \leq 225$	150	150
$225 < D_c \leq 560$	250	250
$D_c > 560$	300	300
^a National regulations concerning safety distances within accessible trenches should be followed.		

4.6.2 Parallel excavations and works of third parties

Pipe systems for district heating in operation can be endangered by (future) excavation and construction works. These excavation works can belong to the project under consideration or are caused by third parties, such as road works or works from other pipeline owners, laying pipes in a parallel trench. These activities can result in loss of soil cover or insufficient lateral restraint. Prior to parallel excavations, a corresponding calculation check shall be made, as the removal of the restraining soil will result in a risk of buckling, see 6.5.9.

If the soil cover is increased/reduced or its load changed substantially, a check of the statics is imperative.

Additional precautions according to the static specifications shall be taken in case a pipeline is cut or equipped with branch lines.

A risk analysis shall be carried out in order to minimize the possible detrimental influence of future construction works and, if necessary, additional protective measures, such as warning tapes to indicate the position of the district heating system and/or protective plates may be part of the design

4.6.3 Minimum distance between district heating pipes and underground structures

Due attention shall be given to the required minimum distance between district heating pipes and (underground) structures, taking into account possible pressures exerted by the district heating pipes on the structure (e.g. building wall) and vice-versa. Calculations shall be made when the expected movement of the pipelines may initiate lateral forces on the structure.

If no specific local requirements are given, the minimum distance between the pipe and the casing/outside of existing other parallel underground conduits shall not be smaller than 0,4 m and for crossing conduits shall not be smaller than 0,2 m.

4.7 Venting and draining

For purpose of putting into operation, operation, enlargement and repair of the district heating network, adequate facilities for draining and venting, either temporary or permanent can be required. In the design phase, a concept draining and venting plan can be made.

NOTE 1 According to [15] the risk of forming air bubbles in the pipe system is a function of flow velocity and slope of the pipe section under consideration. In this study it was concluded that the risk is acceptable low, at flow velocities of more than 0,45 m/s and at pipe slopes up to 3 degrees.

It is recommended that number, locations and dimensions of draining devices are chosen such that pipe sections which are shut off can be emptied within a suitable time span, to be determined by the operator of the pipe system.

NOTE 2 As an example such time span could be chosen to allow to clear damages and restore heat supply within one workshift.

4.8 Valves

Valves in directly buried district heating pipe systems shall withstand the bending moments (and axial forces) occurring under operation conditions defined by the scope of this standard:

- from thermal expansion;
- from soil settlements.

In order to prevent bending moments from thermal expansion, installation of valves in or near expansion cushions sections shall be avoided to the maximum extent possible. However, local circumstances (e.g. installation in urban areas with intense underground infrastructure and limited space) may be such that installation in these sections cannot be avoided. In such cases, the occurring bending moments shall be checked with the values in EN 488.

In expansion sections, bending moments may also occur in the stem or stem extension of the valve, if no special provisions are made. This is not acceptable. Due provisions to allow for the calculated displacement, such as casing, expansion cushions etc. shall be applied as to prevent minimize those bending moments, since the stem extensions of the valves are designed nor tested to withstand such bending moments.

4.9 Procurement of materials

4.9.1 Manufacturer of pipeline components

For the quality control program and documentation for suitable pipeline components, see Table I.2.

NOTE For the quality control of pipe elements see for example EHP 001 [1] and EHP 003 [39].

4.10 Quality control

4.10.1 General

A plan for quality control shall be provided for each project.

Quality control may be divided into five phases:

- design;
- procurement;
- installation and approval, see EN 13941-2;
- setting into operation, see EN 13941-2;
- operation phase see EN 13941-2.

Quality control and inspections shall be ensured for each phase.

4.10.2 Design phase

It is recommended to check the design and compare the project file with the specified objectives and the intended operation of the network.

For the quality control program and service life documentation in the design phase, see Table I.1.

4.10.3 Installation phase

4.10.3.1 General

During the installation phase, the following shall be ensured:

- checking of the pipe elements;
- check each phase of the execution, paying special attention to the design details;
- require the inspections, tests and certificates specified in the quality control plan for applied materials prior to setting into operation;
- update of the documentation by the purchaser and the supplier in accordance with 4.5:
 - 1) aspecification of materials;
 - 2) requirements for suppliers (planning phase, civil engineering works, pipe installation, steel welding, assembling of joints, PE-welding, quality control etc.);

- 3) quality control plan, with specification of applicable test procedures, the evaluation of test results, the test frequency;
- 4) design report;
- 5) report on setting into operation;
- 6) maintenance records;
- 7) inspection certificates for the materials, works certificates, welding, tests, etc., as specified in the quality control plan, report on transfer to the site.

For explanations of the documents to be compiled for documentation, see EN 13941-2.

4.10.3.2 Companies performing assembly of casing joints and PE welding on casings

For requirements for companies performing assembly of casing joints and PE welding on casings see EN 13941-2.

5 Requirements for components and materials

5.1 Basic requirements

Components and materials, used under the scope of this standard, shall comply with EN 253, EN 448, EN 488, EN 489-1, EN 14419 and the EN 15698 series.

In case of large pipe diameters, high soil- and traffic loads may require a larger wall thickness than specified in EN 253, EN 448 or EN 488 for all pipe components. Also design pressures over 2,5 MPa may require a larger wall thickness.

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 pipe system, the properties of the components shall be calculated using values, which are valid throughout the entire service life.

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

5.2 Steel service pipe components

5.2.1 General

Steel service pipe components under the scope of this standard are:

- a) straight pipe;
- b) bends;
- c) valves;
- d) T-pieces and branch connections;
- e) reducers and extensions;
- f) dished ends;
- g) single use compensators (SUC's);

h) other steel components.

5.2.2 Specification

The technical delivery conditions of the steel service pipe shall be as a minimum in accordance with Table 6.

Table 6 — Technical delivery conditions for service pipes

Type of pipe	Diameter	EN Standard	Material ^a
Seamless	All	EN 10216-2	P 235GH
ERW	All	EN 10217-2	P 235GH
SAW	All	EN 10217-5	P 235GH
^a Equivalent or higher steel grades according to approved EN standards may be used by agreement.			

For higher steel grades than the ones given in Table 6, the yield strength is defined in their related standards. If such higher steel grades are used for pipes, it shall be verified that all components used in the involved part of the system are compatible to the higher yield strength of the pipes.

All steel service pipes and components used for manufacturing of pipe assemblies under the scope of this standard shall as a minimum be delivered to the manufacturer of pipe elements with an inspection certificate 3.1 according to EN 10204. The manufacturer shall keep documentation of the inspection certificates.

In case a material related inspection certificate 3.1 according to EN 10204 is required by the client who orders the pipe elements, this information shall be given whilst placing the order with the manufacturer of the pipe elements.

Any later request for provision of such documentation can be too late and possibly cannot be met by the manufacturer, since the manufacturer has to organize the assignment of 3.1 certificates to pipes and part of pipes before starting the production.

A length of pipe shall not include a circular weld.

5.2.3 Characteristic values for steel

5.2.3.1 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 may 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.

Up to design temperatures of 50 °C, the value of R_e at 20 °C shall be used in the calculation.

In case steel service pipe or steel pipe components are delivered without the required certificate according to 5.2.2 the specified minimum yield strength shall be divided by an extra safety coefficient $\gamma_{m,yield} = 1,2$. This factor shall be multiplied by the partial factor for yielding of base material, according to 7.2 for the relevant limit state.

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

5.2.3.2 Steels without specified elevated temperature properties

In other cases, where the material standards for unalloyed and low alloy steels show no specified value for the yield strength at elevated temperatures, the following equation shall be used for a temperature range between 20 °C and 150 °C as in EN 13480-3:

$$R_{eT} = R_m \cdot \frac{720 - T}{1400} \left(\text{N} / \text{mm}^2 \right) \quad (1)$$

with

T in °C.

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

The following equations shall be used for non-alloy or low alloy steel with temperatures up to 140 °C:

$$E = \left(21,4 - \frac{T}{175} \right) \cdot 10^4 \left(\text{N} / \text{mm}^2 \right) \quad (2)$$

$$\alpha = \left(11,4 + \frac{T}{129} \right) \cdot 10^{-6} \left(1 / \text{K} \right) \quad (3)$$

5.2.4 Specific requirements for bends and T-pieces

5.2.4.1 General

Bends and T-pieces 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 T-piece in a pipe system, the nominal wall thickness of the bend or T-piece at the welding ends shall not be less than the nominal wall thickness of the adjacent straight pipes.

5.2.4.2 Bends

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

5.2.4.3 T-pieces

5.2.4.3.1 Directly welded T-piece

Only set-on branches shall be used. The use of branches welded into the run pipe is not permitted. See Figure 2.

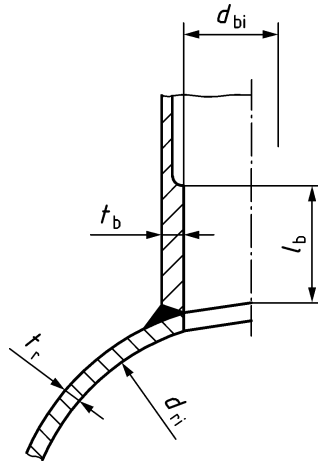


Figure 2 — Set-on branch on directly welded T-piece

NOTE T-pieces can be reinforced by increasing the wall thickness of the run pipe and/or the branch pipe and/or by compensating plates of the run pipe to withstand the internal pressure, bending moments and axial compressive forces according to the requirements of this standard.

5.2.4.3.2 Compensating plates

Reinforcement of T-pieces by compensating plates of the run pipe is limited to a diameter ratio of $d_{b0}/d_{r0} \leq 0,8$. See also A.3.2.6.

5.2.4.3.3 T-pieces with drawn collar

A transitional piece with increased wall thickness shall be welded onto the collar of the T-piece with drawn collar, and the straight pipe with normal wall thickness in order to reduce the local stress concentration for the T-piece (see prEN 17248).

For T-pieces with drawn collar for project class C the nominal design stress should be generally reduced to 90 % of the values according to 5.2.3.1.

5.2.5 Specific requirements for small angular deviations

Small angular deviations of joining pipe sections done by mitering shall not exceed the figures given in Table 7. For small angular deviations see also Figure C.1.

Table 7 — Small angular deviations

Max. axial stress ^a MPa	Max. angular deviation (2θ) ^b °
150	4°
228	2°
252	1°
280	0,5°
> 280	0°
^a Maximum axial stress in the relevant pipe section, resulting from the difference ΔT between the installation temperature and the maximum operating temperature, calculated as $\Delta\sigma = E \cdot \alpha \cdot \Delta T$	
^b Maximum angular deviation excluding installation tolerance, which shall be limited to $\pm 0,25^\circ$	

5.2.6 Specific requirements for reducers

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

Annex A specifies additional requirements for reducers.

As an alternative an equivalent European or international standard may be used, see EN 448.

5.3 Polyurethane foam thermal insulation

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

Average values for PUR are (elasticity modulus):

- $E_{PUR} = 6,5 \text{ MPa}$ (long term at 140 °C);
- $E_{PUR} = 10,0 \text{ MPa}$ (at 23 °C).

5.4 Casing

The casing and welding of casing shall comply with the requirements of EN 253, EN 448 and EN 489-1.

Site made casing is only exceptionally allowed if in a well-prepared and timely available design any solution with standard components is not possible or in the case of pipeline repairs (see EN 13941-2).

It is however strongly recommended to use to the maximum possible extent only prefabricated bonded components.

5.5 Materials for casing and thermal insulation of field joints

See EN 489-1.

5.6 Expansion cushions

5.6.1 General

Expansion cushions may be applied to limit stresses and strains in the pipe system, caused by transverse displacement from (thermal) expansion.

During the entire service life of the pipe system and at the design range of temperatures, materials selected for use in expansion cushions and protective cover, shall:

- possess the required strength;

- provide the required flexibility;
- be stable against chemical and biological effects and suitable for application in groundwater;
- be resistant against forces from pipe own weight, trench backfill and -compaction;
- be resistant against penetration of backfill material and accumulation of mud;
- have sufficient retraction capacity to prevent progressive compaction caused by sand backfill of the soil cavity occurring after pipe displacement;
- values for thermal conductivity shall be known.

NOTE 1 In operation the expansion cushion are compressed and decompressed repeatedly. If the displacement rate of the pipe system is higher than the retraction rate of the expansion cushion, gaps can appear between expansion cushion and soil. Backfilling material can penetrate into the gaps and reduce the available compression.

NOTE 2 The higher the trench backfill of the expansion cushion the higher the pre-compression due to the soil pressure.

The stiffness on the expansion cushions, applied in the field shall comply with the stiffness values entered into the design calculations.

The manufacture type, and brand of the cushions applied shall be known and documented.

5.6.2 Materials

The material of the expansion cushions shall be a closed cell, cross-linked polyethylene foam.

5.6.3 Stiffness properties

Elasticity modulus as a function of the percentage of compression (secant modulus) shall be specified by the manufacturer based on the testing procedure in accordance with Annex F.

Expansion cushions for use in district heating systems are divided in two types:

- a) Type 1: Hard, with stiffness properties, represented by line (1) in Figure 3, $\pm 15 \%$;
- b) Type 2: Average, with stiffness properties, represented by line (2) in Figure 3, $\pm 15 \%$;
- c) When tested in accordance with Table F.1 the values shall fulfil the values of Table 8.

Table 8 — Values for compression tests

c) Compression	d) 40 %	e) 50 %	f) 75 %
g) Type 1	h) 85 kPa $\pm 15 \%$	i) 120 kPa $\pm 15 \%$	j) 480 kPa $\pm 15 \%$
k) Type 2	l) 60 kPa $\pm 15 \%$	m) 90 kPa $\pm 15 \%$	n) 275 kPa $\pm 15 \%$

Expansion cushions with stiffness properties in between line (1) and line (2) of Figure 3 can also be applied.

The use of expansion cushions with stiffness properties, lower then line (2) -15% is not permitted.

The maximum allowable compression is at that point where the compressive stress exceeds 200 kPa.

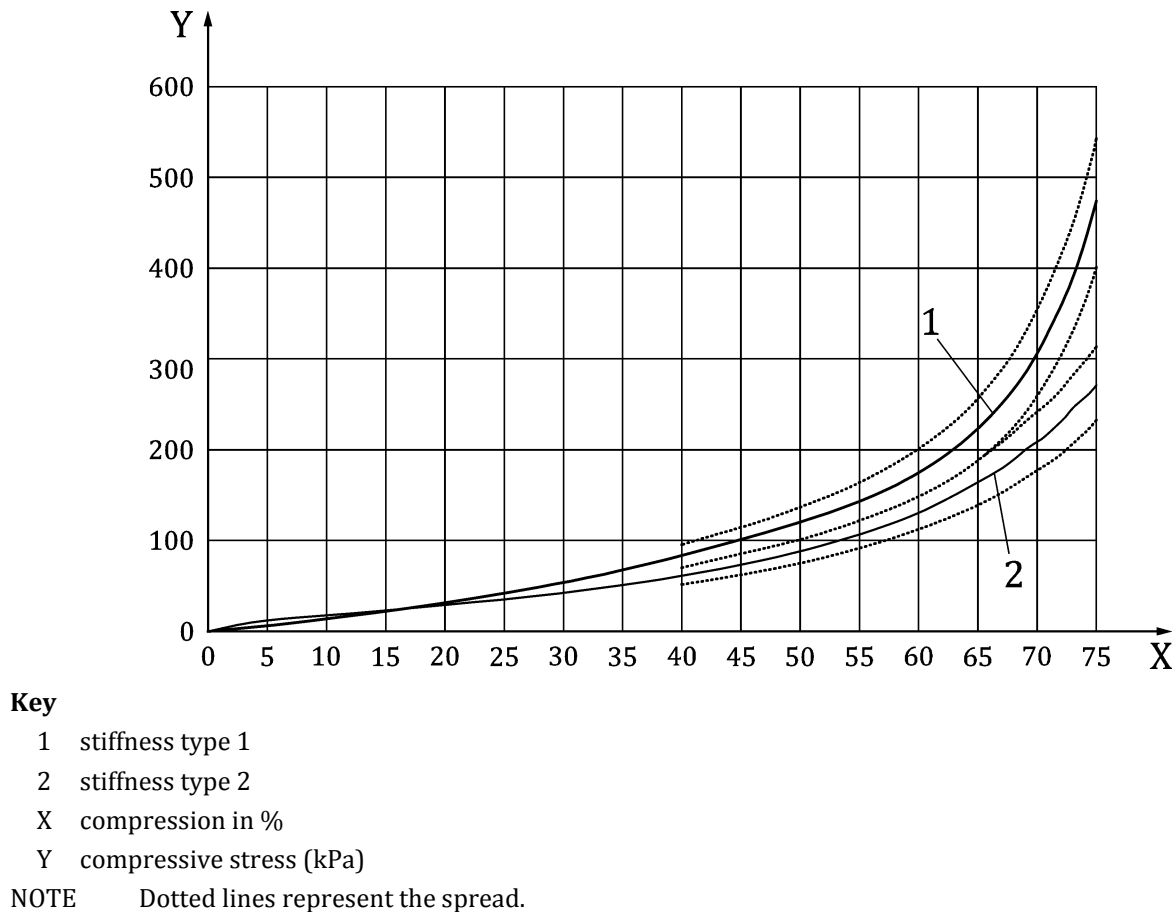


Figure 3 — Required stiffness of expansion cushions

5.6.4 Selecting required thickness of expansion cushions

The thickness of the cushion shall be selected so that:

- a) throughout the service life of the system the average surface temperature at the casing shall not exceed 50 °C; and
- b) for individual time intervals the maximum temperature at the casing may exceed 50 °C but shall not exceed 60 °C. The sum of these individual time intervals shall not exceed, in average, 300 h a year, throughout the entire service life.

NOTE To combine the effects of various temperatures at different time intervals see Annex J.

5.6.5 Marking

Expansion cushions should be marked permanently with their stiffness and manufacturer.

5.7 Valves and accessories

5.7.1 General requirements

Valves and accessories have to be fitted directly to pipe elements. Factory made steel valve assemblies valves shall comply with EN 488.

The applied materials and the manufacturing 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.

Factory made steel valve assemblies for directly buried pipeline systems shall be designed in such a way that they require a minimum of maintenance.

Any pipe element shall be fully welded.

5.7.2 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.

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:

- a) material and grade;
- b) max. operating pressure;
- c) max. axial stress for straight pipe parts or maximum axial force;
- d) max. bending moment (for valves, single use compensators).

6 Design and calculation

6.1 General procedure

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.

For a given pipeline system the design and calculation procedure, as presented in Figure 4, shall be followed.

NOTE In Figure 4, the corresponding subchapter for each step are indicated.

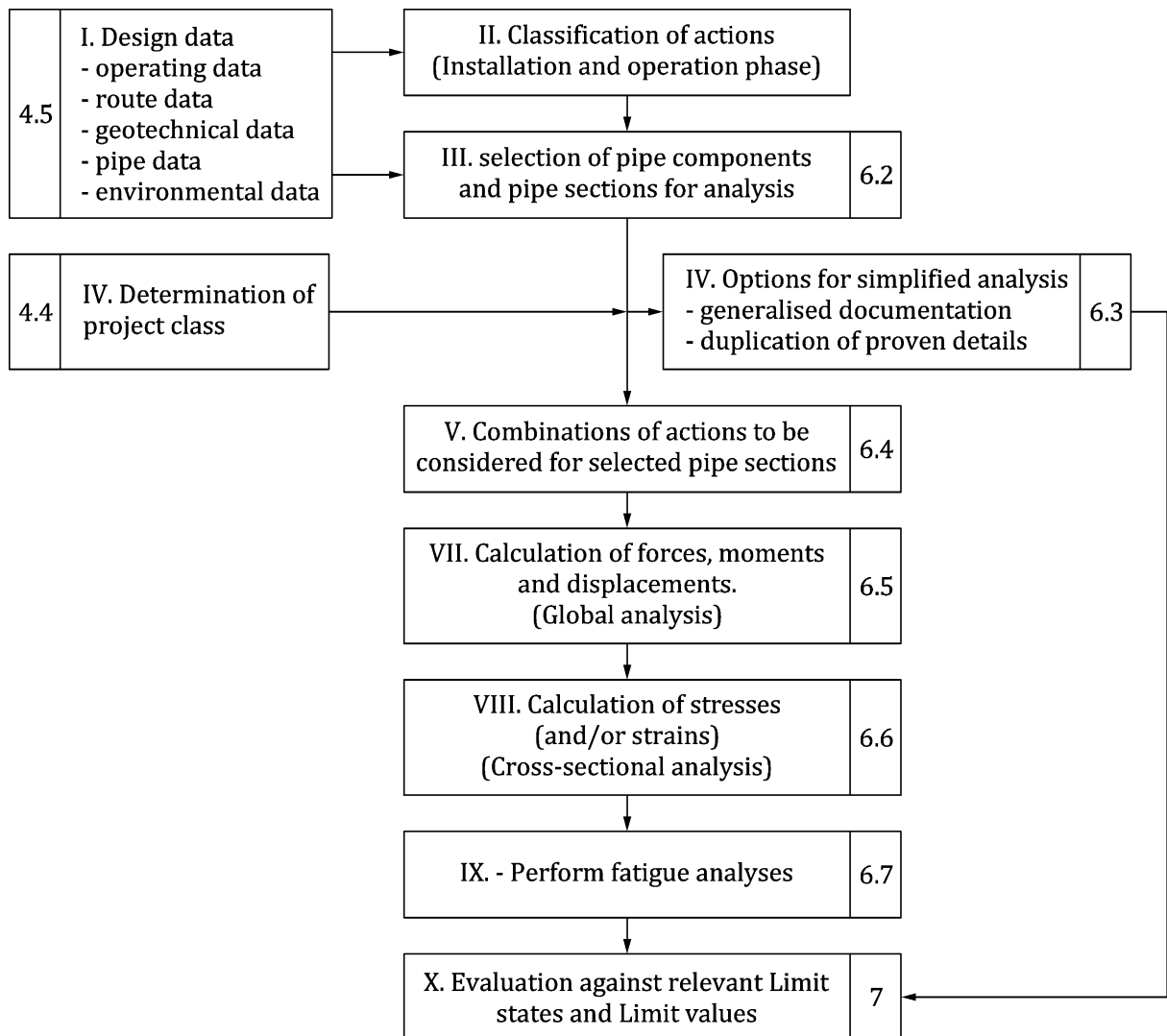


Figure 4 — Flow chart for the design of district heating systems

6.2 Pipeline components, areas, conditions and interfaces to be included in the analyses

6.2.1 Components

Components to be included in the analysis are:

- a) straight sections;
- b) welds;
- c) long bends (elastically laid or pre-manufactured);
- d) small angular deviations;
- e) bends;
- f) branch connections (T-pieces);
- g) reducers;
- h) expansion joints (single use compensators as well as permanent expansion joints);

- i) valves and other accessories;
- j) dished ends and flanged connections;
- k) interface with other systems.

6.2.2 Areas requiring specific analyses

Areas requiring specific analyses are:

- a) areas of possible future parallel excavations near the district heating pipes;
- b) areas of specific requirements due to nearby building foundations in urban areas;
- c) areas subject to soil settlement or mining subsidence;
- d) abrupt change in soil conditions;
- e) crossings:
 - 1) road, railway and waterway crossings;
 - 2) other utility pipes and cables;
 - 3) water barriers and dykes;
- f) areas with a change in pipe installation method.

The analysis shall take due account of the method of thermal expansion compensation.

6.2.3 Special conditions

The analysis shall include both, the required constructive precautions during the installation phase, e.g. less soil cover, as well as the technical requirements in the operating phase, e.g. excavation requirements or buoyancy requirements.

A change in installation method may, in weak (sub)soils, give rise to differential settlements and/or/subsidence, e.g. at the transition between a trench laid pipe section and a jacked or bored pipe section. Special attention shall also be paid to settlement differences between the pipe system and casing, when applied (e.g. at crossings)

6.2.4 Interfaces

Attention shall be paid to interfaces with plant areas, substations or house stations, in particular:

- 1) underground bends at the end of long, straight pipeline sections (thermal expansion and pressure expansion);
- 2) points of transition from an excavated trench to a rigid supported structure, whether above or below ground (for example pumping stations, fixed points, house connections, pipe tunnels, etc.); both the buried and aboveground sections shall be incorporated into one single calculation model, taking due account of any settlement differences, and/or possible restrictions for thermal expansion of the pipe system;
- 3) interfaces with installations, paying special attention to frequent changes in wall thickness in these situations;
- 4) pipe supports in transition zones from an excavated trench to a rigid supported structure;

- 5) intersection points to other connected piping and facilities (e.g. pump and heat exchanger units, heating centres and wall penetrations).

6.3 Simplified analysis procedure

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

Such generalized 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.

Fatigue life should always be checked, by estimation of the equivalent number of full temperature cycles, for the pipe system considered, see 6.7 This number of cycles shall be lower than the number of full temperature cycles presupposed in the generalized documentation (minimum values are given Table 14).

6.4 Actions

6.4.1 General

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

NOTE 1 Self-weight is being 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 pipeline system and areas shall be taken into consideration.

NOTE 2 The installation phase includes transport, handling, welding, laying, backfilling, testing, commissioning (note that actions arising during the installation phase can 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 (see also EN 13941-2).

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

6.4.2 Classification of actions and load combinations

The actions, relevant load combinations and partial safety factors that shall be taken into account in the design are presented in Table 9.

A distinction is made between force controlled and deformation controlled actions.

NOTE 1 Force controlled actions, like internal pressure and top load from soil and traffic can give rise to unbalanced deformations and rupture or collapse once the limit state is exceeded (e.g. internal pressure can lead to tearing of the pipe wall, once the yield stress is exceeded). Deformation controlled action, can lead to (severe) deformations of the steel service pipe but not necessarily to tearing of the pipe wall, because of the plastic material behaviour of the steel, however when they are of a fluctuating nature they can lead to fatigue failure.

The load case 2 (force controlled actions) mainly deals with the equilibrium of the cross section of the pipeline. This has to be ensured with and without internal pressure.

Load case 3 and load case 4 include the effects of deformation controlled actions, e.g. the effects of thermal expansion from temperature variations and the effects from soil settlements, taking due account of pipe-soil interaction.

Load combination 3 deals with the maximum pressure that may be exerted on the PUR. For this load case both force controlled and deformation controlled actions have to be taken into account.

Load combination 4 deals with the limit state of fatigue of the steel service pipe.

Load case 5 is related to the stability of the cross section of (larger pipelines at great depth and high pore water pressure, e.g. at horizontal drillings).

NOTE 2 Because of the lower probability that the ultimate values of the relevant actions (temperature and traffic) will coincide the partial factor for traffic actions is lower for LC 3 and LC 4, then for LC 2.

Table 9 — Classification of actions, partial γ_a load γ_a factor and Load Combinations (LC)

ACTIONS ^f	PARTIAL SAFETY FACTORS γ_a					
	LC 1	LC 2	LC 3	LC 4	LC 5	LC 6
	OPERATIONAL PHASE					
	INSTALLATION PHASE	Force controlled actions, with or without internal pressure	Force controlled and deformation controlled actions γ_a <i>deleted text</i> γ_a	Force controlled and deformation controlled actions (fatigue calculation)	External pressure	Deformation check
FORCE-CONTROLLED ACTIONS						
PRESSURE						
Operating pressure	—	γ_a 1,25 γ_a	γ_a 1,25 γ_a	γ_a 1,25 γ_a	—	—
Pressure surges ^a	—	1,2	1,2	1,2	—	—
External (hydrostatic) pressure	1,05	1,05	—	—	1,05	1,05
Internal vacuum ^b	—	—	—	—	1,2	1,05
Test pressure	1,0	—	—	—	—	—
PERMANENT ACTIONS						
Selfweight, pipe assembly, water fill						
Accessories (valves, etc.)	1,0	1,2	1,2	1,2	1,2	1,2
Buoyancy	1,0	1,0	1,0	1,0	1,0	1,0
Neutral/passive soil pressure ^d	1,5	1,5	1,5	1,5	1,5	1,5
Settlements ^{c,d}	—	1,2	1,2	1,2	1,2	1,2
VARIABLE ACTIONS						
Traffic	1,0	1,35	1,35	1,0	—	1,35
DEFORMATION CONTROLLED ACTIONS						
ACTIONS FROM TEMPERATURE VARIATIONS ^e						
Variations during operation	—		1,0	1,1	—	—
Start-up/shut-down cycles	—		1,2	1,2	—	—
Lateral soil reactions	—		d	d	—	—
Soil/pipe friction	d		d	d	—	—

ACTIONS ^f	PARTIAL SAFETY FACTORS γ_a					
	LC 1	LC 2	LC 3	LC 4	LC 5	LC 6
	INSTALLATION PHASE	OPERATIONAL PHASE				
		Force controlled actions, with or without internal pressure	Force controlled and deformation controlled actions ΔT <i>deleted text</i>	Force controlled and deformation controlled actions (fatigue calculation)	External pressure	Deformation check
PERMANENT ACTIONS						
Pre-stressing						
Thermal, electrical,	1,0	—	1,0	1,0	—	1,0
Mechanical	1,5	1,5	1,5	1,5	—	1,5
Soil settlements ^c	—	—	1,2	1,2	—	1,2
Differential settlements	—	—	1,2	1,2	—	1,2
Deformations during laying	1,0	—	1,0	1,0	—	1,0
<p>^a 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.</p> <p>^b The design pressure for vacuum ≥ -1 MPa.</p> <p>^c If it is not possible that the pipe follows soil settlement, e.g. in case of fixed pipe support (by piles) for pipes crossing roads, the weight of soil shall be treated as a force-controlled action.</p> <p>^d For uncertainty factors to take account for special variation of soil properties and soil parameters, see Annex B.</p> <p>^e When performing fatigue analyses, ΔT shall be taken as the absolute difference between the highest and the lowest value during the complete temperature cycle. When calculating pipe displacements and soil reactions ΔT shall be taken as the absolute difference between the installation temperature and the relevant operational temperature.</p> <p>^f If a load has a favourable influence on the limit state considered, it shall not be taken into account if it is a variable load. If it is a permanent load, it shall be taken into account with a load factor 0,9.</p>						

6.4.3 Temperature variations

Special conditions like energy production from incineration plants, cold plugs, night-set-back at consumers, etc., can give many and/or large temperature variations.

Normally the largest number of full equivalent temperature cycles will occur in the supply pipe for main pipelines and in the return pipe for service connections.

The number of full temperature cycles shall be obtained from a detailed analyses of the expected operation of the power plant or waste incineration plant and the customers installations. In case this information is not available the minimum values as given in 6.7.2 Table 14 shall be used in the fatigue analyses.

The number of full action cycles shall not be chosen lower than the smallest values for the relevant period of operation, according to Table 14.

NOTE For major pipeline the maximum value can be reached e.g. close to incineration plants. For service connections maximum values are typically reached in case of e.g. night-set-back at the consumer.

6.4.4 Top load from soil

For calculation of the neutral soil load on top of the pipe, see 6.5.3.1.

6.4.5 Traffic loads

6.4.5.1 General

Load models used should comply with EN 1991-2. For national highways and regional roads, "Load Model 3" including exceptional transports) can be assumed. For lower category roads, "Fatigue Load Model 2, Lorry 4" can be taken. The latter load system covers the "set of frequent lorries", as may occur on European roads, with the exception of special transports.

In the open field also "Fatigue Load Model 2, Lorry 4" can be taken, with all axle loads divided by a factor 2,0.

Alternative methods for calculation of traffic loads may be derived from CEN/TR 1295-2, [5].

Due attention shall be paid to traffic loads, caused by (temporary) heavy construction traffic during the installation phase of a pipeline, or due to activities of third parties above existing pipelines.

The distribution of axle loads in the subsoil can be calculated according to the method of Boussinesq or Braunschtorfinger [9]. See also CEN/TR 1295-2, [5].

The traffic load per length unit:

$$Q_v = P_v \cdot D_c \quad (4)$$

6.4.5.2 Effect of road constructions in reducing traffic loads

The load-relieving influence of road constructions may be discounted in the calculation of the traffic load, in the following cases:

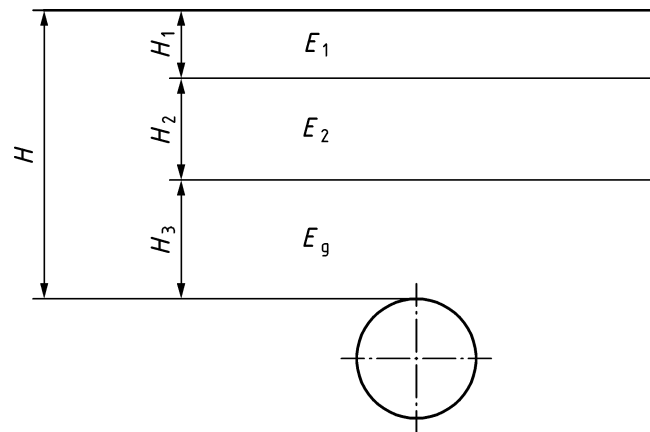
- a) road constructions consisting of a multiple-layer system, i.e. one or more foundation layers have been laid on the subsoil and finished with a top layer;
- b) road constructions, whereby the subsoil is or has been paved with asphalt or concrete.

The calculation method converts the effect of the foundation layer and top layer into a (fictional) equivalent depth of soil cover on the pipe. Subsequently the traffic load at pipe top level is calculated, using this equivalent depth of cover. In case of a three-layer system (subsoil, foundation layer and top layer) for example, the foundation layer is first converted to an equivalent soil cover, and the same procedure is followed for the top layer. The equivalent depth of cover H_{eq} is then obtained by:

$$H_3 + H_{1eq} + H_{2eq} = H_{eq} \quad (5)$$

The equation that shall be used for calculating the equivalent depth of cover (see Figure 5):

$$H_{n,eq} = 0,9 H_n \cdot \sqrt[3]{E_n / E_g} \quad (6)$$

**Key**

- H soil cover above pipe
 E modulus of elasticity

Figure 5 — Calculation of equivalent soil cover

Table 10 includes typical values which can be used in calculations. Other values than those indicated may be used if it is satisfactorily demonstrated by new or existing research that these different values are correct.

NOTE The equation for the equivalent depth of cover can also be written as $H_{eq} = H + \alpha H_1 + \beta H_2$, whereby α is dependent on covering layer and β is dependent on the foundation layer. In case of a certain thickness of the top layer (H_1), thickness of the foundation layer (H_2) and a depth of cover H , the equivalent depth of cover (H_{eq}) can be calculated with this equation. Values for α and β have been included in Table 10.

Table 10 — Typical values for different top layers and foundation layers

Material	E modulus MPa	Factor α or β	γ_{dr} kg/m ³
Polystyrene foam	4 or 14 ^a	0	15 or 40
Subsoil ^b	100 ^b	—	—
Fly ash	150	0,03	—
Lava, macadam, crushed stone, chalk stabilizer, foundation of soft rubble	200	0,13	—
Cellular concrete	300	0,30	400
Asphalt layers, clinkers, concrete rubble foundation	500	0,54	—
Cellular concrete	650	0,680	500
Sand cement, sand asphalt	1000	0,94	—
Cellular concrete	1200	1,060	600
Blast furnace slag	1500	1,220	—
^a $E = 4 + 2 (\gamma_{dr} - 15/5 \text{ MPa is applicable for in-between values})$.			
^b Well compacted sand.			

6.5 Global analysis and pipe-soil interaction

6.5.1 General

Actions, displacements and restraints shall be considered as a whole for the entire pipeline system, considering both static and dynamic aspects.

This means that even in cases where the analysis considers the pipeline in sections, the requirements of equilibrium, including accommodation of actions imposed by abutting structures, shall be fulfilled satisfactorily in the entire pipeline system.

The section of the pipeline under consideration shall also be limited by points, in respect of which the following items are to be ascertained with sufficient accuracy:

- either the displacements (translation and rotations); or
- the forces and moments; or
- the relationship between displacements on the one hand and forces and moments on the other.

When calculating internal forces and deformations, the flexibility of individual pipe components shall be dealt with by the use of flexibility factors, in accordance with Annex C.

The following procedure can be used:

- calculation of bending moments, forces and deformations of the steel service pipe as the action bearing structure;
- calculation of impacts on PUR and the casing, which are assumed to follow the deformations of the steel service pipe.

The calculation model used shall take due account of the interaction between pipe and soil generally caused by temperature expansion of the pipe or by soil settlements.

6.5.2 Modelling pipe-soil interaction

6.5.2.1 General

For a static calculation of the system (global analysis), the forces due to pipe-soil interaction may be represented by a beam-element model comprising three components as shown in Figure 6. The pipeline is represented by a simple structural beam. The interaction between the pipeline and the surrounding soil can be simulated by a series of (discrete) multilinear soil springs, with the reactions from the soil in axial, horizontal and vertical directions f , p and q modelled k_x , k_y and k_z (See Figure 6). These springs represent the amount of action or restraint exerted on the pipeline system as a nonlinear function of the relative displacement between pipe and soil.

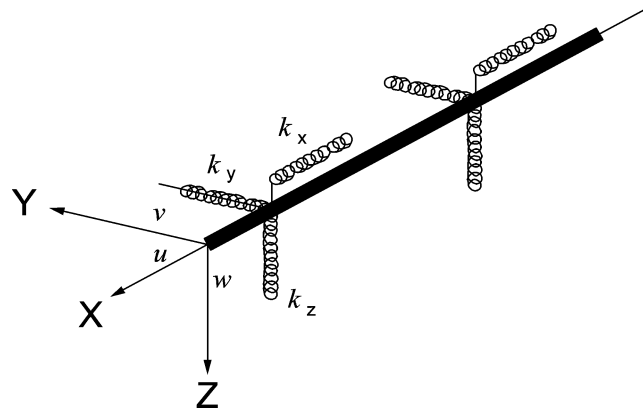


Figure 6 — Modelling pipe-soil interaction

It can be assumed that there are no shear stresses between two adjacent springs, along the pipe axis laying springs or bedding elements.

The amount of restraint is usually as illustrated in Figure 7 where f , p and q refer to axial, horizontal and vertical reactions. If displacements greater than u_u , v_u and w_u occur the soil reactions may reach constant ultimate values of f_u , p_u and q_u respectively.

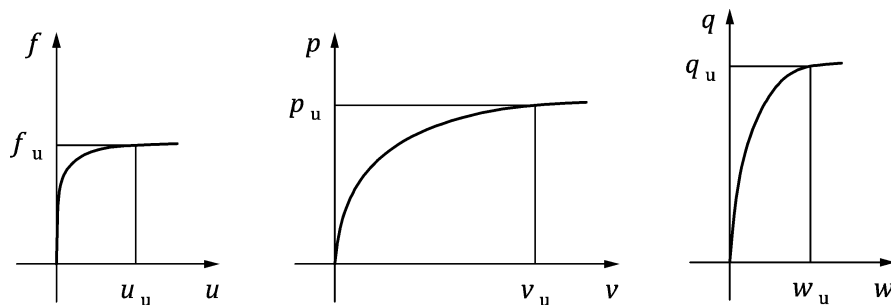


Figure 7 — Load-deformation relationship of soil springs

As an alternative for discrete springs, theories for beams on elastic foundation [20] or finite element methods can be used.

When no soil settlements are to be expected, the most important restraints are:

- a) the ultimate axial resistance f_u , given by the pipe to soil friction, see 6.5.3;
- b) the horizontal pressure p , given by the horizontal modulus of soil reaction, see 6.5.4.

The axial reaction (soil friction) can be applied as a uniform axial action against the expansion of the pipe. The horizontal soil reaction is normally characterized as elastic or elasto-plastic soil springs.

Near areas where expansion cushions are applied or large soil deformations occur the use of linear spring characteristics can give unreliable results, and elasto-plastic soil springs should be used, see Annex B.

6.5.2.2 Flexibility of pipe components

When performing the global analyses, due account shall be taken for the flexibility of pipe components, such as bends and tees. Flexibility factors for these pipe components, in accordance with C.2 shall be introduced into the calculations.

6.5.3 Pipe to soil friction (axial)

6.5.3.1 General

The relevant ultimate values of the friction f_u between casing and surrounding soil shall be determined in due consideration of the installation conditions such as:

- a) type of embedding and backfill material and method and degree of soil compaction, see EN 13941-2;
- b) maximum and minimum groundwater levels;
- c) presence of very stiff street covers preventing lateral soil displacements;
- d) influence of possible future parallel excavations nearby the pipes;
- e) “tunnel effect” due to possible increase in friction because of pipe diameter increase when heating up and friction reduction because of pipe diameter decrease when cooling down.

For sandy soils the relative displacement u_u between pipe and surrounding soil required to reach the maximum friction resistance f_u is approx. $u_u = 1 \text{ mm to } 3 \text{ mm}$.

The maximum friction resistance shall be calculated as:

$$f_u = \mu \cdot \sigma_n \quad (7)$$

For sandy soils the normal stress at a casing shall be calculated on basis of a state of soil pressure at rest, giving the friction per unit length of pipe (see Figure 8):

$$F = \mu \left(\frac{1 + K_0}{2} \cdot \sigma_v \cdot \pi \cdot D_c + G - \gamma_s \cdot \pi \cdot \left(\frac{D_c}{2} \right)^2 \right) \quad (8)$$

with $K_0 = 1 - \sin \varphi'$

For sandy soils K_0 may be valued at 0,50, if no other value is given;

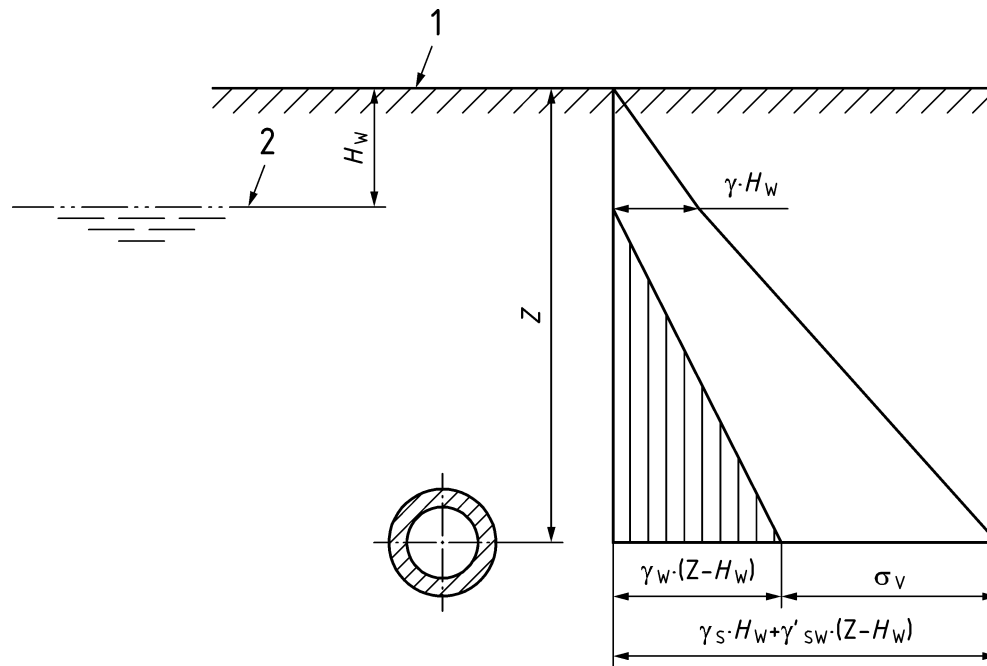
For granular soils:

$$\sigma_v = \gamma_s \cdot H_w + \gamma_{sw} (Z - H_w) \text{ for } H_w < Z \quad (9)$$

$$\sigma_v = \gamma_s \cdot Z \text{ for } H_w \geq Z \quad (10)$$

where

$$\gamma_{sw} = \gamma'_s - \gamma_w \quad (11)$$

**Key**

- 1 grade
- 2 groundwater table

Figure 8 — Calculation of effective soil stress**6.5.3.2 Friction coefficient**

The friction coefficient μ shall be determined with due consideration of the soil type, size and shape of the grains, compaction of soil backfill and deformation velocity.

For sandy soils μ shall be calculated as:

$$\mu = \tan \delta \quad (12)$$

The angle of interface friction δ between the casing and the embedding material should be determined according to EN ISO 12957-1, applying low confining pressures (10 kPa, 20 kPa, and 50 kPa).

The angle of internal soil friction of the embedding material may be determined according CEN ISO/TS 17892-10.

For standard district heating practice sandy soils and PE δ may be taken as approximately equal to $2/3 \varphi$, with a maximum value of δ approximately 20 to 22.

For sandy soils, which are not settlement areas, typical design values for μ used for fatigue analysis and design of expansion provisions may be taken from Table 11.

NOTE 1 In case of well compacted trench backfill, the initial interface friction values (e.g. at start of operation of the district heating system) can be higher, due to dilatation effects, see [22].

NOTE 2 Formula (12) is only valid for granular soils. When soils with cohesive components are used, e.g. clay, the shear stress at the casing is composed of a frictional and an adhesive part. Adhesion can be of significant quantity, therefore the use of granular bedding material is required.

Table 11 — Friction coefficients for sandy soils

Type of movement	Friction coefficient, μ^c
Slow movement or movements in consideration of creep or hysteresis (long term effects) ^a	0,2
Normal movement for low cycle fatigue analysis ^b	0,4
Fast movements with short-term actions ^b	0,6
<p>^a For large diameter pipes in well-graded sand there is a risk for the so-called tunnel-effect when cooling down. The tunnel-effect gives expansions equivalent to $\mu = 0$ to 0,2. The low values of friction coefficients shall be used e.g. when designing expansion facilities.</p> <p>^b For low cycle fatigue analysis (limit state: B1) an average value shall be used. In most cases $\mu = 0,4$ is considered appropriate.</p> <p>^c Specific local soil condition shall be taken into account.</p>	

6.5.3.3 Axial friction at horizontal directional drillings (HDD) in the operational phase

When designing expansion provisions, adjacent to pipe section, installed according the Horizontal directional Drilling method (HDD), the interface friction between the casing and the drilling fluid shall be taken as zero.

In some cases, an axial travel of the pipe in the borehole was found due to the operating and local conditions. It is recommended to evaluate the risk of occurrence of this phenomenon at HDD and, if necessary, to take precautions. Solutions may e.g. be found in the layout of the pipe system at both sides of the drilling. Eventually the use of shafts may be considered.

NOTE 1 At Horizontal drillings the casing will, under ideal conditions, be surrounded by a relatively thick (50 mm – 100 mm) layer of drilling fluid, containing a high percentage of bentonite. The bentonite will stiffen up when being in rest, but even then the drilling fluid around the pipe will show a very low friction value, compared to the friction resistance of the original soil. Pipes at elevated temperatures, showing gradually and repeated displacement due to thermal expansion, such as district heating pipe systems, will repeatedly 'break' through the maximum possible friction resistance and end up at a displacement at the ends of the HDD, comparable with zero friction.

NOTE 2 It is possible to assume a natural fixed point in the middle of the boring when applying zero friction in the expansion calculations.

6.5.3.4 Axial friction at horizontal directional drillings (HDD) in the installation phase

See Annex K.

6.5.4 Horizontal soil reaction (lateral)

6.5.4.1 General

The coefficient of horizontal soil reaction or horizontal bedding constant is defined as the ratio between horizontal soil pressure and horizontal movement of the pipe system.

$$k_h = \frac{p}{v} \quad (13)$$