Pre-insulated solutions

First issue | 09/2023a

LOGSTOR Design
Single Pipes

Kingspan®

Overview

Introduction

This section describes how to
- utilize the pipe systems at an optimum
- solve expansion problems
- install pipe systems

Heat loss calculations, pipeline dimensioning and pressure drop calculations are described separately in the sections about heat loss and pipeline dimensioning.

The design rules have been drawn up to facilitate designing a distribution network on the basis of this Design Manual and comply with the technical requirements in the European standard for design and installation of preinsulated, bonded pipe systems for district heating, EN 13941.

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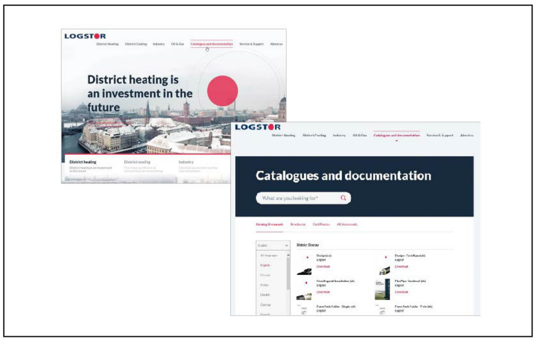
Axial stress level - Advantages and disadvantages

General
The Manual

Manuals

From our webpage www.logstor.com an overview of product catalogues, manuals, and specific instructions appear.



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The information/instructions are general. Application and implementation must take place with due respect to local conditions.

Additional/specific information can be achieved from our technicians.

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Design compliance

Design approach

The LOGSTOR design is based on optimization of technical and economic aspects.

This means LOGSTOR try to use the potential of the materials, but stay within the possibilities for a safe use of the materials and the limits of the European standard.

Validity

By complying with this Design Manual and taking local conditions into account it is ensured that all static requirements in the European standard EN 13941 are fulfilled.

General documentation
This compliance means that dimensions up to and including DN 300 can be designed with this Design Manual as documentation, provided that the data of the project in question are within the stated values and the design is carried out as specified.

Specific documentation
As the standard requires a detailed analysis of the pipe system, the specifications of this manual are only guiding for dimensions larger than DN 300 up to and including DN 600, even though they comply with EN 13941.

Design assistance

How

Design assistance may be obtained either locally from LOGSTOR's distributors and agents or from our production companies.

See also our calculation programs on the Internet.

Technical service

Our technical advisers are always ready to answer any question which may arise in connection with the design and application of the system.

Project evaluation

To evaluate a project it is an advantage that below general information is available:
- Design temperature
- Operating temperature
- Installation temperature
- Design pressure
- Dimension and insulation series
- Soil conditions
- Soil cover
- Other utility lines or obstacles in the ground

On the basis of the above information the system can be evaluated according to below items:

Straight pipes:
- Acceptable axial stress level
- Each subsection can be evaluated individually

Directional changes:
- Movements at bends
- Bends - especially other angles than 90°
- Elastic curves and prefabricated curved pipes

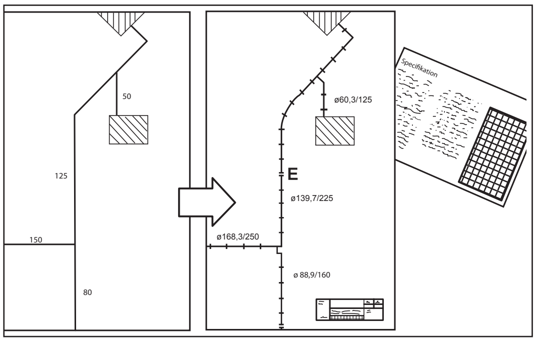
Branches:
- Main pipe movement at branches
- Stress level of the main pipe at branches
- Length of the branch

Reductions:
- 1 or more dimensional offsets

Design assistance

Tender

Our Customer service department can prepare a proposal for an optimum solution, based on a pipe section drawing with the required trench and pipe dimensions.



On the basis of the proposal a complete parts list for tenders may be prepared.

For pipe systems with surveillance, complete system and installation drawings may be prepared

Heat loss calcuation and other calculations

LOGSTOR has a thorough knowledge of calculating heat loss on the basis of specific conditions and will gladly enter into a dialogue regarding specific projects.

Also try our heat loss calculation program. Calculation of the heat loss from a LOGSTOR preinsulated pipe system can be carried out by means of the web-based calculation program "LOGSTOR Calculator".

The use of LOGSTOR Calculator makes it possible to calculate and estimate the energy efficiency of the chosen preinsulated pipe system as regards:
- Energy loss
- Cost for energy loss
- CO_2 emission

The LOGSTOR Calculator also gives you the following opportunities:
- Dimensioning service pipes
- Pressure loss calculation

The calculation program is free available on http://calc.logstor.com.

General
Preconditions

Application

This section contains preconditions for bonded pipe system according to EN 13941.

Contact LOGSTOR technicians, if the actual conditions do not comply with the preconditions forming the basis of this Design Manual.

As for other pipe systems, see the relevant sections in this manual.

Conditions for steel service pipe

The pipe system complies with the requirement in EN 253 and EN 3941 to continuous operation with hot water at various temperatures up to 120°C and at various time intervals with a peak load temperature of up to 140°C. On average the total of the various time intervals must not exceed 300 h per year. Test and documentation in accordance with EN 253 is available.

Steel pipe quality according to EN 13941-1.

Calculations for all dimensions in this manual are based on diameters and wall thicknesses in accordance with EN 253.

The pipe system can be pressure tested with cold water approx 20°C at max. 1.5 x operating pressure.

This Design Manual is valid for steel pipe dimensions up to and including DN 600.

In case of major dimensions contact LOGSTOR, and together we will find the optimum solution.

Recommended water quality

To avoid corrosion in the steel service pipe, treated water must be used. The water treatment depends on the local conditions, but should comply with the following requirements:

Circulating water	
pH value	9.5-10
appearance	clean and mud-free
oil content	oil-free
oxygen content	< 0.02 mg/l
thermal conductivity	< 1500 µS/cm

Conditions for other service pipes (FlexPipes)

See the relevant sections for each type of pipe in this Design Manual.

Service pipe	Max. continuous operating temperature °C	Max. operating pressure bar
SteelFlex	120	25
CuFlex	120	16
AluFlextra	80	10
PexFlextra	80	6

Preconditions

Applied standards

LOGSTOR design rules are based on the relevant valid European standards:

- EN 13941	Design and installation of preinsulated bonded pipe systems for district heating.
- EN 253	Bonded pipes
- EN 14419	Surveillance systems

Other European standards that applies to LOGSTOR products:

- EN 448	Fittings
- EN 488	Valves
- EN 489	Casing joints
- EN 15698-1	TwinPipes
- EN 15632	Flexible pipe systems

Project classes

Definition of project classes

The European standard EN 13941 divides a pipe system into project classes mainly on the basis of the axial stress level of the service pipe and the wall thickness of the pipe in proportion to the diameter.

Project class A: small and medium diameter pipes with low axial stresses.
Project class B: high axial stresses, small and medium diameter pipes.
Project class C: large diameter pipes or pipes with high internal overpressure.

A more detailed description is in the standard EN 13941.

Load cycles

Calculations are carried out with the following minimum "equivalent full action cycles", i.e. number of temperature changes:

Pipeline description	No. of full cycles
Major pipelines (transmission pipelines)	100
Main pipelines (distribution network)	250
House connections*	1000

* In this manual house connections are defined as maximum DN 32 (ø42.4 mm).

The applied number of load cycles corresponds to normal operating conditions.

If the number of load cycles is higher, a special static calculation of the components must be carried out.

Safety factor

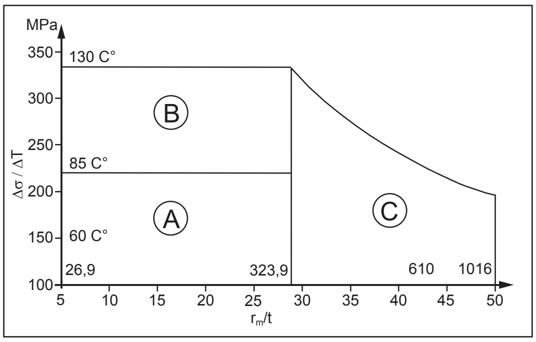
A safety factor for fatigue is connected to each project class.

The safety factor is included in the design instructions.

As the difference between the allowable fatigue stresses in project classes A and B is only approx. 7%, both classes have been calculated for the highest safety factor.

This ensures that the design for project class A is on the safe side.

All static calculations are therefore based either on project class B up to and including DN 300 or project class C for dimensions > DN300.



Units and symbols

Introduction

The following units and their corresponding symbols are based on:
- EN253
- EN13941
- LOGSTOR symbols

Units

Length	m (metre)
	mm (millimetre)
Mass	kg (kilogram)
Force	N (Newton)
Stress	MPa (Newton per square millimetre)
Pressure	Bar (Pascal = Newton per square metre)
	(1 bar = 10^5 Pa = 0.1 MPa = 0.1 N/mm^2)
Temperature	°C (degrees centigrade)

Symbols

A_s	Cross section of service pipe
D	Diameter of casing
d	Diameter of service pipe
E	Modulus of elasticity
F	Friction force
G	Self-weight
I	Momentum of inertia
L_{190}	Installation length for a specific stress level (here 190 MPa)
L_F	Friction length (for the actual max stress level)
L_L	Section locked by friction
L_E	Distance between E-Comps
L_B	Distance between E-Comp and bend
σ_{all}	Allowable axial stress level
L	Length
ΔL	Expansion for the length L
H	Cover over the pipe from top casing to top surface
Z	Distance to centreline of pipe from top surface (Z=H+½D)
R_e	Yield stress
T	Temperature in °C
α	Expansion coefficient
γ	Specific gravity
ρ	Density
ν	Poisson’s ratio
φ	Internal friction angle of soil

Indices

ins	Installation
min	Minimum
max	Maximum
pre	Prestressing

Units and symbols

Characteristic values

Characteristic values for steel service pipe according to EN 13941.

In this manual the general values below are used:

E = 210,000 MPa

α = 1.2E-05

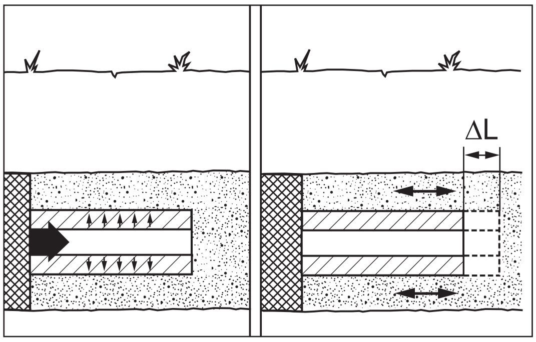
This means that
$E \cdot \alpha$ = 2.52 MPa/°C

If more detailed analyses are wanted, the values, related to temperatures according to the table can be used.

Tempera-ture T	E-modulus E^T MPa	Expansion coefficient α^T	Yield stress Re MPa
20 °C	212,857	1.16E-05	235
50 °C	211,143	1.18E-05	221
70 °C	210,000	1.19E-05	212
90 °C	208,857	1.21E-05	203
100 °C	208,286	1.22E-05	198
110 °C	207,714	1.23E-05	196
120 °C	207,143	1.23E-05	194
130 °C	206,571	1.24E-05	191
140 °C	206,000	1.25E-05	189

System definitions

Bonded pipe system



Our pipe system is a bonded system, i.e. service pipe, insulation layer and outer casing are securely bonded together in a sandwich construction.

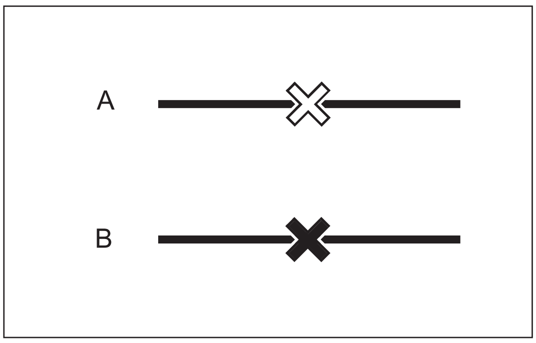
This means that the expansion or contraction occurring in the steel pipe due to temperature variations will be transferred to the outer casing through the insulation so that the movement is between the outer casing and the surrounding friction material.

The movements are hampered by the friction between the outer casing and the surrounding friction material. This means that the movements in a buried bonded pipe system are smaller than the movements in a freely expanding pipe system.

The friction along the outer casing is inducing compressive stresses when heating the steel pipe, and inducing tensile stresses in the steel pipe when cooling the service pipe.

The temperature variations in the water in combination with the friction force on the outer casing, is the basic function of the bonded pipe system, resulting in reduced expansion at the free ends and stress variations in the steel service pipe in the locked zones.

Anchors



An anchor can be defined in 2 ways:

A: Virtual anchor
where the movements of the pipe are controlled by the friction of the friction material against the outer casing we have a virtual anchor.
For this Design Manual a virtual anchor illustrates the center between two free expansion ends.

It can be necessary to use cast anchors where reduction of movement is necessary.

B: Cast anchor
Cast anchors are in general avoided, as the friction controls the movement in buried systems.

Stress level and expansion calculation

Introduction

This section contains the basic formulas for calculating stresses and movements in buried bonded pipe systems.

The formulas give the basis for being able to make the required calculations for a system, which according to EN13941 in project classes A and B can be designed by means of general documentation from a supplier's manual.

In the Design Manual some of the fomulas are incorporated in the tables, which under the given conditions can be applied instead of the formulas and thus simplifying the design of a pipe system.

Contents

Axial stress level
Expansion at bends
Expansion at branches
Friction force

Axial stress level

Maximum axial stress
$L > 2 \cdot L_F$

How to determine the maximum axial stress in a given pipe section depends on:
- the friction force,
- the temperature difference
- the length

For a straight pipe section which is longer than $2 \cdot L_F$ the axial stress level can be calculated according to the following formula:

$$\sigma_{max} = \Delta T \cdot E \cdot \alpha \text{ [MPa]}$$

The temperature difference ΔT is based on the difference between the temperature where the pipes are covered and the max. or min. temperature. The axial stresses will normally be compressive stresses if T_{max} is used, and tensile stresses if T_{min} is used.

The simplified formula using the values for α and E from the section "General: Units and symbols" is then:

$$\sigma_{max} = \Delta T \cdot 2.52 \text{ [MPa]}$$

The formula does not include the contribution of the internal overpressure. The internal overpressure has only a limited effect on the axial stress level for the dimensions included in project classes A and B.

Friction length

On the basis of the established maximum axial stress level the distance from the free end of a pipe section to the point where the maximum stresses are reached can be calculated.

$$L_F = \frac{\sigma_{max} \cdot A_s}{F}$$

Where:

L_F = friction length – the distance from the expansion bend to the point where the maximum axial stress occurs.

σ_{max} = Maximum axial stress level

A_s = Cross-sectional area of the steel pipe which can be taken from the tables in the section: "Straight pipes: Stress reduction with bends - Tables of installation lengths".

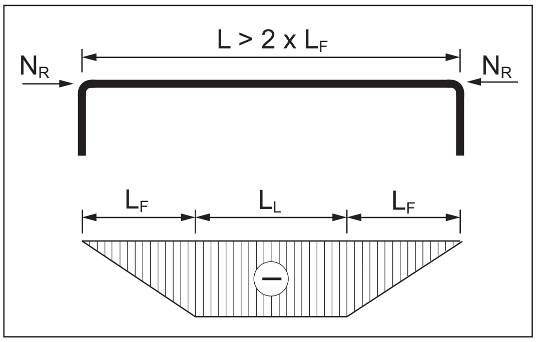
F = Friction force in the ground, i.e. the resistance the soil transfers to the preinsulated pipe against movements, can be taken from the tables in the section: "Straight pipes: Stress reduction with bends - Tables of installation lengths" or calculated according to the section "General: Friction force".

The distance from free end (bend) to maximum axial stress level is also called: section, partly restrained by friction.

N_R = Force from lateral soil reaction against expansion
If the expansion takes place in a bend with foam pads, which is the general LOGSTOR design, then N_R can be set to 0.

L_F = Section, partly restrained by friction

L_L = Section, locked by friction

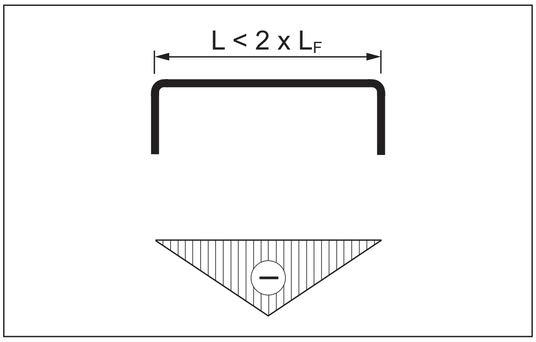


Axial stress level

Maximum axial stress $L < 2 \cdot L_F$

If the distance between 2 expansion bends is shorter than $2 \cdot L_F$ then the friction force is decisive for the stress level. The axial stress level can be calculated from

$$\sigma_{max} = \frac{½ \cdot L \cdot F}{A_S}$$



Axial stress at any point

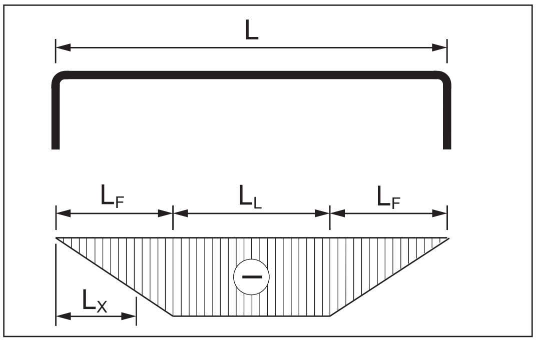
The axial stress level at any point in a pipeline can be found from the following 2 formulas:

$L_X < L_F$

$$\sigma_X = \frac{L_X \cdot F}{A_S}$$

$L_X > L_F$

$$\sigma_X = \Delta T \cdot E \cdot \alpha$$



Expansion at bends

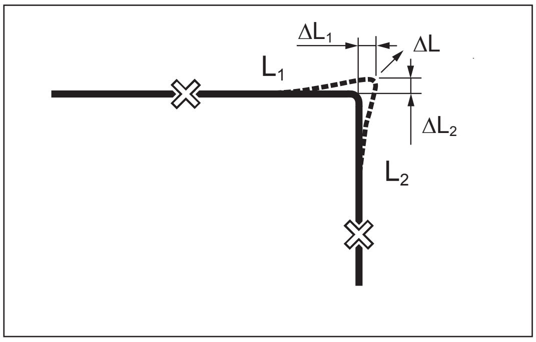
Expansion at free pipe end

The expansion at a bend can be calculated from

$$\Delta L_x = L_x \cdot \alpha \cdot \Delta T - \frac{F \cdot L_x^2}{2 \cdot A_s \cdot E}$$

L_x in the formula is the distance from the free end to the virtual anchor and is maximum the friction length L_F.

For the pipes in project classes A and B the influence of the internal pressure is negligible due to the size of the pipe so the simplified formula above can be used.



Radial movement

At a bend the axial expansion comes from both sides. This will result in radial movement at the bend. The radial movement for a 90° bend can be calculated from:

$$\Delta L = \sqrt{\Delta L_1^2 + \Delta L_2^2}$$

To protect the bend against too high stress from horizontal soil reactions it is important to secure bends using foam pads.

How to handle the movement, see the section "Directional changes".

Expansion at branches

Expansion at branch

A branch pipe will follow the movements of the main pipe at branch point.

It is important to be aware of the axial expansion in the main pipe. This will lead to lateral movement of the same size at the branch pipe

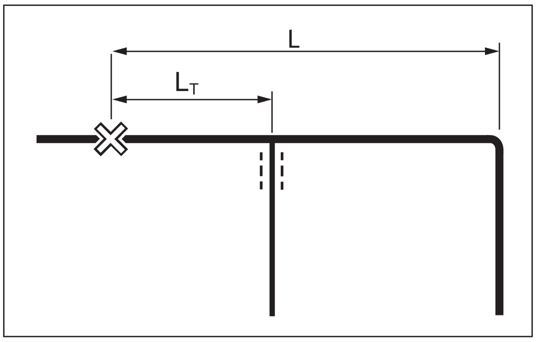
The expansion in the main pipe at the branch can be calculated from the following formula:

$$\Delta L_T = \alpha \cdot \Delta T \cdot L_T - \frac{F\,(2 \cdot L - L_T) \cdot L_T}{2 \cdot E \cdot A_S}$$

L is the distance from the bend to the virtual anchor, but will maximum be the friction length L_F .

To protect the T-branch against too high stress from horizontal soil reactions it is important to secure the branch pipe using foam pads.

How to handle this and find the type of branch to be used (perpendicular or parallel) see the section "Branches".



Friction force

Friction force

The friction force can be calculated from the following formula:

$$F = \mu \cdot \left(\frac{1 + K_0}{2} \cdot \sigma_V \cdot \pi \cdot D + G - \gamma_S \cdot \pi \cdot \left(\frac{D}{2}\right)^2 \right)$$

Where:

μ	Normally, use 0.4 as friction coefficient between friction material and PE outer casing
K_0	coefficient of soil pressure at rest (0.46 can be used)
σ_V	effective soil stress at pipe centreline level, = $\gamma_s \cdot Z$
γ_s	Gravity of soil (kN/m^3)
Z	Distance to centreline of the pipe from top surface ($Z = H + ½D_C$)
H	Soil cover over the pipe from top casing to top surface
D	Casing diameter
G	Weight of water-filled preinsulated pipe

Instead of the above fomula the friction force for each dimension can be found in the tables in the section: "Straight pipes: Stress reduction with bends - Tables of installation lengths" as a function of the soil cover and insulation series.

If the pipeline lies at or under the groundwater level, this must be taken into account in the calculation. From EN 13941 it appears, how to make this calculation.

Examples of stress level and expansion calculation

Introduction

The following examples are calculated with 2 different temperature sets. As a result this will show the differences in:

- Stress level
- Friction length
- Expansion movement

This is then used to assess:
- The stress reduction requirement
- The stress reduction method

Contents

Axial stress level
Expansion at bends
Expansion at branches

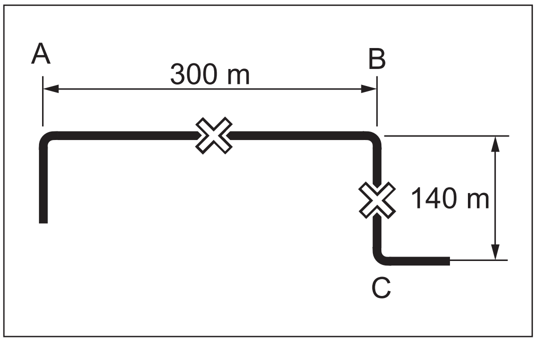
1a, Axial stress level

Conditions for example 1a

ø 114.3 mm, series 2
Soil cover H = 0.8 m
Max. design temperature T_{max} = 120°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

Values from the table in the section: "Straight pipes: Stress reduction with bends - Tables of installation lengths"

F = 3.35 kN/m
A_s = 1252 mm^2



Maximum axial stress

Calculation of the maximum thermal axial stress level in a pipe system:
$\sigma_{max} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max} = (120 - 10) \cdot 2.52 = 277$ MPa

Section A-B

Calculation of friction length:

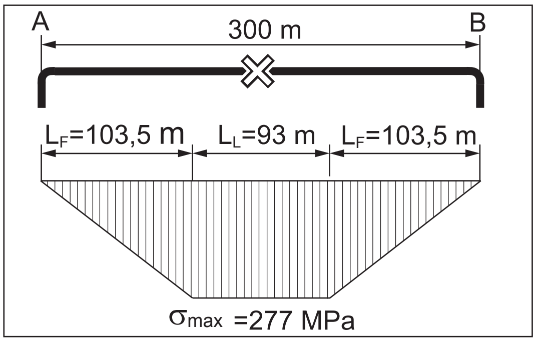
$$L_F = \frac{\sigma_{max} \cdot A_s}{F}$$

$$L_F = \frac{277 \cdot 1252}{3.35 \cdot 1000} = 103.5 \text{ m}$$

For section A-B the distance is more than twice as long as the friction length which means that there are 2 partly restrained sections of 103.5 m each.

In the middle there is a section locked by friction. The length of this section is:

$L_L = L - (2 \cdot L_F) = 300 - (2 \cdot 103.5) = 93$ m



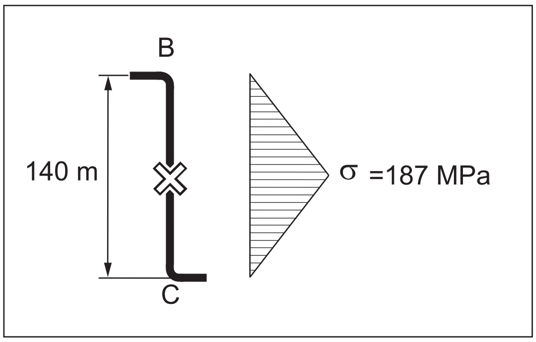
Section B-C

For section B-C the distance is < 2 · L_F which means that the axial stress is lower than σ_{max}.

The maximum stress level is:

$$\sigma_{B\text{-}C} = \frac{\frac{1}{2} \cdot L \cdot F}{A_s}$$

$$\sigma_{B\text{-}C} = \frac{0.5 \cdot 140 \cdot 1000 \cdot 3.35}{1252} = 187 \text{ MPa}$$



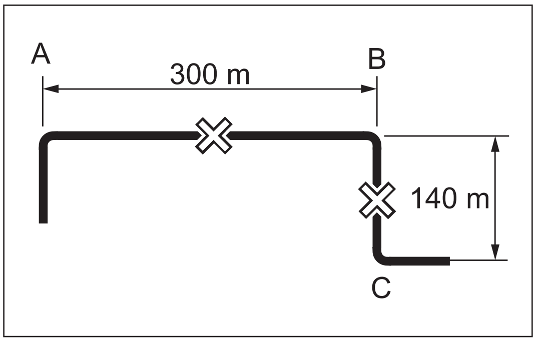
1b, Axial stress level

Conditions for example 1b

ø 114.3 mm, series 2
Soil cover H = 0.8 m
Max. design temperature T_{max} = 80°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths":

F = 3.35 kN/m
A_s = 1252 mm^2



Maximum axial stress

Calculation of the maximum thermal axial stress level in a pipe system:
$\sigma_{max} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max} = (80 - 10) \cdot 2.52 = 176$ MPa

Section A-B

Calculation of friction length:

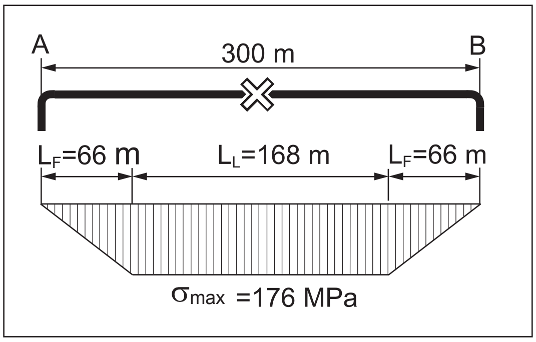
$$L_F = \frac{\sigma_{max} \cdot A_s}{F}$$

$$L_F = \frac{176 \cdot 1252}{3.35 \cdot 1000} = 66 \text{ m}$$

For section A-B the distance is more than twice as long as the friction length which means that there are 2 partly restrained sections of 66 m each.

In the middle there is a section locked by friction. The length of this section is:

$L_L = L - (2 \cdot L_F) = 300 - (2 \cdot 66) = 168$ m

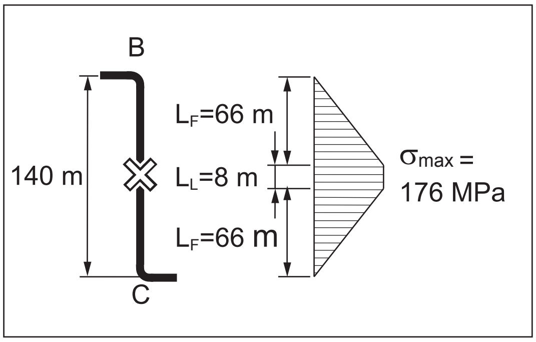


Section B-C

For section B-C the distance is more than twice as long as the friction length L_F, which means that there are 2 partly restrained sections of 66 m.

In the middle there is a section locked by friction. The length of this section is:

$L_L = L - (2 \cdot L_F) = 140 - (2 \cdot 66) = 8$ m



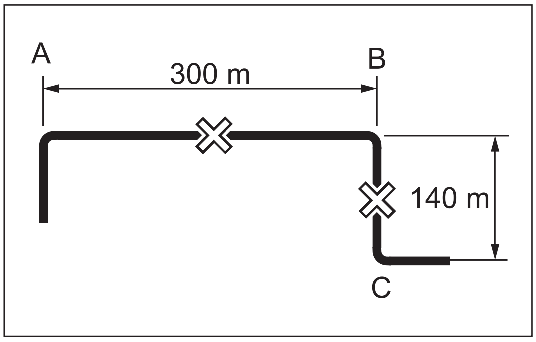
2a, Expansion at bends

Conditions for example 2a

ø 114.3 mm, series 2
Soil cover H = 0.8 m
Max. design temperature T_{max} = 120°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths":

F = 3.35 kN/m
A_s = 1252 mm^2

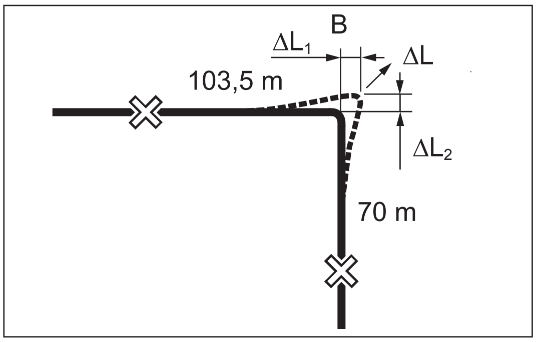


Calculation of movement at point B

The calculation of the expansion at the end of a pipe section at point B is divided into 3 parts:

1. Calculation of expansion from pipe section A–B, ΔL_1
2. Calculation of expansion from pipe section B–C, ΔL_2
3. Total radial movement of expansion bend B, ΔL

The distance L is the distance from the virtual anchor to the bend and can maximum be the friction length L_F.



From A-B:
The distance from the bend to the virtual anchor is ½ · 300 = 150 m.
L_F is 103.5 m (calculated in example 1a).
L = 103.5 m (< 150 m) is used for L_1 in the example.

$$\Delta L_1 = L_1 \cdot \alpha \cdot \Delta T - \frac{F \cdot L_1^2}{2 \cdot A_s \cdot E}$$

Calculation of ΔL_1:

$$\Delta L_1 = 103500 \cdot 1.2 \cdot 10^{-5} \cdot (120 - 10) - \frac{3.35 \cdot 103500^2}{2 \cdot 1252 \cdot 210000} = 68 \text{ mm}$$

From B-C:
The distance from the bend to the virtual anchor is ½ · 140 = 70 m.
L_F is 103.5 m (calculated in example 1a).
L = 70 m (< 103.5 m) is used for L_2 in the example.

Calculation of ΔL_2:

$$\Delta L_2 = 70000 \cdot 1.2 \cdot 10^{-5} \cdot (120 - 10) - \frac{3.35 \cdot 70000^2}{2 \cdot 1252 \cdot 210000} = 61 \text{ mm}$$

Radial movement at point B:
The radial displacement at B is:

$$\Delta L = \sqrt{\Delta L_1^2 + \Delta L_2^2}$$

$$\Delta L = \sqrt{68^2 + 61^2} = 91 \text{ mm}$$

How to handle this expansion, see the section "Directional changes".

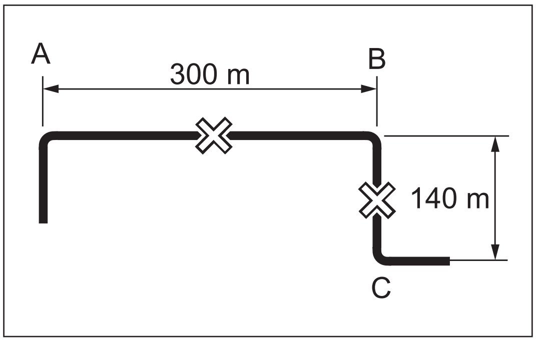
2b, Expansion at bends

Conditions for example 2b

ø 114.3 mm, series 2
Soil cover H = 0.8 m
Max. design temperature T_{max} = 80°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

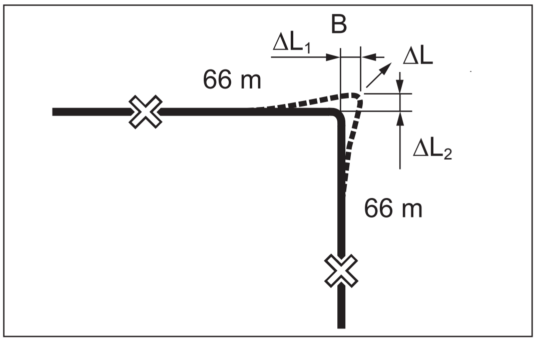
Values from the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths":

F = 3.35 kN/m
A_s = 1252 mm^2



Calculation of movement at point B

From A-B:
The distance from the bend to the virtual anchor is
½ · 300 = 150 m.
L_F is 66 m (calculated in example 1b).
L = 66 m (< 150 m) is used for L_1 in the example.



$$\Delta L_1 = L_1 \cdot \alpha \cdot \Delta T - \frac{F \cdot L_1^2}{2 \cdot A_s \cdot E}$$

Calculation of ΔL_1:

$$\Delta L_1 = 66000 \cdot 1.2 \cdot 10^{-5} \cdot (80 - 10) - \frac{3.35 \cdot 66000^2}{2 \cdot 1252 \cdot 210000} = 28 \text{ mm}$$

From B-C:
The distance from the bend to the virtual anchor is ½ · 140 = 70 m.
L_F is 66 m (calculated in example 1b).
L = 66 m (< 70 m) is used for L_2 in the example.

Calculation of ΔL_2:

$$\Delta L_2 = 66000 \cdot 1.2 \cdot 10^{-5} \cdot (80 - 10) - \frac{3.35 \cdot 66000^2}{2 \cdot 1252 \cdot 210000} = 28 \text{ mm}$$

Radial movement at point B:

$$\Delta L = \sqrt{\Delta L_1^2 + \Delta L_2^2}$$

$$\Delta L = \sqrt{28^2 + 28^2} = 40 \text{ mm}$$

How to handle this expansion, see the section "Directional changes".

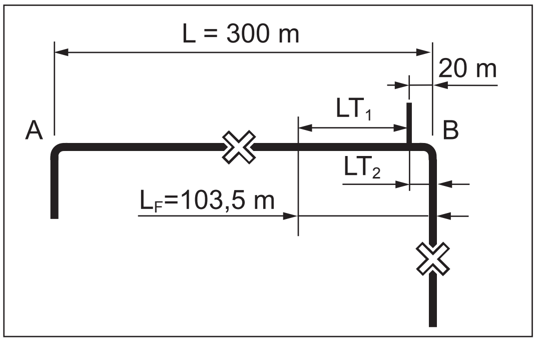
3a, Expansion at branches

Conditions for example 3a

ø 114.3 mm, series 2
Soil cover H = 0.8 m
Max. design temperature T_{max} = 120°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths":

F = 3.35 kN/m
A_s = 1252 mm^2



Calculation of movement at branch point D

To find the movement in the main pipe at the branch, we need to find:

The distance from the bend to the virtual anchor for section A-B is ½ · 300 = 150 m.
L_F is 103.5 m (calculated in example 1a).
L = 103.5 m (< 150 m) is used in the example.

$L_{T1} = L - L_{T2} = 103.5 - 20 = 83.5$ m

$$\Delta L_T = \alpha \cdot \Delta T \cdot L_{T1} - \frac{F\,(2 \cdot L - L_{T1}) \cdot L_{T1}}{2 \cdot E \cdot A_s}$$

$$\Delta L_T = 1.2 \cdot 10^{-5} \cdot (120\text{-}10) \cdot 83500 - \frac{3.35\,(2 \cdot 103500 - 83500) \cdot 83500}{2 \cdot 210000 \cdot 1252} = 45 \text{ mm}$$

How to handle this movement, see the section "Branches".

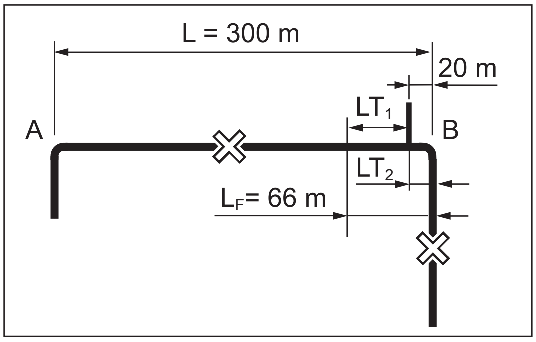
3b, Expansion at branches

Conditions for example 3b

ø 114.3 mm, series 2
Soil cover H = 0.8 m
Max. design temperature T_{max} = 80°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths":

F = 3.35 kN/m
A_s = 1252 mm^2



Calculation of movement at branch point B

To find the movement in the main pipe at the branch, we need to find:

The distance from the bend to the virtual anchor for section A-B is 0.5 · 300 = 150 m.
L_F is 66 m (calculated in example 1b).
L = 66 m (< 150 m) is used in the example.

$L_{T1} = L - L_{T2} = 66 - 20 = 46$ m

$$\Delta L_T = \alpha \cdot \Delta T \cdot L_{T1} - \frac{F\,(2 \cdot L - L_{T1}) \cdot L_{T1}}{2 \cdot E \cdot A_s}$$

$$\Delta L_T = 1.2 \cdot 10^{-5} \cdot (80\text{-}10) \cdot 46000 - \frac{3.35\,(2 \cdot 66000 - 46000) \cdot 46000}{2 \cdot 210000 \cdot 1252} = 13 \text{ mm}$$

How to handle this movement, see the section "Branches".

References

LOGSTOR Design Tool:

https://designtool.logstor.com/Tool/Form.aspx?ApplicationId=18749619-698b-47c3-8dbe-c54c42282ccb

Determination of allowable stresses

Introduction

This section describes the conditions to examine before determining the allowable axial stress level.

It also describes how the allowable stress level is determined and how it can be reduced, if necessary.

It also shows the typical stress diagrams of the different systems with and without stress reduction.

Contents

Determination of allowable axial stress level
Axial stress level without stress reduction
Axial stress level reduction with bends
Axial stress level reduction with heat prestressing
Axial stress level reduction with E-Comp

Determination of allowable axial stress level

Allowable axial stress level

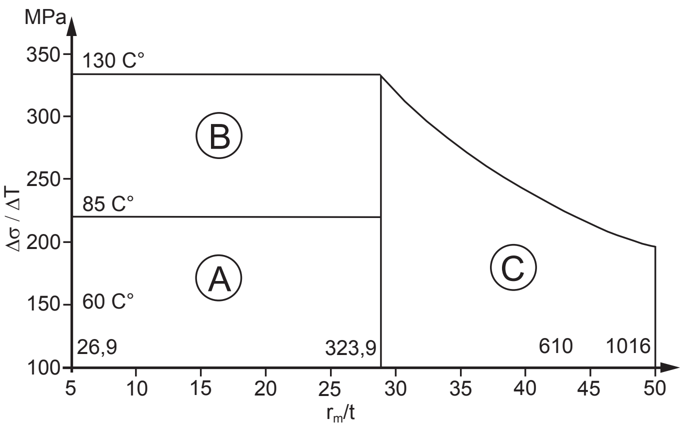
The determination of the maximum axial stress level for straight pipe sections must take place with due regard to the stability of the pipe itself (local stability) as well as the stability of the pipe section in relation to the surroundings (global stability).

Local stability

Stability of the pipe itself is to be understood as protection against local buckling or folding.

There is a risk of local buckling or folding at high axial stresses and relatively large diameters in relation to the wall thickness.

However, this risk is non-existing, when the axial stress level lies below the limit curve (limit state C1 according to EN 13941) in below illustration.



See detailed values for the limit curve under the section "Straight pipes: Straight pipes without stress reduction”.

Global stability

To ensure the stability of the straight pipe sections various parameters must be assessed, because they influence the maximum stress level. This may be determined by conditions present at the time of design or conditions influencing the pipes in connection with future measures.

- Excavation along and across the pipeline
- Distance to existing and future pipe systems
- Parallel excavation at existing and future pipe systems
- Stability of curved pipes with little cover
- Risk of buckling for pipes with high axial stresses
- Application of bevelling
- Complexity of the pipeline and the trench
- Possible obstacles in the trench in connection with the construction work
- Reductions on straight pipe sections
- Number of branches and other components
- Position of valves
- Expansion size at bends

Determination of allowable axial stress level

Allowable axial stress level, *continued*

EN 13941 makes it possible to use an axial stress level with a limit according to the curve on the previous page.

Each pipeline owner must then on the basis of the above mentioned determine the actual stress level.

The stress level must not be assessed exactly alike in all parts of a pipe system, but may be determined on the basis of local conditions.

LOGSTOR's Design Manual gives the possibility of applying the entire stress range in the project class curve for stability, but the individual conditions must be checked and secured in relation to the stated restrictions in order to fulfill the requirements of the standard.

This may mean that certain areas of a pipe system can be established without stress reducing measures and other areas can meet the requirements of global stability by taking stress reducing measures.

In addition to the possibility of using the entire stress level in the standard, in this manual LOGSTOR has specified requirements to stress reducing measures for a stress level of 190 MPa.

So in addition to the stability requirement each pipeline owner can also determine his own level, if this is wanted.

An axial stress level of 190 MPa has been used throughout many years and gives a 1.1 safety against reaching the yield stress of steel. However, this still means that the global stability of the pipe system must be secured in accordance with the specifications in the following sections.

If the system is established without stress reducing measures, see the section "Straight pipes: Straight pipes without stress reduction".

If it is wanted or necessary to reduce the axial stresses this can be done by means of:

- Bends
- Heat prestressing in open trench
- E-Comp

They are described on the following pages and in detail in the sections "Straight pipes": "Stress reduction with bends", "Stress reduction by prestressing in open trench", and "Stress reduction with E-comps".

For an optimally designed system this means that local conditions have been taken into consideration and if stress reduction is necessary in the straight pipe sections, then the advantages of each method is used and combined, so a technically and economically optimum system is obtained.

Axial stress level without stress reduction

Definition of low and high axial stresses

When a straight pipe section is built without stress reduction, - except for natural directional changes - the temperature variation load is absorbed as stresses in the section locked by friction and as expansion at bends, coming from the partly restrained section.

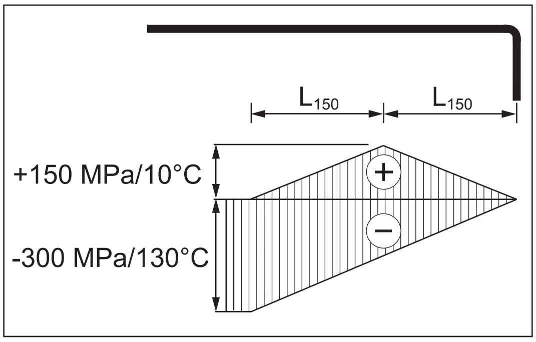
Low axial stress
Low design temperatures - below 95°C (a temperature difference of 85°C from installation of 10°C) - result in low axial stresses, and are defined in project class A for small pipes.

High axial stress
At high design temperatures the yield stress (R_e) of the steel is exceeded. This is called high axial stress and is defined in project class B for small pipes.

Straight pipe section without reduction

Thermal axial stress level in a pipe section without reduction of the axial stress in the service pipe.

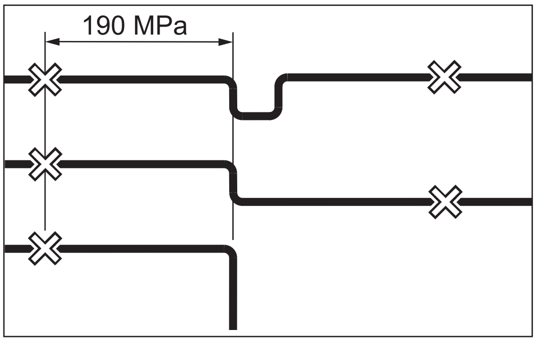
In a pipe system, installed at high axial stresses the maximum axial stresses will be -300 MPa when heating from 10° C to 130° C after backfilling.



Axial stress level reduction with bends

Expansion bends

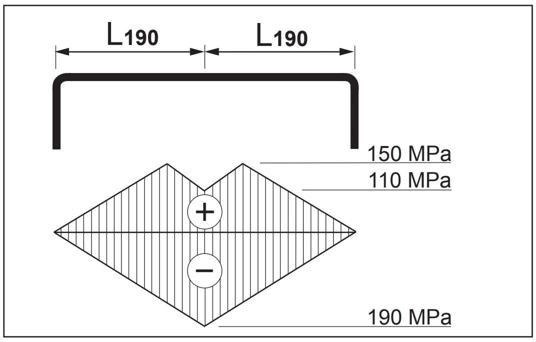
The axial stresses in straight pipe sections can be reduced by building in expansion bends with a distance which ensures that the axial stresses do not exceed the actual allowable stress level.



Expansion bends are used to the extent where they form a natural part of the pipeline and where there are no other possible solutions, because they are bulky and costly.

In some traditional systems U-bends are replaced by axial compensators. If this is the case, please contact LOGSTOR.

The axial stresses in a pipe system is reduced by dividing the pipe system into sections between the expansion bends. These sections are called installation lengths and the index indicates the maximum axial stress level.



In a pipe system with a maximum operating temperature of 130°C and a minimum temperature of 10°C, the maximum axial stress will be like in the illustration.

For details see the section "Straight pipes: Stress reduction with bends".

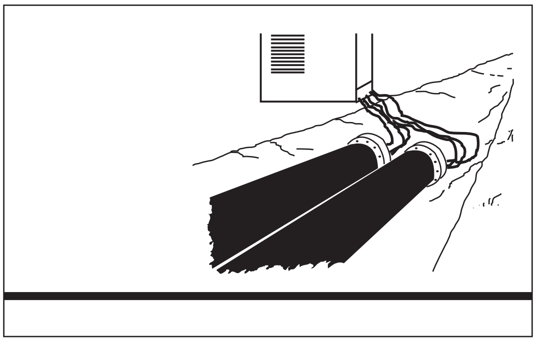
Axial stress level reduction with heat prestressing

Heat prestressing

Reducing axial stresses by heat prestressing in open trench ensures that the pipe section is stressfree at the prestress temperature (a mean temperature).

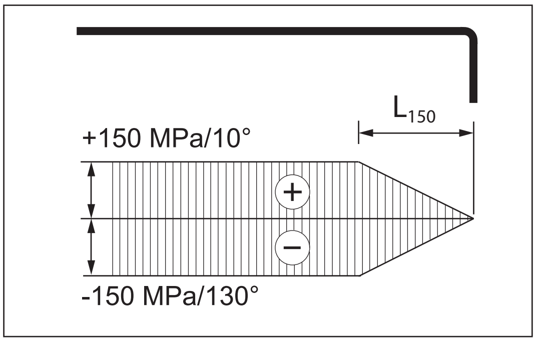
After backfilling the expansions at the bends will be limited, and the temperature variations in the system will be converted to tensile and compressive stresses in the straight pipes.

Prestressing can be done with water, steam or electricity.



In a pipe system with a maximum operating temperature of 130°C and a minimum temperature after backfilling of 10°C the maximum axial stress will be ± 150 MPa, when the heat prestressing has been carried out at 70°C, a temperature difference of 60°C.

For details, see the section "Straight pipes: Stress reduction by prestressing in open trench".



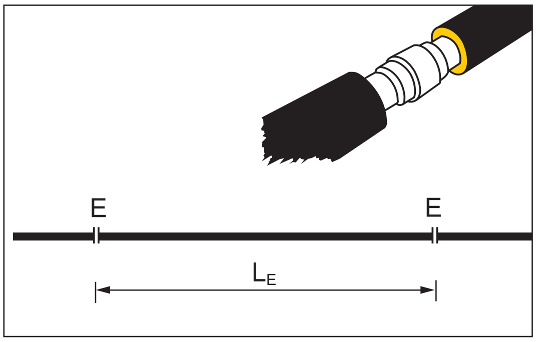
Axial stress level reduction with E-Comp

E-Comp

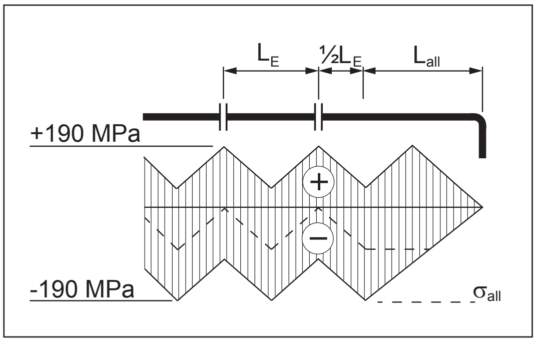
The E-system is a simplified installation technique where the temperature variations are converted to tensile and compressive stresses in the steel pipe and where the E-Comps are installed to absorb part of the first movement.

The E-Comp is a compensator that operates only once to absorb expansion.

After the first heating and welding of the E-Comp the system will have long sections that are locked without movements.



In a pipe system with a maximum operating temperature of 130°C and a minimum temperature after backfilling of 10°C, the maximum axial stress will be like in the illustration, if the allowable stress level is 190 MPa



Axial stress level - Advantages and disadvantages

Advantages and disadvantages

System	Advantages	Disadvantages
Without stress reduction Typical application: - Transmission pipelines - Main pipelines	Simple installation The trench can be backfilled continuously No preheating costs or additional compensation components Long friction locked sections in which the pipes cannot move	**Low axial stresses** None **High axial stresses** High axial stresses Large first time expansion Not possible on large dimensions at high temperatures Additional carefulness in connection with excavation and parallel excavation
Stress reduction with bends Typical application: - Main pipelines - Distribution pipelines	Reduced axial stresses The trench can be backfilled continuously Less restrictions in connection with later excavation and parallel excavation	Additional costs for bends The entire pipe system moves in the ground Increased pressure loss
Stress reduction with heat prestressing Typical application: - Large transmission pipelines outside urban areas	Reduced axial stresses No additional costs for compensation components Long locked sections in which the pipes cannot move Less restrictions in connection with later excavation and parallel excavation	The entire trench must be open during preheating Additional costs for heating source Heating source must be available before the trench is backfilled
Stress reduction with E-Comp Typical application: Transmission pipelines in urban areas	The trench can be partially backfilled prior to heating Often not necessary to reduce stresses in the return pipe Long locked sections in which the pipes cannot move after heating Less restrictions in connection with later excavation and parallel excavation	Re-establishing hole around the E-Comp can first be done after heating Addition costs for E-Comps The number of E-Comps increases in relation to the installation depth

It may be advantageous to combine the different methods in order to obtain the best technical and financial solution to the system.

Trench
Overview

Introduction

This section contains design rules for the trench, distances between pipes and back-fill material around pipe pairs

Contents

Trench dimension
Backfill material
Soil cover
Excavating pipes

Trench dimension

Basis

To obtain a good friction between soil and outer casing the trench should be made so there is minimum 100 mm stoneless friction material around the pipes to protect the casing against sharp stones and to establish a homogeneous friction between outer casing and the backfill material.

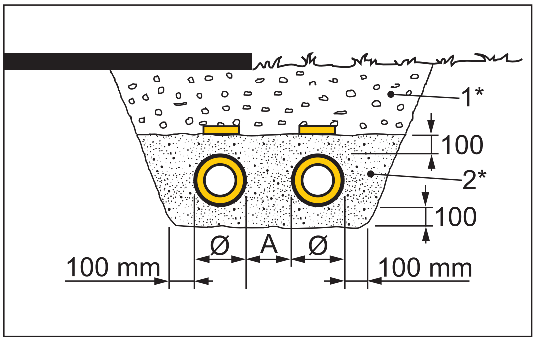
Cross section

The cross section of the trench must as a rule be designed according to the requirements in EN13941 as well as local rules and regulations as regards safety and work environment.

To ensure sufficient friction material around the pipes the measurements in the illustrated cross section must be complied with.

Place 2 warning tapes or a warning net which covers the pipes minimum 100 mm over the pipes.

1*) Backfill material for the upper zone
2*) Backfill material (friction material)



LOGSTOR recommends the distance A between pipes according to the table.

Existing cables and pipes already in the ground and possible need for trench drainage should be taken into account.

In areas with poor soil quality, it may be necessary to replace a major quantity of the soil to avoid settlement/displacement.

Outer casing Ø mm	Distance A between casings mm
90 - 225	150
250 - 560	250
630 - 1400	300

Backfill material

Friction material

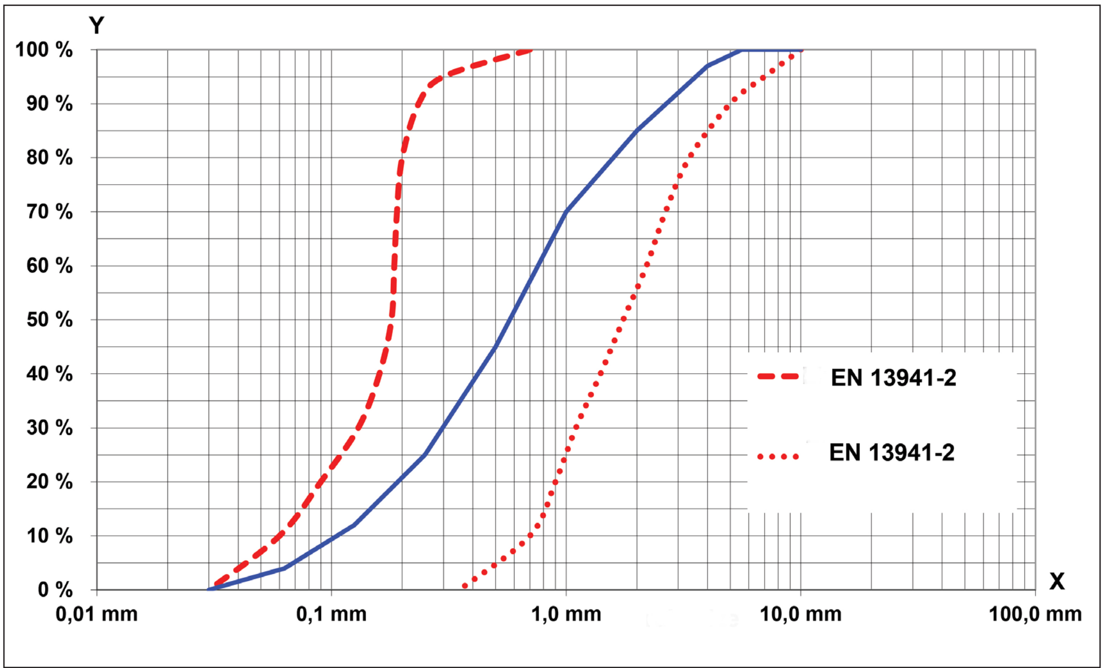
The backfill material in the friction zone (zone 2) must comply with below requirements, and a sieve analysis must lie e.g. like the blue curve between the two red limit curves according to EN 13941-2:

- Maximum grain size ≤ 10 mm
- Coefficient of uniformity $\frac{d_{60}}{d_{10}} \geq 1.8$

The coefficient is found by means of a sieve test.

d_{60} is the grain size, where 60% fall through the sieve.

d_{10} is the grain size, where 10% fall through the sieve.



x-axis: Grain size in mm
y-axis: Amount passing in weight percent

The material should not contain harmful quantities of plant residues, humus, clay or silt lumps.

Especially, in connection with major pipes it is important to pay attention to the amount of fine-grained material in the backfill to prevent the risk of a tunnelling effect, when the pipes are cooled.

Compacting

Fill all around the pipes, and pay special attention that an even and well-compacted backfilling is obtained.

Compact the gravel between and at the sides of the outer casings.

The friction is based on a mean compaction of 97% standard proctor with no values less than 94% standard proctor.

Please note that special requirements from e.g. road builders must be taken into account.

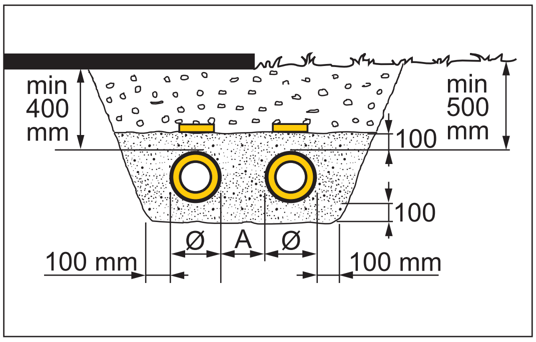
As regards expansion zones be aware of special requirements, see the section "Expansion absorption".

Soil cover

Minimum soil cover

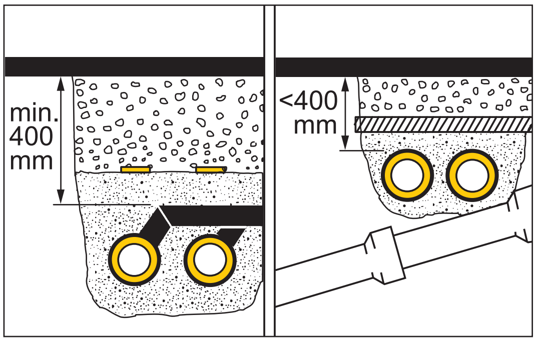
It is recommended to have a minimum soil cover of 400 mm from the bottom of the road asphalt / concrete to the top of the outer casing.

From the top of unpaved areas to the top of the outer casing a minimum soil cover of 500 mm is recommended



At branches the 400 mm are measured from the top of the branch pipe.

If the minimum soil cover cannot be achieved, the pipes must be protected against overload e.g. by means of a re-inforced concrete plate or a steel plate



If the groundwater level is above the top of the pipe, it is necessary to check the global stability as regards the high axial stress level used.

For further information contact LOG-STOR.

Traffic load

If the minimum soil cover complies with the above recommendations, the pipes are safe for heavy traffic loads (100 kN wheel load) up to DN 600.

If the soil cover is minor, it is necessary to use e.g. a steel plate or a reinforced con-crete plate.

Soil cover

Maximum soil cover

To ensure the bond between steel service pipe and PUR foam, the pipes cannot be installed too deep in the ground.

If the following maxima are complied with, the frictional force will be within the limit for the shear stress in the pipes according to EN 13941.

Under special conditions, the pipes can be installed deeper, especially if they are in the locked zones.

For further information contact LOGSTOR.

Steel pipe Ø mm	Max soil cover over pipe		
	Series 1 m	Series 2 m	Series 3 m
26.9	2.00	1.70	1.50
33.7	2.60	2.10	1.80
42.4	2.60	2.30	2.00
48.3	3.00	2.60	2.30
60.3	3.30	2.90	2.50
76.1	3.70	3.30	2.90
88.9	3.60	3.20	2.90
114.3	3.90	3.40	3.00
139.7	4.10	3.70	3.30
168.3	4.40	3.90	3.50
219.1	4.60	4.10	3.60
273.0	4.50	4.00	3.50
323.9	4.70	4.20	3.70
355.6	4.70	4.20	3.60
406.4	4.70	4.20	3.70
457.0	4.80	4.20	3.70
508.0	4.70	4.10	3.60
610.0	4.90	4.30	3.90

Use of original material for backfilling

In the zones, locked by friction, L_L, the material which is excavated, can be reused, if it is sandy and after elimination of objects larger than 60 mm.

The backfill material must not contain more than 2% organic material.

It must be reestablished in a way which complies with the requirements of local authorities.

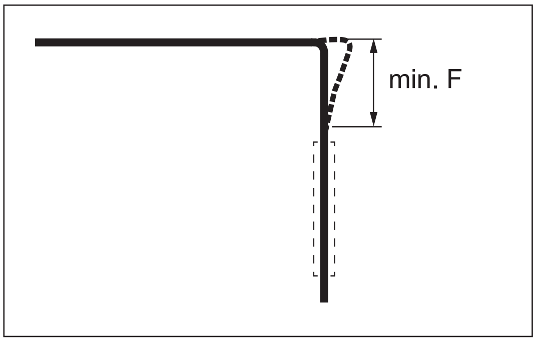
Branch connections to these zones shall be backfilled with friction material, see the section "Trench: Backfill material".

Crossings in protective pipes

Crossings in protective pipes can be used with due regard to the following:

- Use of supports to safeguard the pipes and joints.
- The distance between supports is set in correlation to the axial stress level in the steel pipe, see global stability.
- Less friction in the protective pipe which can lead to major expansion at bends, especially if the protective pipe is situated close to an end.

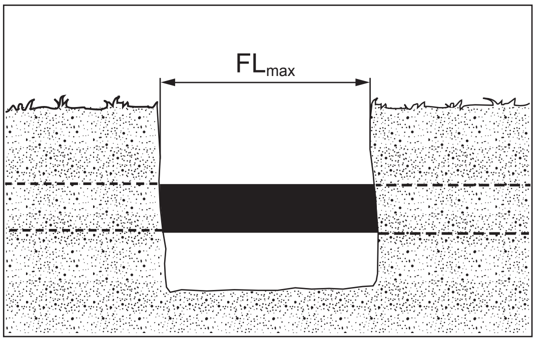
- If the pipe is exposed to lateral movement, i.e. near bends and branches, there must be sufficient space or it shall be ensured that the protective pipe is stopped where the lateral movement is zero.
  Length of the F-measurement, see the section "Directional changes".



Excavating pipes

Maximum free length

The allowable length of excavating a pipe in operation depends on the actual axial stress level in the service pipe at the point.



The table shows the maximum excavated lengths, FL_{190} at a 190 MPa axial stress level.

If the axial stresses are over the yield point, the third column applies.

This will occur, if the axial stress is higher than approx. 210 MPa or at a temperature difference of 85°C

If there is another stress level the following formula can be used to calculate the length FL_{max}:

$$FL_{max} = FL_{190} \cdot \sqrt{\frac{190}{\sigma}}$$

Example:
Actual stress level is 120 MPa
Pipe: Ø 219.1; FL_{190} = 6.5 m

$$FL_{max} = 6.5 \cdot \sqrt{\frac{190}{120}} = 8.1 \text{ m}$$

Steel pipe Ø mm	FL_{190} m	σaxial > ReT (ΔT > 85° C) m
26.9	0.7	0.5
33.7	0.9	0.7
42.4	1.2	0.8
48.3	1.4	1.0
60.3	1.7	1.2
76.1	2.2	1.5
88.9	2.6	1.8
114.3	3.3	2.3
139.7	4.1	2.8
168.3	4.9	3.4
219.1	6.5	4.4
273.0	8.1	5.5
323.9	9.6	6.5
355.6	10.5	7.1
406.4	12.0	8.1
457.0	13.6	9.1
508.0	15.1	10.2
610.0	18.1	12.2

Distance to other utility lines

Preinsulated pipes shall be installed with due regard to other utility lines.

Often there will be local regulations in different countries or regions.

If there are special requirements to the casing temperature, this can be calculated by means of LOGSTOR Calculator, which is free to use on http://calc.logstor.com.

References

Handling & Installation — Section: "Excavation, installation, and backfilling of trench"

Straight pipes
Overview

Introduction

This section gives a detailed account of the methods which can be used to reduce the axial stresses and of the maximum stress level for high axial stresses in straight pipe sections.

Contents

Straight pipes without stress reduction
Stress reduction with bends
Stress reduction by prestressing in open trench
Stress reduction with E-Comps

Straight pipes without stress reduction

Definition

When a straight pipe section is built without stress reduction - except for natural directional changes - the temperature variation load is absorbed as stresses in the section, locked by friction and as expansions at bends, coming from the partly restrained section.

Low axial stress

Low design temperatures, below 95°C (a temperature difference of 85°C from installation at 10°C), result in low axial stresses and are defined in project class A for small pipes.

High axial stress

At high design temperatures the yield stress (Re) of the steel is exceeded. This results in high axial stresses and is defined in project class B for small pipes.

Stress diagram

The maximum axial stress in the section, locked by friction can be calculated from the following formula.

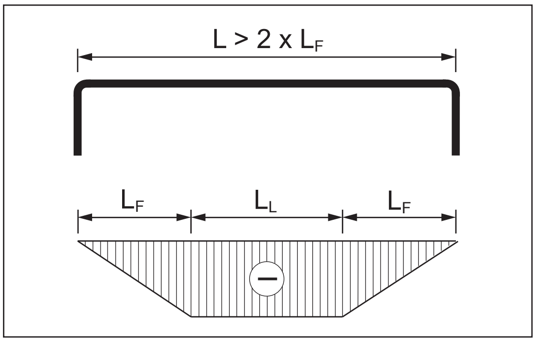
$\sigma_{max} = (T_{max} - T_{ins}) \cdot 2.52$ [MPa]

From the bends the stress rises from zero to σ_{max}. This distance is called L_F, friction length

The diagram is based on a distance between the bends which is longer than $2 \cdot L_F$.

For details see the section "General: Axial stress level".

L_L = section, locked by friction
L_F = friction length



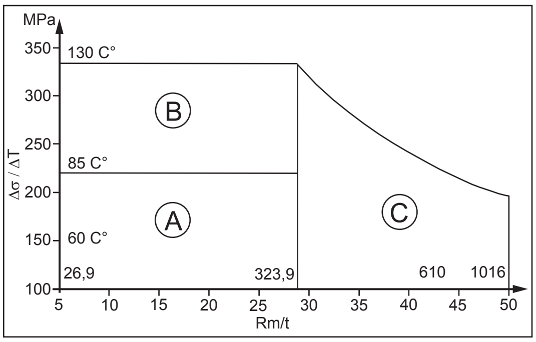
Maximum temperature/axial stress level

From the illustration the maximum allowable stress or temperature difference for high axial stress systems appears for EN 253 steel qualities and dimensions.

The diagram is stated in EN 13941.

The horizontal axis is the relation between the middle radius and wall thickness of the steel pipe.

The vertical axis is the maximum axial stresses and the temperature difference between installation and maximum temperature.



Straight pipes without stress reduction

Maximum temperature/axial stress level, *continued*

For dimensions up to and including ø 323.9 mm, the allowable temperature load is ΔT = 130°C, corresponding to an axial stress level of 334 MPa.

For major dimensions the allowable temperature load decreases due to risk of local instability.

If the stress limits in the table or the maximum temperature differences are fulfilled, the pipes can be installed without any stress reduction.

[1)]Temperature difference is based on α and E at 130°C

See detailed stress determination in the section "General: Project classes" for parameters to be assessed when checking the global stability.

ø mm	Limit	
	$\Delta\sigma$ [MPa]	ΔT [°C] [1)]
355.6	308	120
406.4	279	109
457	249	97
508	225	88
610	212	83
711	205	80
813	198	77
914	200	78
1016	198	77
1219	188	73

Conclusion

Installation without stress reduction gives the lowest initial costs.

For systems, operating at low temperatures this installation method is absolutely preferable.

For systems with high axial stresses it is an advantage, especially for smaller dimensions in areas with or without few other underground utility lines.

For large dimensions local conditions may make it appropriate to operate with a lower maximum stress level due to:

- Large movements at branches and bends.
- Areas with many obstacles in the ground.
- Many directional changes
- The complexity of the system
- Global stability

See the section "Trench" for information about distances.

Straight pipes
1a, example without stress reduction

Conditions for example 1a

Straight pipe section:	1800 m
Dimension:	ø139.7 mm, series 2
Soil cover:	H = 0.8 m
Maximum design temperature:	T_{max} = 130°C
Minimum design temperature:	T_{min} = 10°C
Installation temperature:	T_{ins} = 10°C

Maximum axial stress

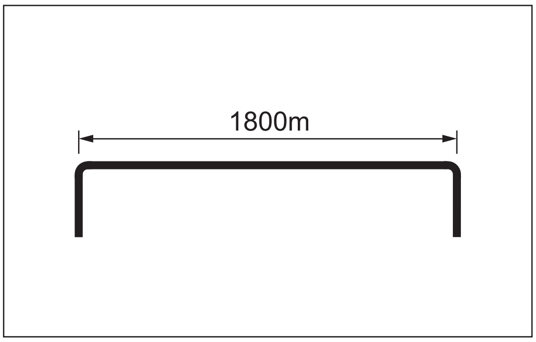
Maximum stress level in the section, locked by friction:

$\sigma_{max} = (T_{max} - T_{ins}) \cdot 2.52$ [MPa]

$\sigma_{max} = (130 - 10) \cdot 2.52 = 302$ MPa

The straight pipe section can be installed without any stress reduction as the temperature difference is less than 334 MPa, which is the limit for a ø139,7 mm pipe, see the section: "Straight pipes: Straight pipes without stress reduction".

As mentioned in the section "General: Project classes" this is possible in consideration of the global stability, the bends and the branches.



1b , example without stress reduction

Conditions for example 1b

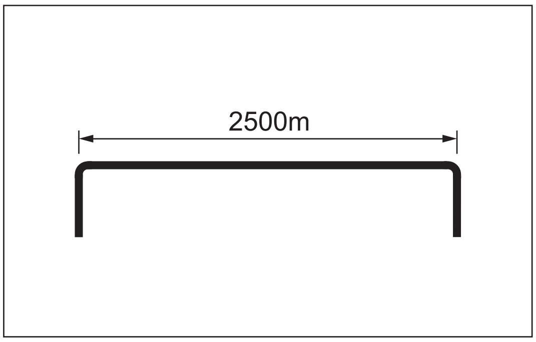
Straight pipe section:	2500 m
Dimension:	ø 457 mm, series 1
Soil cover:	H = 1.0 m
Maximum design temperature:	T_{max} = 100°C
Minimum design temperature:	T_{min} = 10°C
Installation temperature:	T_{ins} = 0°C

Maximum axial stress

Maximum stress level in the section, locked by friction:

$\sigma_{max} = (T_{max} - T_{ins}) \cdot 2.52$ [MPa]

$\sigma_{max} = (100 - 0) \cdot 2.52 = 252$ MPa



The straight pipe section can be installed without any stress reduction as the axial stress difference is less than 270 MPa, which is the limit for a ø 457 mm pipe, see the section: "Straight pipes: Straight pipes without stress reduction".

As mentioned in the section "General: Project classes" this is possible in consideration of the global stability, the bends and the branches.

Stress reduction with bends

Definition

When reducing stresses by means of bends, the pipes are covered before the system is heated.

The distances between the expansion bends have been adjusted to ensure that the distance between 2 bends is only so long that the axial stresses do not exceed the determined stress level.

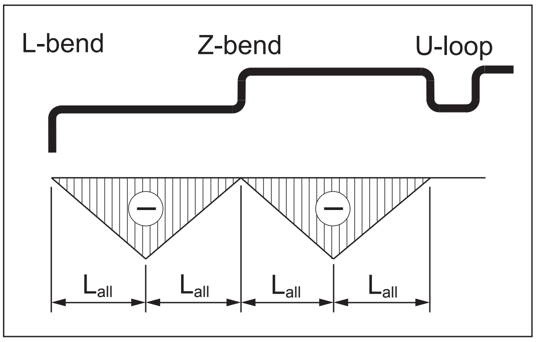
The distance from a bend to the point with the wanted stress level is called the installation length, and has the indices with the actual stress level.

Example:

L_{190} is the distance giving the stress level of 190 MPa.

This means that the length between 2 bends can be maximum 2 $\cdot L_{190}$.

If it is longer, the indicated stress level will be exceeded.



Installation length L_{190}

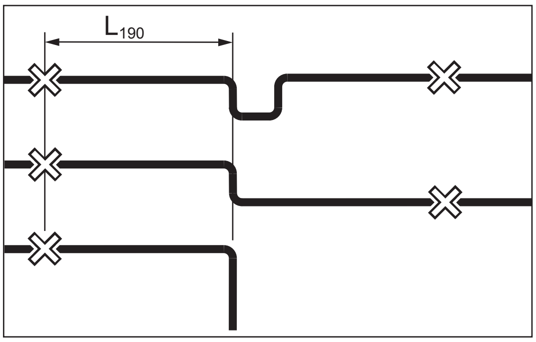
In principle the allowable stress can be chosen freely, provided it lies within the limit curve for local stability, see the section "General: Detemination of allowable axial stress level".

In the tables in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" the installation length L_{190} for 190 MPa axial stress level is stated as a function of the cover. This level can be converted into another level by means of the formulas on the next page.

An area or a section with stress reduction by means of bends can be combined with a system with high axial stresses without problems, if a stress reduction in certain areas of the system is required due to stability etc.

Bends to be used can be L, Z, or U-bends. The angle must always be between 80 and 90°, otherwise the bends cannot be considered to expand freely and special calculations need to be done.

Calculation of the bend itself, see section "Directional changes".



Stress reduction with bends

Installation length L_{190}, *continued*

Stress reduction - especially with U-bends - is an expensive method, and should consequently only be used when other solutions are not applicable.

The use of axial compensators can be considered to be an expansion, but was mainly used earlier. In case of use, please contact LOGSTOR Denmark Holding ApS.

Installation length, other stress levels

To calculate the installation length for other stress levels the following formulas can be used:

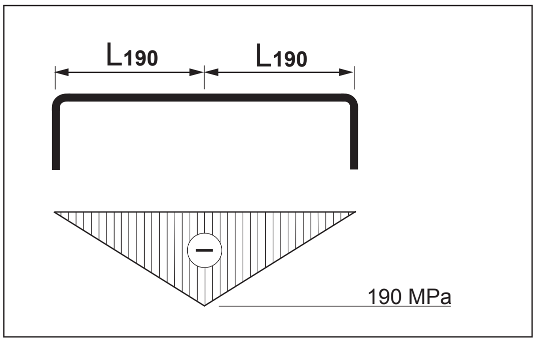
$$L_{all} = L_{190} \frac{\sigma_{all}}{190}$$

where L_{190} is derived from the table for the actual dimension and cover

or

$$L_{all} = \frac{\sigma_{all} \cdot A_s}{F}$$

where the cross-sectional area A_s and the friction force F are derived from the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" for the actual dimension and cover.



Stress reduction with bends - Tables of installation lengths

Conditions for the tables

Allowable axial stress level	σall	190 MPa
Internal friction angle of soil	φ	32.5 °
Gravity of soil	γ	19 kN/m^3
Friction coefficient, PE/soil	μ	0.40

Series 1, L_{190}

d	D_C	A_s	Friction force F				Installation length L_{190}			
			H=0.60 m	H=0.80 m	H=1.00 m	H=1.50 m	H=0.60 m	H=0.80 m	H=1.00 m	H=1.50 m
mm	mm	mm	kN/m	kN/m	kN/m	kN/m	m	m	m	m
26.9	90	198	0.97	1.28	1.59	2.38	39	29	24	16
33.7	90	254	0.97	1.29	1.6	2.38	50	38	30	20
42.4	110	325	1.2	1.58	1.96	2.91	52	39	32	21
48.3	110	373	1.2	1.58	1.96	2.92	59	45	36	24
60.3	125	523	1.37	1.81	2.24	3.33	72	55	44	30
76.1	140	667	1.55	2.04	2.52	3.74	82	62	50	34
88.9	160	862	1.79	2.35	2.9	4.29	91	70	56	38
114.3	200	1252	2.28	2.97	3.66	5.4	105	80	65	44
139.7	225	1539	2.59	3.38	4.16	6.11	113	87	70	48
168.3	250	2065	2.93	3.8	4.66	6.83	134	103	84	57
219.1	315	3034	3.8	4.89	5.99	8.72	152	118	96	66
273	400	4210	4.98	6.37	7.75	11.22	161	126	103	71
323.9	450	5600	5.75	7.31	8.87	12.78	185	145	120	83
355.6	500	6158	6.49	8.23	9.96	14.3	180	142	117	82
406.4	560	7919	7.47	9.41	11.35	16.21	201	160	133	93
457	630	8920	8.60	10.79	12.97	18.44	197	157	131	92
508	710	9930	9.93	12.39	14.85	21.01	190	152	127	90
610	800	13448	11.70	14.47	17.25	24.18	218	177	148	106

Stress reduction with bends - Tables of installation lengths

Series 2, L_{190}

d	D_C	A_s	Friction force F				Installation length L_{190}			
			H=0.60 m	H=0.80 m	H=1.00 m	H=1.50 m	H=0.60 m	H=0.80 m	H=1.00 m	H=1.50 m
mm	mm	mm	kN/m	kN/m	kN/m	kN/m	m	m	m	m
26.9	110	198	1.19	1.57	1.95	2.91	32	24	19	13
33.7	110	254	1.19	1.58	1.96	2.91	40	31	25	17
42.4	125	325	1.36	1.8	2.23	3.32	45	34	28	19
48.3	125	373	1.37	1.8	2.23	3.32	52	39	32	21
60.3	140	523	1.54	2.03	2.51	3.73	64	49	40	27
76.1	160	667	1.78	2.33	2.89	4.28	71	54	44	30
88.9	200	862	2.25	2.94	3.64	5.37	73	56	45	30
114.3	225	1252	2.57	3.35	4.13	6.08	93	71	58	39
139.7	250	1539	2.89	3.76	4.63	6.79	101	78	63	43
168.3	280	2065	3.29	4.26	5.23	7.66	119	92	75	51
219.1	355	3034	4.3	5.53	6.76	9.84	134	104	85	59
273	450	4210	5.63	7.19	8.75	12.65	142	111	91	63
323.9	500	5600	6.42	8.15	9.89	14.22	166	131	108	75
355.6	560	6158	7.31	9.25	11.20	16.05	160	126	105	73
406.4	630	7919	8.45	10.63	12.82	18.28	178	141	117	82
457	710	8920	9.76	12.22	14.68	20.84	174	139	115	81
508	800	9930	11.28	14.05	16.82	23.76	167	134	112	79
610	900	13448	13.25	16.37	19.50	27.30	193	156	131	94

Series 3, L_{190}

d	D_C	A_s	Friction force F				Installation length L_{190}			
			H=0.60 m	H=0.80 m	H=1.00 m	H=1.50 m	H=0.60 m	H=0.80 m	H=1.00 m	H=1.50 m
mm	mm	mm	kN/m	kN/m	kN/m	kN/m	m	m	m	m
26.9	125	198	1.36	1.79	2.22	3.31	28	21	17	11
33.7	125	254	1.36	1.79	2.23	3.31	35	27	22	15
42.4	140	325	1.53	2.02	2.5	3.72	40	31	25	17
48.3	140	373	1.54	2.02	2.51	3.72	46	35	28	19
60.3	160	523	1.77	2.32	2.88	4.27	56	43	35	23
76.1	180	667	2.01	2.63	3.26	4.82	63	48	39	26
88.9	200	862	2.25	2.94	3.64	5.37	73	56	45	30
114.3	250	1252	2.87	3.73	4.6	6.77	83	64	52	35
139.7	280	1539	3.25	4.22	5.19	7.62	90	69	56	38
168.3	315	2065	3.72	4.81	5.9	8.64	105	82	66	45
219.1	400	3034	4.87	6.26	7.65	11.11	118	92	75	52
273	500	4210	6.29	8.03	9.76	14.1	127	100	82	57
323.9	560	5600	7.23	9.18	11.12	15.97	147	116	96	67
355.6	630	6158	8.29	10.48	12.66	18.12	141	112	92	65
406.4	710	7919	9.61	12.07	14.53	20.69	157	125	104	73
457	800	8920	11.11	13.88	16.66	23.59	153	122	102	72
508	900	9930	12.83	15.95	19.07	26.88	147	118	99	70
610	1000	13448	14.87	18.33	21.80	30.47	172	139	117	84

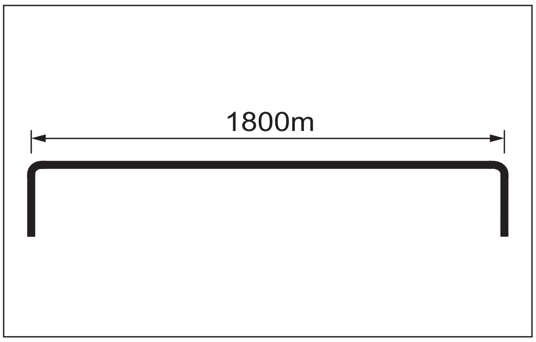
2a, example of stress reduction with bends

Conditions for example 2a

Straight pipe section:	1800 m
Dimension:	ø 139.7 mm, series 2
Soil cover:	H = 0.8 m
Maximum design temperature:	T_{max} = 130°C
Minimum design temperature:	T_{min} = 10°C
Installation temperature:	T_{ins} = 10°C

Maximum distance between bends

According to the section: "Straight pipes: Straight pipes without stress reduction" a straight pipe section can be installed with high axial stresses without any stress reduction.



If the axial stress level - for reason of stability or wish from the owner of the pipe system - is to be reduced for example to 190 MPa, it is done as follows:

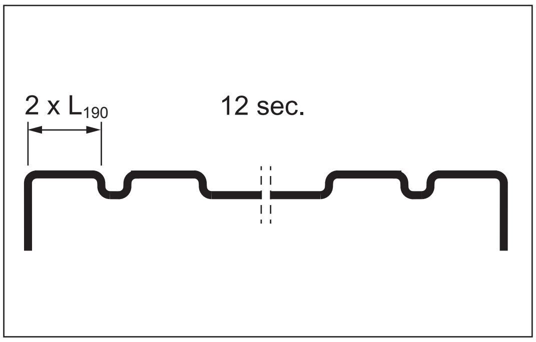
From the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" it appears that L_{190} = 78 m

The 1800 m have to be divided into sections:

$$\text{Min No. of sections} = \frac{L}{2 \cdot L_{all}} = \frac{1800}{2 \cdot 78}$$

$$= 11.5 \cong 12 \text{ sections max } 2 \cdot L_{190} \text{ long}$$

Each section has to be separated by means of L, Z or U bends.



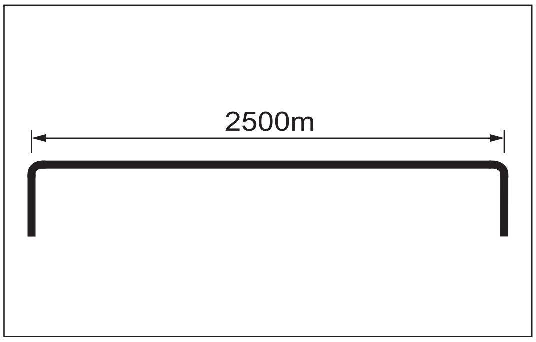
Straight pipes
2b, example of stress reduction with bends

Conditions for example 2b

Straight pipe section:	2500 m
Dimension:	ø 457 mm, series 1
Soil cover:	H = 1.0 m
Maximum design temperature:	T_{max} = 100°C
Minimum design temperature:	T_{min} = 10°C
Installation temperature:	T_{ins} = 0°C

Maximum distance between bends

According to the section: "Straight pipes: Straight pipes without stress reduction" a straight pipe section can be installed with high axial stresses without any stress reduction.



If the axial stress level - for reason of stability or wish from the owner of the pipe system - is to be reduced for example to 190 MPa, it is done as follows:

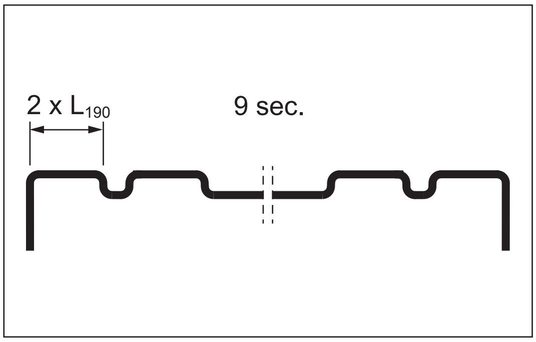
From the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" it appears that L_{190} = 147 m

The 2500 m have to be divided into sections:

$$\text{Min No. of sections} = \frac{L}{2 \cdot L_{all}} = \frac{2500}{2 \cdot 147}$$

$$= 8.5 \cong 9 \text{ sections max } 2 \cdot L_{190} \text{ long}$$

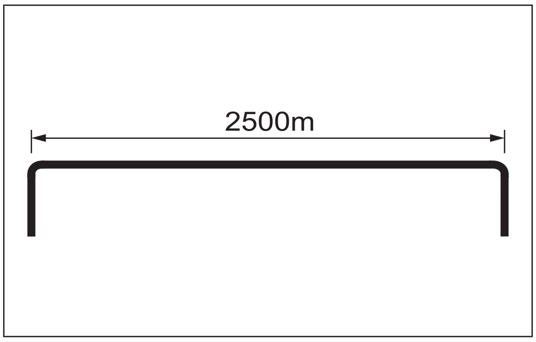
Each section has to be separated by means of L, Z or U bends.



2c, example of stress reduction with bends

Example 2c

The same as example 2b, but with higher maximum temperature.



Maximum design temperature T_{max} = 130°C

The axial stress level shall be within the limit for local stability (see table in the section "Straight pipes: Straight pipes without stress reduction").

The stress level shall be reduced to 270 MPa

The installations length L_{270} can be calculated in two ways:

1)

$$L_{all} = L_{190} \frac{\sigma_{all}}{190}$$

From the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" it appears that L_{190} = 147 m

$$L_{270} = 147 \cdot \frac{270}{190} = 209 \text{ m}$$

or 2)

$$L_{all} = \frac{\sigma_{all} \cdot A_s}{F}$$

From the table on page in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" it appears that:

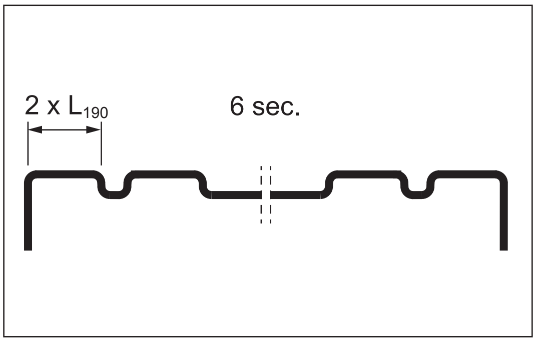
A_s = 8920 mm^2
F = 11.51 kN/m^2

$$L_{270} = \frac{270 \cdot 8920}{11.51 \cdot 1000} = 209 \text{ m}$$

The 2500 m have to be divided into sections:

$$\text{Min No. of sections} = \frac{L}{2 \cdot L_{all}} = \frac{2500}{2 \cdot 209}$$

$$= 5.9 \cong 6 \text{ sections max } 2 \cdot L_{270} \text{ long}$$



Each section has to be separated by means of L, Z or U bends.

References

LOGSTOR Calculator: http://calc.logstor.com/

Straight pipes
Stress reduction by prestressing in open trench

Definition

When pipes are heat prestressed, they are heated to the mean temperature of the system prior to backfilling.

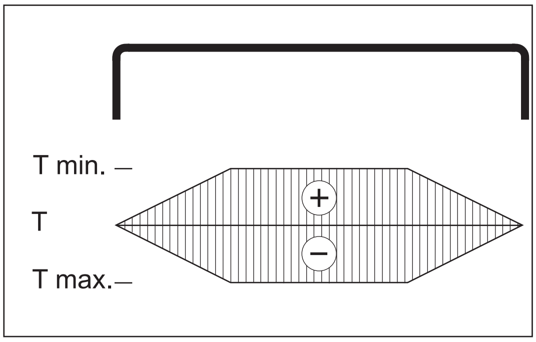
All subsequent temperature variations are consequently absorbed as compressive or tensile stress variations in the long sections, locked by friction.

Heat prestressing is suitable, when the trench may be open for some time e.g. in connection with major transmission pipelines.

Because the trench is backfilled at mean temperature, the movements at the bends will be relatively small, but in both directions.

As expansions at maximum temperature and as contractions at minimum temperature

This also means that - even though a system is heat prestressed - the cyclic fatigue of the bends is the same as in other systems.



Description

For smaller pipe dimensions heat prestressing can be carried out with water from the existing system. For larger dimensions (> DN 300) it is recommended to use electricity or vacuum steam to heat the pipes.

All pipe heating methods have the following requirements in common:
- Strict temperature control
- Heating in open trench
- Control of the linear expansion
- Securing the pipe longitudinally and transversely

When the preheating temperature has been reached and the pipes have expanded the calculated length, the trench can be backfilled.

It is important that the prestressing temperature is maintained during backfilling.

As the weight of the pipes might reduce the full expansion movement, it may be necessary to enable the pipes to expand by lifting them or preheating adequately short sections.

When preheating in sections, allowance must be made for possible contractions and expansions of the already established preheated sections.

Stress reduction by prestressing in open trench

Prestressing temperature and axial stress

Usually the mean temperature of the system is used when prestressing, which results in the compressive and tensile stresses in the pipes settling at the same level.

When choosing another prestressing temperature, the maximum axial stresses can be calculated according to the following formulas:

Tensile stress during cooling:
$\sigma = (T_{Pre} - T_{Min}) \cdot \alpha \cdot E$

Compressive stress during heating:
$\sigma = (T_{Max} - T_{Pre}) \cdot \alpha \cdot E$

For the simplified calculation 2.52 is used for $\alpha \cdot E$

It must be ensured that the axial stresses do not exceed the allowable stress σ_{all}, and special attention shall be paid to the tensile stress from cooling.

The pipes are more sensible to high tensile stresses than high compressive stresses.

Expansion

Prior to preheating the expansion at the bends must be calculated.

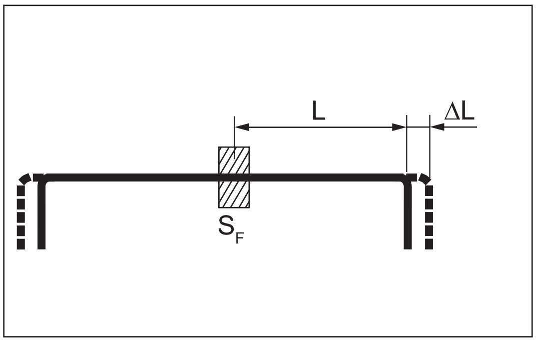
$\Delta L = (T_{Pre} - T_{Ins}) \cdot \alpha \cdot L$

$T_{Pre} = 0.5 \cdot (T_{max} + T_{min})$ = Heat prestressing temperature

T_{max} = Maximum design temperature
T_{Ins} = Installation temperature
α = Expansion coefficient of steel

The length L is determined as the distance from sand fixation to the pipe end.

Sand fixation (S_F):
The point where the pipes are locked by backfilling the trench.



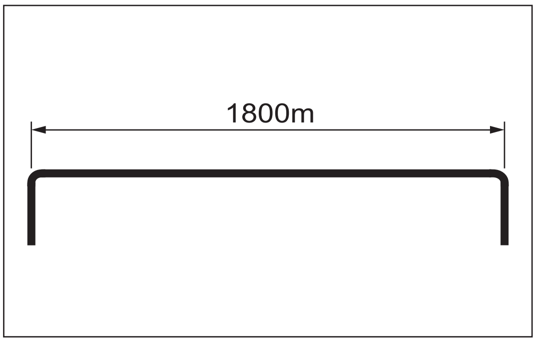
Straight pipes
3a, example of stress reduction by heat prestressing

Conditions for example 3a

Straight pipe section:	1800 m
Dimension:	ø 139.7 mm, series 2
Soil cover:	H = 0.8 m
Maximum design temperature:	T_{max} = 130°C
Minimum design temperature:	T_{min} = 10°C
Installation temperature:	T_{ins} = 10°C

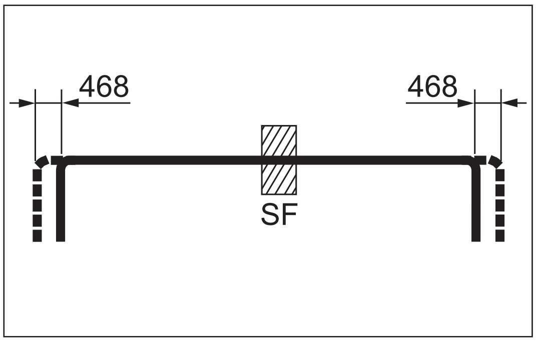
Expansion and stresses

According to the section: "Straight pipes: Straight pipes without stress reduction" the straight pipe section can be installed with high axial stresses without any stress reduction.



If the axial stress level - for reason of stability or wish from owner - is to be reduced, the pipe section can be prestressed.

$T_{Pre} = 0.5 \cdot (T_{max} - T_{min}) = 0.5 \cdot (130 - 10) = 70°C$



A sand fixation is established in the middle - 900 m from one end.

The expected expansion at the 2 ends when heat prestressing in open trench will then be:

$\Delta L = (T_{Pre} - T_{Ins}) \cdot \alpha \cdot L$

$\Delta L_1 = \Delta L_2 = (70 - 10) \cdot 1.2^{-5} \cdot 900 \cdot 1000 =$ 468 mm.

In this example the prestressing temperature has been set at the middle between the installation and the maximum temperature.

The axial stress will be:

$\sigma_{Max} = (T_{Max} - T_{Pre}) \cdot 2.52$

$\sigma_{Max} = (130 - 70) \cdot 2.52 = 151$ MPa

As compressive stress at T_{max} and as tensile stress at T_{min}.

3b, example of stress reduction by heat prestressing

Conditions for example 3b

Straight pipe section:	1800 m
Dimension:	ø 457 mm, series 2
Soil cover:	H = 0.8 m
Maximum design temperature:	T_{max} = 130°C
Minimum design temperature:	T_{min} = 10°C
Installation temperature:	T_{ins} = 0°C

Expansion and stresses

Normally, the prestressing temperature is set as the average of the minimum and maximum design temperature.

If another temperature is chosen, it can be more convenient to use the return water in the system.

In this example the prestressing temperature is 55°C.

The pipe is divided into two parts of 1250 m.

A sand fixation is established 700 m from one end of the 1250 m.

The expected expansion at the 2 ends when heat prestressing in open trench will then be:

$\Delta L = (T_{Pre} - T_{Ins}) \cdot \alpha \cdot L$

$\Delta L_1 = (55 - 0) \cdot 1.2^{-5} \cdot 700 \cdot 1000 = 462$ mm

$\Delta L_2 = (55 - 0) \cdot 1.2^{-5} \cdot 1250 \cdot 1000 = 825$ mm

The stress at maximum design temperature, T_{max} = 130°C:

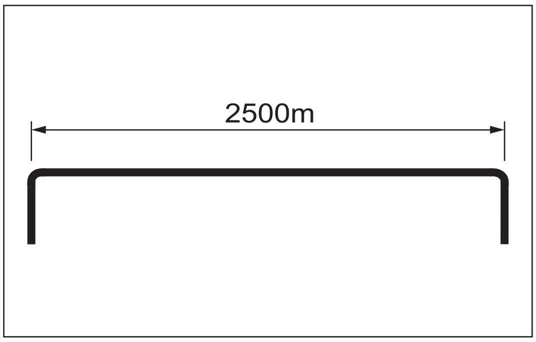
$\sigma_{Max} = (T_{Max} - T_{Pre}) \cdot 2.52$

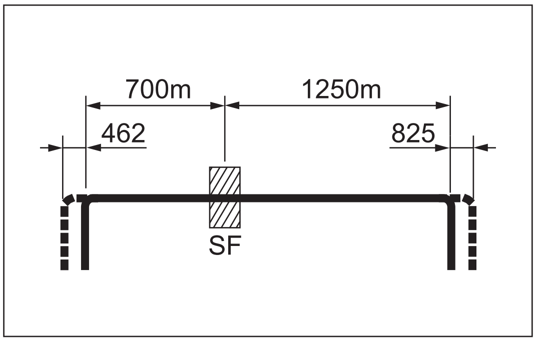
$\sigma_{Max} = (130 - 55) \cdot 2.52 = 189$ MPa as compressive stress.

The stress at minimum design temperature, T_{min} = 10°C:

$(T_{Pre} - T_{Min}) \cdot 2.52$

$\sigma_{Min} = (55 - 10) \cdot 2.52 = 113$ MPa as tensile stress.





Straight pipes
Stress reduction with E-Comps

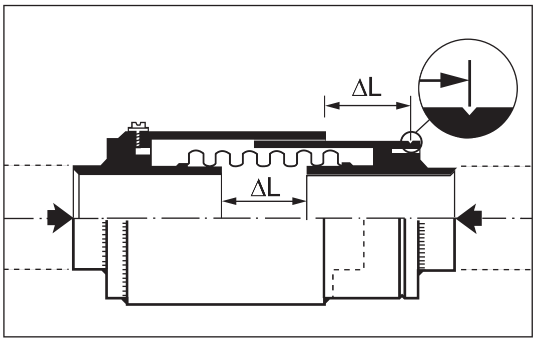
Definition

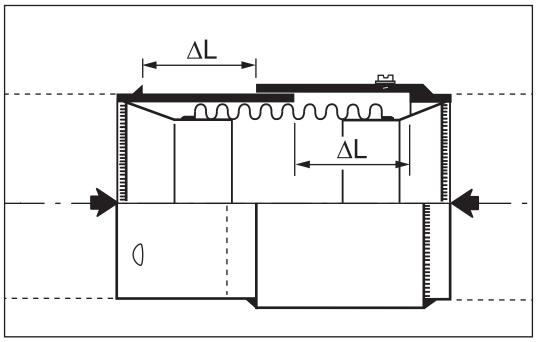
To compensate a pipe with E-Comps is statically a combination, where the temperature variations are converted to tensile and compressive stresses in the steel service pipe and where the E-Comps are installed to absorb a part of the first movement.

The system can be backfilled continually during construction except where E-Comps have been installed to absorb part of the first movement. Here it is necessary to keep a hole open until prestressing has been carried. If this is not possible it is necessary to make a temporary jointing and cover the trench temporarily.

The E-Comp

The E-Comp is a component, set to absorb the movement, occuring as a result from the temperature variation between the installation and the prestressing temperature. After having absorbed the movement the E-Comp is welded and can be regarded as a straight pipe.



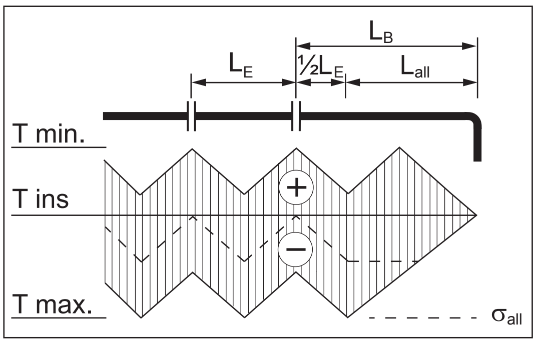


Stress diagram

The diagram shows a typical stress curve for a system, stress reduced with E-Comps.

The dotted line illustrates the stress level at the moment when the prestressing temperature is reached. Then the E-Comps are welded, and all temperature variations will now be absorbed as changes in the stress level in the areas, served by the E-Comps.

L_E Distance between E-Comps
L_B Distance between E-Comp and bend



Stress reduction with E-Comps

Line of actions

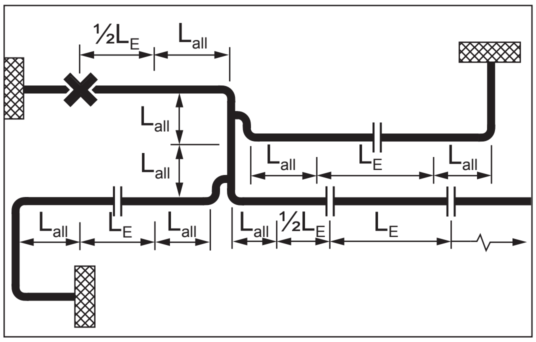
- The E-Comp is set to the calculated remaining movement that it shall absorb.
- The E-Comp is welded-in between 2 straight pipe lengths (min. 6 m) without directional changes
- PE foil is placed around the pipes on the section which the E-Comp serves. (Only if it is a precondition for the calculation)
- The trench can be backfilled except where there are E-Comps
- When the construction work is complete and prior to heating the system, the fixation of the E-Comp is removed.
- When the E-Comp has been closed, it is welded and pressure tested prior to installing a casing joint over it.

For a detailed description of the procedure, see the section "E-Comps: Installing E-Comps" in Handling & Installation.

System utilization

The friction length L_{all} is set from the bend.

Then the necessary number of E-Comps is placed in the section in between the friction lengths.



The required number is determined on the basis of the chosen stress level, soil cover, and temperature conditions of the system.

In order to reduce the friction, PE foil can be installed around the pipes in the sections, served by the E-Comp.

This increases the distance between the E-Comps, as the friction is reduced by 30%.

The E-system does not require anchors, because the friction force will be so high, that the movement is absorbed by the E-Comps during prestressing.

Anchors are only used to protect buildings or components against large movements.

Stress level

The allowable stress level can be chosen freely as long as it lies within the limit curve for local stability, see the section "General: Project classes".

The following tables include E-Comps for a maximum axial stress level of 190 MPa at a maximum temperature of 130°C.

The required temperature during prestressing is 85°C, and the distances are based on PE foil being installed around the pipes at the E-Comps.

Straight pipes
Tables, stress reduction with E-Comps

Conditions for the tables

Allowable axial stress level	σall	190 MPa
Internal friction angle of soil	φ	32.5°
Gravity of soil	γ	19 kN/m^3
Friction coefficient, PE casing/soil	μ	0.40
Friction coefficient, PE casing with foil/soil	μ	0.28
T_{max}		130 °C
T_{Pre}: (necesarry temperature)		85 °C
T_{Ins}:		10 °C

Series 1

d	D_C	Distance E-Comp L_{190}							
		H = 0.60 m		H = 0.80 m		H = 1.00 m		H = 1.50 m	
mm	mm	L_E, m	L_B, m	L_E, m	L_B, m	L_E, m	L_B, m	L_E, m	L_B, m
26.9	90	45	62	34	47	28	37	19	25
33.7	90	58	79	44	59	35	48	24	32
42.4	110	60	82	46	62	37	50	25	34
48.3	110	69	94	52	71	42	57	28	38
60.3	125	84	114	64	87	52	70	35	47
76.1	140	95	129	73	98	59	79	40	54
88.9	160	107	145	81	111	66	89	45	60
114.3	200	122	165	93	127	76	103	51	70
139.7	225	132	178	101	137	82	111	56	76
168.3	250	156	212	121	164	98	133	67	91
219.1	315	177	240	137	187	112	152	77	105
273	400	187	254	147	199	120	163	83	113
323.9	450	216	293	170	230	140	190	97	132
355.6	500	210	285	166	225	137	186	95	130
406.4	560	235	319	187	253	155	210	108	147
457	630	230	312	183	249	152	207	107	146
508	710	222	301	178	241	148	201	105	142
610	800	255	346	206	280	173	235	123	167

Straight pipes
Tables, stress reduction with E-Comps

Series 2

d	D_C	Distance E-Comp L_{190}							
		H = 0.60 m		H = 0.80 m		H = 1.00 m		H = 1.50 m	
mm	mm	L_E, m	L_B, m	L_E, m	L_B, m	L_E, m	L_B, m	L_E, m	L_B, m
26.9	110	37	50	28	38	23	31	15	21
33.7	110	47	64	36	49	29	39	19	26
42.4	125	53	72	40	54	32	44	22	30
48.3	125	61	82	46	62	37	50	25	34
60.3	140	75	102	57	78	46	63	31	42
76.1	160	83	113	63	86	51	69	35	47
88.9	200	85	115	65	88	53	71	36	48
114.3	225	108	147	83	112	67	91	46	62
139.7	250	118	160	91	123	74	100	50	68
168.3	280	139	189	107	146	87	119	60	81
219.1	355	156	212	122	165	99	135	68	93
273	450	166	225	130	176	107	145	74	100
323.9	500	194	263	152	207	126	170	87	118
355.6	560	187	253	148	200	122	165	85	115
406.4	630	208	282	165	224	137	186	96	130
457	710	203	275	162	220	135	183	95	129
508	800	195	265	157	213	131	178	93	126
610	900	225	305	182	247	153	208	109	148

Series 3

d	D_C	Distance E-Comp L_{190}							
		H = 0.60 m		H = 0.80 m		H = 1.00 m		H = 1.50 m	
mm	mm	L_E, m	L_B, m	L_E, m	L_B, m	L_E, m	L_B, m	L_E, m	L_B, m
26.9	125	32	44	25	33	20	27	13	18
33.7	125	41	56	31	43	25	34	17	23
42.4	140	47	64	36	48	29	39	19	26
48.3	140	54	73	41	56	33	45	22	30
60.3	160	66	89	50	68	40	55	27	37
76.1	180	74	100	56	76	45	62	31	42
88.9	200	85	115	65	88	53	71	36	48
114.3	250	97	131	74	101	60	82	41	56
139.7	280	105	142	81	110	66	89	45	61
168.3	315	123	167	95	129	78	105	53	72
219.1	400	138	187	107	146	88	119	61	82
273	500	148	201	116	158	96	130	66	90
323.9	560	172	233	135	184	112	152	78	105
355.6	630	165	223	130	177	108	146	75	102
406.4	710	183	248	145	197	121	164	85	115
457	800	178	242	142	193	119	161	84	114
508	900	172	233	138	187	115	157	82	111
610	1000	201	272	163	221	137	186	98	133

Stress reduction with E-Comps

Distances at other stress levels

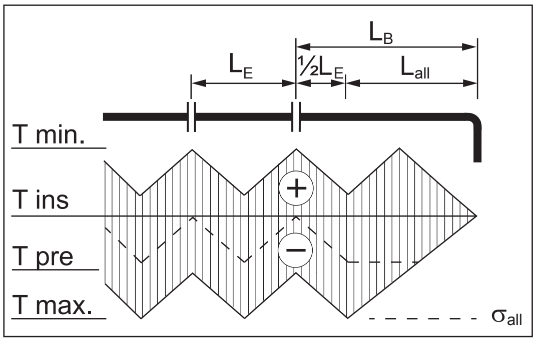
To calculate the distance L_E at other stress levels the following formula is applicable:

$$L_E = 2 \cdot \frac{(2 \cdot \sigma_{all} - \alpha \cdot E \cdot (T_{max} - T_{min})) \cdot A_s}{F}$$

L_B = Distance between E-Comp and bend
L_E = Distance between E-Comps
σ_{all} = Allowable axial stress level
$(\alpha \cdot E)$ is set to 2.52
T_{max} = Maximum design temperature
T_{min} = Minimum design temperature
T_{Pre} = Prestressing temperature
T_{Ins} = Installation temperature

The following can be found in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths".
A_s = the cross-sectional areal of the service pipe
F = Frictional force at the relevant soil cover.

If foil is used, F shall be reduced by 30%.



Prestressing temperatures

It must be checked whether the temperature, required to shut the compensators is obtainable or not.

$$T_{Pre} = T_{Ins} + \frac{\sigma_{all}}{\alpha \cdot E} = T_{Ins} + \frac{\sigma_{all}}{2.52}$$

It is important that the calculated prestressing temperature can be optained during preheating. If not, it is necessary to reduce the distance between the E-Comps!

For further information please contact LOGSTOR.

Presetting

The E-Comps are compressed to the right presetting which is identical to the calculated gap ΔL, built-in to absorb the expansion from the prestressing.

Please note that presetting only can be carried out, when the actual installation temperature is known.

The presetting values for E-Comps shall be calculated after the following formulas for movements coming from both sides.

If the distances differ, they shall be calculated for both sides.

If they are the same, multiply by 2 as shown here:

$$\Delta L_E = 2 \cdot (\alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_E - \frac{F \cdot ½L^2_E}{2 \cdot E \cdot A_s})$$

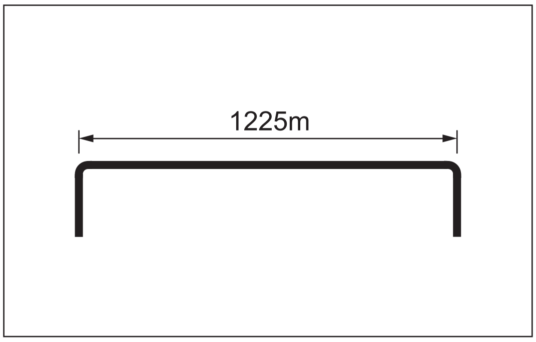
The formula for an E-Comp next to a bend:

$$\Delta L_B = \alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_B - \frac{F \cdot ½L^2_B}{2 \cdot E \cdot A_s} + ½ \cdot \Delta L_E$$

4a, example of stress reduction with E-Comps

Conditions for example 4a

This example shows how distances and presetting of the E-Comp are carried out, when the actual temperature sets comply with the conditions of the tables in the section: "Straight pipes: Tabels, stress reduction with E-Comps" so they are applicable.



Straight pipe section: 1225 m
Dimension: ø139.7 mm series 2
Soil cover: H = 0.8 m
Max. design temperature: T_{max} = 130°C
Min. design temperature: T_{min} = 10°C
Installation temperature: T_{Ins} = 10°C
PE foil to reduce the friction.

According to the section "Straight pipes: Straight pipes without stress reduction" the straight pipe section can be installed with high axial stresses without any stress reduction.

If the axial stress level - for reason of stability or wish from owner - is to be reduced to 190 MPa the following is found:

Values from table in the sectin: "Straight pipes: Tabels, stress reduction with E-Comps":
σ_{all} = 190 MPa
L_E = 91 m
L_B = 123 m

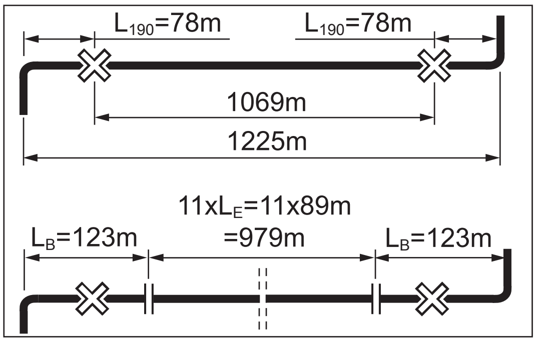
Values from table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths"
L_{190} = 78 m
A_s = 1539 mm^2
F = 3.76 kN/m

4a, example of stress reduction with E-Comps

Calculation of sections

$$\text{No. of sections} = \frac{L - (2 \cdot L_{190})}{L_E}$$

$$= \frac{1225 - (2 \cdot 78)}{91} \approx 12$$



The distance from the bend to the first E-Comp:
$L_B = ½ \cdot L_E + L_{190}$.

This means that $2 \cdot ½L_E$ is used at bends, so the actual number of sections are 12-1 = 11 pcs.

If the distance between the 12 E-Comps is completely utilized, what is left for L_B is:
$L_B = 0.5 \cdot (1225 – ((12\text{-}1) \cdot 89)) = 123$ m.

In this case it corresponds to the table value for L_B, but it can be shorter, if the total length is not obtained.

Prestressing temperature

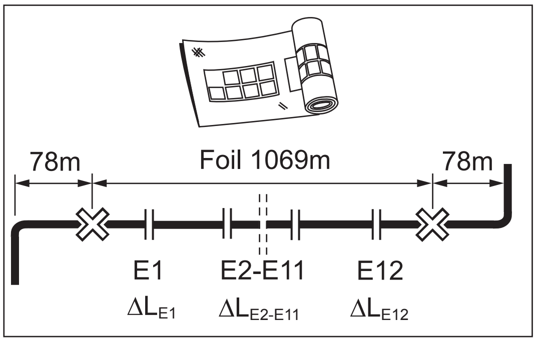
The necessary prestressing temperature is calculated as follows:

$$T_{Pre} = T_{Ins} + \frac{\sigma_{all}}{2.52} = 10 + \frac{190}{2.52} = 85°C$$

Presetting

The presetting distances ΔL are calculated as follows:

$$\Delta L_E = 2 \cdot (\alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_E - \frac{F \cdot ½L^2_E}{2 \cdot E \cdot A_s})$$



PE foil is installed between the E-Comps, so F shall be reduced by 30%.

The PE foil is installed in the illustrated sections.

$$\Delta L_E = 2 \cdot (0.000012 \cdot (85 - 10) \cdot (0.5 \cdot 89000) - \frac{3.76 \cdot 0.7 \cdot (0.5 \cdot 89000)^2}{2 \cdot 210000 \cdot 1539}) = 64 \text{ mm}$$

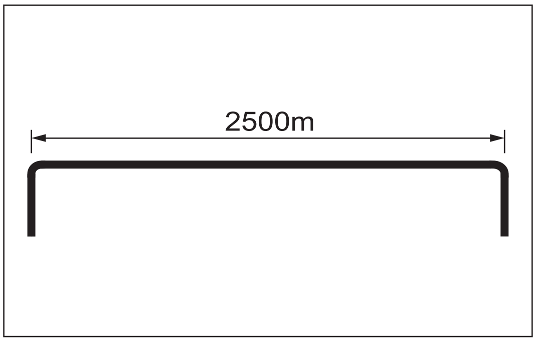
$$\Delta L_B = \alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_B - \frac{F \cdot ½L^2_B}{2 \cdot E \cdot A_s} + ½ \cdot \Delta L_E$$

$$\Delta L_B = (0.000012 \cdot (85 - 10) \cdot (0.5 - 123000) - \frac{3.76 \cdot 0.7 \cdot (0.5 \cdot 123000)^2}{2 \cdot 2100000 \cdot 1539} + 0.5 \cdot 64 = 72 \text{ mm}$$

4b, example of stress reduction with E-Comps

Conditions for example 4b

This example shows how distances and presetting of the E-Comp are carried out, when the actual temperature sets differ from the conditions in the section: "Straight pipes: Tabels, stress reduction with E-Comps" so everything has to be calculated manually.



Straight pipe section: 2500 m
Dimension: ø 457 mm series 1
Soil cover: H = 1.0 m
Max. design temperature: T_{max} = 100°C
Min. design temperature: T_{min} = 10°C
Installation temperature: T_{Ins} = 0°C
PE foil to reduce the friction.

According to the section "Straight pipes: Straight pipes without stress reduction" the straight pipe section can be installed with high axial stresses without any stress reduction.

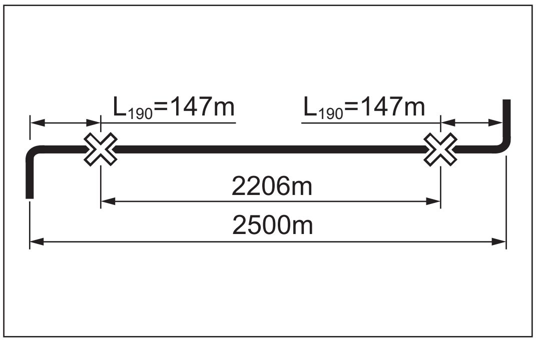
If the axial stress level - for reason of stability or wish from owner - is to be reduced to 190 MPa the pipe section can be prestressed by means of E-Comps.

Values from table in the section: "Straight pipes: Tables, stress reduction with E-Comps"
L_{190} = 147 m
A_s = 8920 mm^2
F = 11.51 kN/m

Calculation of L_E

The distance L_E is calculated for the actual temperatures and stress levels.

PE foil is installed between the E-Comps, so F shall be reduced by 30%.



$$L_E = 2 \cdot \frac{(2 \cdot \sigma_{all} - \alpha \cdot E \cdot (T_{max} - T_{min})) \cdot A_s}{F}$$

$$L_E = 2 \cdot \frac{(2 \cdot 190 - 2.52 \cdot (100 - 0)) \cdot 8920}{0.7 \cdot 11.51} = 283 \text{ m}$$

4b, example of stress reduction with E-Comps

Calculation of sections

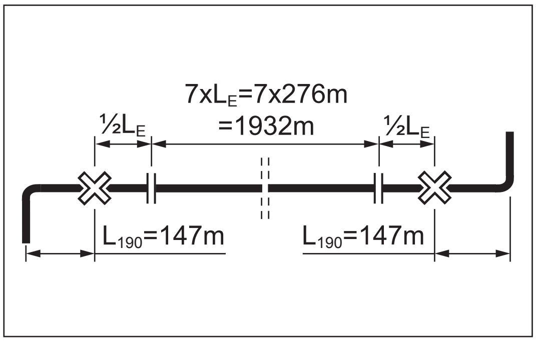
The distance from the bend to the first E-Comp:

$L_B = ½ \cdot L_E + L_{190}$.

From each end L_{190} is deducted which means:

$$\text{No. of sections} = \frac{L - (2 \cdot L_{190})}{L_E}$$

$$= \frac{2500 - (2 \cdot 147)}{283} \approx 8$$



Distance between E-Comps:

$$L_E = \frac{L - (2 \cdot L_{190})}{\text{No. of } L_E}$$

$$L_E = \frac{2500 - (2 \cdot 147)}{8} = 276 \text{ m}$$

Prestressing temperature

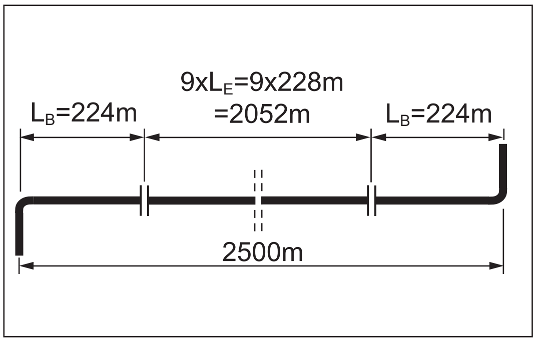
The necessary prestressing temperature is calculated as follows:

$$T_{Pre} = T_{Ins} + \frac{\sigma_{all}}{2.52} = 0 + \frac{190}{2.52} = 75°C$$

Presetting

The presetting distances ΔL are calculated as follows:

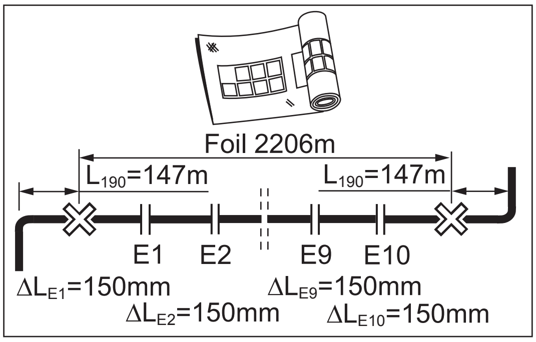
$$\Delta L_E = 2 \cdot (\alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_E - \frac{F \cdot ½L^2{}_E}{2 \cdot E \cdot A_s})$$



$$\Delta L_E = 2 \cdot (0.000012 \cdot (85 - 10) \cdot (0.5 \cdot 89000) - \frac{3.76 \cdot 0.7 \cdot (0.5 \cdot 89000)^2}{2 \cdot 210000 \cdot 1539}) = 64 \text{ mm}$$

Straight pipes
4b, example of stress reduction with E-Comps

Presetting, ***continued***



As the maximum length an E-Comp can absorb is 150 mm (see the section "Expansion and anchoring: E-Comp" in the Product Catalogue), the distance L_E needs to be reduced. This means an additional number of E-Comps must be used.

Number of section: 9 pcs – try with 2 more!

Distance between E-Comps:

$$L_E = \frac{2500 - 2 \cdot 147}{10} = 228 \text{ m}$$

$L_B = ½ \cdot (2500 – (10\text{-}1) \cdot 228) = 224$ m

With revised distances the presetting is:

$$\Delta L_E = 2 \cdot (\alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_E - \frac{F \cdot ½L^2_E}{2 \cdot E \cdot A_s})$$

$$\cdot_E = 2 \cdot (0.000012 \cdot (75 - 0) \cdot (0.5 \cdot 226000) - \frac{11.51 \cdot 0.7 \cdot (0.5 \cdot 226000)^2}{2 \cdot 210000 \cdot 8920}) = 150 \text{ mm}$$

$$\Delta L_B = \alpha \cdot (T_{Pre} - T_{Ins}) \cdot ½L_B - \frac{F \cdot ½L^2_B}{2 \cdot E \cdot A_s} + ½ \cdot \Delta L_E$$

$$\Delta L_B = 0.000012 \cdot (75 - 0) \cdot (0.5 \cdot 226000) - \frac{11.51 \cdot 0.7 \cdot (0.5 \cdot 226000)^2}{2 \cdot 210000 \cdot 8920} + 0.5 \cdot 150 = 150 \text{ mm}$$

References

Handling & Installation — Section "E-Comps"

Directional changes

Overview

Introduction

This section contains guidelines for designing directional changes in preinsulated pipe systems. It gives directions as to the type of directional change to choose for a specific purpose to obtain a technically and economically optimum system.

Directional changes must be carried out so neither the PUR insulation foam nor the service pipe is exposed to excessive load in accordance with EN13941. If the design directions in the following are observed, the maximum loads will be on level with the requirements in EN 13941. Temperature changes in the medium result in an expansion or contraction of the preinsulated pipes at directional changes, what may lead to fatigue of the steel pipes or deformation of the PUR-foam with the risk of inexpedient heating of the PEHD-casing.

This section contains formulas and tables, making the design more simple. Some of the formulas are integrated in tables which can be used under the stated conditions instead of the formulas to simplify the design with directional changes.

Contents

Elastic curves
Prefabricated curved pipes
Mitering
80-90° bends with foam pads
5-80° bends with foam pads

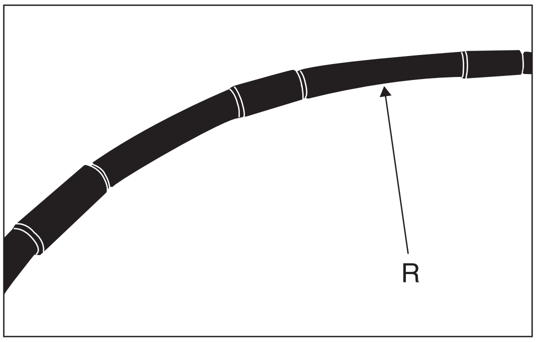
Directional changes
Elastic curves

General

With the LOGSTOR steel pipe system minor directional changes can be made by utilizing the elasticity of the pipes.

From a static point of view an elastic curve is regarded as a straight pipe. This means that an elastic curve does not result in stress concentrations like e.g. small angular deviations, arising when mitering the service pipe ends. It is therefore recommended to use elastic curves wherever possible.

The pipes are welded together in a straight section, installed in a curved trench by pulling the pipes in a soft curve. The shape of the curve is ensured by bending the pipe elastically around e.g. sand sacks.



Application

Elastic curves can be used instead of small traditional bends or small mitred bends.

The minimum bending radius is R = 500 · d, where d is the outside diameter. From the table the minimum bending radius and the corresponding angular deflections, measured over 12 and 16 m lengths respectively appear.

Minimum bending radius applies to all insulation series.

The stated minimum bending radius corresponds to a bending stress of 210 MPa in the service pipe.

Elastic curves can be used for horizontal and vertical directional changes, provided that the global stability of the pipe is secured.

For example at vertical directional changes it must be ensured that soil cover and soil pressure suffice to secure the stability of the pipe.

Calculation of angular motion and arc height, see the section "Curves: Utilizing elastic radius" in Handling & Installation.

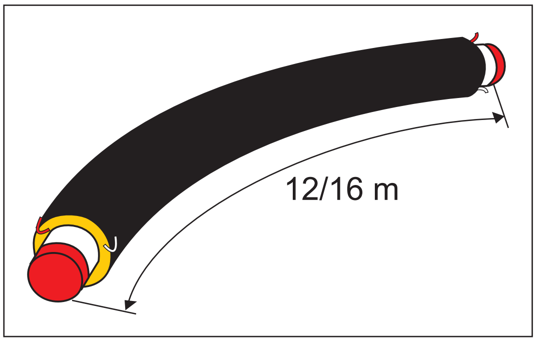
For further support please contact LOGSTOR.

d	Min. allowable radius	Angle for 12 m	Angle for 16 m
mm	m	°	°
26.9	13.5	51	-
33.7	16.9	41	-
42.4	21.2	32	-
48.3	24.2	28	-
60.3	30.2	23	-
76.1	38.1	18	-
88.9	44.5	15	-
114.3	57.2	12	16
139.7	69.9	9.8	13
168.3	84.2	8.2	11
219.1	110	6.3	8.4
273.0	137	5.0	6.7
323.9	162	4.2	5.7
355.6	178	3.9	5.2
406.4	203	3.4	4.5
457.0	229	3.0	4.0
508.0	254	2.7	3.6
610.0	305	2.3	3.0

Directional changes
Prefabricated curved pipes

General

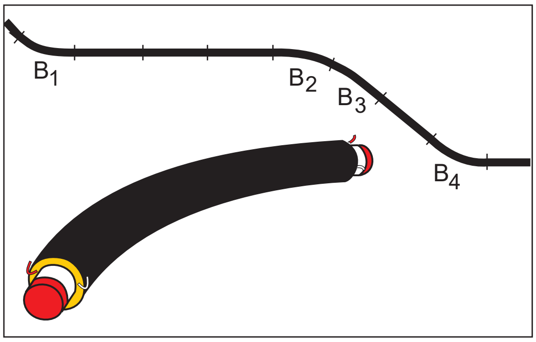
Curved pipes are used with advantage when the required radius is less than the allowable, elastic radius of the pipe dimension.



Application

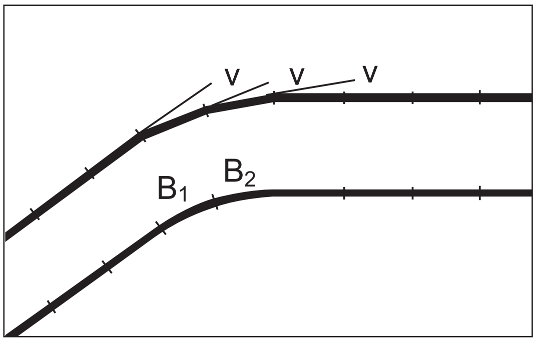
Curved pipes are used instead of traditional bends.

Especially in replacement of other angles than 90° the use of curved pipes is advantageous. Due to the larger radius moments and fatigue, stresses are considerably lower than in bends and can be used almost without limitations in the axial stresses or angles.

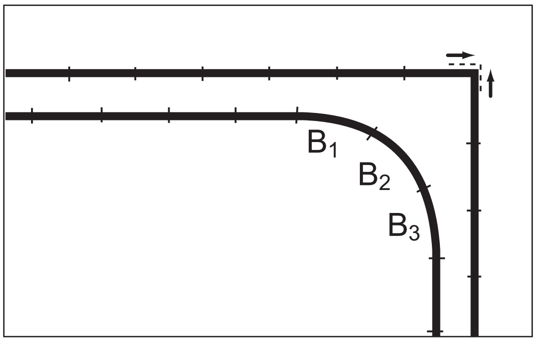


Possible solutions with curved pipes

- In replacement of mitred bends



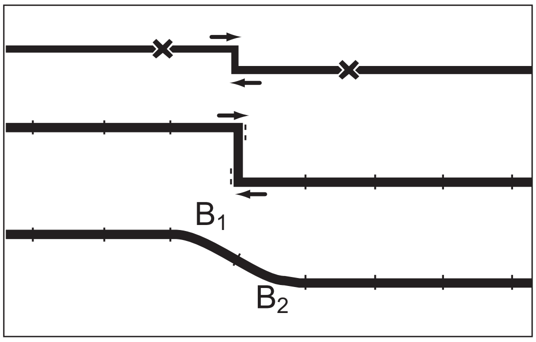
- For directional changes



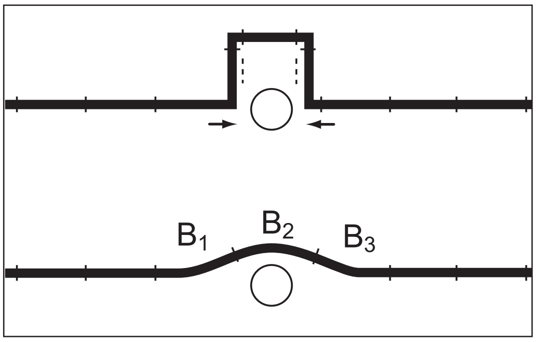
Prefabricated curved pipes

Possible solutions with curved pipes, *continued*

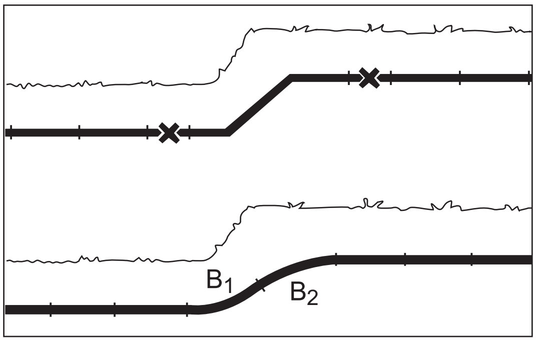
- In replacement of Z-bends it may be advantageous to use curved pipes.
  When using Z-bends there are limits to how short the distance between the parallel pipe runs can be.
  The distance is optional when using curved pipes.



- Bypassing obstacles

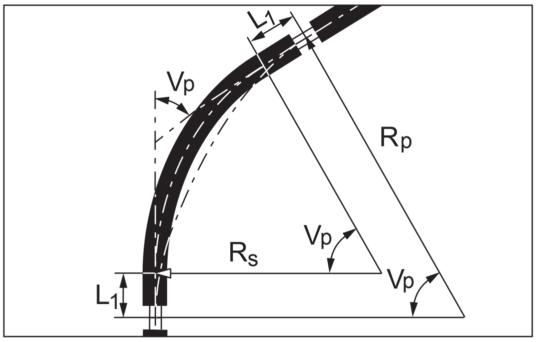


- Establishing level changes
  However, it must be ensured that the required stability is present, so the pipeline does not surface.



Prefabricated curved pipes

Designations of curved pipes



A factory-made curved pipe is delivered with a straight pipe piece at both ends (L_1), which have the same length in each dimension. L_1 appears from the tables on the following page.
Due to the straight pipe piece the actual bending radius is minor than the design radius.
A curved pipe is defined by the following designations:
V_p: Design/bending angle
R_p: Design radius
R_s: Segment radius (radius of the bent piece)
L_1: Length of straight pipe piece
Tol: Tolerance of angle+/- (see the section "Directional changes: Curved pipes" in the Product Catalogue).

Ordering curved pipes

When ordering curved pipes state angle and length of the curved pipes (12 or 16 m).
If surveillance is built into the system, it is significant for the position of the alarm wires whether the pipe is curved to the left, the right, up or down see the section "Directional changes: Curved pipes" in the Product Catalogue.
This must also be stated when ordering.

Max. angles and axial stresses

From the tables on the next page the maximum angle which a curved pipe can be delivered in as well as the stress level at which the maximum angle can be used appear. The values apply to horizontal directional changes and all insulation series with a soil cover of 0.6-1.5 m.

$V_{p.max}$: Max. design angle which each dimension can be bent in.
$R_{p.min}$: Min. design radius corresponding to maximum design angle.
L_1: Length of the straight pipe piece at the ends of the curved pipe.
σ_{max}: Max. axial stress at max. angle. In connection with higher axial stress the max. angle is reduced - see later in this section.
Soil pressure: The surrounding soil shall secure the global stability of the pipe. The table value states the passive soil pressure which must be present for the soil to render sufficient restraint.

The upper limit for the stress level, σ_{max}, ensures that:
- there is sufficient restraint in the soil to ensure the stability of the pipe system (Note: the groundwater level must not be above the pipes).
- the PUR insulation is not overloaded.

Prefabricated curved pipes

R_p at other angles

For minor values of V_p . R_p can be calculated as follows:

$$R_p = \frac{180 \cdot L_b}{\pi \cdot V_p}$$

where
L_b: The length of the curved pipe (12 or 16 m).

12 m curved pipe

d x t mm	V_p. max °	R_p. min m	L_1 m	σ_{max} MPa	Soil pressure MPa
76.1 x 2.9	25	27.5	0.6	334	0.068
88.9 x 3.2	33	20.8	0.6	270	0.083
114.3 x 3.6	38	18.1	0.56	207	0.086
139.7 x 3.6	43	16.0	0.63	175	0.093
168.3 x 4.0	45	15.3	0.67	148	0.101
219.1 x 5.0	41	16.8	0.89	135	0.104
273.0 x 5.0	36	19.1	1.02	134	0.102
323.9 x 5.6	29	23.7	1.21	139	0.108
355.6 x 5.6	25	27.0	1.16	157	0.107
406.4 x 6.3	18	38.2	1.47	165	0.117
457.0 x 6.3	8	85.9	1.48	270	0.122
508.0 x 6.3	3	229.2	1.38	244	0.109

For further information see the section "Directional changes: Curved pipes" in the Product Catalogue.

16 m curved pipe

d x t mm	V_p. max °	R_p. min m	L_1 m	σ_{max} MPa	Soil pressure MPa
114.3 x 3.6	13	70.5	2.49	334	0.061
139.7 x 3.6	16	57.3	2.47	334	0.078
168.3 x 4.0	19	48.3	2.45	334	0.101
219.1 x 5.0	19	48.3	2.42	334	0.104
273.0 x 5.0	17	53.9	2.38	334	0.102
323.9 x 5.6	17	53.9	2.36	290	0.108
355.6 x 5.6	18	50.9	2.35	262	0.107
406.4 x 6.3	17	53.9	2.34	250	0.117
457.0 x 6.3	10	91.7	2.38	270	0.109
508.0 x 6.3	4	229.2	2.29	244	0.097
610.0 x 7.1	1.3	705.2	2.26	230	0.078

For further information ssee the section "Directional changes: Curved pipes" in the Product Catalogue

Prefabricated curved pipes

Max. design angle at other stress levels

The design angle V_p must be reduced, if the actual stress level σ is higher than the stated level in the table on the previous page.

The reduced design angle V_p is found as:

$$V_p = V_{pmax} \cdot \frac{\sigma_{max}}{\sigma}$$

where σ_{max} is found in the table on the previous page, and σ is the actual stress level at the location where the curved pipe is to be installed.

σ_{max} ≤ 190MPa

For systems where the axial stress level does not exceed 190 MPa, curved pipes with design angles/radii as stated in below table can be used.

The table applies to curved pipes in all insulation series with a soil cover of 0.6-1.5 m, where the groundwater level is below the pipes.

If the acutal stress level is < 190 MPa, where the curved pipe will be installed, a curved pipe with a major angle than stated in the table can be used.

The angle can be calculated by means of above formula.

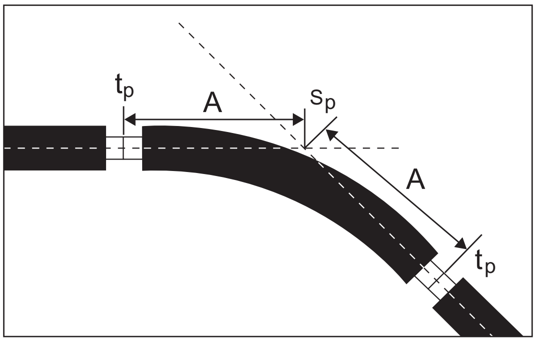
Note! The angle cannot exceed the values for 12 as well as 16 m curved pipes, respectively on the previous page.

d x t mm	12 m curved pipe		16 m curved pipe	
	$V_{p\ max}$	$R_{p\ min}$ m	$V_{p\ max}$ °	$R_{p\ min}$ m
76.1 x 2.9	25	27.5	-	-
88.9 x 3.2	33	22.2	-	-
114.3 x 3.6	38	18.1	13	70.5
139.7 x 3.6	39	17.3	16	57.3
168.3 x 4.0	35	19.6	19	48.3
219.1 x 5.0	29	23.5	19	48.3
273.0 x 5.0	25	27.1	17	53.9
323.9 x 5.6	21	32.4	17	53.9
355.6 x 5.6	20	34.4	18	50.9
406.4 x 6.3	15	45.8	17	53.9
457.0 x 6.3	8	85.9	10	91.7
508.0 x 6.3	3	229.2	4	229.2
610.0 x 7.1	-	-	1.3	705.2

Prefabricated curved pipes

Marking curved pipe

To ensure that the trench of the pipe system is correctly designed the point where the tangents of the curved pipe intersect can be marked in the system drawing and on site, respectively.



In practice this means that the casing joints are placed at point t_p in the system drawing.

The distance A from the point where the tangents intersect s_p to the tangent point t_p is marked to place the joints correctly.

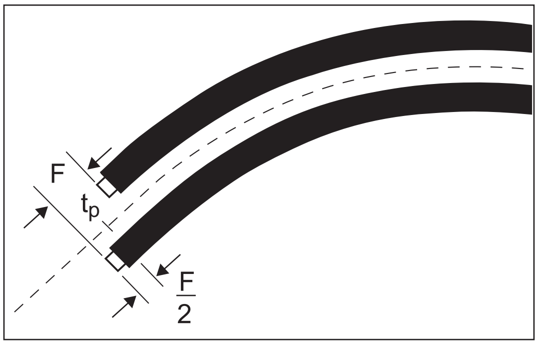
The distance A is calculated after the following formula:

$$A = R_p \cdot \tan\left(\frac{V_p}{2}\right)$$

where
Rp: Design radius
Vp: Design/bending angle

Flow and return pipe are usually bent in the same angle, because for minor dimensions the deviations are in practive without significance for the installation.

In conncection with major dimensions and angles it may be appropriate to mark the displaced ends of the flow and return pipe, so the pipe curves have the same distance to each other in the curve.



The displacement measurement (F) is determined as:

$$F = \frac{(D + A) \cdot V_p}{115}$$

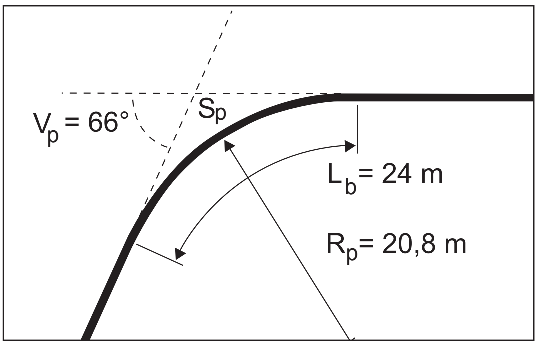
where
D: Outer casing diameter
A: Distance between outer casings
V_p: Design/bending angle

Directional changes

Prefabricated curved pipes - example

Conditions

Dimension ø168.3/280 (series 2)
Soil cover: H = 0.8 m
Axial stress level: σ =185 MPa
Design angle: V_p = 66°
Pipe length: L_b = 24 m



From the table in the preceding page in this section the following values for ø168.3 mm curved pipe appear:
- $V_{p.max}$ = 45° (Max. bending angle)
- σ_{max} = 148 MPa (Allowable stress level)

As the design angle V_p (66°) is larger than the allowable angle $V_{p.\,max}$ (45°), 2 x 12 m curved pipes with an angle of 33° each must be used.

The max. allowable stress level at an angle of 33° is determined by:

$$V_p = V_{p,\,max} \cdot \frac{\sigma_{max}}{\sigma}$$

$$\sigma = V_{p,\,max} \cdot \frac{\sigma_{max}}{V_p}$$

$$\sigma = 45 \cdot \frac{148}{33} = 202 \text{ MPa}$$

As the axial stress level is 185 MPa, 2 curved pipes of 33° can be used.

The design radius is:

$$R_p = \frac{180 \cdot L_b}{\pi \cdot V_p}$$

$$R_p = \frac{180 \cdot 12}{\pi \cdot 33} = 20{,}8 \text{ m}$$

When ordering the 2 curved pipes state length and angle.

If the pipe system includes surveillance, it must be stated whether the pipe will be bent to the left, the right, up or down due to the position of the alarm wires see the section "Directional changes: Curved pipes" in the Product Catalogue.

The A-measurement is calculated (used in the system drawing and on site):

$$A = 20{,}8 \cdot \tan\left(\frac{66}{2}\right) = 13{,}5 \text{ m}$$

Mitering

General

Mitering can be used for minor directional changes. The use of mitering should however be minimised as much as possible, as stress concentrations will occur in the mitre area, increasing the risk of weaknesses in the mitre.

LOGSTOR therefore recommends that minor directional changes as far as possible be made with elastic curves or curved pipes.

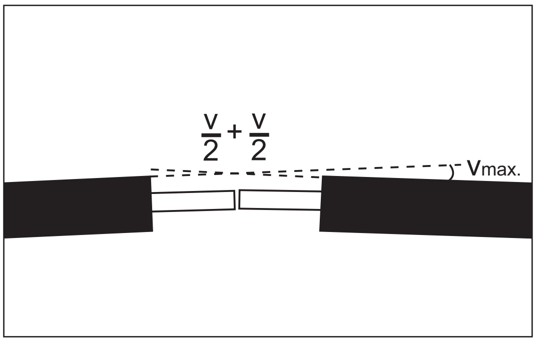
Possible applications

Mitering can be carried out in horizontal as well as vertical direction.

It is important that compression around the mitre is carried out especially thorough to secure the mitre against lateral and vertical movement.

When mitering, it must be ensured that there is sufficeint global stability.

Mitering in series should be avoided.



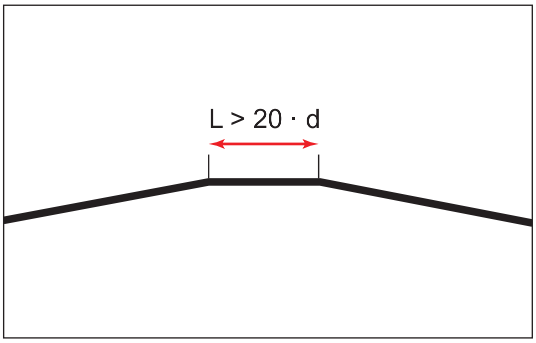
Mitering

From the table it appears, which max. angles may be used in relation to the axial stress level.

Max. axial stress level MPa	V_{max} Allowable mitre °
150	4
228	2
252	1
280	0,5
>280	0

Min. distance between mitres

When installing more mitres in a pipe section, the distance between the mitres must be minimum 20 · d, where d is the diameter of each service pipe.



Mitering

Conditions for mitering

In connection with mitering it is essential that thorough compression is carried out around the mitre. This minimises the lateral movement, which may result in fatigue stress in the mitre.

IMPORTANT! Foam pads may not be used around mitres!

LOGSTOR straight casing joints may be used at mitres with the below angles, provided the above is complied with:

°v	Max. mitre of straight casing joints				
	BXJoint	SX-WPJoint	BS-/B2SJoint	EWJoint	BandJoint
0	ø 90-630 mm	ø 90-450 mm	ø 90-1000 mm	ø 90-1400 mm	ø 90-1400 mm
1	ø 90-630 mm	ø 90-450 mm	ø 90-1000 mm	ø 90-1400 mm	ø 90-1400 mm
2	ø 90-630 mm	ø 90-450 mm	ø 90-1000 mm	ø 90-1400 mm	ø 90-1400 mm
3	ø 90-630 mm	ø 90-450 mm	ø 225-1000 mm	ø 225-1000 mm	ø 90-710 mm
4	ø 90-630 mm	ø 90-450 mm	-	ø 225-500 mm	ø 90-500 mm
5	ø 90-630 mm	ø 90-450 mm	-	-	-

Steel service pipe must be checked statically.

Directional changes

80-90° bends with foam pads

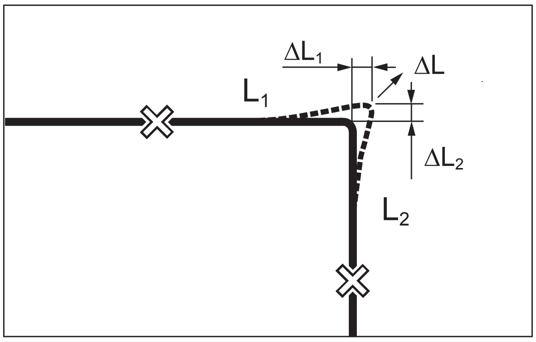
General

Axial expansion of straight pipe sections causes lateral displacement at bends.

To ensure that bend and PUR foam are not exposed to larger forces than they can withstand, the load from the soil pressure must be reduced.

This can be done på absorbing the expansion in foam pads, see below.

Description of foam pads, see the section "Expansion absorption".



Fatigue/ load cycles

On basis of the actual temperatures and installation conditions the movement at the bend is calculated. All bends are secured against fatigue in accordance with EN13941 with the stated min. temperature variations, described in the section "General: Project classes".

Likewise all bends in this manual are calculated with safety factores for project class B or C, respectively as described.

Length of expansion zone

To determine the length of the expansion zone it is necessary to calculate the axial expansion of the pipe system.

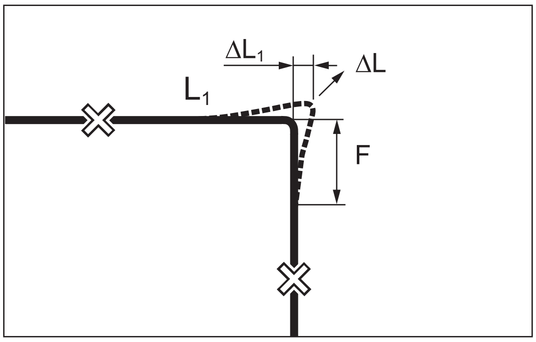
Detailed formulas are described in the section "General: Expansion at bends".

The actual expansion ΔL_1

For the section L_1 the actual expansion ΔL_1 is calculated.

Now the length F which is necessary to absorb the expansion from L_1 can be found in the following curves.

F = the length from the bend to be protected with foam pads to prevent the soil pressure from resulting in too high stresses in the PUR foam.



When calculating the axial expansion both soil cover and insulation series are taken into account.

On the horizontal axis of the graph the actual ΔL is found.

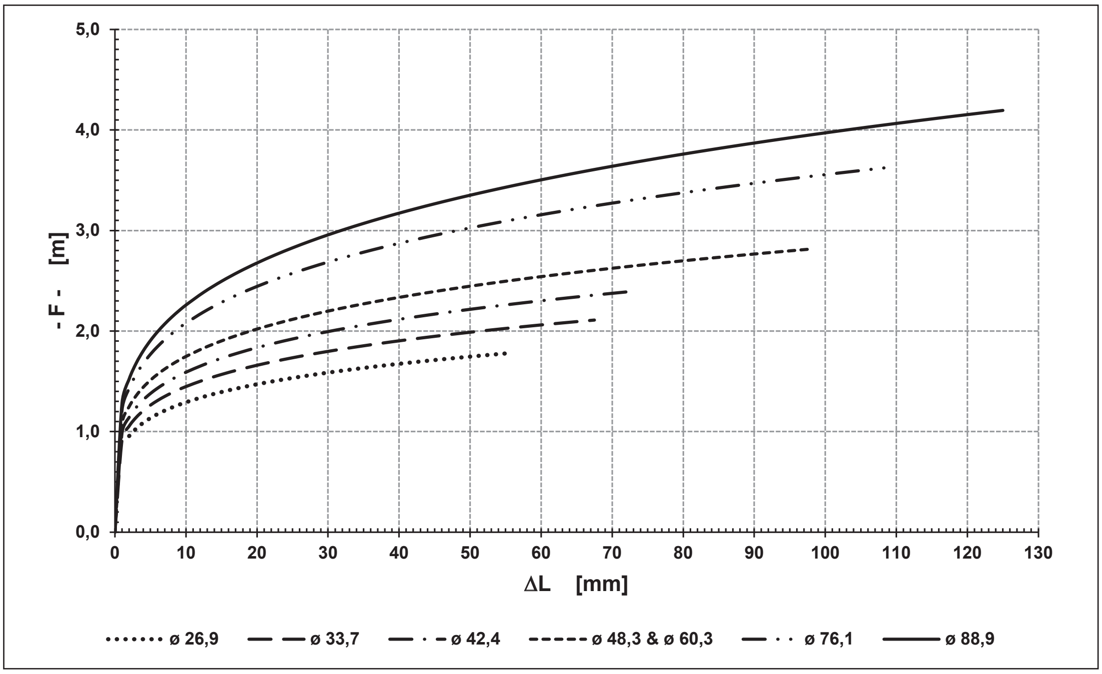
This measurement is displaced vertically up to the curve for the actual dimension, and the F-length is read from the vertical axis.

The curves apply to all insulation series.

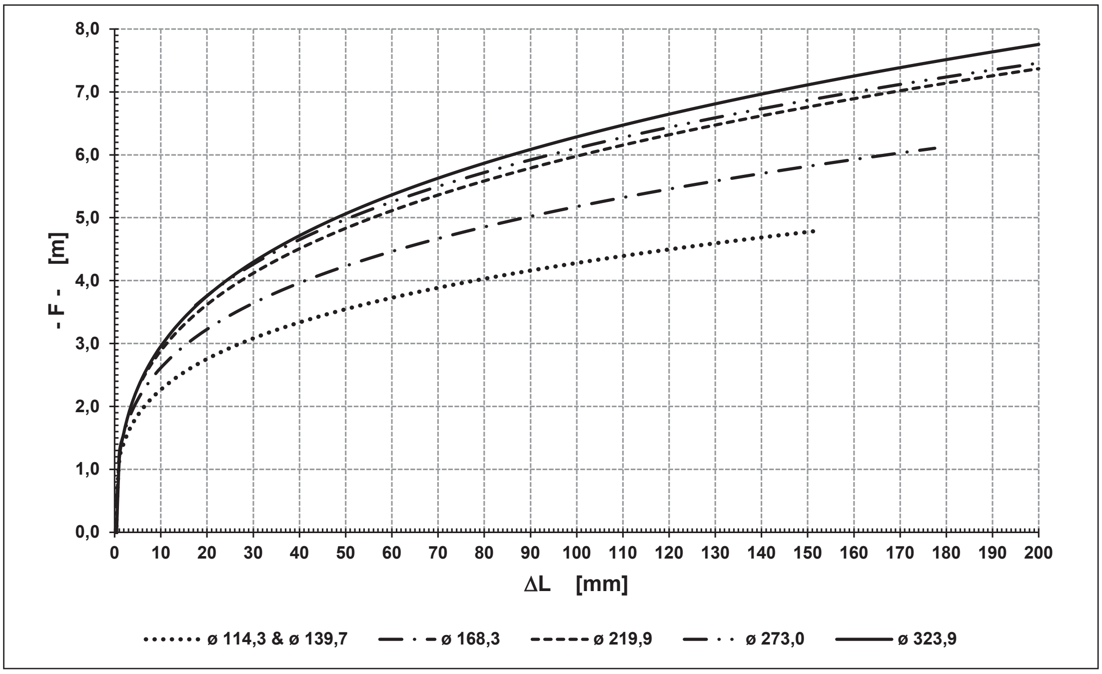
Directional changes

80-90° bends with foam pads

Expansion zone, F- length ø 26.9 – ø 114.3 Series 1. 2, and 3

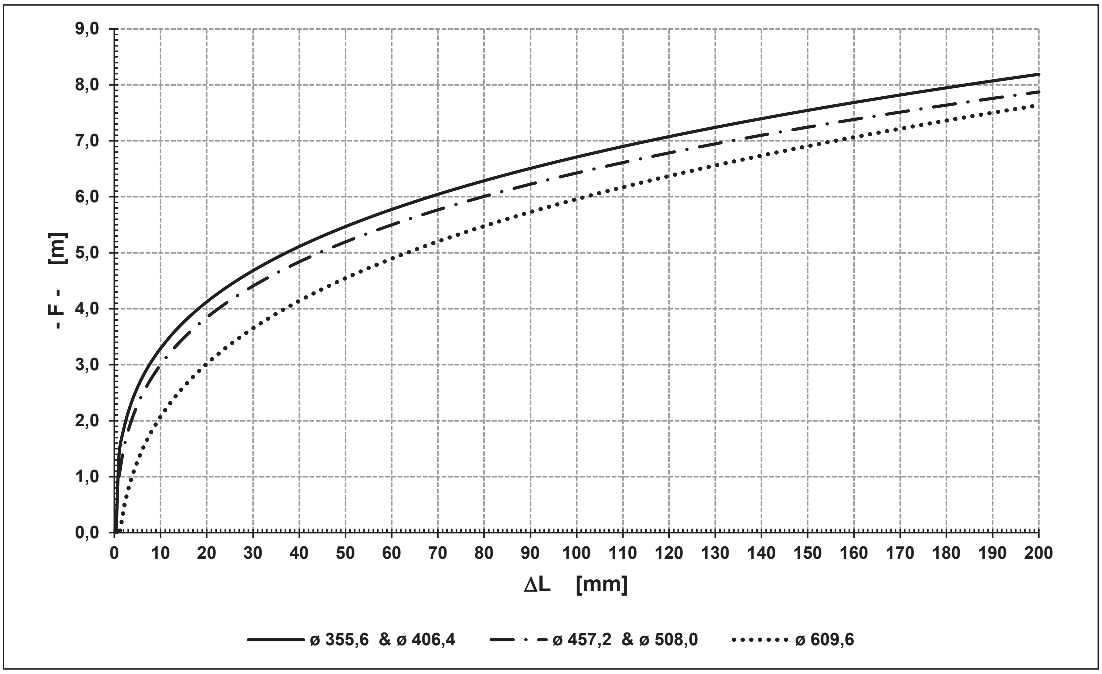


Expansion zone, F- length ø 139.7 – ø 323.9 Series 1, 2, and 3



80-90° bends with foam pads

Expansion zone, F- length ø 355 – ø 610.0 Series 1, 2, and 3



Foam pads

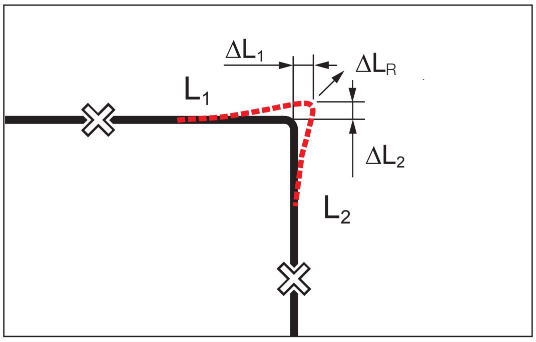
To detemine the number and thickness of the foam pads, required to absorb the expansion in the bend, the resulting expansion ΔL_R is calculated.

$$\Delta L_R = \sqrt{\Delta L_1^2 + \Delta L_2^2}$$

Foam pads may max. be compacted 70%, so the required foam pad thickness is found by:

$$t_{\text{foam pad}} = \frac{\Delta L_R}{0{,}70}$$

The foam pads are available in thicknesses of 40 mm. The thickness can therefore be 40 mm, 80 mm or 120 mm, see also the section "Expansion absorption: Foam pads".



Directional changes
80-90° bends with foam pads

Foam pad length

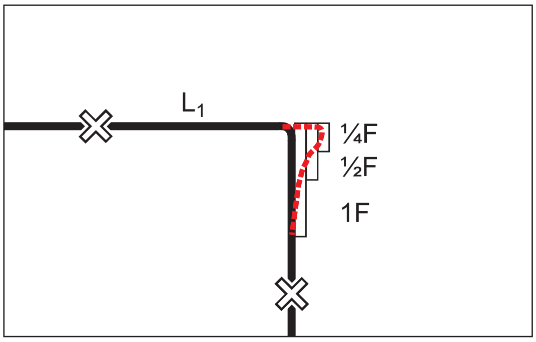
The length of the foam pad is minimum the F-length.

In case there are more foam pad layers, the number of layers is reduced in accordance with the deflection line of the bend.

In practice this means that the length of the 1st layer of foam pads is always minimum the same as the F-length.

The 2nd layer of foam pads is minimum ½ F long, and the 3rd layer is minimum ¼ F long.

The length of each layer is rounded up to the nearest half or whole meter.



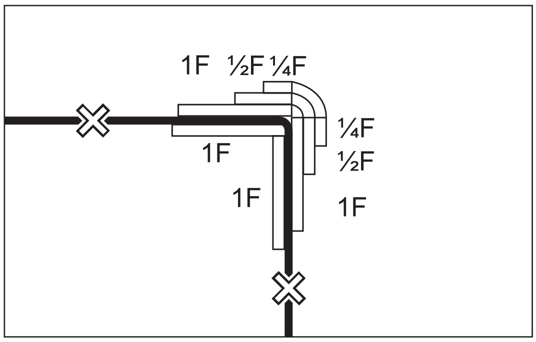
Position of foam pads

Foam pads are always placed on the outside of a bend to absorb the expansion.

On the inside of the bend foam pads may be placed in the full length of the F-length

As the friction prevents the full withdrawal of the bend, it is only necessary to install foam pads in one layer.

In heat prestressed systems the same number of foam pads are placed in- and outside of the bend, provided the expansion has been calculated in relation to a prestressing temperature which equals the mean temperature.



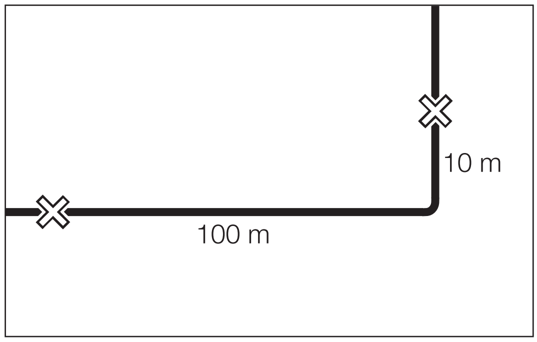
80-90° bends with foam pads - Example

Conditions for the example

ø 60.3. series 2
Soil cover, H = 0.8 m
Max. design temperature T_{max} = 105°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C
L_1 = 100 m
L_2 = 10 m

From table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" for ø 60.3 series 2.

F = 2.03 kN/m
A_s = 523 mm²



Max. stress level

$\sigma_{max.} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max.} = (105 - 10) \cdot 2.52 = 239$ [MPa]

Friction length L_F:

$$L_F = \frac{\sigma_{max} \cdot A_s}{F}$$

$$L_F = \frac{239 \cdot 523}{2{,}03 \cdot 1000} = 61{,}6 \text{ m}$$

Expansion

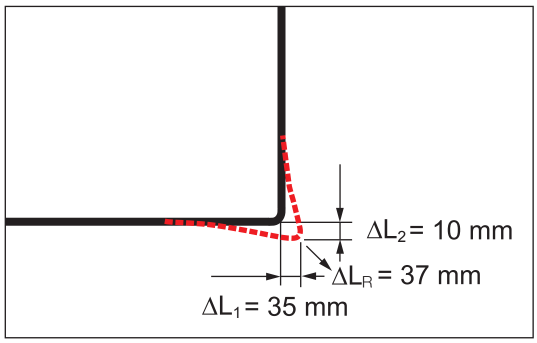
$$\Delta L = L \cdot \alpha \cdot \Delta T - \frac{F \cdot L^2}{2 \cdot A_s \cdot E}$$

L_F. is used as L_1 as it is shorter than the actual length.

$$\Delta L_1 = 61600 \cdot 1{,}2 \cdot 10^{-5} \cdot (105 - 10) - \frac{2{,}03 \cdot 61600^2}{2 \cdot 523 \cdot 210000} = 35 \text{ mm}$$

The actual length = 10 mm is used as L_2.

$$\Delta L_2 = 10000 \cdot 1{,}2 \cdot 10^{-5} \cdot (105 - 10) - \frac{2{,}03 \cdot 10000^2}{2 \cdot 523 \cdot 210000} = 10 \text{ mm}$$

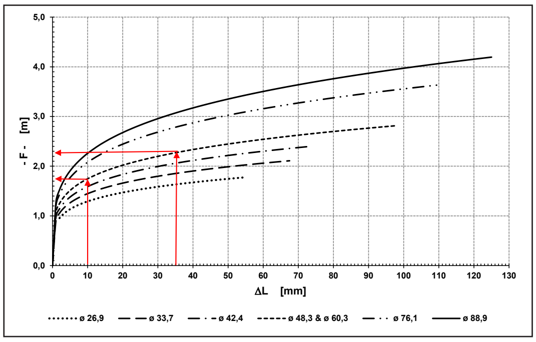


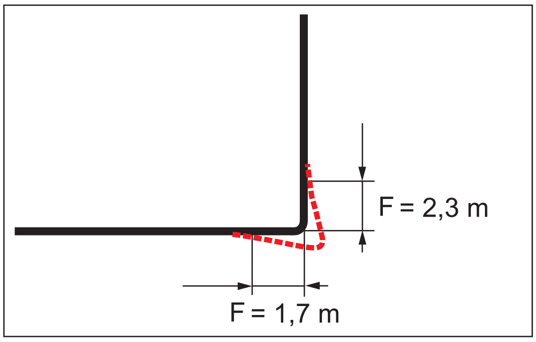
Directional changes

80-90° bends with foam pads - Example

F-length

From table in the section "Directional changes: 80-90° bends with foam pads" it is found:
- 35 mm equals F= 2.3 m
- 10 mm equals F = 1.7 m





Foam pads

Radial expansion in bend:

$$\Delta L_R = \sqrt{\Delta L_1^2 + \Delta L_2^2}$$

$$\Delta L_R = \sqrt{35^2 + 10^2} = 37 \text{ mm}$$

Thickness of foam pads:
- Min. thickness:

$$t = \frac{\Delta L_R}{0{,}70} = \frac{37}{0{,}70} = 53 \text{ mm}$$

Number of layers of each 40 mm:

$$t = \frac{t}{40} = \frac{53}{40} = 2 \text{ layers}$$

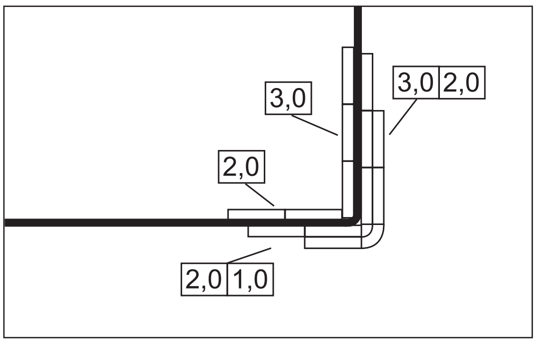
Position of foam pads

The length of the foam pads is minimum the F-length.

The length is rounded up to nearest half or whole meter.

The length of the foam pads is phased out, so the inner layer is always full length, the next layer is half length and so on.

On the inside the foam pads are placed in one layer.



Directional changes
80-90° bends with foam pads - Z-bend

General

Z-bends are considerably more flexible than L-bends. Therefore the required Z-length can be calculated as follows:

$Z = 0.45 \cdot (F_1 + F_2)$

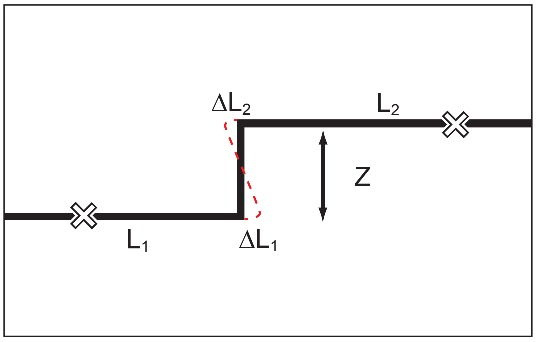
Where:

F_1 = the required F-length from L_1 for a 90° bend

F_2 = the required F-length from L_2 for a 90° bend

The expansion of each section and the corresponding F-length are found as described in the section "Directional changes 80-90° bends with foam pads"

Likewise the number and thickness of the foam pads are determined as described in the section "Directional changes 80-90° bends with foam pads". However, the resulting expansion equals the expansion from L_1 and L_2. respectively.



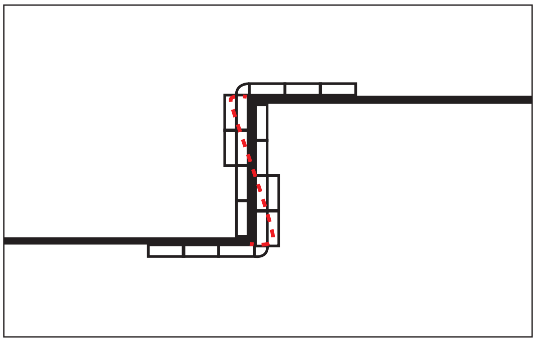
Length of foam pads

The length of the foam pads is minimum the Z-length.

The length of the foam pads is reduced, so the inner layer is always full length, the next layer is ½ length, and the outer layer is ¼ length, see the section "Directional changes 80-90° bends with foam pads".

On the axial side (the outside of the Z-bend) 1 layer of foam pads (40 mm) is placed):

- ≤ DN50:
  1 layer of foam pads, length min. 1 m
- DN65 – DN125:
  1 layer of foam pads, length min. 2 m
- DN150 – DN600:
  1 layer of foam pads, length min. 3 m



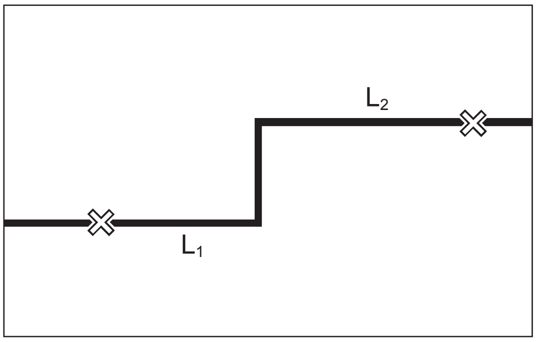
80-90° bends with foam pads - Z-bend - example

Conditions for the example

ø 273.0, series 2
Soil cover, H = 1.0 m
Max. design temperature T_{max} = 130°C
Min. design temperature T_{min} = 10°C
Installation temperatur T_{ins} = 10°C
L_1 = 78m
L_2 = 21m

From table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" for ø 273.0 series 2.

F = 8.75 kN/m
A_s = 4210 mm²



Max. stress level

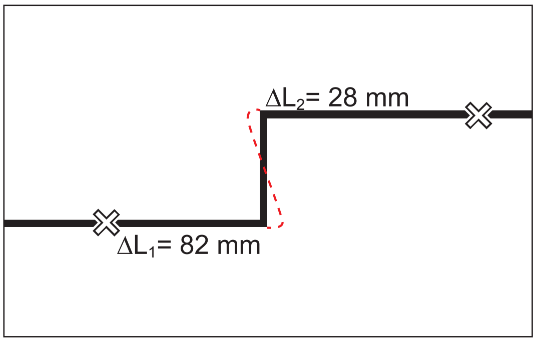
In this example the stress level in the system has been reduced to 190 MPa by using stress reduction with the bends:
σ_{max} = 190 MPa

Expansion

$$\Delta L = L \cdot \alpha \cdot \Delta T - \frac{F \cdot L^2}{2 \cdot A_s \cdot E}$$

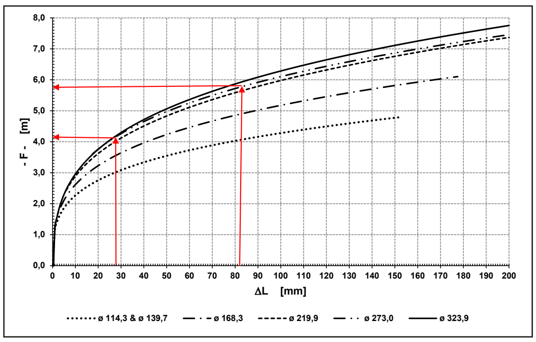
$$\Delta L_1 = 78000 \cdot 1{,}2 \cdot 10^{-5} \cdot (130 - 10) - \frac{8{,}75 \cdot 78000^2}{2 \cdot 4210 \cdot 210000} = 82 \text{ mm}$$

$$\Delta L_2 = 21000 \cdot 1{,}2 \cdot 10^{-5} \cdot (130 - 10) - \frac{8{,}75 \cdot 21000^2}{2 \cdot 4210 \cdot 210000} = 28 \text{ mm}$$



F-length

From table in the section "Directional changes: 80-90° bends with foam pads" it is found:
- L_1:
  ΔL = 82 mm equals F = 5.8 m
- L_2:
  ΔL = 28 mm equals F = 4.2 m

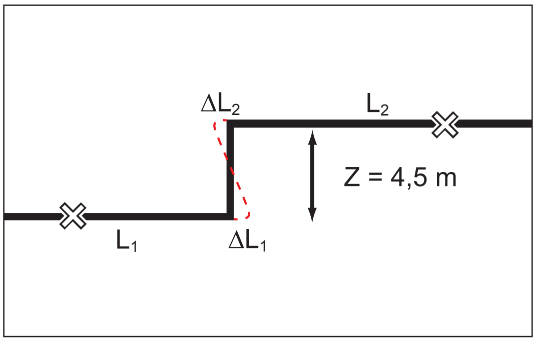


80-90° bends with foam pads - Z-bend - example

Required Z-length

$Z = 0.45 \cdot (F_1 + F_2)$

$Z = 0.45 \cdot (5.8 + 4.2) = 4.5$ m



Foam pads

The minimum thickness of the foam pads is found from the radial lateral expansion ΔL_R, which for Z-bends equals ΔL:

For the expansion from L_1 it is found:

$$t_1 = \frac{\Delta L}{0{,}70} = \frac{82}{0{,}70} = 117 \text{ mm}$$

Number of layers of each 40 mm:

$$\frac{t_1}{40} = \frac{117}{40} = 3 \text{ layers}$$

For the expansion from L_2 it is found:

$$t_2 = \frac{\Delta L}{0{,}70} = \frac{28}{0{,}70} = 40 \text{ mm}$$

Number of layers of each 40 mm:

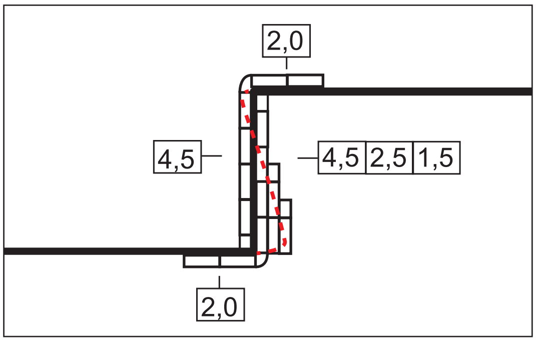
$$\frac{t_2}{40} = \frac{40}{40} = 1 \text{ layer}$$

Length of foam pads

The length of the foam pads is minimum the Z-length.

The length of the foam pads is reduced, so the inner layer is always full length, next layer is ½ length and so on.

On the axial part 40 mm foam pads are placed in min. 2 m length for a ø 273.0 as illustrated.



Directional changes
80-90° bends with foam pads - U-bend

General

A U-bend is more flexible than a Z-bend. The required U-length is therefore calculated as

$U = 0.8 \cdot F_{max}$

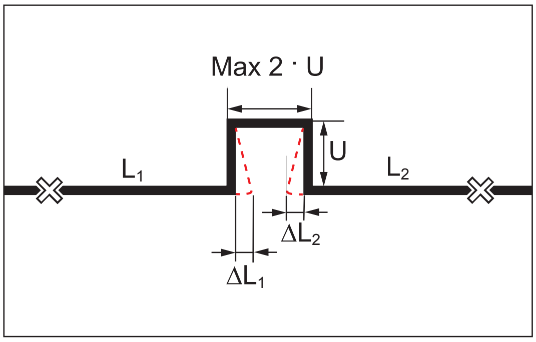
where F_{max} is the largest F-length for ΔL_1 or ΔL_2 for a 90° bend.

The bottom of the U-bend is minimum 2 · the leg length of a standard, preinsulated bend, and maximum 2 · U-length.

If the bottom of the U-bend is longer than
2 · U, the bend is calculated like 2 Z-bends.

The expansion of each section and the corresponding F-length are found as described in the section "Directional changes 80-90° bends with foam pads".

The number and thickness of the foam pads are also found as described in the section "Directional changes 80-90° bends with foam pads". However, the resulting expansion equals the expansion from L_1 and L_2, respectively.



Length of foam pads

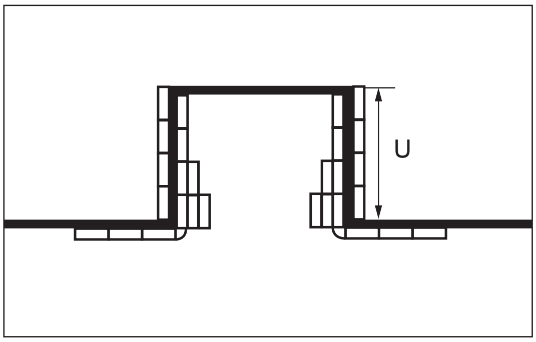
The length of the foam pads is minimum the U-length.

The length of the foam pads is reduced, so the inner layer is always full length, next layer is ½ length, and outer layer is ¼ length, see the section "Directional changes 80-90° bends with foam pads".

On the outside of the bend 1 layer of foam pads (40 mm) in the length "U" is installed.

On the axial part (access/exit from the U-bend) 1 layer of foam pads is placed as illustrated.

- ≤ DN50:
  1 layer of foam pads, length min. 1 m
- DN65 – DN125:
  1 layer of foam pads, length min. 2 m
- DN150 – DN600:
  1 layer of foam pads, length min. 3 m



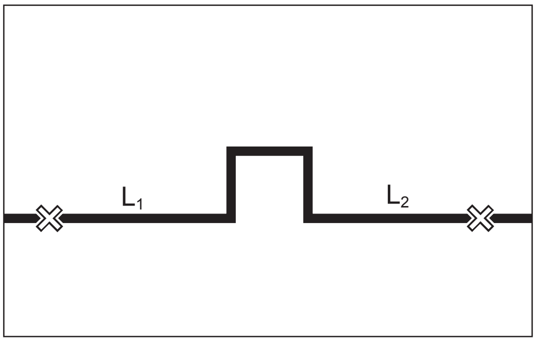
80-90° bends with foam pads - U-bend - Example

Conditions for the example

ø 114.3, series 1
Soil cover, H = 0.8 m
Max. design temperature T_{max} = 110°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C
L_1 = 120 m
L_2 = 65 m

From table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" ø 114.3 series 1.

F = 2.97 kN/m
A_s = 1252 mm²



Max. stress level

$\sigma_{max.} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max.} = (110 - 10) \cdot 2.52 = 252$ [MPa]

Friction length L_F:

$$L_F = \frac{\sigma_{max} \cdot A_s}{F}$$

$$L_F = \frac{252 \cdot 1252}{2,97 \cdot 1000} = 106,2 \text{ m}$$

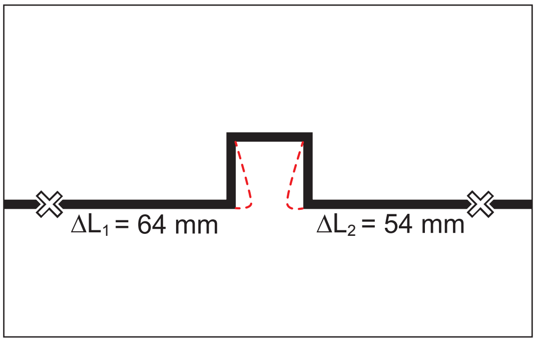
Expansion

$$\Delta L = L \cdot \alpha \cdot \Delta T - \frac{F \cdot L^2}{2 \cdot A_s \cdot E}$$

L_F is used as L_1 because it is shorter than the actual length.

$$\Delta L_1 = 106200 \cdot 1,2 \cdot 10^{-5} \cdot (110 - 10) - \frac{2,97 \cdot 106200^2}{2 \cdot 1252 \cdot 210000} = 64 \text{ mm}$$

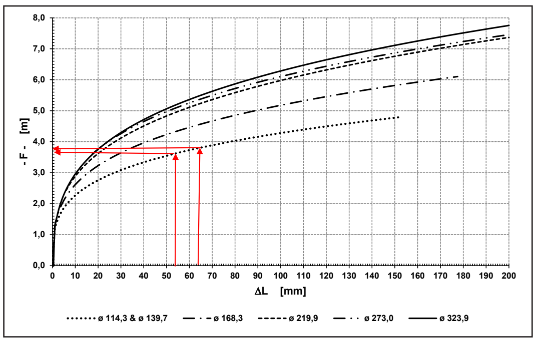
$$\Delta L_2 = 65000 \cdot 1,2 \cdot 10^{-5} \cdot (110 - 10) - \frac{2,97 \cdot 65000^2}{2 \cdot 1252 \cdot 210000} = 54 \text{ mm}$$



F-length

From table in the section "Directional changes: 80-90° bends with foam pads" it is found:

- L_1:
  ΔL = 64 mm equals F = 3.8 m
- L_2:
  ΔL = 54 mm equals F = 3.6 m



80-90° bends with foam pads - U-bend - Example

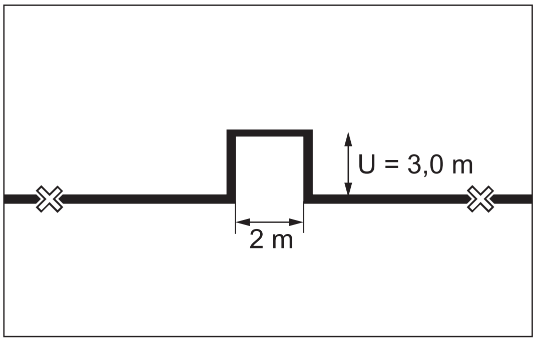
Required U-length

$U = 0.8 \cdot F_{max}$

$U = 0.8 \cdot 3.8 = 3$ m

The length of the bottom of the U-bend is max. $2 \cdot U = 6$ m.

Typically, $2 \cdot$ leg length is used on a standard bend, here $2 \cdot 1 = 2$ m



Foam pads

The minimum thickness of the foam pads is found by the radial lateral expansion ΔL_R, which for U-bends equals ΔL:

For the expansion from L_1 it is found:

$$t_1 = \frac{\Delta L}{0,70} = \frac{64}{0,70} = 91 \text{ mm}$$

Number of layers of each 40 mm:

$$\frac{t_1}{40} = \frac{91}{40} = 3 \text{ layers}$$

For the expansion from L_2 it is found:

$$t_2 = \frac{\Delta L}{0,75} = \frac{54}{0,75} = 72 \text{ mm}$$

Number of layers of each 40 mm:

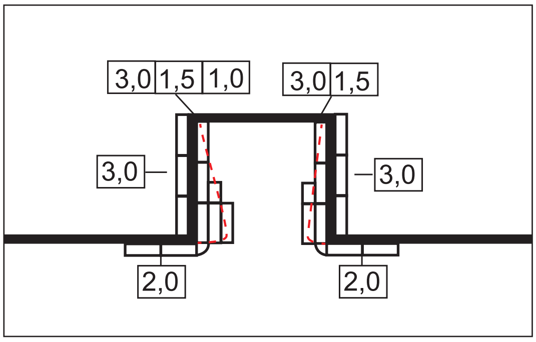
$$\frac{t_2}{40} = \frac{72}{40} = 2 \text{ layers}$$

Length of foam pads

The length of the foam pads is minimum the U-length. The length is rounded up to nearest half or whole meter.

The length of the foam pads is reduced, so the inner layer is always full length, next layer is ½ length, and the outer layer is min. 1/4 length.

On the axial part 40 mm foam pads in min. 2 m length is installed for a ø 114.3.



5-80° bends with foam pads

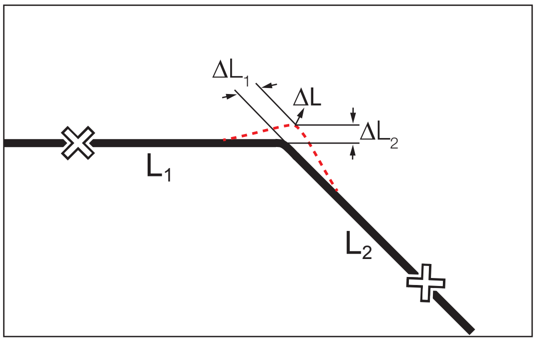
General

Axial expansion of straight pipe sections results in a lateral displacement at bends.

To ensure that bend and PUR-foam are not exposed to larger stresses than they can withstand, the stress from the soil pressure is reduced.

This can be done by absorbing the expansion in foam pads, see below.

For description of foam pads, see the section "Expansion absorption".



Application rules

The directions in this section apply to pipe systems, installed traditionally, where the first time expansion is given by the difference between the maximum and minimum temperature.

Directional changes are made by means of a 5-80° preinsulated bend or by welding in a bend segment. The directional change must not be carried out by mitering the pipe ends.

For 5-10° directional changes it is presupposed that the passive soil pressure suffices to ensure that the bend moves in axial direction with minimum radial movements. These directional changes can therefore be carried out without foam pads.

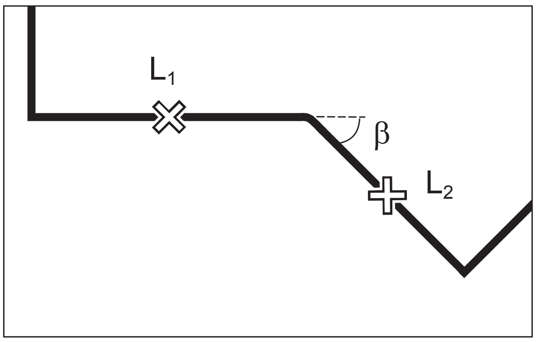
10-80° directional changes must be furnished with foam pads as described in this section.

80-90° directional changes are calculated like 90° bends, see the section "Directional changes 80-90° bends with foam pads".

When using 5-80° bends in systems which are heat prestressed in an open trench, please contact LOGSTOR for support.

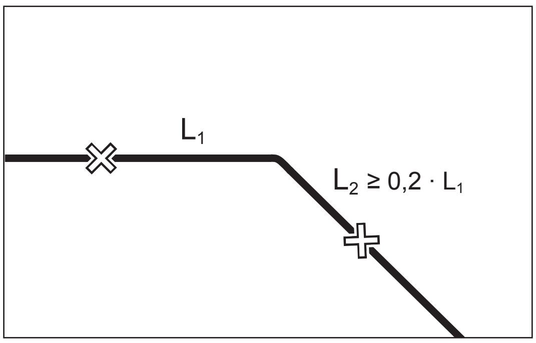
On basis of the actual temperatures and installation conditions the axial movement at tne bend is calculated. The calculation presupposes free movement at the bend.

The basis for the expansion which is used in this section is that the imaginary anchor is placed in the middle between the 90° bend and the bend with the minor angle.



The lengths L_1 and L_2 may differ. However, L_2 must as a minimum be 20% of L_1.

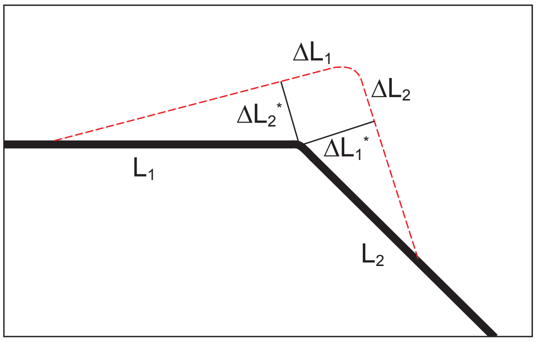
$L_2 \geq 0.2 \cdot L_1$



5-80° bends with foam pads

Application rules, *continued*

For directional changes between 5-80° distinction is made between the axial movements ($\Delta L_1/\Delta L_2$) and the resulting movements ($\Delta L_1^*/\Delta L_2^*$), what is described in the following.



Fatigue/load cycles

The application of the directions in this section ensures the bend against fatigue in accordance with EN13941 with the stated min. temperature variations, described in the section "General: Project classes".

Likewise, all bends in this manual are calculated with safety factors for project class B or C respectively as described.

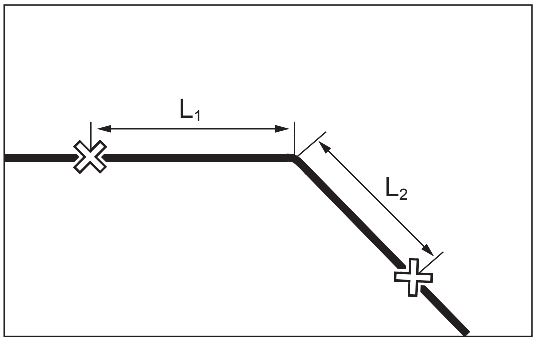
Max. lengths

A directional change in a given angle can be used. provided the sum of the axial movements does not exceed a given total movement.

When calculating the movement, insulation series and installation depths must be taken into account so the curve in the diagram on the next page applies to all situations.

The length (L_1/L_2) is defined as the distance from the directional change to the imaginary anchor.

The diagram on the following page defines the sum of the axial movements as a function of the angle of the directional change.



Axial movement

The axial movement in ΔL_1 and ΔL_2 is calculated as follows:

$$\Delta L_x = L_x \cdot \alpha \cdot \Delta T - \frac{F \cdot L_x^2}{2 \cdot A_s \cdot E}$$

For further information about calculating the axial movement at a free pipe end, see the section "General: Expansion at bends".

The sum of the axial movements is determined as follows:

$$\sum \Delta L = \Delta L_1 + \Delta L_2$$

In the diagram on the following page it can now be checked that $\sum \Delta L$ does not exceed the allowable value of the actual angle.

Axial movement *continued*

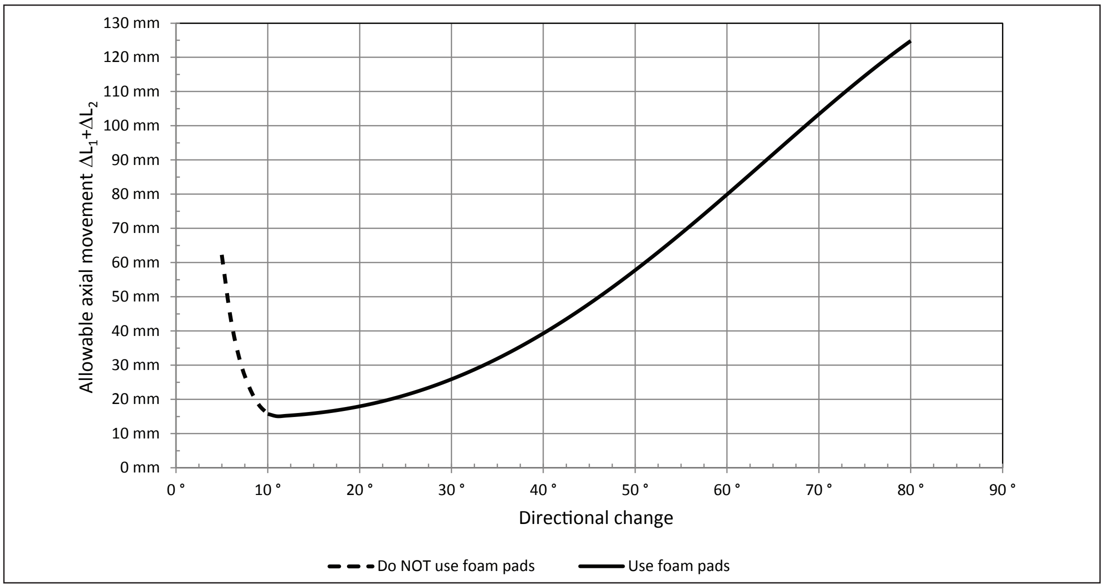
From the horizontal axis of the diagram the angle of the directional change is found.

This measurement is displaced perpendicularly to the curve, and the size of the maximum allowable movement is read from the perpendicular axis. Check that the actual $\sum\Delta L$ is less than the read value.

The curve applies to all dimensions up to DN600 in insulation series 1, 2 or 3, which are installed with a soil cover of 0.6-1.5 m.

LOGSTOR is at your disposal with further support.

Limit curve for total movement ø26.9-ø610.0 Series 1. 2 and 3, H = 0.6-1.5 m

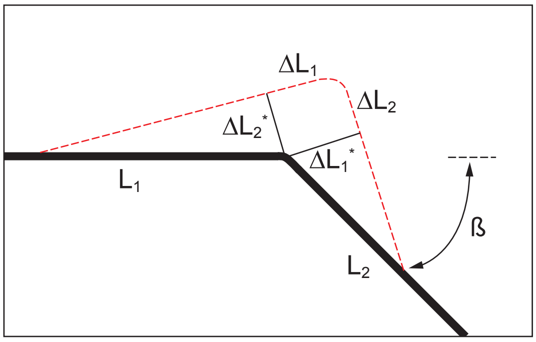


Length of the expansion zone

To establish the length of the expansion zone it is necessary to calculate the resulting movements in the bend.

$$\Delta L_1^* = \frac{\Delta L_2}{\tan ß} + \frac{\Delta L_1}{\sin ß}$$

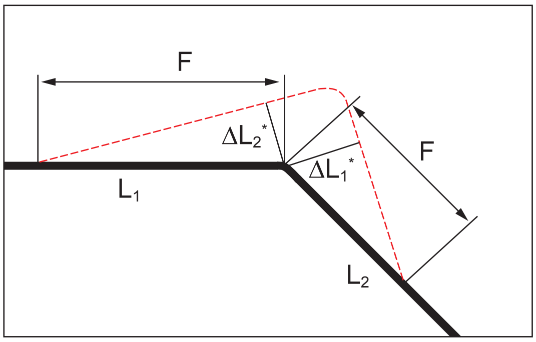
$$\Delta L_2^* = \frac{\Delta L_1}{\tan ß} + \frac{\Delta L_2}{\sin ß}$$



5-80° bends with foam pads

Length of the expansion zone, *continued*

Now the length F which is necessary to absorb the expansion from L_1 and L_2 respectively can be found in the curves in the section "Directional changes: 80-90° bends with foam pads".



ΔL_1* determines the F-length along L_2, and ΔL_2* gives the F-length along L_1.

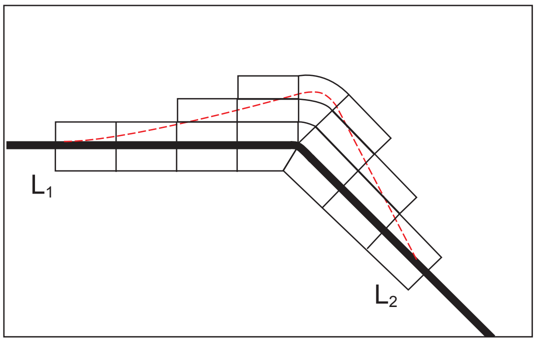
F = the length from the bend to be protected with foam pads to prevent the soil pressure from causing too high stresses in the PUR-foam.

Find the actual ΔL* on the horizontal axis of the diagram and displace it perpendicularly up to the actual dimension curve and read the F-length from the perpendicular axis.

The curves are valid for all insulation series.

Foam pads

ΔL* determines the number and thickness of foam pads, necessary to absorb the expansion in the bend.



At bends with different lengths the highest of the resulting expansions. ΔL_1* or ΔL_2* are used.

As to determining thickness, length, and position of foam pads, see ithe section "Directional changes: 80-90° bends with foam pads" as well as the following example.

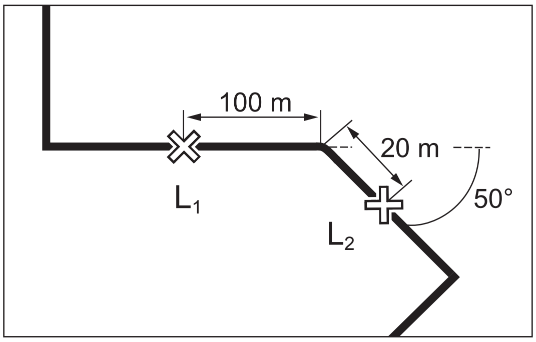
The inner side of the bend is furnished with 1 layer of foam pads in a length corresponding to the F-length.

5-80° bends with foam pads - Example

Conditions for the example

ø 60.3, series 2
Soil cover, H = 0.8 m
Max. design temperature T_{max} = 105°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C
L_1 = 100 m
L_2 = 20 m
Angle ß = 50°

From the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" for ø 60.3 series 2:
F = 2.03 kN/m
A_s = 523 mm²



Axial expansion

$$\Delta L = L \cdot \alpha \cdot \Delta T - \frac{F \cdot L_2^2}{2 \cdot A_s \cdot E}$$

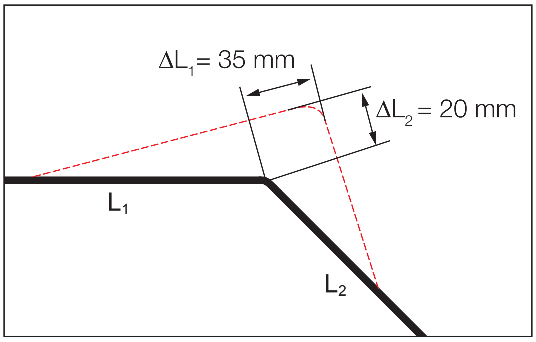
L_F (= 61.6) is used as L_1. as it is shorter than the actual length.

$$\Delta L_1 = 61600 \cdot 1{,}2 \cdot 10^{-5} \cdot (105 - 10) - \frac{2{,}03 \cdot 61600^2}{2 \cdot 523 \cdot 210000} = 35 \text{ mm}$$

As L_2 the actual length = 20 mm is used.

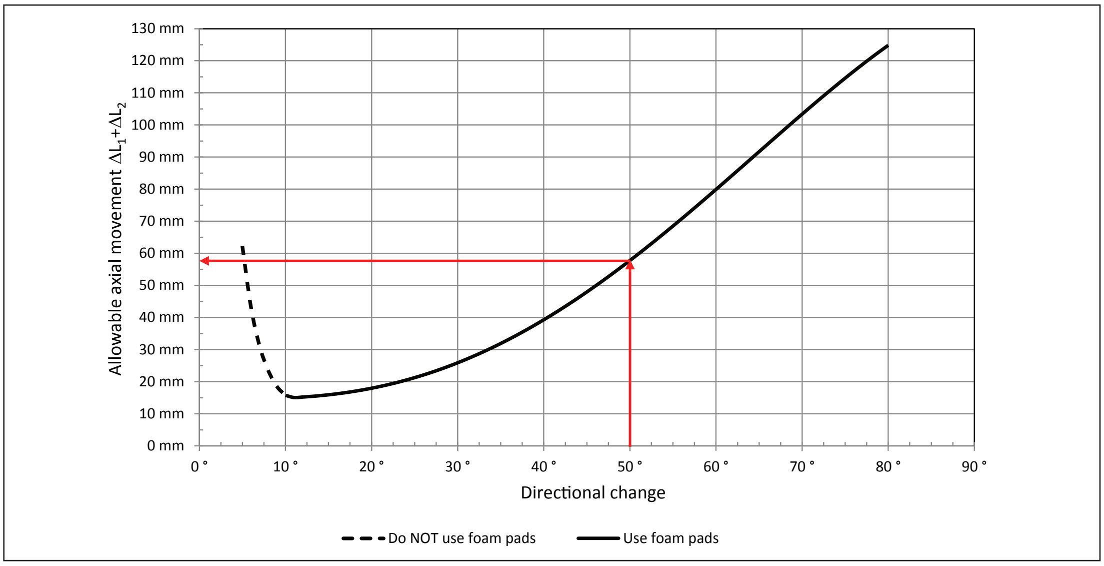
$$\Delta L_2 = 20000 \cdot 1{,}2 \cdot 10^{-5} \cdot (105 - 10) - \frac{2{,}03 \cdot 20000^2}{2 \cdot 523 \cdot 210000} = 19 \text{ mm}$$

The sum of the movements is:
$\sum \Delta L = \Delta L_1 + \Delta L_2$
$\sum \Delta L = 35 + 19 = 54$ mm



5-80° bends with foam pads - Example

Control of movement



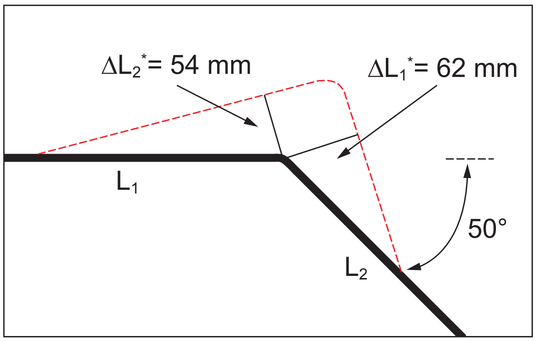
From the diagram the following appears for a 50° angle:

Max. total movement: $\sum \Delta L \leq 58$ mm

A 50° angle can therefore be used in the position in question.

Resulting expansion

The resulting expansion is calculated for each leg:



$$\Delta L_1^* = \frac{\Delta L_2}{\tan \beta} + \frac{\Delta L_1}{\sin \beta}$$

$$\Delta L_1^* = \frac{19}{\tan 50} + \frac{35}{\sin 50} = 62 \text{ mm}$$

$$\Delta L_2^* = \frac{\Delta L_1}{\tan \beta} + \frac{\Delta L_2}{\sin \beta}$$

$$\Delta L_2^* = \frac{35}{\tan 50} + \frac{19}{\sin 50} = 54 \text{ mm}$$

Foam pads

The thickness of the foam pads is determined by the largest resulting expansion, here ΔL_1*:

Min. thickness:

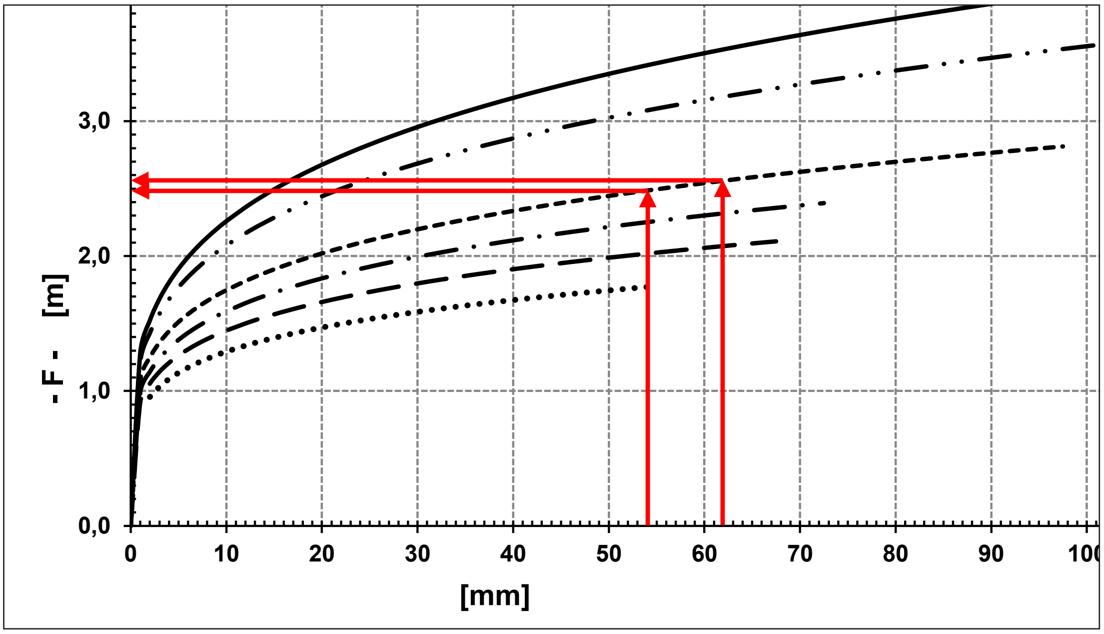
$$t = \frac{\Delta L^*_{max}}{0,70} = \frac{62}{0,70} = 89 \text{ mm}$$

Number of layers of each 40 mm:

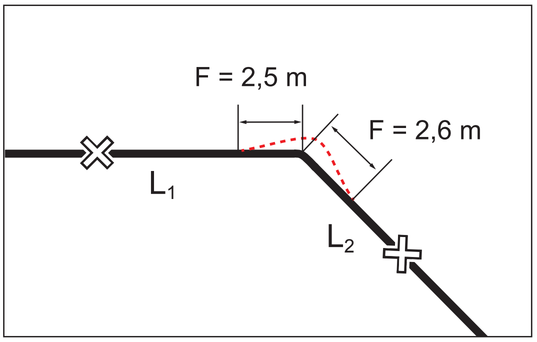
$$\frac{t}{40} = \frac{89}{40} = 3 \text{ layers}$$

5-80° bends with foam pads - Example

F-length



On basis of the resulting expansion the F-length for each leg is found in the diagram from "Directional changes: 80-90° bends with foam pads":
- 54 mm gives F = 2.5 m
- 62 mm gives F = 2.6 m



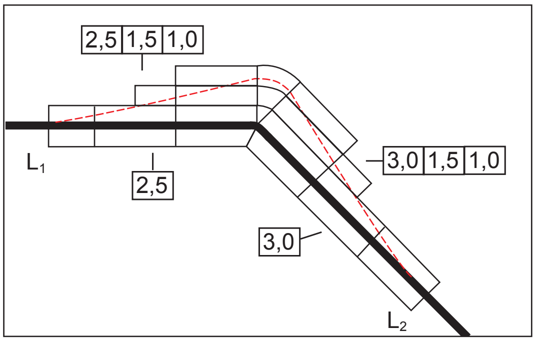
Positioning foam pads

The length of the foam pads is minimum the F-lengths.

The length is rounded up to nearest half or whole metre.

The length of the foam pads is reduced. so the inner layer is always full length. The next layer is half length and so on.

The inner side of the bend is furnished with 1 layer of foam pads in a length corresponding to the F-length.



References

LOGSTOR Design Tool:

https://designtool.logstor.com/Tool/Form.aspx?ApplicationId=18749619-698b-47c3-8dbe-c54c42282ccb

Overview

Introduction

This section contains guidelines for designing with branches in preinsulated pipe systems.

Branching is to be carried out so neither PUR foam nor service pipe is overstrained.

Calculating the strain on branches is very complex, because the strain from the main pipe and the branch must be combined. This section therefore gives simple directions for the positioning of branches, based on normal practice and LOGSTOR's calculation experience.

Reference is made to measurements, formulas, and calculation principles, described in detail in other sections.

LOGSTOR gladly offers to assist you with further support in connection with the positioning and calculation of branches.

The online program "LOGSTOR Design Tool" which is available on LOGSTOR's website supports and facilitates the branch calculations. The program is based on the specifications found in this section.

Contents

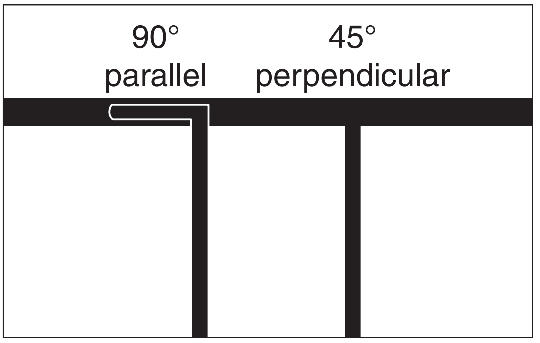
General
Application
Conditions
45° perpendicular branch
90° parallel branch
Straight branches
Reinforcement of branch fittings

General

Introduction

Branches can be made as 90° parallel branches or 45° perpendicular branches (branches with offset).

These branch types can be made as branch fittings and preinsulated branches respectively, see the section "Branches" in the Product Catalogue.



Stress level

Generally, preinsulated branches with a main pipe dimension up to and including DN 300 can be used everywhere in systems with high axial stresses (systems without stress reduction, see the section "Straight pipes: Straight pipes without stress reduction").

If the main pipe and branch dimension are the same, LOGSTOR's standard preinsulated branches can be used in systems with a stress level of up to 190 MPa.

Branch fittings, including branches carried out by means of hot tapping can be used in systems with high axial stresses, provided reinforcement plates are used, cf. table in the section "Branches: Reinforcement of branch fittings".

Fatigue cycles

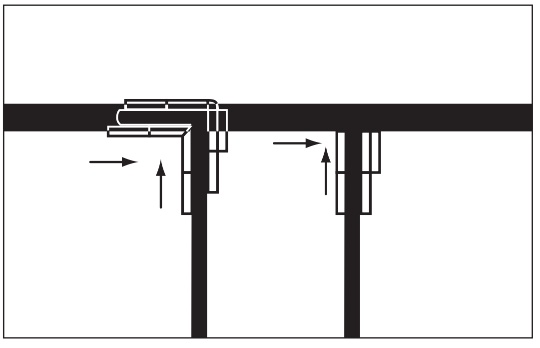
All branches, described in this section, are secured against fatigue in accordance with EN13941 with the stated min. load cycles and project classes which are described in the section "General: Project classes".

Expansion

A branch must be secured and checked on the main pipe as well as the branch pipe.

On basis of the present temperatures and installation conditions the movements at the main pipe and the branch pipe respectively are calculated. These movements are compensated for by installing foam pads on all branches.

There may be situations where it is necessary to move a branch, if the movement is too large.



Length of expansion zone

To establish the length and thickness of the expansion zone it is necessary to calculate the axial expansion of the main pipe and branch pipe at the branch. The movement is calculated on basis of the present temperatures and installation conditions.

To calculate the movement of the main pipe (ΔL_T) the formula in the section "General: Expansion at branches" is used.

To calculate the axial movement of the branch pipe (ΔL_a) at 90° parallel branches the formula in the section "General: Expansion at bends" is used.

The length of the expansion zone (F-length) appears from the diagrams in the section "Directional changes: 80-90° bends with foam pads".

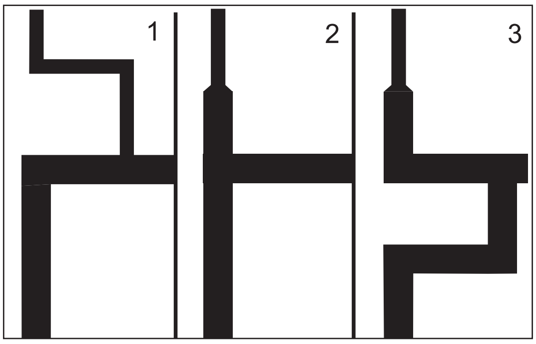
Also see examples in the sections "Branches: 45° perpendicular branch - example" and "Branches: 90° preinsulated parallel branch - example".

Application

Application

Generally the largest dimension should have the simplest trench layout, because it results in the best solution statically as well as hydraulically.

From the illustration 3 examples of solutions to the same situation appear.



All solutions can be used in consideration of the conditions in this manual.

However, LOGSTOR recommends to use solution No. 1. This solution results in the lowest pressure loss and can reduce the axial stresses.

Branches are installed so the branch pipe is level with or above the main pipe. Under-crossing branches should as far as possible be avoided at low flow velocities due to risk of local corrosion.

Conditions

Conditions

The guidelines for designing with branches in this section apply under the following conditions for the pipe systems:
- Max. operating temperature: 110°C ($\Delta T \leq 100$°C)
- Soil cover over main pipe: 0.6-1.0 m
- Soil cover over branch pipe: min. 0.5 m
- When using branch fittings these must be reinforced in accordance with the table in the section "Branches: Reinforcement of branch fittings"

In case of preinsulated branches or branch fittings in systems which are heat pre-stressed in an open trench, please contact LOGSTOR for support.

As to the geometric design of the individual branch, see the section "Branches" in the Product Catalogue.

45° perpendicular branch

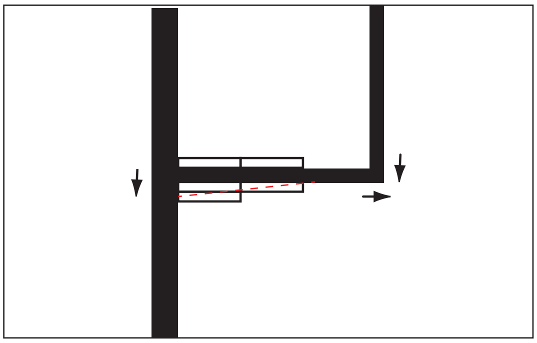
Axial movements and foam pads

The branch is strained by the axial movements in the main pipe and the branch pipe respectively.

The axial movement of the main pipe results in movement in the branch. This movement is compensated for by furnishing the branch with foam pads.

The length of the foam pads equals the F-length.

The F-length appears from the curve for the relevant branch dimension, see the section "Directional changes: 80-90° bends with foam pads".



Length of branch pipe

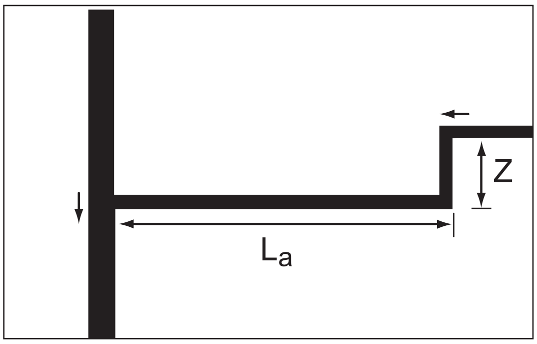
The length of the branch pipe is restricted by the loads, transmitted from the branch. This is done by minimising the length as stated below.

The length of the branch pipe L_a for a 45° perpendicular branch must lie within the following:

Branch, DN	$L_{a,min}$	$L_{a,max}$
20-50	F-length	20 m
65-125	F-length	12 m
150-300	F-length	8 m

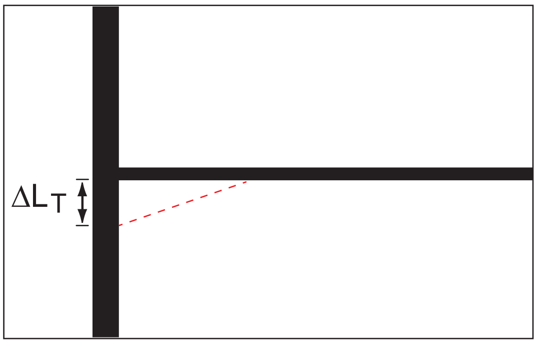
At branch pipes longer than $L_{a,max}$ a Z-bend must be established as shown in the illustration.

Alternatively, the branch can be replaced by a 90° parallel branch.



Position on main pipe

A 45° perpendicular branch may be placed where the expansion in the main pipe
$\Delta L_T \leq 56$ mm what corresponds to 2 layers of foam pads.

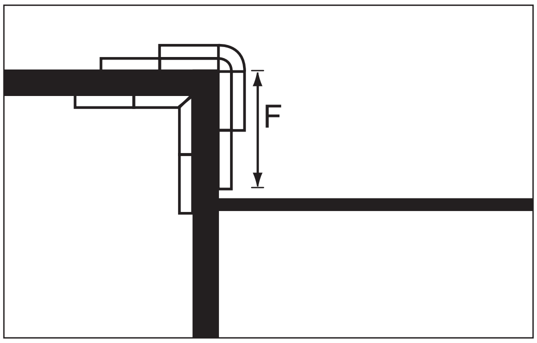


45° perpendicular branch

Position on main pipe,
continued

When a branch is placed near a bend in the main pipe, the branch must be placed outside the F-length.

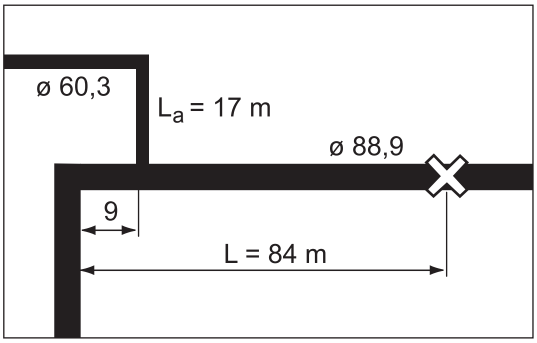
As to calculating the F-length for a bend, see the section "Directional changes: 80-90° bends with foam pads".



45° perpendicular branch - Example

Conditions

Soil cover:
Main pipe: H_h = 0.8 m
Branch: H_a = 0.6 m
Max. design temperature T_{max} = 95°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C
D_h = ø88.9/160 (series 1)
L = 84 m
D_a = ø60.3/125 (series 1)
L_a = 17 m
From the table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths" the following is found for ø88.9 at
H = 0.8 m
F = 2.35 kN/m
A_s = 862 mm²
Preinsulated components are used.



Check of branch

2 cheks are performed in connection with the branch:
- Axial movement in the main pipe, ΔL_T:
  Check that $\Delta L_T \leq 56$ mm
- Length of the branch, L_a:
  Check L_a cf. table in the section "Branches: 45° perpendicular branch".

The above movements are calculated in the following.

Determination of friction length

Calculation of the axial stress level:

$\sigma_{max} = \Delta T \cdot 2.52$ [MPa]

$\sigma_{max} = (95 - 10) \cdot 2.52 = 214$ [MPa]

Determination of the friction length

$$L_F = \frac{\sigma_{max} \cdot A_s}{F}$$

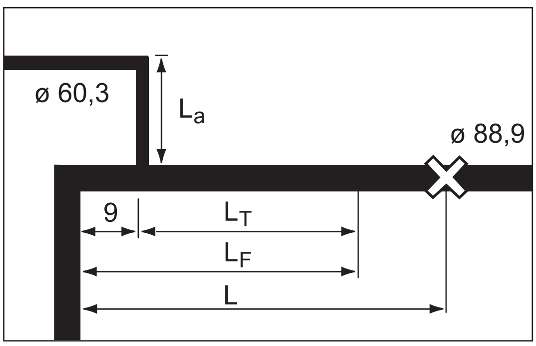
$$L_F = \frac{214 \cdot 862}{2.35 \cdot 1000} = 78.5 \text{ m}$$

As L > L_F , L = L_F is used in the calculation, because only L_F, contributes to the movement.

Calculating L_T

L_T is:

L_T = 78.5 - 9 = 69.5 m



45° perpendicular branch - Example

Axial movement in the main pipe

The expansion in the main pipe at the branch is determined by the formula in the section "Expansion at branches".

$$\Delta L_T = \alpha \cdot \Delta T \cdot L_T - \frac{F\,(2 \cdot L - L_T) \cdot L_T}{2 \cdot E \cdot A_s}$$

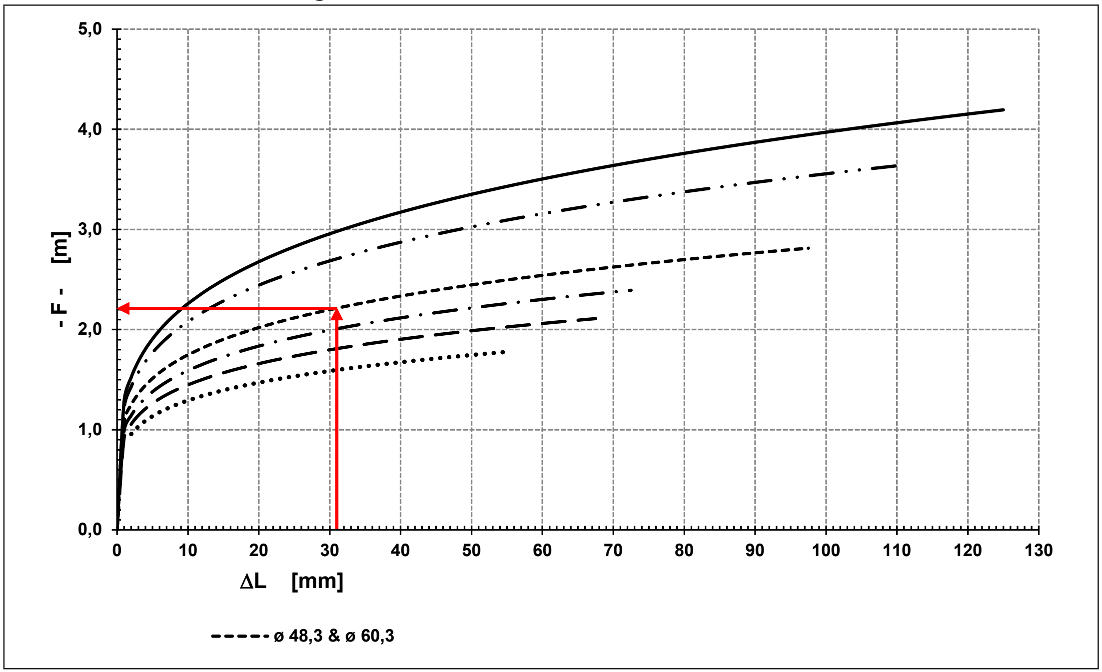
$$\Delta L_T = 1.2 \cdot 10^{-5} \cdot (95\text{-}10) \cdot 69500 - \frac{2.35 \cdot (2 \cdot 78500 - 69500) \cdot 69500}{2 \cdot 210000 \cdot 862} = 31 \text{ mm}$$

Check of branch

- Check of axial movement in the main pipe:
  $\Delta L_T \leq 56$ mm
  ΔL_T is calculated to be 31 mm - OK.
- Check of branch length:
  For a branch pipe in DN 50 it appears from the table in the section "Branches: 45° perpendicular branch", that $L_{a,max}$ = 20 m.
  L_a = 17 m - OK.

F-length

The length of the foam pad is determined on basis of the diagram in the section "Directional changes: 80-90° bends with foam pads".
From the curve for the branch pipe dimension the following appears:
ΔL = 31 mm for a ø60.3 gives F = 2.2 m



Foam pads

The minimum thickness of the foam pads is determined by ΔL_T (see in the section "Directional changes: 80-90° bends with foam pads", if necessary):

$$t = \frac{\Delta L_T}{0.70} = \frac{31}{0.70} = 44 \text{ mm}$$

Number of layers of 40 mm each:

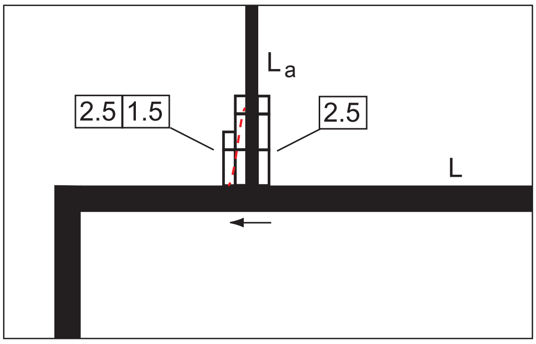
$$t = \frac{t}{40} = \frac{44}{40} = 2 \text{ layers}$$

45° perpendicular branch - Example

Foam pads, ***continued***

The length of the foam pads is reduced, so the inner layer is always full length (rounded up to nearest half or whole metre), the next layer is ½ length and so on.

The opposite side of the branch is furnished with 1 layer of foam pads in the F-length.



90° parallel branch

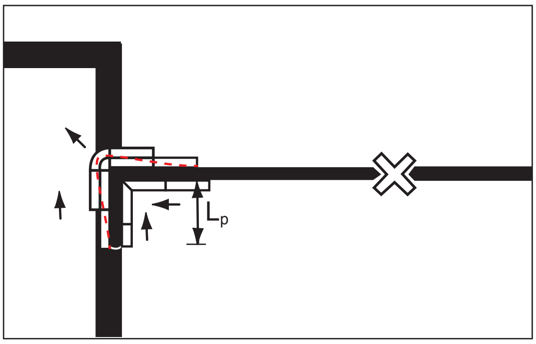
Axial movements and foam pads

The branch is strained by the axial movements in the main pipe and the branch pipe respectively.

The axial movement of the main pipe and the branch pipe results in the branch pipe moving radially. This movement is compensated for by furnishing the branch with foam pads.

The length of the foam pads equals the F-length, determined on basis of the movement of the main pipe and the branch pipe respectively.

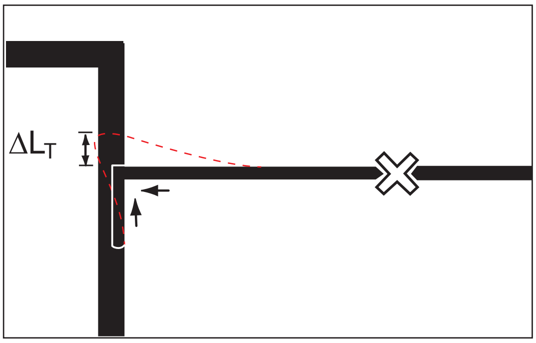
The F-length appears from the curve for the relevant branch dimension, see the section "Directional changes: 80-90° bends with foam pads".



Position on main pipe

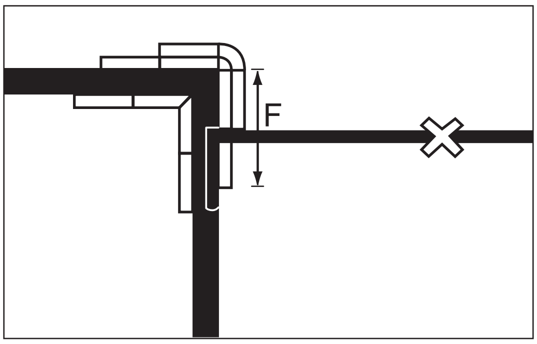
A 90° parallel branch must be placed, where the expansion in the main pipe, ΔL_T, does not exceed the table values:

Main pipe	Branch	
	DN 20 - 25	DN 32 - 300
DN 20 -125	30 mm	56 mm
DN 150 - 300	40 mm	56 mm



When a branch is placed close to a bend in the main pipe, the branch must be installed outside the F-length.

As to calculating the F-length for a bend, see the section "Directional changes: 80-90° bends with foam pads".



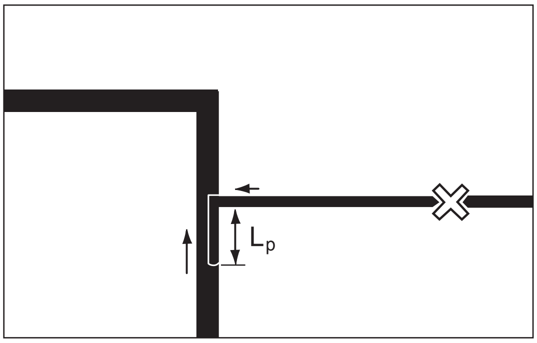
90° parallel branch

Parallel length of branch pipe

The parallel part of the branch pipe L_p results in stresses in the branch itself. This strain is kept at an acceptable level by limiting values for the length of L_p.

L_p must be so long that the axial movement in the branch, ΔL_a, can be absorbed. At the same time L_p must be kept so short that it does not overstrain the branch.

The length of the parallel part of the branch pipe L_p for a 90° parallel branch must therefore lie within the following range:



DN	$L_{p,min}$ m	$L_{p,max}$ m
20-50	Component measurement	2.1
65-80	Component measurement	2.5
100-125	2.0*	3.0
150	2.5*	4.0
200-300	3.0*	5.0

*: If $\Delta L_a \leq 30$ mm, the component measurement can be used as $L_{p,min}$

Component measurement is a preinsulated standard bend and branch

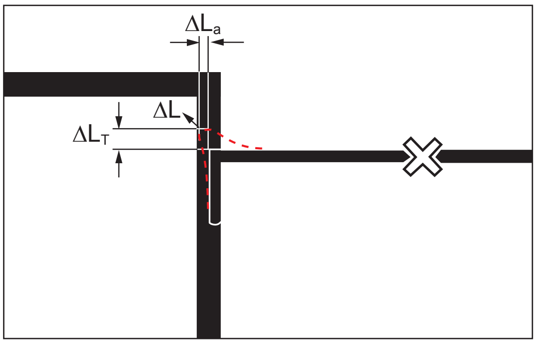
Radial movement in branch

The radial movement in the branch, ΔL, must be < 84 mm, corresponding to 3 layers of foam pads.

ΔL is calculated as follows:

$$\Delta L = \sqrt{\Delta L_a^2 + \Delta L_T^2}$$

With it a limit for the length of L_a is implicitly set, because the axial movement of L_a is included in the formula for ΔL.



90° preinsulated parallel branch - Example

Conditions

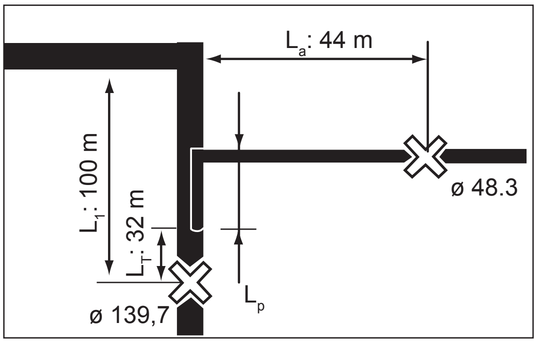
Soil cover:
Main pipe: H_h = 0.8 m
Branch: H_a = 0.6 m
Max. design temperature T_{max} = 110°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

$ød_1/D_1$ = ø 139.7/250 (series 2)
L_1 = 100 m
As the friction length can be calculated to 103.1 m, the relevant length L_1 is used in the calculations
L_T = 32 m

$ød_a/D_a$ = ø 48.3/125 (series 2)
L_a = 44 m
As the friction length can be calculated to 48.0 m, the relevant length L_1 is used in the calculations
L_p = komponentmål

For ø 139.7 at H_h = 0.8 (table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths") the following is found:
F = 3.76 kN/m
A_s = 1539 mm²

For ø 48.3 at H_a = 0.6 (table in the section "Straight pipes: Stress reduction with bends - Tables of installation lengths") the following is found:
F = 1.37 kN/m
A_s = 373 mm²



Check of branch

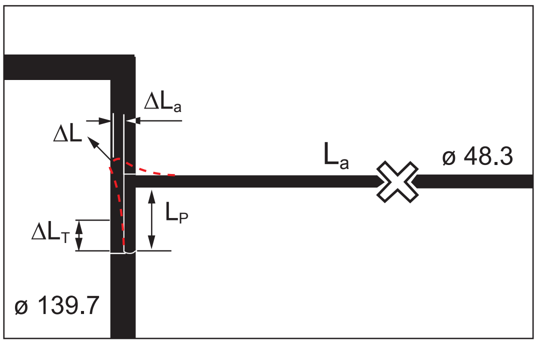
3 checks are performed in connection with the branch.

Axial movement in the main pipe ΔL_T:
Check that $\Delta L_T \leq$ table value in the section "Branches: 90° parallel branch".

Parallel length of the branch, L_p:
Check $L_p/\Delta L_a$ cf. table in the section "Branches: 90° parallel branch".

Radial movement in the bend of the branch, ΔL:
Check that $\Delta L \leq$ 84 mm.

The above movements are calculated in the following.



90° preinsulated parallel branch - Example

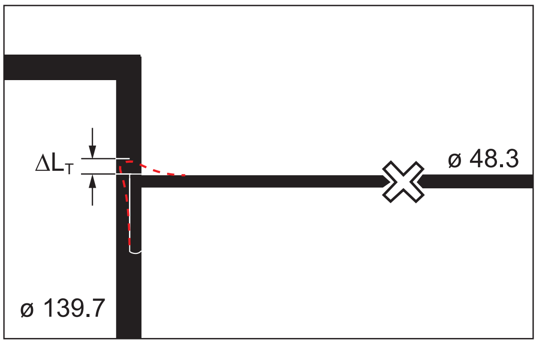
Axial movement in main pipe, ΔL_T

The movement in the main pipe at the branch is determined by the formula in the section "General: Expansion at branches":

$$\Delta L_T = \alpha \cdot \Delta T \cdot L_T - \frac{F\,(2 \cdot L - L_T) \cdot L_T}{2 \cdot E \cdot A_s}$$

$$\Delta L_T = 1{,}2 \cdot 10^{-5} \cdot (110\text{-}10) - 32000 - \frac{3{,}76 \cdot (2 \cdot 100000 - 32000) \cdot 32000}{2 \cdot 210000 \cdot 1539}$$

$= 7$ mm



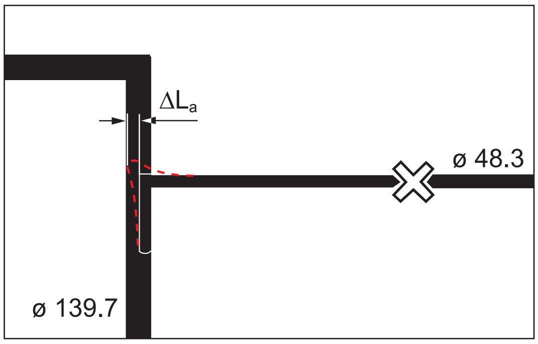
Axial movement in branch, ΔL_a

The axial expansion in the branch is determined by the formula in the section "General: Expansion at bends":

$$\Delta L_a = L_a \cdot \alpha \cdot \Delta T - \frac{F_a \cdot L_a^2}{2 \cdot A_{s,a} \cdot E}$$

$$\Delta L_a = 44000 \cdot 1{,}2 \cdot 10^{-5} \cdot (110\text{-}10) - \frac{1{,}37 \cdot 44000^2}{2 \cdot 373 \cdot 210000}$$

$= 36$ mm

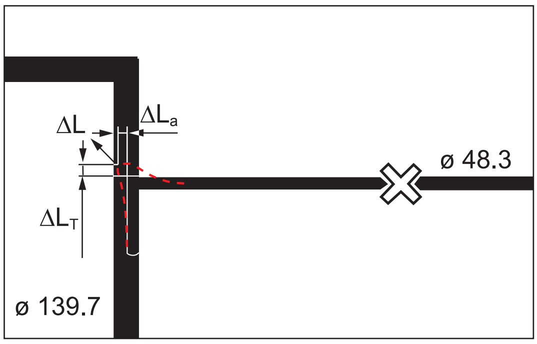


Radial movement in branch

The radial movement in the branch, ΔL, is determined as follows:

$$\Delta L = \sqrt{\Delta L_a^2 + \Delta L_T^2}$$

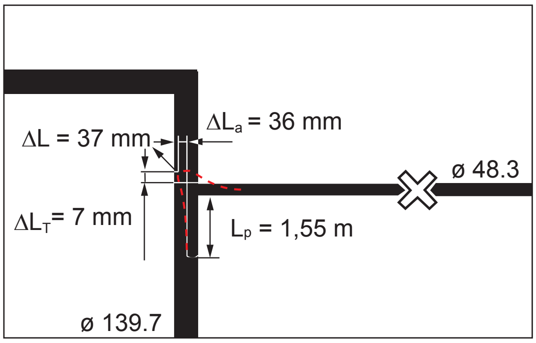
$$\Delta L = \sqrt{36^2 + 7^2} = 37 \text{ mm}$$



90° preinsulated parallel branch - Example

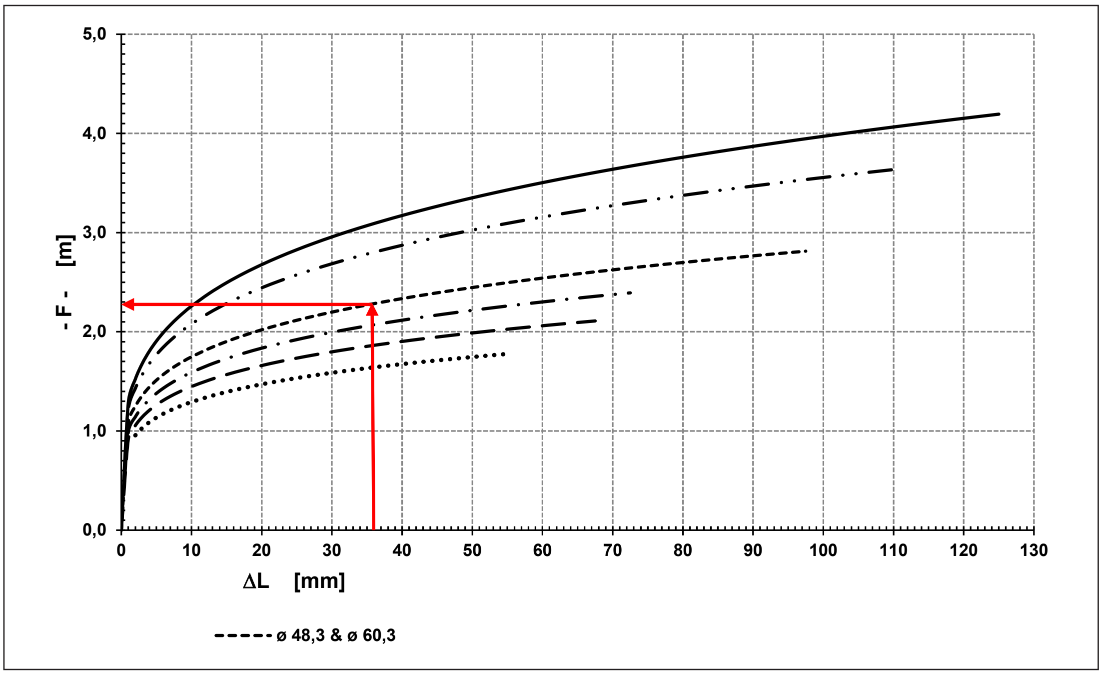
Check of branch

- Check of axial movement in the main pipe:
  From the table in the section "Branches: 90° parallel branch" it appears for a DN 125/250
  DN 40 branch:
  $\Delta L_T \leq 56$ mm
  ΔL_T is calculated to 7 mm - OK.
- Check of parallel length of the branch:
  It appears from the table in the section "Branches: 90° parallel branch" that for a branch pipe in DN40 $L_{p,min}$ = the component measurement. There is no upper limit for ΔL_a.
  L_p = 1.55 m (component measurement) - OK.
  ΔL_a is calculated to 36 mm - OK.
- Check of radial movement in the bend of the branch:
  $\Delta L \leq 84$ mm
  ΔL is calculated to 37 mm - OK.
  The branch length of 44 m and the movement of the main pipe total a radial movement ≤ 84 mm.



F-length for L_p

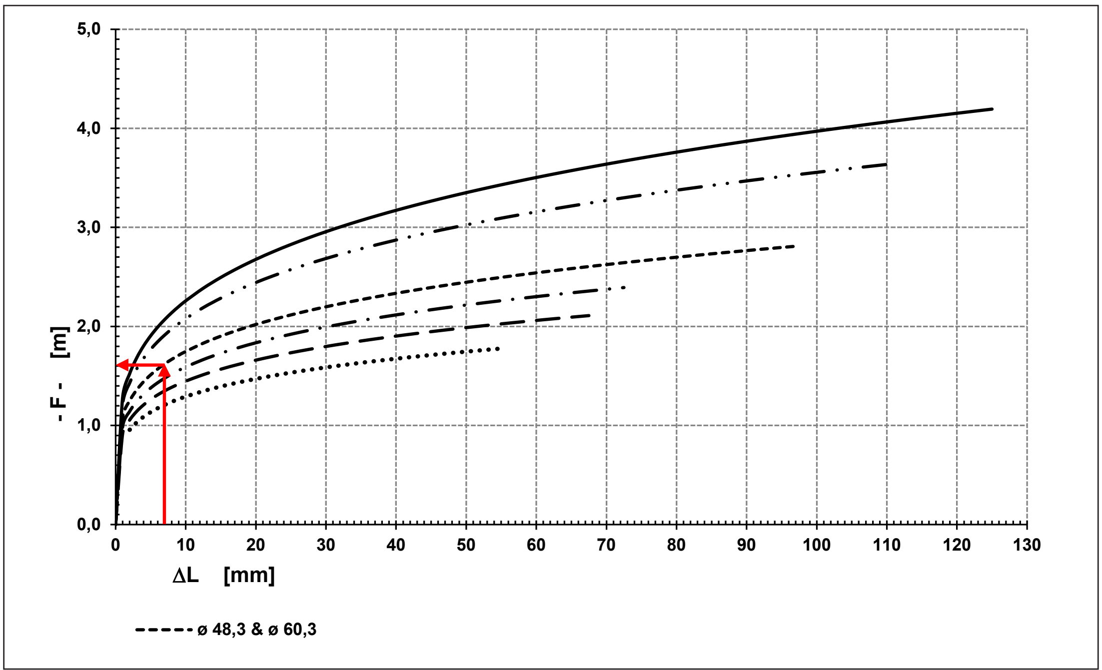
The length of the foam pad on the parallel part of the branch is established on the basis of the diagram in the section "Directional changes: 80-90° bends with foam pads".
From the curve for the branch pipe dimension (ø48.3) the following is read:
ΔL_a = 36 mm gives F = 2.3 m.
The F-length is larger than the component measurement (2.3 m > 1.55 m), so foam pads are only installed in a length of 1.55 m, see next page.



90° preinsulated parallel branch - Example

F-length for L_a

The length of the foam pad on the side of the branch is determined on the basis of the diagram in the section "Directional changes: 80-90° bends with foam pads". From the curve for the branch pipe dimension (ø48.3) it appears:
ΔL_T = 7 mm gives F = 1.6 m



Thickness of foam pads

The minimum thickness of the foam pads is determined on the basis of the radial expansion, ΔL, in the bend of the branch (see the section "Directional changes: 80-90° bends with foam pads"):

Thickness of foam pads (minimum thickness):

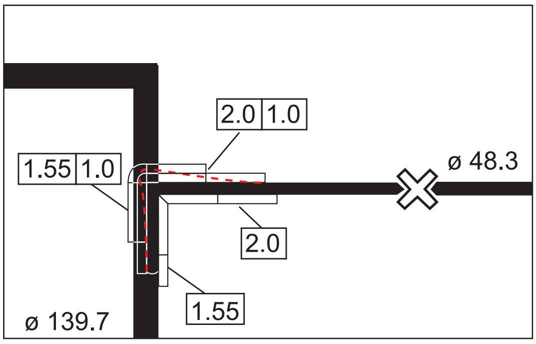
$$t = \frac{\Delta L}{0{,}70} = \frac{37}{0{,}70} = 52 \text{ mm}$$

Number of layers of 40 mm:

$$\frac{t}{40} = \frac{52}{40} = 2 \text{ layers}$$

Positioning foam pads

Foam pads in the length and number of layers, established in the preceding, are placed on the branch pipe.
The foam pad length for the parallel part equals the component measurement of
1.55 m.
All other foam pad lengths are rounded up to nearest half or whole metres.
The inside of the branch bend is furnished with 1 layer of foam pads in the F-length.



90° parallel branch fitting - Example

Introduction

A parallel branch fitting is determined in the same way as a parallel preinsulated branch, because the same design rules apply.

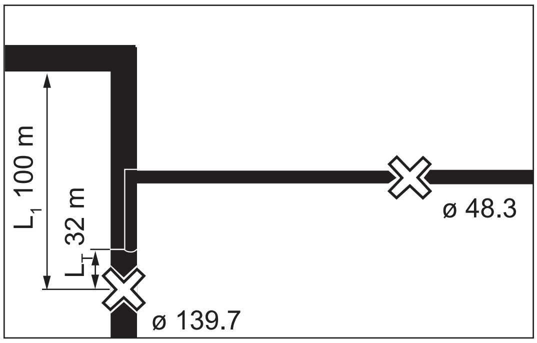
A branch fitting which is carried out with main pipe and pipe dimension, soil cover, operating temperatur, and in the same position as in the example in the section "Branches: 90° preinsulated parallel branch - Example" can therefore be carried out with foam pads as described in the example.

Please note! The length of the parallel part of the branch ΔL_p is as a minimum also the component measurement, when it is carried out as a branch fitting.

In connection with branch fittings the stress level in the main pipe must be determined in the location where the branch fitting is placed. By doing so it is determined whether reinforcement plates must be used, cf. the section "Branches: Reinforcement of branch fittings".

Stress level at branch

The branch is placed in the section, partly restrained by friction ($L_x < L_F$), so the stress level at the branch is determined by the formula in the section "General: Axial stress level".



$$\sigma_x = \frac{L_x \cdot F}{A_s}$$

$$\sigma_T = \frac{(L_1 - L_T) \cdot F}{A_s}$$

$$= \frac{(100 - 32) \cdot 3{,}76}{1539}$$

$$= 166 \text{ MPa}$$

The branch fitting must be reinforced, as the stress level at the branch is > 150 MPa.

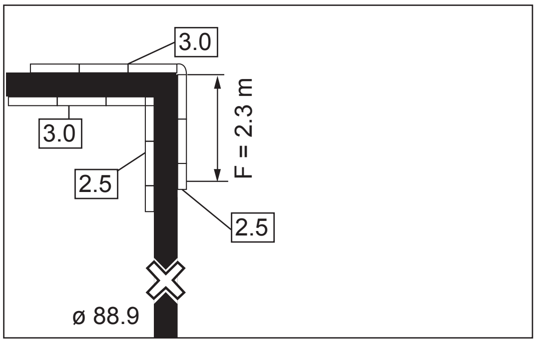
Positioning branch at bend

Postioning branch at bend

A branch is to be placed near a bend, so the branch pipe continues on level with the main pipe.

The F-length for the movement in the main pipe where the branch is to be placed appears from the illustration.

As for calculating the F-length for bends, see the section "Directional changes: 80-90° bends with foam pads".



Conditions

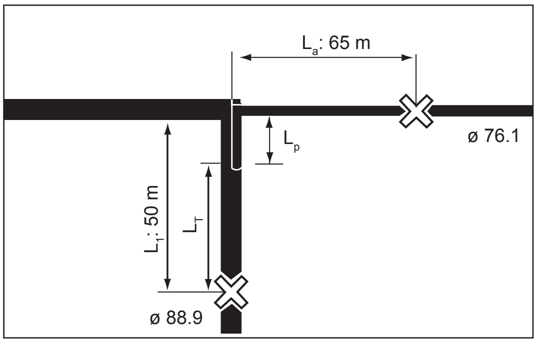
Soil cover
Main pipe: H_h = 0.8 m
Branch: H_a = 0.6 m
Max. design temperature T_{max} = 80°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C

ød_1/D_1 = ø 88.9/180 (series 2)
L_1 = 50
The friction length can be calculated to 51.7 m, so the relevant length L_1 is used in the calculations.

ød_a/D_a = ø 76.1/160 (series 2)
L_p = 1.6-2.5 m, see table in the section "Branches: 90° parallel branch"
L_a = 65 m
The friction length can be calculated to 66.1 m, so the relevant length L_1 is used in the calculations.

For ø 88.9 at H_h = 0,8 (table in the section "Straight pipes: Straight pipes -Stress reduction with bends - Tables of installation lengths") it is found:
F = 2.94 kN/m
A_s = 862 mm²

For ø 76.1 at H_a = 0.6 (table in the section "Straight pipes: Straight pipes - Stress reduction with bends - Tables of installation lengths") it is found:
F = 1.78 kN/m
A_s = 667 mm²



Positioning branch at bend - Example

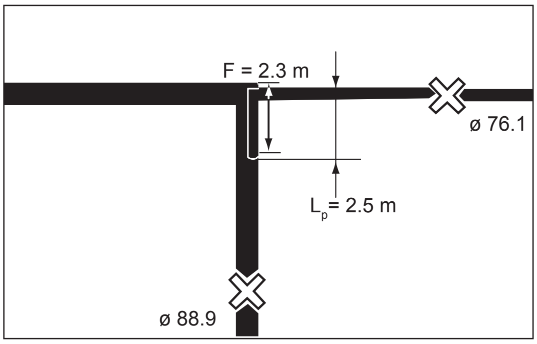
Criteria for positioning

A branch must be installed outside the F-length which is given by the movement in the main pipe. The relevant F-length is 2.3 m.

Likewise the branch length L_p must be between 1.6-2.5 m as it appears from the table in the section "Branches: 90° parallel branch" . The component measurement for a DN 65 is 1.6 m.

The length L_p can then be 2.3-2.5 m.

It is chosen to carry out L_p in 2.5 m.



Check of branch

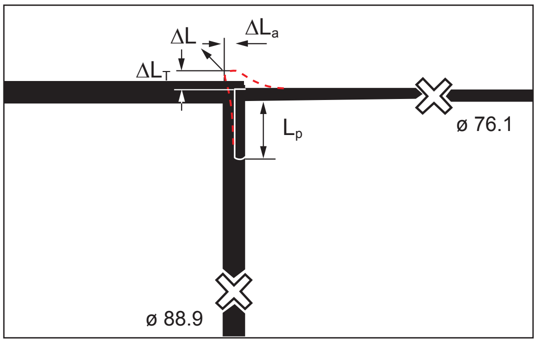
3 checks are performed in connection with the branch.

Axial movement in the main pipe ΔL_T:
Check that $\Delta L_T \leq$ table value in the section "Branches: 90° parallel branch" .

Parallel length of the branch, L_p:
Check $L_p/\Delta L_a$ cf. table in the section "Branches: 90° parallel branch" .

Radial movement in the bend of the branch, ΔL:
Check that $\Delta L \leq 84$ mm.

The above movements are calculated in the following.



Axial movement in main pipe ΔL_T

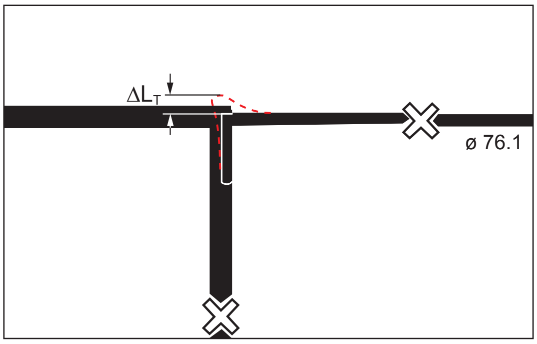
The movement in the main pipe at the branch is determined by the formula in the section "General: Expansion at branches":

$$\Delta L_T = \alpha \cdot \Delta T \cdot L_T - \frac{F\,(2 \cdot L - L_T) \cdot L_T}{2 \cdot E \cdot A_s}$$

$$\Delta L_T = 1{,}2 \cdot 10^{-5} \cdot (80 - 10) \cdot 47500$$

$$- \frac{2{,}94 \cdot (2 \cdot 50000 - 47500) \cdot 47500}{2 \cdot 210000 \cdot 862}$$

$$= 20 \text{ mm}$$



Positioning branch at bend - Example

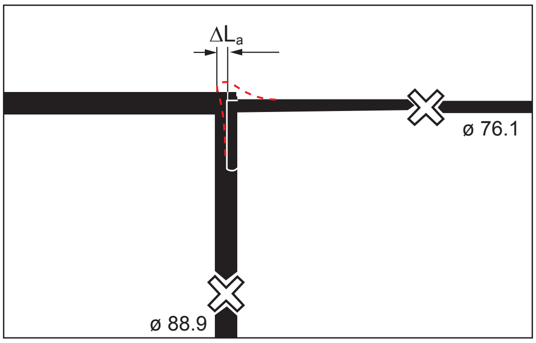
Axial movement in branch ΔL_a

The axial expansion in the branch is determined by the formula in the section "General: Expansion at bends".

$$\Delta L_a = L_a \cdot \alpha \cdot \Delta T - \frac{F_{0,6} \cdot L_a^2}{2 \cdot A_{s,a} \cdot E}$$

$$\Delta L_a = 65000 \cdot 1{,}2 \cdot 10^{-5} \cdot (80\text{-}10) - \frac{1{,}78 \cdot 65000^2}{2 \cdot 667 \cdot 210000}$$

$$= 28 \text{ mm}$$

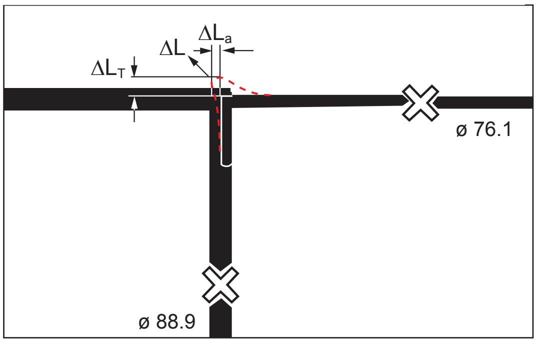


Radial movement in branch

The radial movement in the branch, ΔL, is determined:

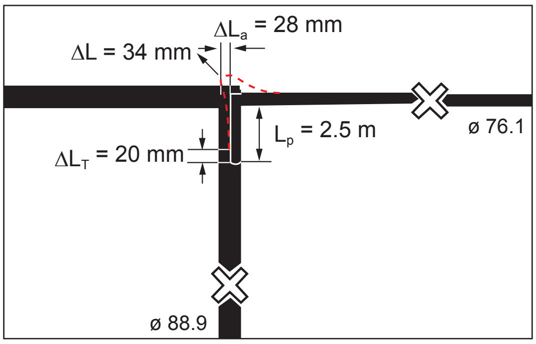
$$\Delta L = \sqrt{\Delta L_a^2 + \Delta L_T^2}$$

$$\Delta L = \sqrt{28^2 + 20^2} = 34 \text{ mm}$$



Check of branch

- Check of axial movement in the main pipe:
  From the table in the section "Branches: 90° parallel branch" fås t appears for a DN 80/200
  DN 65 branch:
  $\Delta L_T \leq 56$ mm
  ΔL_T is calculated to 20 mm - OK.
- Check of parallel length of the branch, L_p:
  It appears from the table in the section "Branches: 90° parallel branch" that $L_{p,max}$ = 2,5 m for a DN 65 branch.
  L_p = 2.5 m - OK.
- Check of radial movement in the bend of the branch:
  $\Delta L \leq 84$ mm
  ΔL is calculated to 34 mm - OK.
  The branch length of 65 m and the movement of the main pipe total a radial movement ≤ 84 mm.



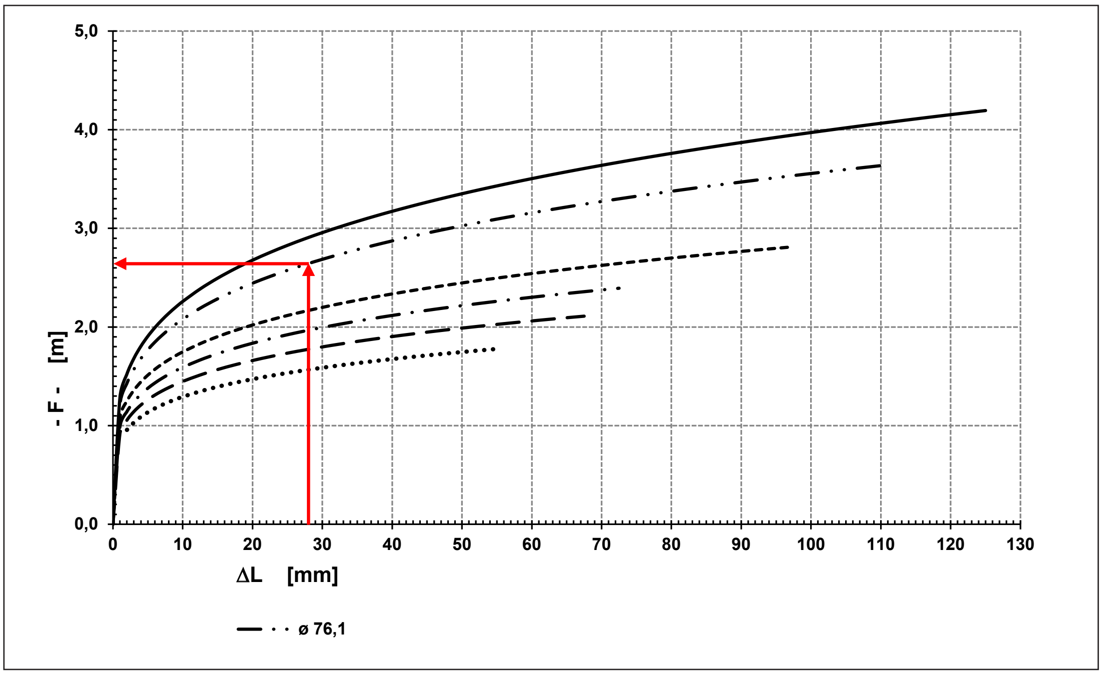
Positioning branch at bend - Example

F-length for L_p

The length of the foam pad on the parallel part of the branch is established on the basis of the diagram in the section "Directional changes: 80-90° bends with foam pads". From the curve for the branch pipe dimension (ø76.1) the following is read:

ΔL_a = 28 mm gives F = 2.7 m.

F-length > L_p (2.7 m > 2.5 m), so foam pads are only installed in a length of 2.5 m, see next page.

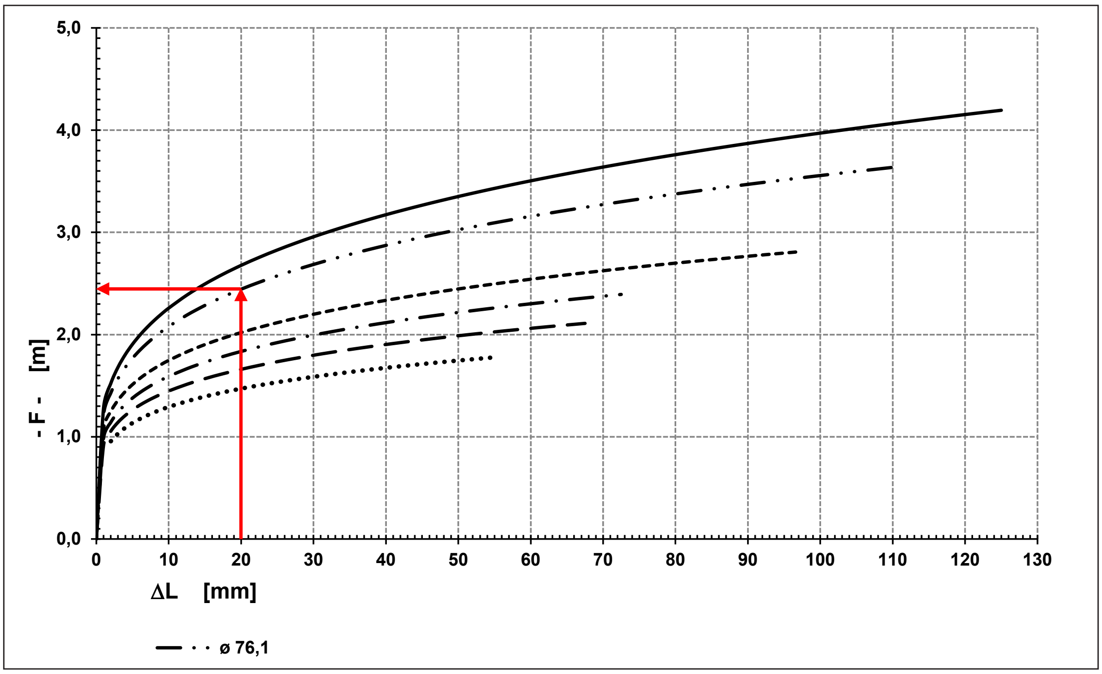


Positioning branch at bend - Example

F-length for L_a

The length of the foam pad on the side of the branch is determined on the basis of the diagram in the section "Directional changes: 80-90° bends with foam pads".

From the curve for the branch pipe dimension (ø76.1) it appears:
ΔL_T = 20 mm gives F = 2.5 m



Thickness of foam pads

The minimum thickness of the foam pads is determined on the basis of the radial expansion, ΔL, in the bend of the branch (see the section "Directional changes: 80-90° bends with foam pads"):
Thickness of foam pads (minimum thickness):

$$t = \frac{\Delta L_T}{0,70} = \frac{48}{0,70} = 69 \text{ mm}$$

Number of layers of 40 mm:

$$\frac{t}{40} = \frac{69}{40} = 2 \text{ layers}$$

Positioning branch at bend - Example

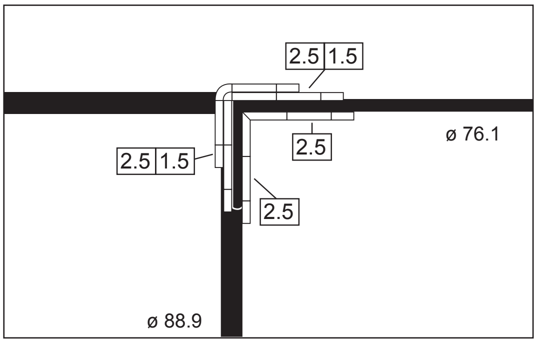
Positioning foam pads

Foam pads in the length and number of layers, established in the preceding, are placed on the branch pipe.

Foam pads on the bend of the main pipe do not appear from the illustration.

The lengths are rounded up to nearest half or whole metres.

The inside of the branch bend is furnished with 1 layer of foam pads in the F-length.



References

LOGSTOR Design Tool:

https://designtool.logstor.com/Tool/Form.aspx?ApplicationId=18749619-698b-47c3-8dbe-c54c42282ccb

Straight branches

Application

Straight branches are typically used when establishing service valves, see the section "Isolation valves".

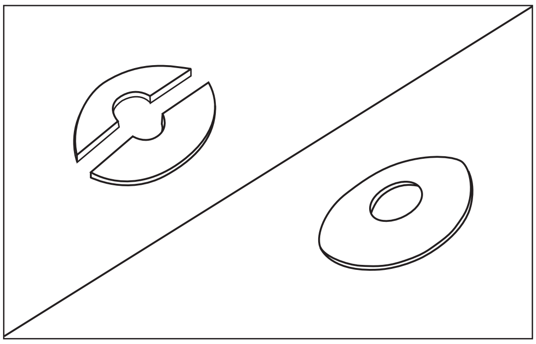
As to other possible applications please contact LOGSTOR for guidance.

Reinforcement of branch fittings

Application

In connection with branch fittings reinforcement must be used in a number of combinations as a compensation for the cut cross-sectional area on the main pipe.

Reinforcement plates are either 2-part or one plate, see also the section "Branches: Reinforcement plates" in the Product Catalogue.



Stress level

The stress level in the main pipe at the branch defines, whether reinforcement plates are to be used at branch fittings.

Combinations, marked by x must be reinforced, when σ_{axial} > 150 MPa.

Combinations, marked by x must always be reinforced irrespective of the stress level.

NOTE! If the branch pipe and the main pipe have the same dimension, weld T-pieces must be used.

Branch ø mm Main pipe ø mm	26.9	33.7	42.4	48.3	60.3	76.1	88.9	114.3	139.7	168.3	219.1
26.9											
33.7	x										
42.4	x	x									
48.3	x	x	x								
60.3	x	x	x	x							
76.1	x	x	x	x	x						
88.9	x	x	x	x	x	x					
114.3	x	x	x	x	x	x	x				
139.7	x	x	x	x	x	x	x	x			
168.3	x	x	x	x	x	x	x	x	x		
219.1	x	x	x	x	x	x	x	x	x	x	
273	x	x	x	x	x	x	x	x	x	x	x
323.9	x	x	x	x	x	x	x	x	x	x	x
355.6	x	x	x	x	x	x	x	x	x	x	x
406.4	x	x	x	x	x	x	x	x	x	x	x
457	x	x	x	x	x	x	x	x	x	x	x
508	x	x	x	x	x	x	x	x	x	x	x
610	x	x	x	x	x	x	x	x	x	x	x

See the section "Installing branch fittings: Reinforcement plates" in Handling & Installation for information on welding on reinforcement plates and installing branch fittings.

Reinforcement of branch fittings

References	Product Catalogue	Directional changes: Preinsulated bends Branches Branches: Preinsulated T-piece - 45° Branches: Preinsulated T-piece - 90°
	Handling & Installation	Installing branch tittings
	Design	General: Expansion at bends General: Expansion at branches Straight pipes: Straight pipes without stress reduction Straight pipes: Stress reduction with bends - Tables of installation lengths Direction changes: 80-90° bends with foam pads Isolation valves: Venting or draining

Reductions
Overview

Introduction

This section describes the design rules to apply when establishing reductions, taking the actual, axial stress level of the pipe section into consideration.

Contents

Guidelines for use

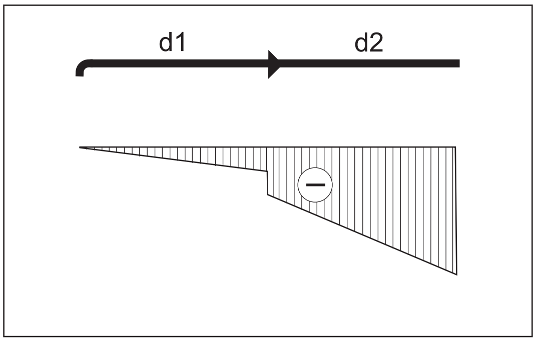
Guidelines for use

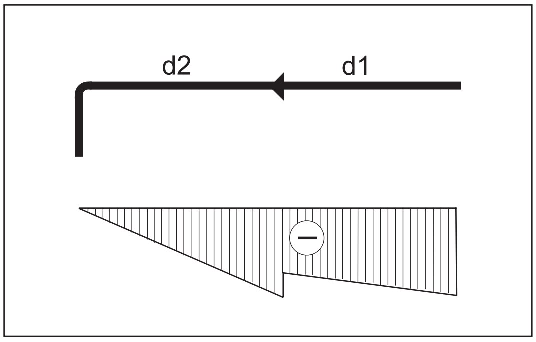
Stress diagram

When reducing the service pipe dimension, the axial stress level is reduced, corresponding to the relation between the steel cross section of the two pipe dimensions, A.

$$\sigma_2 = \sigma_1 \cdot \frac{A_1}{A_2}$$

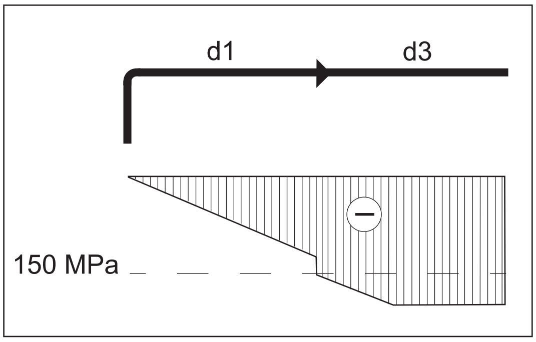
Dimensions:
d1 > d2



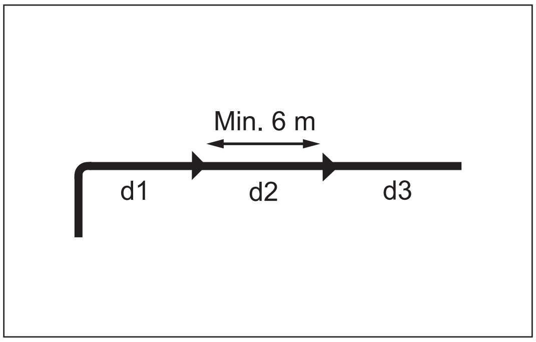


Stress level < 150 MPa

One reduction with 2 dimensional offsets can be placed where the stress level in the minor cross section (d3) is < 150 MPa.

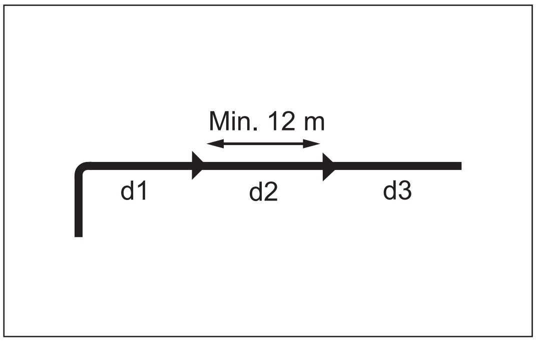


In case two reductions with 1 dimensional offset each are required, they can be placed in series with a distance of min. 6 m provided the stress level in the smallest cross section (d3) is < 150 MPa.



Stress level > 150 MPa

Two reductions with 1 dimensional offset each can be placed in series with a distance of min. 12 m, provided that the stress level is > 150 MPa.



Branches

Preinsulated T-pieces can be placed at random in relation to the reduction, because LOGSTOR standard T-pieces are carried out with additional wall thicknes and therefore can be used in systems with high, axial stress levels.

When branching by welding branches directly onto the main pipe, these must be reinforced by means of reinforcement plates, cf. the section "Branches: Reinforcement of branch fittings"

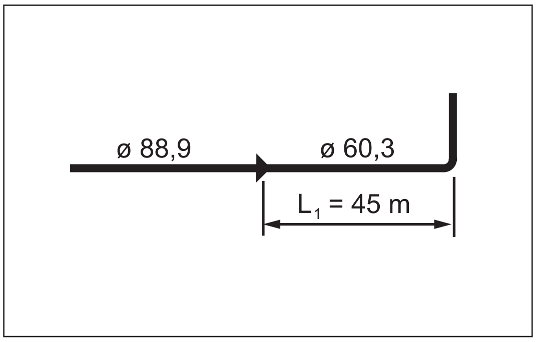
Guidelines for use - Example 1

Conditions

Dimension ø 88.9 series 2 to be reduced to ø 60.3. (2 dimensional offsets in 1 reduction)

Soil cover H = 0,8 m
Max. design temperature T_{max} = 120°C
Min. design temperature T_{min} = 10°C
Installation temperature T_{ins} = 10°C
L_1 = 45 m

From the section "Straight pipes: Stress reduction with bends - Tables of installation lengths":
ø 60.3:
F = 2.03 kN/m
A_s = 523 mm²



Determining the stress level

Determination of the stress level at the reduction:

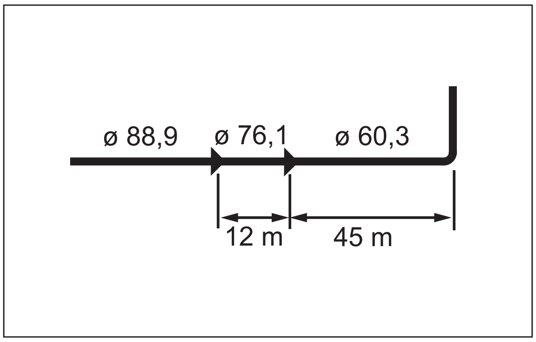
$$\sigma_x = \frac{L_x \cdot F}{A_s}$$

$$\sigma_{45m} = \frac{45 \cdot 1{,}81 \cdot 1000}{523} = 155{,}7 \text{ MPa}$$

The stress level in the smallest dimension is > 150 MPa, so reduction with 2 dimensional offsets in one reduction must not be done.

Two reductions witn a distance of min. 12 m may be established.

Alternatively, the reduction can be moved closer to the bend, so the stress level is reduced.



References

Product Catalogue	Reductions
Handling & Installation	Insulating joints: Other insulation methods - Insulation shells

Isolation valves

Overview

Introduction

This section contains instructions for establishing valve arrangements, used in connection with isolation and venting/draining preinsulated bonded pipe systems.

Contents

General
Venting or draining

Isolation valves
General

Application

The isolation valve is built-in to split the pipeline into adequate sections, taking into consideration:
- the suitable water quantity
- costs, if it is necessary to drain the system
- supply safety
- easy repair of the system

Preinsulated isolation valves can be installed at any point in the single pipe system and installed directly in the ground at the same time as the pipes are installed. The friction material, used around the preinsulated valves, is the same type as the one used around the preinsulated pipes.

Preinsulated isolation valves are applicable for all pipe systems with the following static conditions: max. ΔT = 130 °C and max. PN = 25.

They are suitably to build-in everywhere in the system without any restrictions, as they are tested for high axial stresses and bending moments according to EN 448.

It is recommended to place them outside the expansion zones of bends (F-length).

Valve arrangements

The isolation valve is a maintenance free ball valve in a full-welded casing and with a stainless polished valve ball in a spring loaded teflon seat which makes the valve watertight even at low pressures.

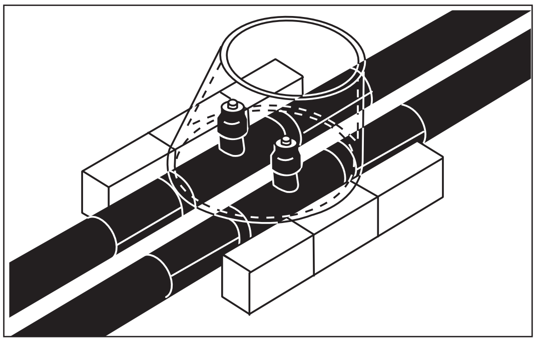
To ensure the correct functionality of the valve, it must be operated frequently, (i.e. 2 to 4 times per year dependent on the water quality).

Installation instructions

The valves must be installed, so the free movement of the spindle is ensured, when the pipe expands in the soil.

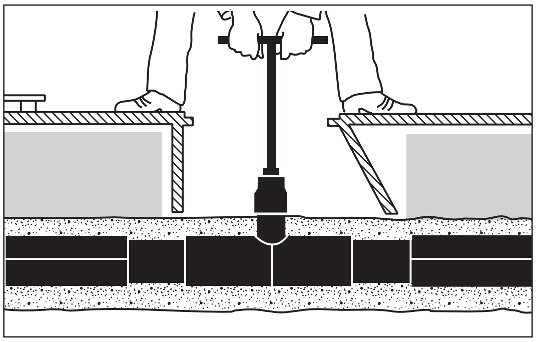
The simplest way to establish access to the valves is to place a concrete chamber on two rows of foundation bricks.

The concrete chamber must not rest on the preinsulated pipe.



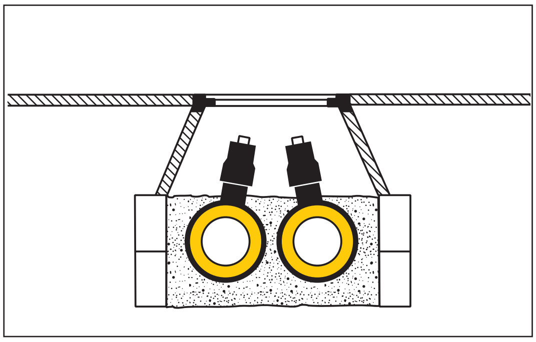
In this way the possible movement of the service pipe is ensured, and the tops of the spindles are kept free of friction material.

Spindle tops must not be permanently under water.



Installation instructions, *continued*

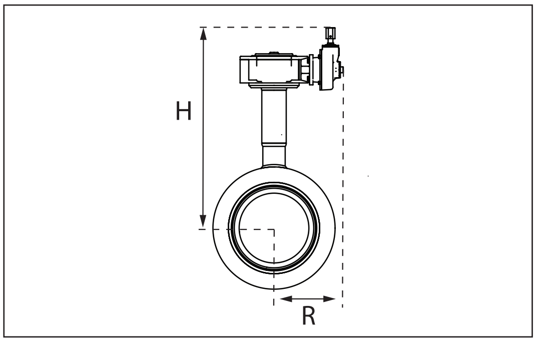
The shown chamber construction can also be used for major dimensions, if the spindles are tilted to enable operation from the chamber.



Gear

For steel pipe dimensions ≥ ø 219.1 mm the valve must be operated with a gear. Up to DN 300 a normal portable planet gear is usually used.

In case of larger dimensions a fixed gear - with electric actuator, if necessary - can be installed.



The physical size of a fixed gear depends on the make, but the measurements in the table may be used as guidelines.

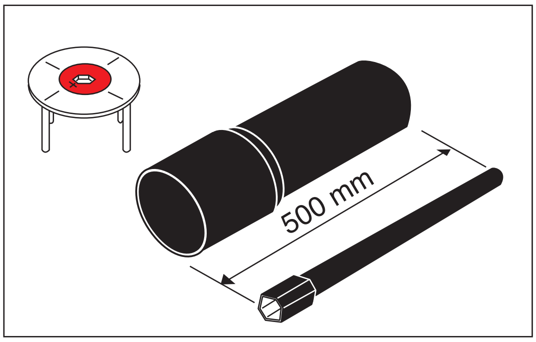
The valve chamber must be designed so there is ample space for valve, gear and possible movement of the service pipe.

Dimension	Height (H)	Radius (R)
323.9	804	375
355.6	830	375
406.4	890	425
508	1040	605

Spindle extension

At large installation depths the fixed spindle can be extended with a detachable extension arrangement. The standard length of an extension arrangement is 500 mm, but other lengths may be ordered, if required.

The spindle top and spindle must not be permanently under water.



General

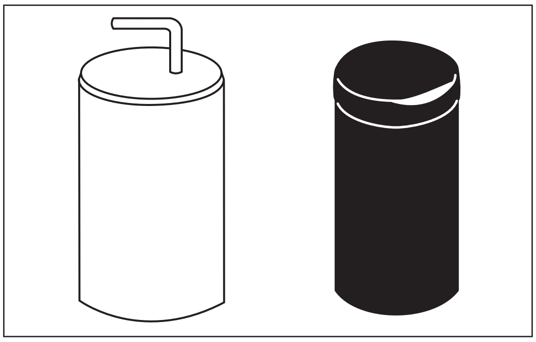
Cover

A cover either of galvanized steel or PE can be used in water-logged areas.

At periodic floodings the cover effectively prevents water from penetrating into the spindle top and the venting/draining valves, exposing these to corrosion or deposits.

The galvanized solution works due to its gravity.

The PE solution works, because the PE cap comes to a stop against the chamber cover.



References

Product Catalogue	Valve arrangements
Handling & Installation	Isolation valves and venting

Venting or draining

Application

Venting and draining can be carried out with either preinsulated components or branch joint solutions.

Preinsulated solutions either in combination with an isolation valve or as a separate preinsulated venting/draining component are applicable for all pipe systems with the following static conditions: max. ΔT = 130°C and max. PN = 25.

Separate venting/draining arrangements, made with branch joints must be designed with due regard to the actual axial stress level.

Reinforcement plates need to be installed according to the rules in the section "Branches: Reinforcement of branch fittings".

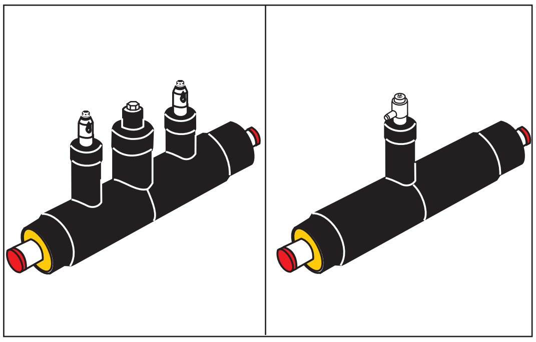
Venting/draining arrangements

It is recommended that the venting/ draining arrangement is positioned upwards.

This minimizes the installation costs and reduces the risk of dirt gathering e.g. in drains, which may increase the risk of corrosion.

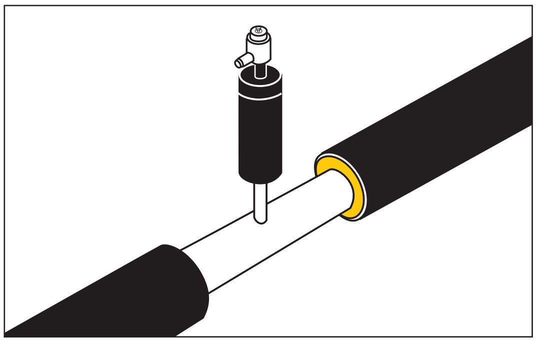
Possibly use a suction pipe when draining.

Venting/draining are available as preinsulated isolation valves with 1 or 2 stainless venting/draining service valves or as a separate preinsulated component.



A preinsulated branch pipe piece with service valve can be installed at high/ low points for venting/draining together with a vertical branch joint. This increases the flexibility.

It must be ensured that there is sufficient height so there is room for venting and casing joint.

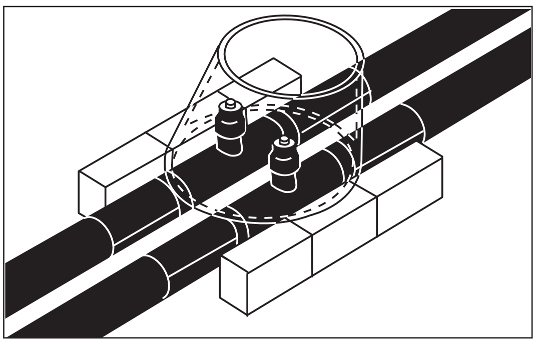


Positioning

Venting/draining arrangements are suitably to build-in everywhere in the system without any restrictions.

It is however recommended to keep them outside the F-length at bends.

The vent/drain must be installed in a way, which ensures free movement when the pipe moves in the soil. See the section "Isolation valves: General".



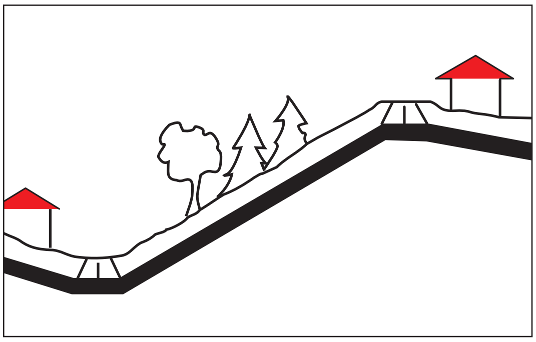
Venting or draining

Positioning, *continued*

When following the surface of the ground, the pipeline will have a lot of small not defined high and low points.

For pipelines with a slope > 3°, measured from the horizontal, it is advantageous to place valves/chamber at the lowest and highest points. This facilitates draining and venting, if needed.

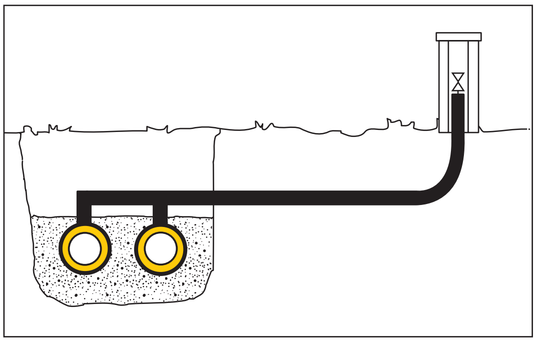
Experience shows that pipelines with a level difference < 3° do not have air pockets, getting stuck in the system. Air pockets which naturally build up at the highest points in the pipe system are carried along under normal flow.



Separate venting with FlexPipes

Venting with FlexPipes to a weatherproof cabinet is a good solution, because the valves are not in the traffic areas.

Install a thermostatic valve between the 2 venting arrangements to protect long pipelines to the cabinet against frost.



References

Product Catalogue:	Isolation valves: General Tools: Tools for operation isolation valves
Handling & installation:	Isolation valves and venting

Overview

Introduction

This section contains preconditions of using anchors in preinsulated pipe systems.

Contents

Design
Anchor blocks

Design

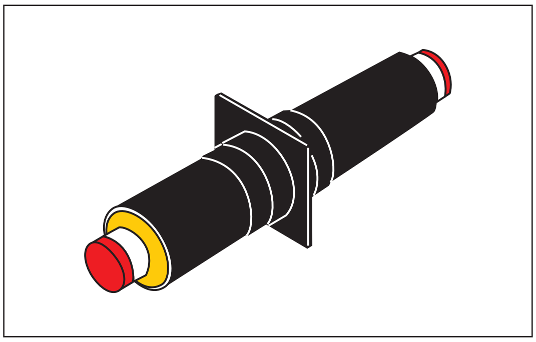
Application

Generally, pipe systems are designed without anchors, because they limit the possibility of using the stress regulating properties of the pipes, and often they are statically not required unless to control movements or forces in the system.

If it is necessary to establish an anchor to control movements or forces in the pipe system, the maximum allowable axial stress difference is limited to 150 MPa where the anchor is installed.

If it is necessary to reduce the axial stresses to secure this level, it can be done by installing E-Comps, expansion bends or by means of heat prestressing in accordance with the section "Straight pipes".

Measurements of preinsulated anchor, see the section "Expansion and anhcoring: Anchors" in the Product Catalogue.



Anchor blocks

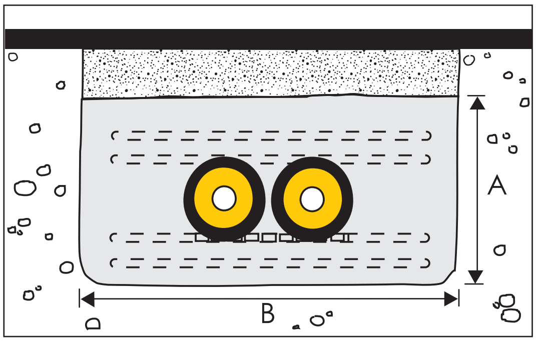
Concrete anchor block, conditions

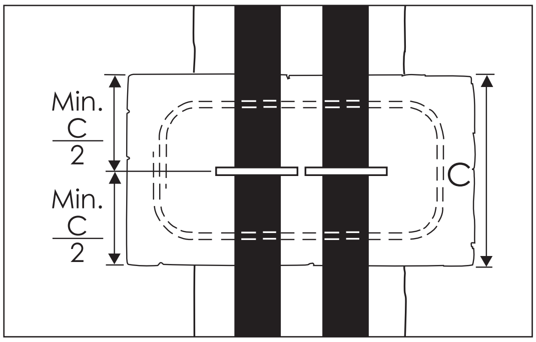
The required dimensions of the anchor blocks according to below table are based on the following conditions:

Compressive strenght of the soil:
150 kN/m^2
Reinforcement:
Tentor B 500
Re = 500 MPa
Quality of the concrete:
Compressive strength = 25 MN/m^2
Load:
The block is loaded on one side.

In connection with large pipe dimensions the anchor blocks often become very large.

Contact LOGSTOR for alternative solutions.





Size and reinforcement of concrete anchor block

Dimensions of anchor block.

Required reinforcement.

Steel pipe ø out mm	A m	B m	C m	Reinforcement bar No.	Reinforcement bar Ø mm
26.9 / 33.7	0.45	0.8	0.75	4	8
42.4 / 48.3	0.50	1.0	0.75	6	8
60.3	0.60	1.2	0.75	6	8
76.1	0.80	1.1	0.75	4	12
88.9	0.80	1.5	0.75	4	12
114.3	0.80	2.1	0.75	4	12
139.7	1.00	2.1	0.75	4	12
168.3	1.10	2.5	0.75	6	12
219.1	1.30	3.2	0.85	6	12
273.0	1.50	3.8	1.10	6	16
323.9	1.70	4.5	1.30	4	20
355.6	1.80	4.7	1.20	4	20
406.3	2.00	5.4	1.40	6	20
457.0	2.10	5.8	1.50	6	20
508.0	2.30	5.9	1.60	8	20
558.8	2.40	6.3	1.60	8	20
609.6	2.60	7.1	1.90	8	20

References

Product Catalogue — Expansion and anchoring: Anchors
Design — General: System definitions
Handling & Installation — Expansion and anchorage: Installing prefabricated anchor

Terminations
Overview

Introduction

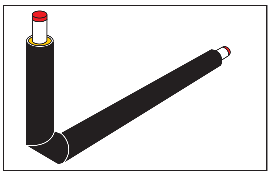
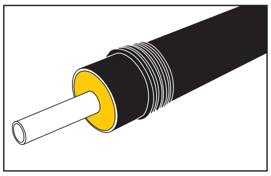
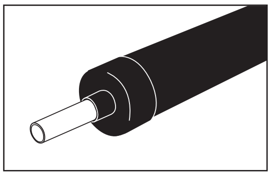
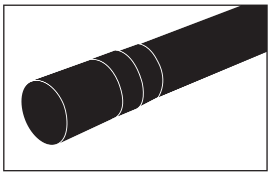
This section describes the components for termination e.g. in connection with foundations, cellars, house entries, and concrete ducts which ensure a correct position and protection of the insulation under varying installation conditions.

Contents

General
House entry pipe
Wall entry sleeve
End-cap
End fitting

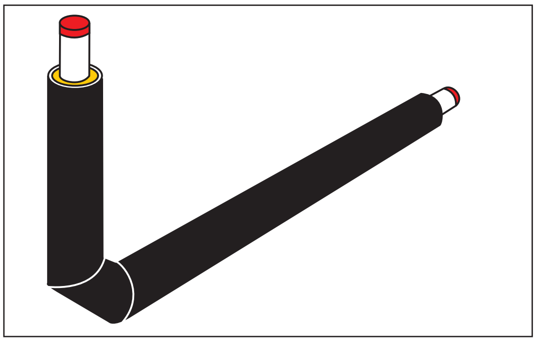
General

Possible termination solutions

Termination:	**Used for:**	**Illustration:**
House entry pipe	Entry through foundation and floor in one working operation	
Wall entry sleeve	Sealing between pipes and recasting in connection with horizontal wall entry	
End-cap	Protection of insulation against water ingress	
End fitting	Protection of the pipe end in connection with termination in the ground	

House entry pipe

Application



To enter through a foundation or a floor in one working operation the house entry pipe is used.

Prefabricated house entry pipes facilitate the installation of district heating pipes in buildings without cellars.

When using a house entry pipe it has to be secured that the expansion movement at the entry is at a minimum to protect the pipe and foundations/floor.

Terminations
Wall entry sleeve

Application

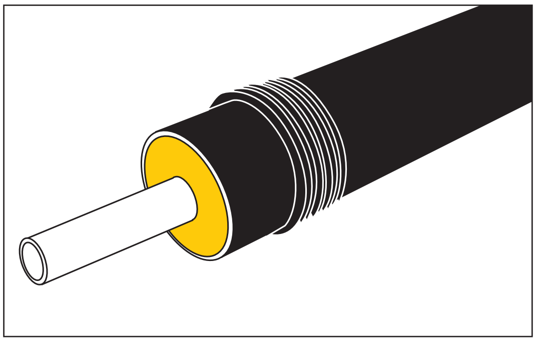
Where pipes are installed through masonry – at wells, foundations etc. – sealing rings are installed to prevent water ingress.

Exposed to groundwater pressure the wall entry sleeves may not be water-tight

For constructions with a very high hydrostatic pressure, wall entry sleeves which are fixed to the internal or external wall and pressed against the PE casing are recommended.

PUR will creep over time, and it is therefore recommended in such cases to use types which can be readjusted.

In general pay attention to the expansion movements which may occur at a horizontal wall entry. They may have an impact on internal installations.

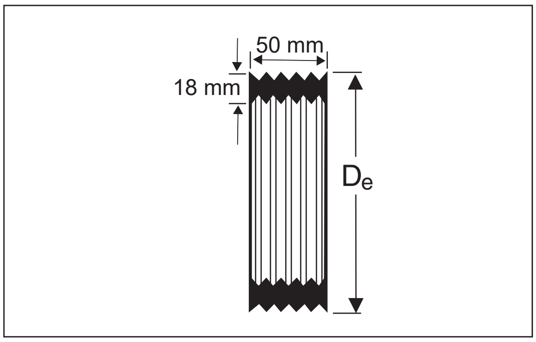


Description

The wall entry sleeves are made of an extremely resistant rubber which, together with a good sealing effect, also allows minor expansion movements at the entry point.

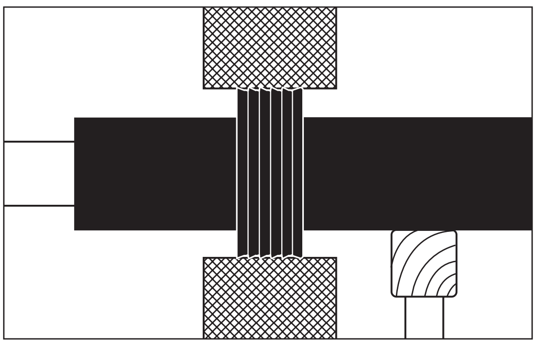
Note! $D_e - 2 \cdot 18$ mm is smaller than the nominal diameter, so the sleeve fits tightly around the outer casing.

For D_e please see the section "Terminations: Wall entry sleeve" in the Product Catalogue.



Bore in the base

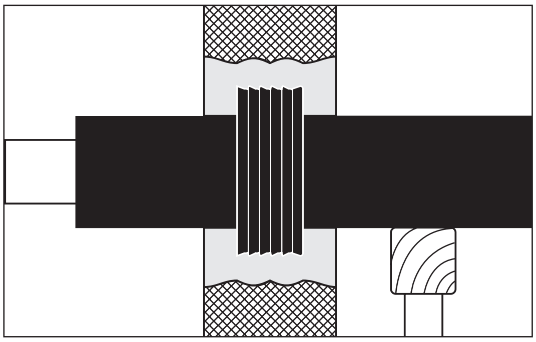
If the holes are drilled, their diameter should be 1-3% smaller than D_e.



Wall entry sleeve

Concreting

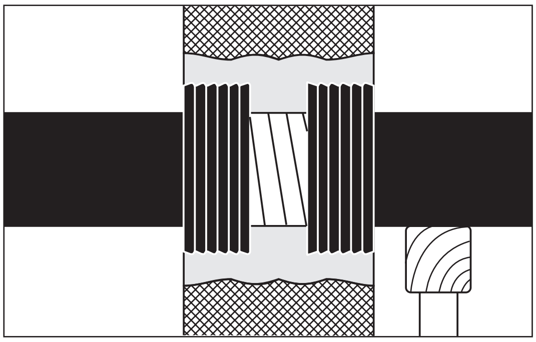
When encasing a pipe with wall entry sleeves in a core, the pipe should be supported, so the concrete can flow all the way around the wall entry sleeve.



Use more wall entry sleeves, when the entry pipe is subject to minor side loads or in thick walls.

This gives a better sealing effect.

Apply grease tape between the wall entry sleeves to allow minor axial movement.



Terminations
End-cap

Application

The end-cap is used indoors to seal the pipes in order to prevent moisture from penetrating into the insulation.

End-caps are used in connection with terminations in chambers, connections to concrete ducts, in cellars etc.

Chambers and ducts must not be flooded, resulting in water around the end-cap.

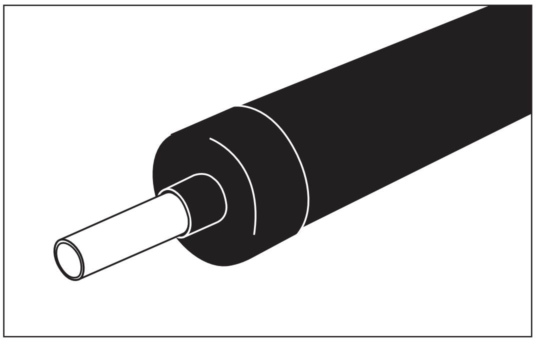
It is recommended to use a termination pipe when there is risk of the end-cap coming into direct contact with water.

Description

Standard end-cap is placed on the pipe end before welding it together with the non-insulated pipes.

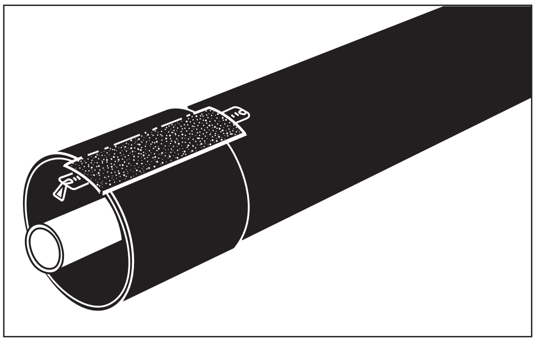
The end-cap is heat-shrunk on the service pipe as well as the outer casing.

For standard end-caps the allowable continuous operating temperature is max. 120°C and the peak temperature (short-term) is max. 130°C.



The split end-cap with zipper is i.a. used when repairing or in connection with subsequent installation.

On outer casing dimensions > ø 450 mm it is however used as a standard end-cap and for repairs.



End fitting

Application

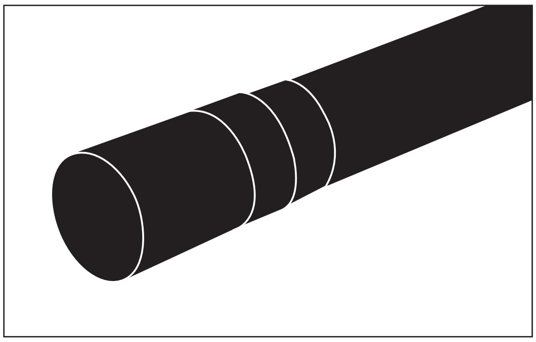
To terminate a pipe system in the ground a PE end fitting is used. Which end fitting to use depends on the dimension.

Types of end fittings

For dimensions ø90 – 630 mm end fittings with insulation shells are used.

To terminate a pipe system with a ø 710 – 1000 mm outer casing PE end fittings for foaming are used.

If an end fitting is placed at the end of a section where it expands in the ground, the expansion must be absorped by foam pads, placed at the end to avoid unintended influences.



References

Product Catalogue:	Terminations
Handling & installation:	Terminations

Expansion absorption
Overview

Introduction

This section describes how lateral expansion movements in a pipe system can be absorbed.The lateral expansion absorption in pipe systems can take place after two principles:

1. Expansion absorption in foam pads.
   This ensures that the PUR compressive stress does not exceed the limit value, established in EN 13941, for σ_{PUR} = 0.15 MPa.
   Foam pads functions by partially absorbing/distributing expansion movements. As foam pads have a lower compressive strength than the PUR insulation, the deformation of the PUR insulation is reduced.
   Foam pads can be installed as and when required along the movable part of bends/branches (see the sections "Directional changes" and "Branches").
2. Expansion absorption in sand pads.
   Here the PUR compressive stress will often exceed the limit value, established in EN 13941, for σ_{PUR} = 0.15 MPa.
   When using sand pads, calculation is usually made with a $\sigma_{PUR} \leq$ 0,25 MPa. At this load the shrinkage of the PUR foam over 30 years will be < 10%.
   σ_{PUR} increases with the installation depth and insulation thickness, therefore the use of sand pads is limited. If sand pads are used the load on the PUR-foam shall be assesed/calculated in each case. The PUR compressive stress will often exceed the value, established in EN 13941, therefore sand pads will not be described further in this manual, even though they have been used for many years. For more detailed information about this method contact LOGSTOR.

Contents

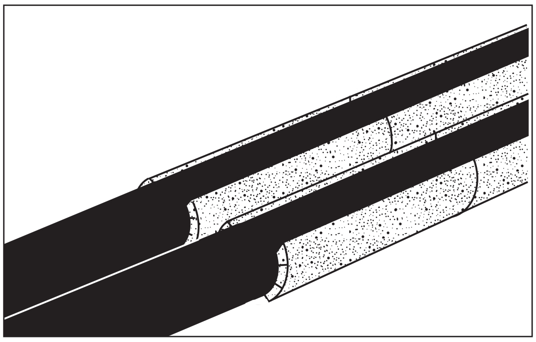
Foam pads

Foam pads

Application

Foam pad can be used to absorb expansion movements when the first movement does not exceed the following intervals:

- 5 < ΔL ≤ 28 mm (1 layer = 40 mm)
- 28 < ΔL ≤ 56 mm (2 layers = 80 mm)
- 56 < ΔL ≤ 84 mm (3 layers = 120 mm)

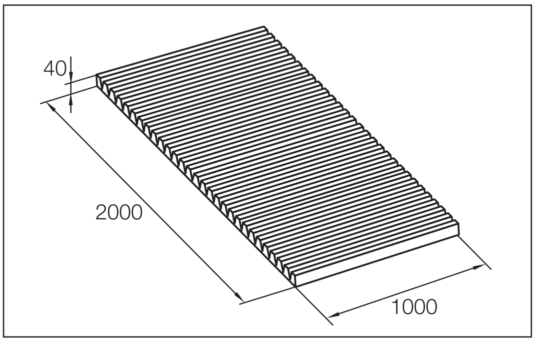


It is recommended not to use more than 3 layers of foam pads (120 mm) at a max. temperature of 130°C and normal varying operation. This ensures that the continuous surface temperature of the outer casing will not exceed 50°C with peak temperatures up to 60°C for max. 300 h per annum, which is stated in EN 13941 as the upper limit.

If more than 3 layers are required, please contact LOGSTOR for support.

Square measurement of foam pads

The foam pads are available in one size which is adjusted to the actual casing diameter.



Material

Foam pads, supplied by LOGSTOR, are made of crosslinked PE with closed cells.

Properties

Rigidity on compression:

Deformation	Compressive stress
40%	0.06 MPa
50%	0.09 MPa
75%	0.275 MPa

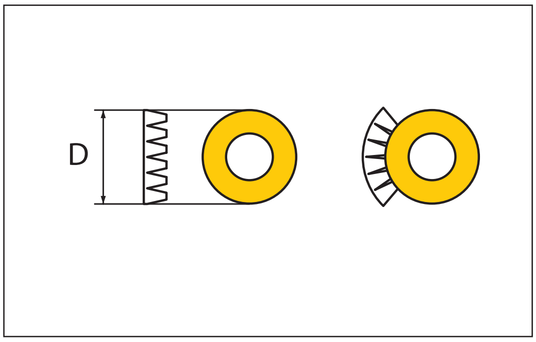
Thermal conductivity: 0.05 W/mK at 50°C

NOTE!
The design rules, laid down in this manual, are conditional on the use of LOGSTOR foam pads.

Foam pads

Actual foam pad measurement

The casing diameter determines the height of the foam pad.



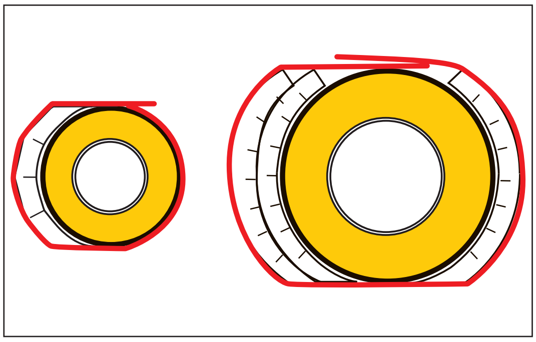
Installing foam pads

Install the pads on one or both sides of the outer casing in accordance with the system drawing.

In case of minor dimensions filament tape may be used to secure the pads.

For major dimensions and several layers it is recommended to wrap the pads in geotextile etc.

This also prevents friction material from entering between the foam pad and the outer casing, when backfilling the trench.



Stating the number of foam pads

To determine the necessary number of foam pads, see the sections "Directional changes" and "Branches".

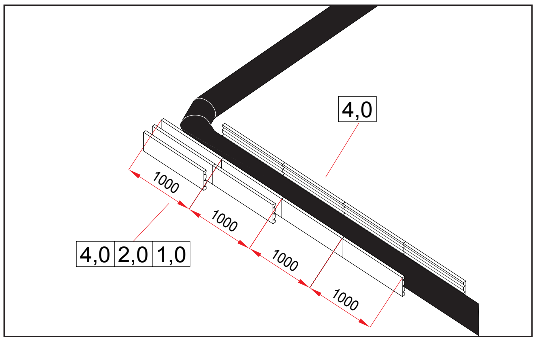
From the system drawing the necessary number of foam pads to absorb the expansion appears.

1st layer:
The length of the inner 40 mm foam pads, stated in meters, appears from the first number - here 4 m. This corresponds to 4 foam pads, as they are each 1 m long.

2nd layer:
If an additional layer of foam pads is required, the length of this layer, measured from the bend, appears from the 2nd number - here 2 m.

3rd layer:
A 3rd layer of foam pads, if required, appear from a 3rd number - here 1 m.

On the inside of the bend a similar statement may be found, see illustration.



Expansion absorption
Foam pads

References	Product Catalogue	Expansion and anchorage
	Design	Directional changes Branches
	Handling & Installation	Expansion and anchorage

Flexible pipes
Overview

Introduction

The flexible pipe systems consist of the FlexPipe with a smooth LDPE outer casing and the more flexible FlextraPipe with a corrugated HDPE outer casing. Both pipe systems are complete flexible pipe systems for distribution networks and minor branch pipes.

The long flexible pipes are especially usable for:
- Branch pipes without joints
- Passage of vegetation and other obstacles
- Hilly areas
- Tunnelling and thrust boring methods

This section contains general design rules for using flexible pipe systems.

The actual design rules for each individual service pipe type are described in their respective section.

Contents

General
Trench
Connection to main pipe
Terminations

Flexible pipes
General

Introduction

FlexPipes are available with 4 different types of service pipe for District Heating and District Cooling.

Possible combinations of outer casing, application, and service pipe type appear from below table.

Which type to use depends on several factors:
- Application: Heating/cooling
- Operational conditions: Pressure and temperature
- Jointing methods: Press couplings / soldering / welding / compression couplings (DW)
- Tradition

Read more under the different types of flexible pipe or ask LOGSTOR, if in doubt.

Fields of application

Pipe type	Materials			Fields of applica-tion		Pressure bar	Continuous operating temperature °C	Max. temperature (short-term) °C	Dimensional range Ø mm	Surveillance
	Service pipe	Insulation	Outer casing	District Heating	Distruct cooling					
FlexPipes:										
SteelFlex	Steel	PUR	PE-LD	x	x	25	120	140	20-28	x
CuFlex	Copper	PUR	PE-LD	x	x	16**	120	140*	15-35	x
FlextraPipes:										
PexFlextra	PEXa	PUR	PE-HD	x	x	6*	80	100	20-110	
AluFlextra	Alu/PEX	PUR	PE-HD	x	x	10	80	100	20-32	

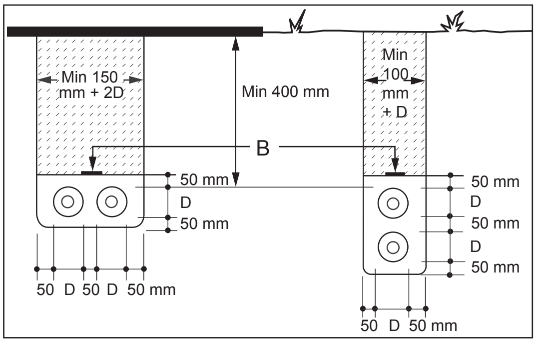
* 6 bar = SDR 11

** PN 16 is calculated at max. 120°C (the Swedish District Heating Association D 213).

Flexible pipes
Trench

Installation methods

FlexPipes are installed in trenches or by means of tunnelling techniques either next to or on top of each other in accordance with the illustration and below minimum measurements.



FlextraPipes are installed in trenches like FlexPipes, but FlextraPipes can only be used in connection with tunnelling, if they are pulled through a conductor pipe.

When installed in trenches, the pipes must be surrounded by 50 mm backfill material with properties as described below.

Min. 400 mm soil cover from the bottom of the road asphalt/concrete.

B = Warning tape or net

At directional corners the corners of the trench are curved to a minimum radius of 0.6 – 1.6 m dependent on the outer casing dimension.

Bending radius

See the relevant section.

Backfill material

The following material specifications apply to backfill material under normal conditions:

Maximum grain size: ≤ 10 mm
Coefficient of uniformity: $\frac{d_{60}}{d_{10}} = >1.8$

Purity: The material should not contain harmful quantities of plant residues, humus, clay or silt lumps.

Grain form: Large keen-edged grains, which may damage pipe and joints, should be avoided.

Careful and even compaction is required.

Flexible pipes
Connection to main pipe

Perpendicular connection

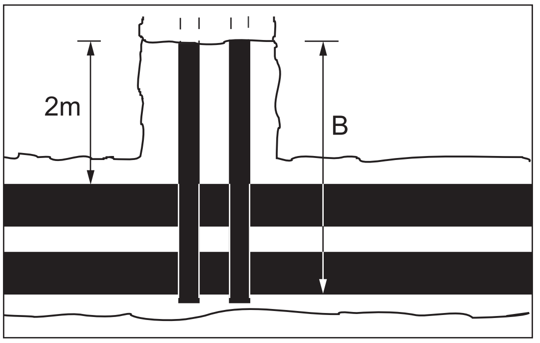
The best way to obtain a faultless installation between a flexible pipe and a main pipe is to have the flexible pipe ends completely straightened prior to installation.

Straightening the ends is best done before the requested length is cut off the pipe coil.

In case of perpendicular connection to a main pipe min. 2 m of the branch pipe trench must remain uncovered to provide room for later installation of press couplings/welding.

Movements in the main pipe and long branch pipes may require special measures; see the section "Branches" and the limitations, described under the relevant flexible pipe section.

B = 2 m straight flexible pipe + trench width.

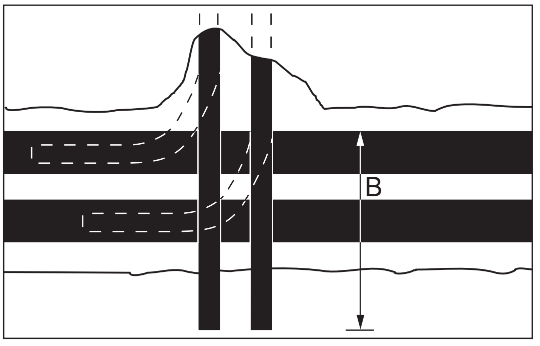


Parallel connection

To provide sufficient space FlexPipes installed by tunnelling may be installed parallel to the main pipe.

Movements in the main pipe and long branch pipes may require special measures; see the section "Branches" and the limitations, described under the relevant flexible pipe section.

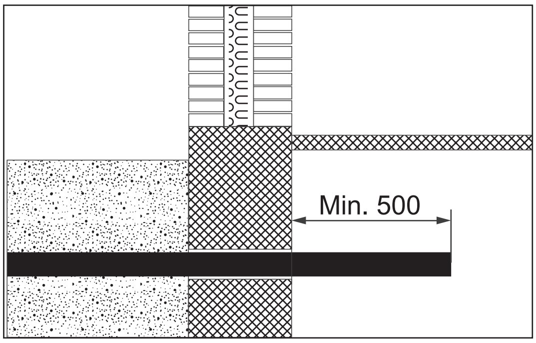
B = 2 m straight flexible pipe + trench width



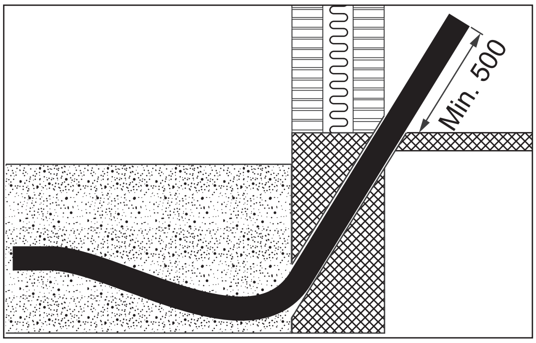
Terminations

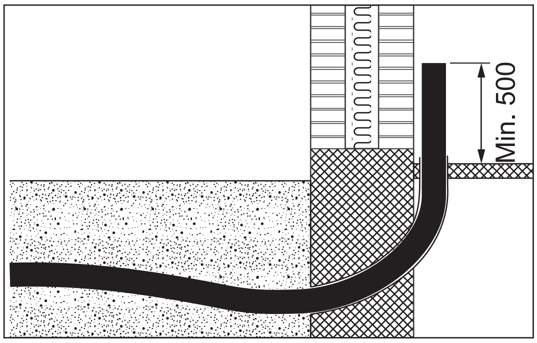
Termination in house

For house connections through a cast inlet pipe or straight/tilted bore in the base make sure that the flexible pipe is led through the base in the same working process as installation and backfilling.



The flexible pipe is terminated min. 500 mm from the indoor base/above the floor.

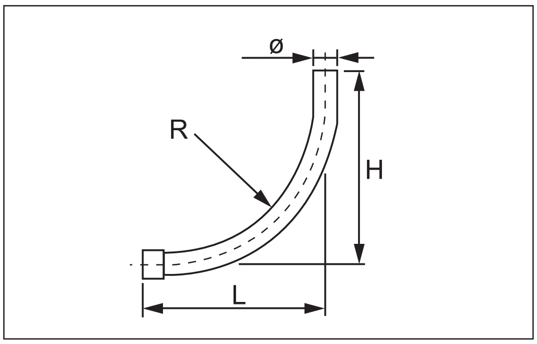




Inlet pipe

For house entry it may be advantageous to use an inlet pipe in accordance with below table.

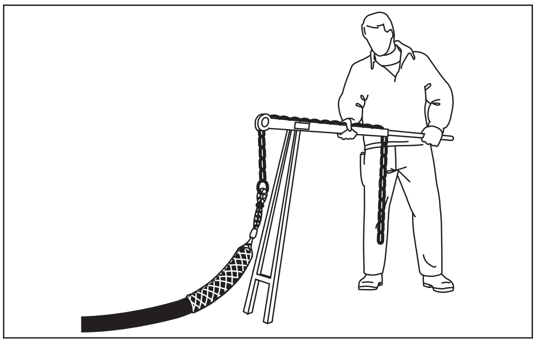
Flexible pipe ø out. mm	R ø mm	H mm	L mm	ø mm
77	800	107	1050	125
90	800	124	1050	125
110	900	142	1250	140
125	1000	158	1350	160



Inlet pipe, *continued*

It is recommended to use a pulling sleeve and a pulling tool when pulling the flexible pipe through the inlet pipe.

The pulling tool may be manual as illustrated here or with an electric winch.

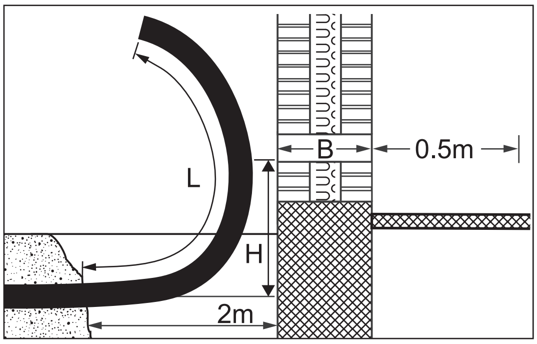


Termination in cabinet

For termination through the wall above ground, covered with a cabinet, an open trench of min 2 m from the wall must be available for later wall penetration.

Note! The flexible pipe end must be long enough for later wall penetration and installation inside the building.

L_{min} = 2 m + H + B + 0.5 m

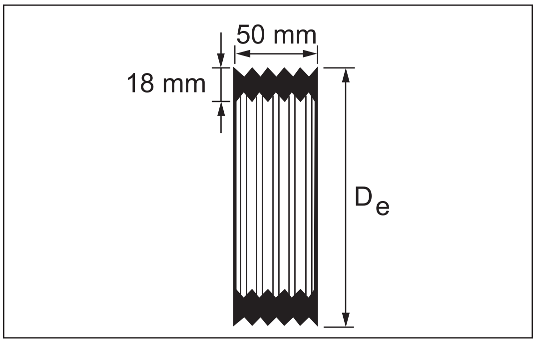


Bore in the base

The stated bore diameters are recommended for bore in the base using sealing rings.

For constructions with a high hydrostatic pressure, sealing rings which are fixed to the internal or external wall and pressed against the PE casing are recommended.

Outer casing ø out. mm	Bore diameter ø mm		Sealing ring out. D_e mm
	Min	Max	
77	101	105	107
90	116	122	124
110	135	140	142
125	151	156	158
140	167	171	173
160	187	191	191
180	207	211	209



References

Design

PexFlextra
AluFlextra
CuFlex
SteelFlex

PexFlextra
Overview

Introduction

PexFlextra is a complete flexible pipe system.

PexFlextra has a corrugated casing.

The wide dimensional range makes FlextraPipe applicable for house entries as well as minor distribution pipelines.

Contents

Design rules
Examples of installation combinations

Design rules

General

FlextraPipes are characterized by:

- Operating temperature: 80°C for 29 years
- Maximum operating temperature: 90°C for 7760 hours
  95°C for 1000 hours
- Malfunction: 100°C for 100 hours
- Maximum operating pressure: 6 bar
- Connection of service pipes by means of press couplings
- A high flexibility when bending the pipe in the required curve

Bending radius

At directional changes FlextraPipes can be bent on site to the minimum bending radius R.

The flexibility of the FlextraPipe depends on the temperature of the pipe.

At temperatures below 5°C heat the outer casing to lukewarm with a gas torch prior to uncoiling or bending the pipe.

On installation it may be necessary to ensure the position of the pipes e.g. by means of partial backfilling.

Outer casing ø out. mm	Min. bending radius, R m
90	0.7
110	0.9
125	1.0
140	1.1
160	1.6
180	1.8

Expansion

FlextraPipe is a flexible pipe system which does not require special measures to be taken for installation in the ground.

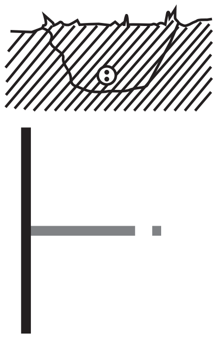
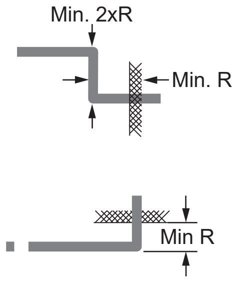
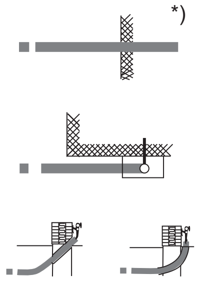
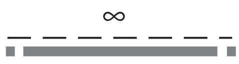
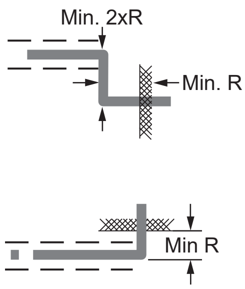
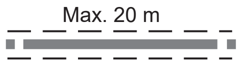
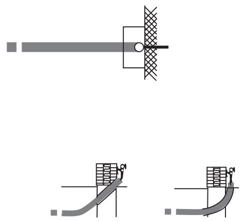
It is self-compensating, and due to the properties of the PEX service pipe it is not necessary to pay attention to the expansion in buried systems.

When connecting a FlextraPipe and a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the FlextraPipe system. This is ensured by establishing the connection from the steel pipe to the FlextraPipe at a branch or after a bend. If the connection is a direct extension of a steel pipeline, the length of the steel pipeline must not exceed 14 m.

When branching from a steel main pipeline with FlextraPipe make sure that movements in the main pipeline is not transferred to the branch pipe. For details, see illustration on the next page.

Examples of installation combinations

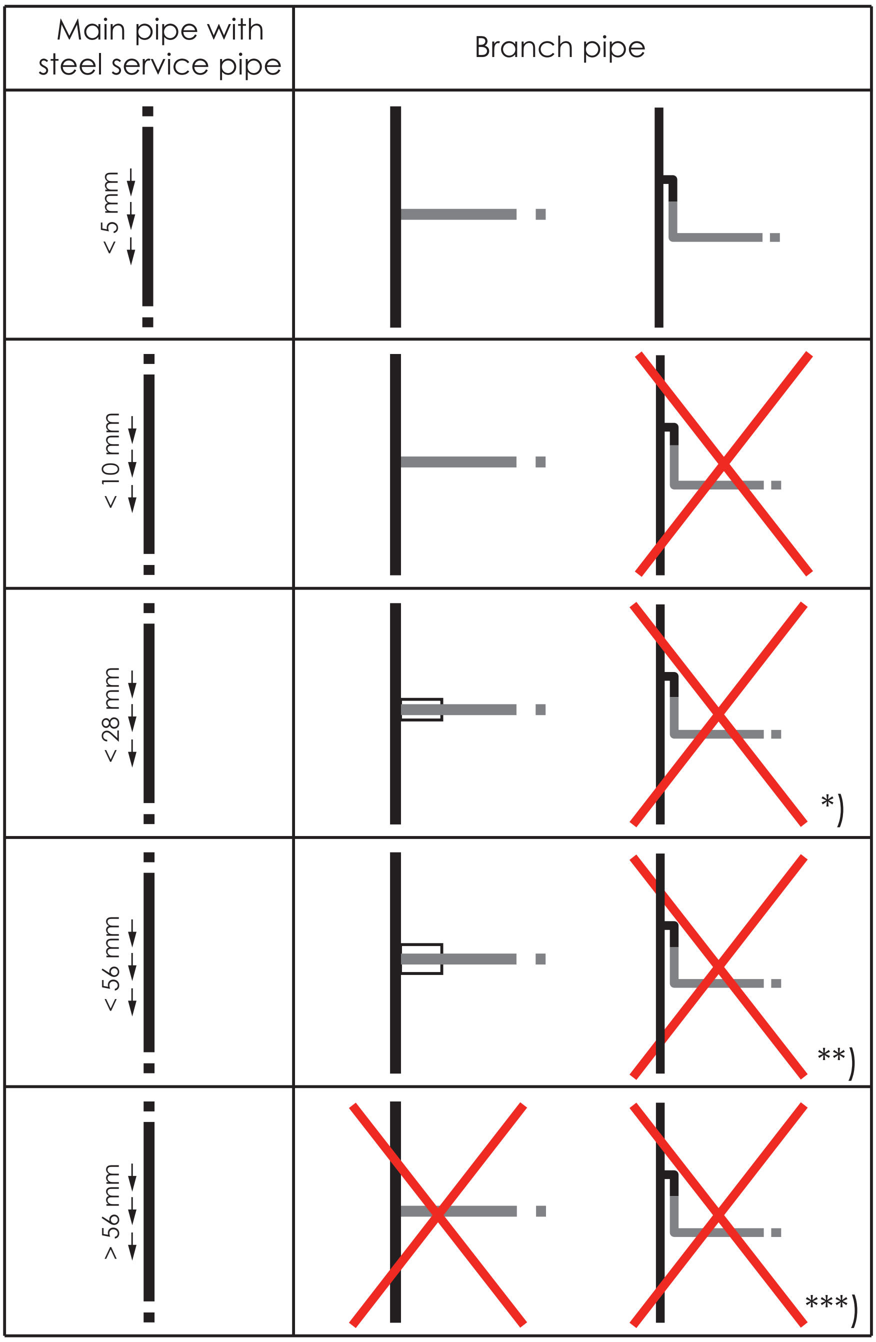
Branch pipe lengths and introduction in houses

Branch point	Branch pipe	Introduction in building
		Movement not allowed  Movement allowed 
		Movement not allowed 
		Movement allowed 

*) Movement is not allowed when using mounting immediately inside the wall.

Examples of installation combinations

The main pipe



*) The branch is furnished with a 40 mm thick and 1 m long foam pad.
**) The branch is furnished with a 80 mm thick and 1 m long foam pad.
***) Movement of main pipe > 56 mm: Branches with FlextraPipe must not be carried out.

References

Product Catalogue	The FlexPipe system Terminations with FlexPipes
Handling & Installation	The FlexPipe system
Design	Branches

AluFlextra
Overview

Introduction

AluFlextra is a complete flexible pipe systems

AluFlextra DH has a corrugated casing.

FlextraPipe is applicable for house entries as well as minor distribution pipelines.

Contents

Design rules
Examples of installation combinations

General

AluFlextra is characterized by:

- Operating temperature: 80°C for 29 years
- Maximum operating temperature: 90°C for 7760 hours
  95°C for 1000 hours
- Malfunction: 100°C for 100 hours
- Maximum operating pressure: 10 bar
- Connection of service pipes by means of press couplings
- A high flexibility when bending the pipe in the required curve

Bending radius

At directional changes the FlextraPipe can be bent on site to the minimum bending radius R.

The flexibility of the FlextraPipe depends on the temperature of the pipe.

At temperatures below 5°C heat the outer casing to lukewarm with a gas torch prior to uncoiling or bending the pipe.

On installation it may be necessary to ensure the position of the pipes e.g. by means of partial backfilling.

Outer casing ø out. mm	Min. bending radius, R m
90	0.7
110	0.9

Expansion

AluFlextra is a flexible pipe system which does not require special measures to be taken for installation in the ground.

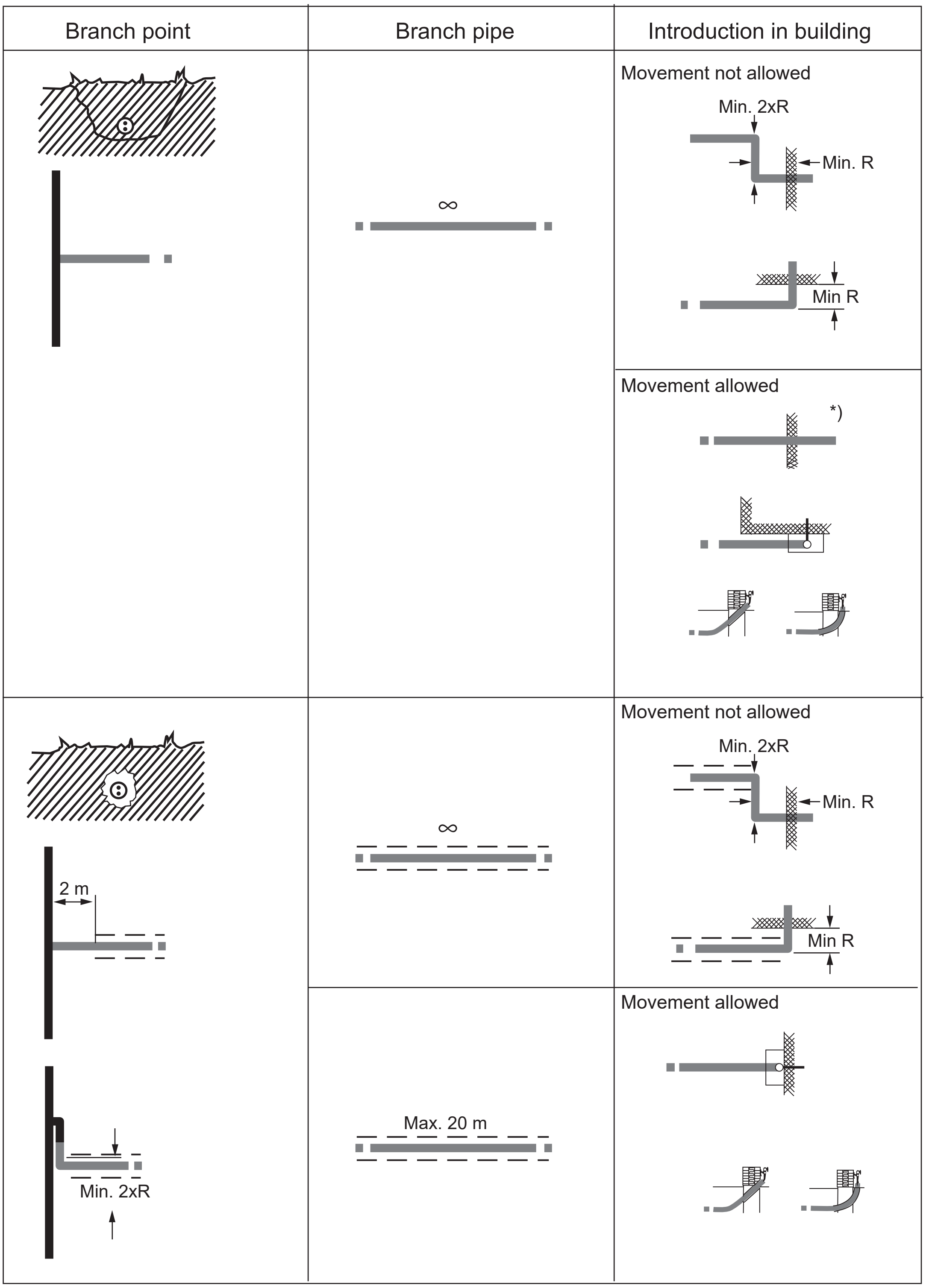
It is self-compensating, and due to the properties of the service pipe it is not necessary to pay attention to the expansion in buried systems.

When connecting a FlextraPipe and a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the FlextraPipe system. This is ensured by establishing the connection from the steel pipe to the FlextraPipe at a branch or after a bend. If the connection is a direct extension of a steel pipeline, the length of the steel pipeline must not exceed 2 m from the nearest expansion bend.

When branching from a steel main pipeline with FlextraPipe make sure that movements in the main pipeline is not transferred to the branch pipe. For details, see illustration on the next page.

Examples of installation combinations

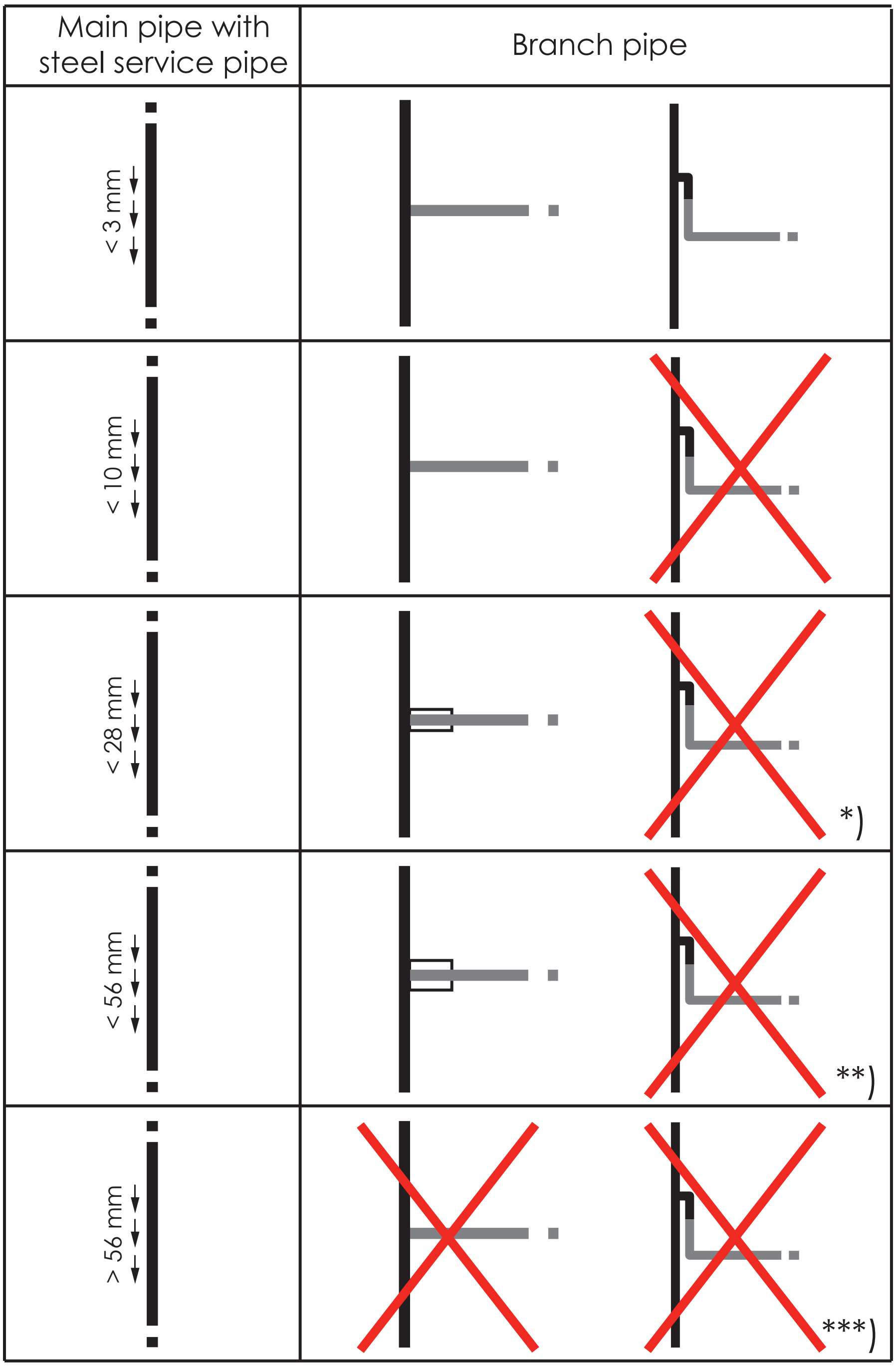
Branch pipe lengths and introduction in houses



*) Movement is not allowed when using mounting immediately inside the wall.

Examples of installation combinations

The main pipe



*) The branch is furnished with a 40 mm thick and 1 m long foam pad.
**) The branch is furnished with a 80 mm thick and 1 m long foam pad.
***) Movement of main pipe > 56 mm: Branches with FlextraPipe must not be carried out.

References	Product Catalogue	The FlexPipe system Terminations with FlexPipe
	Handling & Installation	The FlexPipe system
	Design	Branches

CuFlex
Overview

Introduction

CuFlex pipes form a complete flexible pipe system for distribution networks and minor house connections.

Contents

Design rules
Examples of installation combinations

Design rules

General

CuFlex is characterized by:

- A continuous operation with hot water up to 120°C and in different time intervals with a peak load temperature of 140°C. The sum of these time intervals must not exceed 300 hours per year.
- An operating pressure of max. 16 bar
- Connection of the service pipe with press couplings or soldering sleeves
- A high flexibility and a high form stability of the service pipe when bending the pipe in the required curve.

Bending radius

At directional changes the CuFlex pipe can be bent on site to the minimum bending radius R.

The flexibility of the CuFlex pipe depends on the temperature of the pipe.

At temperatures below 5°C heat the outer casing to lukewarm with a gas torch prior to uncoiling or bending the pipe.

On installation it may be necessary to ensure the position of the pipes e.g. by means of partial backfilling.

Outer casing ø out. mm	Min. bending radius, Rq m
90	0.9
110	1.1

Expansion

CuFlex is a flexible pipe which does not require special measures when installed in the ground.

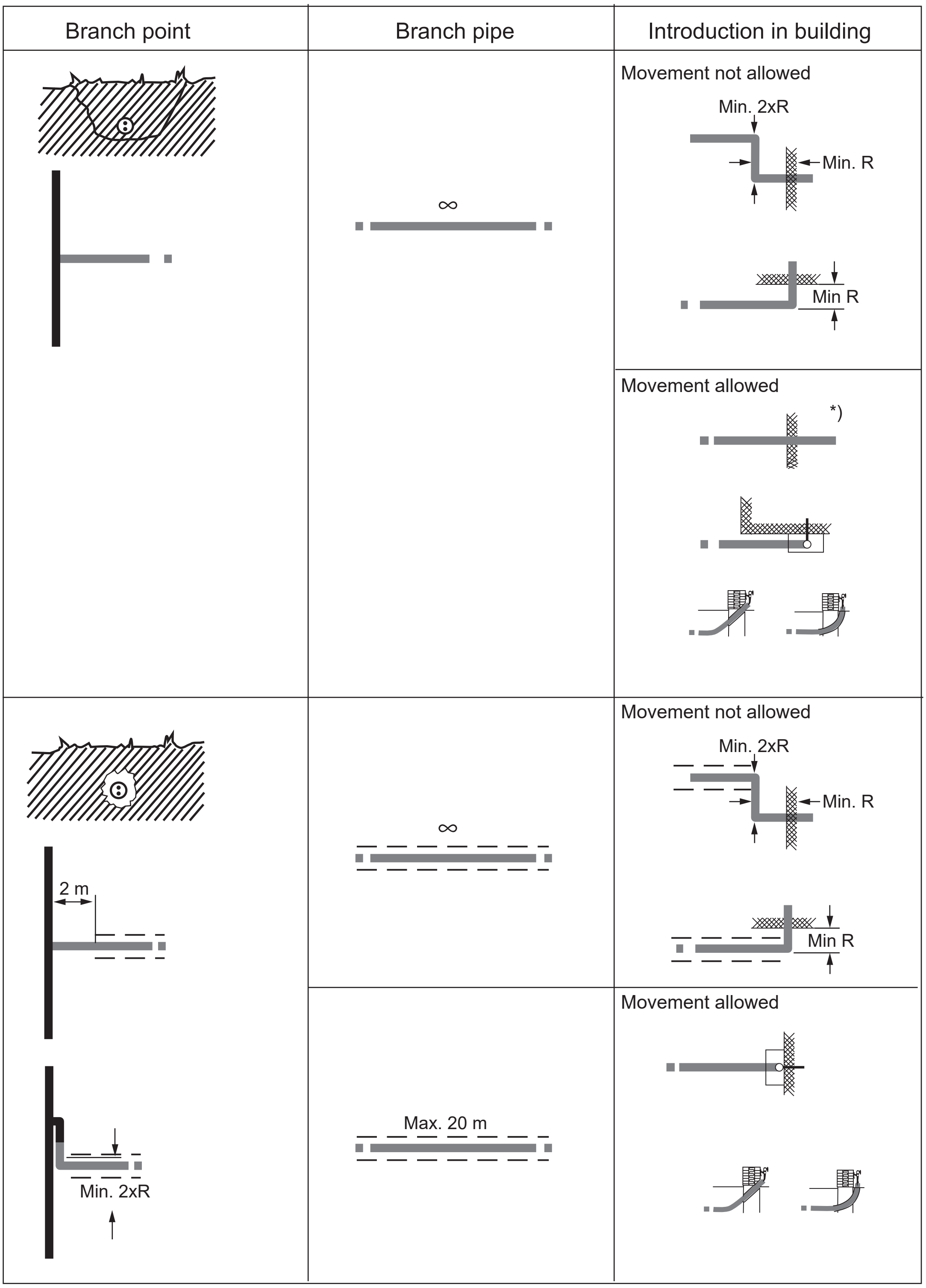
It is a self-compensating system, and due to the properties of the CuFlex service pipe it is not necessary to pay attention to expansion in CuFlex pipes, installed in the ground.

When connecting a CuFlex pipe to a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the CuFlex system.
This is ensured by establishing the connection from steel to CuFlex at a branch or after a bend. If the connection is a direct extension of a steel pipeline, the length of the steel pipeline must not exceed 2 m.

When branching from a steel main pipeline with a CuFlex pipe make sure that the movements in the main pipeline are not transferred to the branch.

Examples of installation combinations

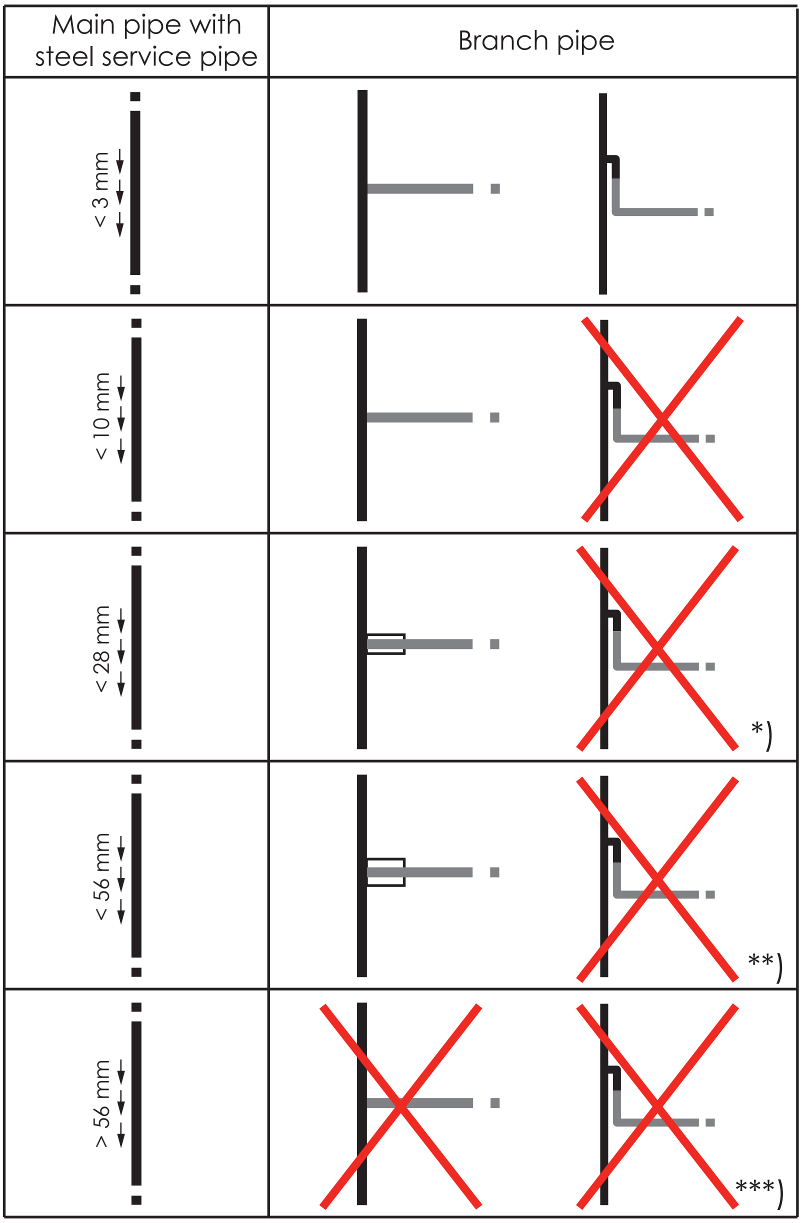
Branch pipe lengths and introduction in houses



*) Movement is not allowed when using mounting immediately inside the wall.

Examples of installation combinations

Movements in the main pipe



*) The branch is furnished with a 40 mm thick and 1 m long foam pad.
**) The branch is furnished with a 80 mm thick and 2 m long foam pad.
***) Movement of main pipe > 56 mm: Branches with CuFlex must not be carried out.

References

Product Catalogue	The FlexPipe system Terminations with FlexPipe
Handling & Installation	The FlexPipe system
Design	Branches

SteelFlex
Overview

Introduction

SteelFlex pipes form a complete flexible pipe system which is primarily used for house connections.

SteelFlex is available in small dimensions, ensuring a good flexibility during installation.

Contents

Design rules
Examples of installation combinations

SteelFlex
Design rules

General

SteelFlex is characterized by:
- A continuous operation with hot water up to 120°C and in different time intervals with a peak load temperature of 140°C. The sum of these time intervals must not exceed 300 hours per year.
- A high pressure, max 25 bar
- The service pipe being welded as is the case with other steel service pipes.
- A high form stability of the steel service pipe when bending the pipe in the required curve.

Bending radius

At directional changes the SteelFlex pipe can be bent on site to the minimum bending radius R.
The flexibility of the SteelFlex pipe depends on the temperature of the pipe.
At temperatures below 5°C heat the outer casing to lukewarm with a gas torch prior to uncoiling or bending the pipe.
On installation it may be necessary to ensure the position of the pipes e.g. by means of partial backfilling.

Outer casing ø out. mm	Min. bending radius, R m
90	0.9
110	1.1

Expansion

When the service pipe in a SteelFlex pipe expands with the temperature, stresses will built-up in the steel pipe.

In straight pipe runs SteelFlex may be cold installed regardless of the length without it being overloaded. It may however be necessary to reduce the stresses at the branch point and axial movements at the introduction into a building.

The stresses can be reduced by expansion absorption in curves and bends, which are established during installation of the flexible pipe.

45° perpendicual branch
When connecting SteelFlex to a 45° branch the SteelFlex pipe lenght can maximum be L_{max}. If the SteelFlex pipe is longer, a Z-bends with a distance between bends of 2 x R must be established, see the illustration in the section "SteelFlex: Examples of installation combinations".

Outer casing ø out. mm	L_{max} m
90	25
110	20

90° parallel branch
When connecting SteelFlex to a paralllel branch, the parallel part of the branch must be minimum 2 x R long. Hereafter there is no limitations to the SteelFlex length, see the illustration in the section "SteelFlex: Examples of installation combinations".

Expansion, ***continued***

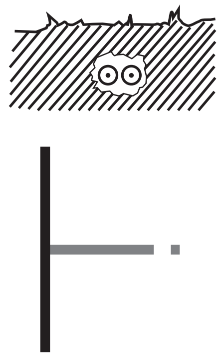
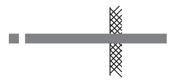
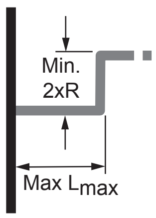
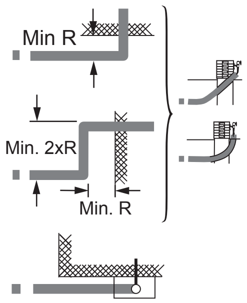
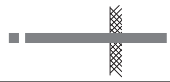
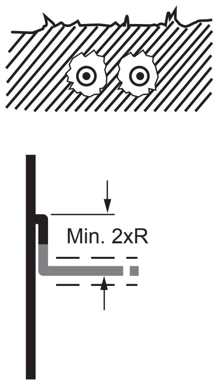
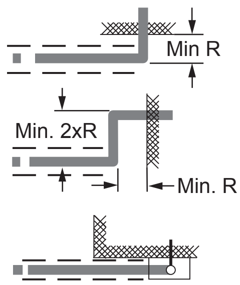
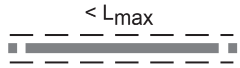
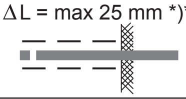
When branching from a steel main pipeline with a SteelFlex pipe make sure that the movements in the main pipeline are not transferred to the branch

Branching with a SteelFlex pipe must not be carried out, if the movement in the main pipeline is > 56 mm.

Further details, see illustration on the next page.

Examples of installation combinations

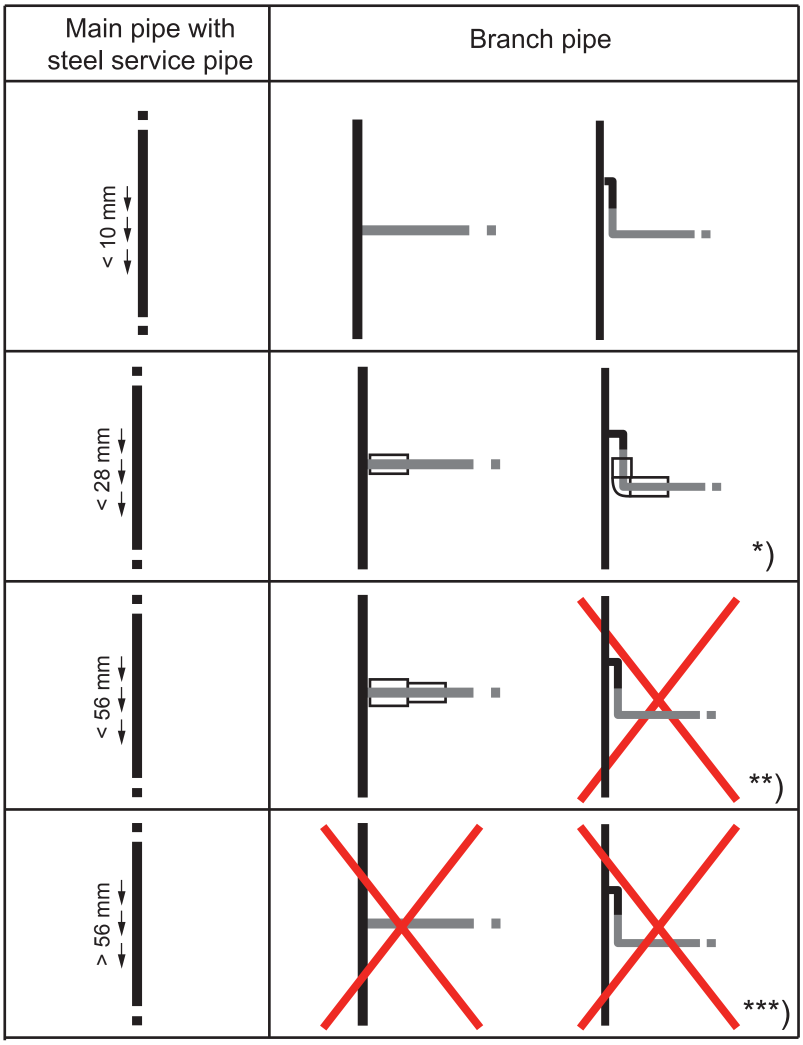
Branch pipe lengths and introduction in houses

Branch point	Branch pipe	Introduction in building: Movement not allowed	Introduction in building: Movement allowed
	 L max		 ΔL = max 25 mm *)
 Min. 2xR, Max L_{max}	 ∞	 Min R, Min. 2xR, Min. R	
	 < L_{max}		 ΔL = max 25 mm *)
 Min. 2xR	 ∞	 Min R, Min. 2xR, Min. R	
	 < L_{max}		 ΔL = max 25 mm *)**)

*) Movement is not allowed when using mounting immediately inside the wall.
**) Pay attention to extra movement in connection with tunnelling.

Examples of installation combinations

Movements in the main pipe



*) The branch is furnished with a 40 mm thick and 1 m long foam pad.
**) The branch is furnished with a 80 mm thick and 1 m long foam pad on the first meter and a 40 mm thick and 1 m long foam pad on the other meter.
***) Movement of main pipe > 56 mm: Branches with SteelFlex must not be carried out

References

Product Catalogue	The FlexPipe system Terminations with FlexPipe
Handling & Installation	The FlexPipe system
Design	Branches

Heat loss
Overview

Introduction

This section reflects LOGSTOR's know-how about calculation of insulation values and heat loss from preinsulated pipe systems.

It describes the possibilities of calculating the following parameters with the online calculation program "LOGSTOR Calculator":

- The heat loss in relation to the ageing of the PUR foam
- The economy
- The emission (CO_2 emission)

These calculations may be carried out as:
- Standard calculations according to EN 13941
- Advanced calculations, taking the influence of the temperature on the lambda (l) values into account

In addition to showing the results of the calculations the program can illustrate the results and differences between different pipe systems in graphs. The advanced model can also show graphic images of isotherms in and around the pipes.

The heat loss values can also be included in the described analysis of life cycle costs.

LOGSTOR's Total Cost of Ownership (TCO) Tool can be used as a guide to choose the most optimal preinsulated pipe system. The calculation includes investment costs for preinsulated materials, excavation works, installation as well as operating costs for heat loss and the carbon tax.

So, the calculation takes into account costs of CAPEX; pipe materials, excavation works, and pipe installation as well as costs of OPEX; energy loss, investments and carbon tax. When calculating the energy loss, the insulation values and the heat loss in the preinsulated pipes are used.

Contents

General
Calculations

Calculation of heat loss

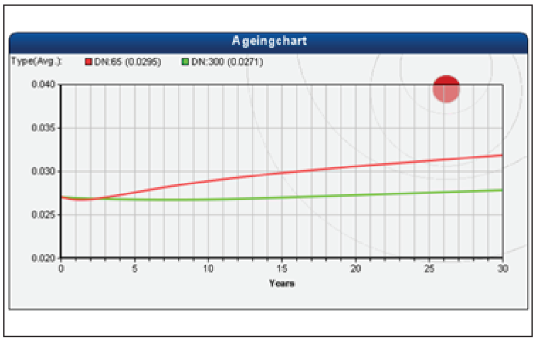
To calculate the heat loss from different pipe systems LOGSTOR has developed the online calculation program, LOGSTOR Calculator.

With this program it is possible to calculate the heat loss of all pipe products in LOGSTOR´s standard district heating product assortment.

The program also enables adjustment of the parameters, influencing the heat loss in order to gain the most exact result.

Each combination of pipe types and dimensions has its specific ageing curve dependent on the thickness of the insulation and outer casing, and whether it is a traditionally or continuously (conti) produced pipe with or without diffusion barrier.

Taking these parameters into account, LOGSTOR Calculator can show the ageing curve which is valid for a specific pipe.



LOGSTOR Calculator contains two calculation methods:

- Standard according to EN 13941
- Advanced

Standard calculation according to EN 13941

When calculating the heat loss in accordance with EN 13941 the formula basis and principles, stated in the standard are used.

In the heat loss calculations a coefficient of thermal conductivity, λ_{50}, is used for the PUR foam. This is the standardized test λ–value at a temperature of 50°C in the foam.

In addition the change in the λ–value of the PUR foam over time is calculated.

So the heat loss for all types of pipes in LOGSTOR's assortment - standard produced pipes without diffusion foil as well as conti produced pipes with diffusion foil - can be calculated.

As for production methods, see the section "The Bonded Single Pipe: General" in the Product Catalogue.

Dependent on the pipe system the heat loss is calculated with and without ageing over the chosen period with corresponding values for economy and emission.

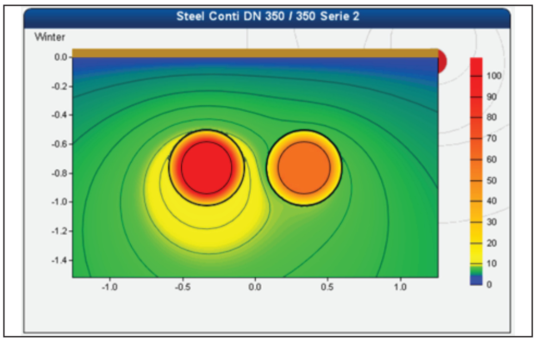
Advanced calculation

In addition to the ageing of the PUR-foam due to diffusion the advanced calculation method also takes the influence of the temperature on the λ-value of the materials into account.

These variables are included in the advanced calculation method, resulting in a more precise heat loss calculation.

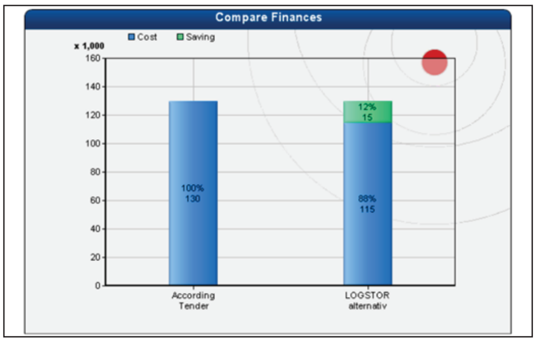
The method is based on the fomulas and priciples in accordance with "Steady-state heat loss from insulated pipes" by Petter Wallentén.

This method also gives a graphic illustration (isotherm image) of the temperature influence in the soil and pipes and shows the surface temperature on the outer casing.



Economy calculation

With LOGSTOR Calculator a financial calculation can be made. It is based on the calculation rate of interest and the energy price.
The result is the present value of the heat loss from the system based on the chosen time period.
This function facilitates the assessment of which type of pipe is the most profitable.
The period for the financial calculation can be set between 1-30 years.
In order to make a financial calculation an energy price per kWh and a rate of interest for cost purposes must be entered.
The result of the financial calculation is tailor-made to be included directly in the assessment of the total life cycle costs.

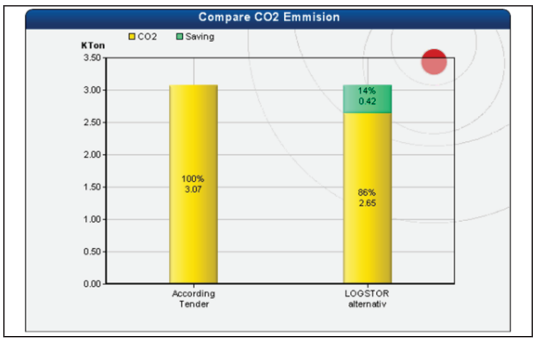


Emission

The program can also show the approximate size of the emission, resulting from producing the energy in the heat loss from the pipeline

The result may be shown for one year or as a sum over a chosen period.

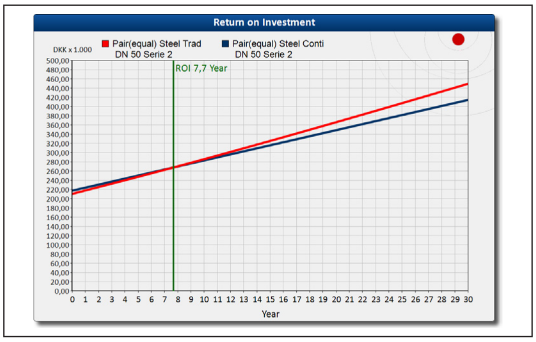
The result is based on the chosen fuel type and the efficiency of the heat production plant.



Return on Investment (ROI)

When comparing 2 projects, it is possible to calculate a simple payback time on basis of the difference in the energy loss in the pipelines.

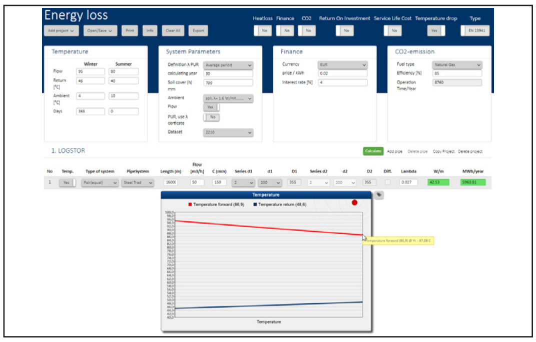
To make the calculation the energy price in kWh and the difference in costs between the 2 projects, i.e. material and installation costs, must be known. If the operational costs per annum differ, they can also be entered. Now the simple payback time - i.e. the number of years, before the 2 systems balance - is calculated.



Temperature drop

It is possible to calculate the temperature drop for a given pipeline with a given flow - either in m^3/h or as an effect in kW.

The calculations are based on flow, ambient temperature, and the λ-valuve of the soil.



Life cycle costs

To assess which type of pipe is most economical to invest in, a life cycle cost analysis have to be made.
The service life is typically set at 30 years for a district heating system, even though it may easily be in operation much longer.
The calculation of the life cycle costs includes the following parameters:
Investments:
- Pipe materials
- Pipe work
- Excavation
- Inspection (design and quality)
Operational costs:
- Power for pumps
- Heat loss in the pipeline
Maintenance:
- Repairs
- Management
The value of the heat loss during the service life can be calculated directly in LOGSTOR Calculator with the chosen preconditons and form part of the basis of assessing which pipe system to choose and the rentability of the project.

References

The Calculator program	http://calc.logstor.com
Product Catalogue	The Bonded Single Pipe: General
TCO Tool	https://www.logstor.com/dk/service-support/e-vaerktoejer/logstor-tco-tool

Pipeline dimensioning
Overview

Introduction

Pipe dimensions can be calculated with LOGSTOR's online calculation program, Calculator.

This program enables dimensioning of pipelines which are part of one of the pipe systems, included in LOGSTOR's standard district heating assortment.

The program is especially usable to dimension a few pipe sections or house connections.

The pressure loss of a given pipeline can also be calculated.

In a pipe system with many branches the critical route and differential pressure should be calculated, taking parameters such as level differences, single resistances etc. into account.

These parameters are not included in the program, and it is therefore recommended only to use the program as a supplementary tool for dimensioning pipelines.

In connection with dimensioning and pressure loss calculation the formula basis and principles according to Colebrook & White are used.

Contents

General

Pipeline dimensioning
General

Basic parameters

In order to establish the correct pipe dimension, it is necessary to know the:
- Energy supply the pipeline must provide
- Actual temperature difference
- Allowable pressure loss

Normally, cooling from the flow pipe to the return pipe has been determined in advance.

The cooling and the energy supply requirements determine the water flow in kg/sec.

The required energy supply of a household is determined in consideration of heating, domestic water heating, and whether heat exchangers or hot water containers are installed or not.

The energy supply of a distribution pipeline is determined by adding the consumption of the individual consumers and multiplying it by a simultaneity factor.

To this the heat loss to the surroundings is added:

$P = \Sigma (q \cdot S) + \phi$

P = Total energy supply, W

q = Consumer energy supply, W

S = Simultaneity factor in %

Simultaneity factors

The following simultaneity factors are normally applied when determining the energy supply for single-family houses, but local experience or regulations can/must also be taken into consideration:

Heating:

$$s = 0.62 + \frac{0.38}{n}$$

Hot domestic water:

$$s_\Delta = \frac{1.0 \cdot n^{-0.5} \cdot (51 - n)}{50}$$

n being the number of houses

For more than 50 houses the factor s_Δ for hot domestic water is = 0

Limit values

LOGSTOR recommends the following maximum velocities to prevent:
- Possible noise nuisances
- Risk of erosion in transmission lines.

Type of pipeline	Maximum velocity m/s
Transmission pipeline	3.5
Main pipe	2.5
Branch pipe	1.0

The minimum velocity is determined in consideration of the flow temperature at the consumer's at the utmost end of the pipeline and the differential pressure available in the pipeline.

References

The calculation program, Calculator http://calc.logstor.com

Contact details

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For the product offering in other markets please contact your local sales representative or visit www.logstor.com

To ensure you are viewing the most recent and accurate product information, please scan the QR code directly above.

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