Pre-insulated solutions

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LOGSTOR Design
TwinPipes

Kingspan®

Overview

Introduction

This manual describes how to
- utilize the TwinPipe systems at an optimum
- solve expansion problems
- install TwinPipe systems

Dimensioning of pipelines, pressure drop calculations and heat loss calculations are described separately in sections "Heat loss" and "Pipeline dimensioning"

The design rules have been drawn up to facilitate designing a TwinPipe on the basis of the technical requirements in the European standard for design and installation of preinsulated, bonded pipe systems for district heating, EN 13941-1.

At present this standard does not include special requirements to design of TwinPipes. They will be included in the next revision of the standard. The stated rules in this design manual are therefore based on the present single pipe requirements and with the expected future requirements to TwinPipes in EN 13941-1 as well as the requirements in the pipe standard DS/EN 15698-1.

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The Manual

Manuals

This manual is part of LOGSTOR Denmark Holding ApS's manual collection which at present consists of:

- Product Catalogue
- Design
- Handling & Installation

Use of the manual

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This manual contains LOGSTOR's input related to choice and optimization of different pipe system solutions. LOGSTOR does however not give any warranty regarding neither the accuracy of the manual, nor the fit for purpose of the solutions as proposed herein. If you decide to use this manual, such usage will be wholly and completely at your own risk.

Application and implementation must take place with due respect to local conditions. Support and specific information can be achieved from our technicians.

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The English version of the manual is the master/pattern copy, whereas the other copies are translations, made according to the best knowledge of the translators.

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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 the designed TwinPipe system is on level with the static requirements in the European standard EN 13941-1.

General documentation
This compliance means that dimensions up to and including DN 250 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.

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 www.logstor.com.

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 for return and flow respectively
- Operating temperature for return and flow respectively
- 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

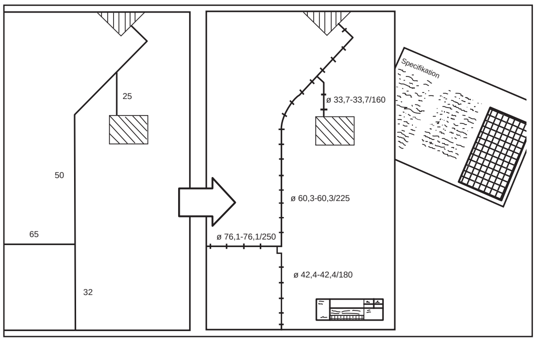
Design assistance

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 calculation 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
- Costs of energy loss, including service life costs and return on investment (ROI)
- Temperature drop
- 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

Preconditions

Application

This section contains preconditions for TwinPipe bonded pipe systems according to EN 13941-1.

Contact LOGSTOR technicians, if the actual conditions do not comply with the pre-conditions 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 3941-1 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 15698-1.

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 250.

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:

Circulation 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/ FlextraPipes)

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
PertFlextra	70	10

Preconditions

Applied standards

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

- EN 13941-1	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 15698-2	TwinPipe fittings
- EN 15632-1/2/4	Flexible pipe systems
- EN 17878-1/2	Factory made flexible pipe systems with a lower temperature profile

Project classes

Definition of project classes

The European standard EN 13941-1 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 13941-1.

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
Transmission pipelines	100
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

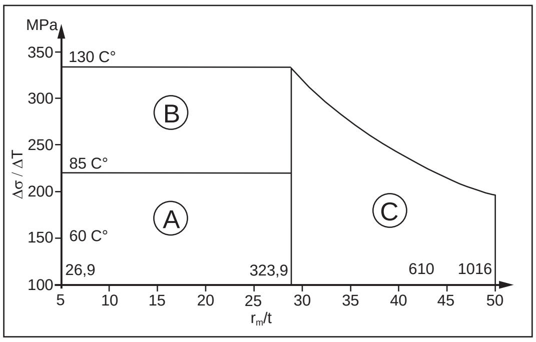
A safety factor for fatigue is connected to each project class.

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 for TwinPipes are therefore based on project class B.



Units and symbols

Introduction

The following units and their corresponding symbols are based on:
- EN 253
- EN 15698
- EN 13941-1
- 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	Total cross sectional area of the service pipes
D	Diameter of casing
d	Diameter of service pipe
E	Modulus of elasticity
F	Friction force
G	Self-weight
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
σ_{all}	Allowable axial stress level
L	Length
ΔL	Expansion for the length L
H	Cover (measured from casing top to soil surface
Z	Distance from centreline of pipe to soil surface (Z=H+½D)
R_e	Yield stress
T	Temperature in °C
α	Expansion coefficient
γ	Specific weight of the soil
ρ	Soil density
φ	Internal friction angle of backfilling material (friction material)

Indices

ins	Installation
min	Minimum
max	Maximum
pre	Prestressing
f	Flow
r	Return

Units and symbols

Characteristic values

Characteristic values for steel service pipe according to EN 13941-1.

In this manual the general values below are used:

E = 210,000 MPa

α = 1.2E-05

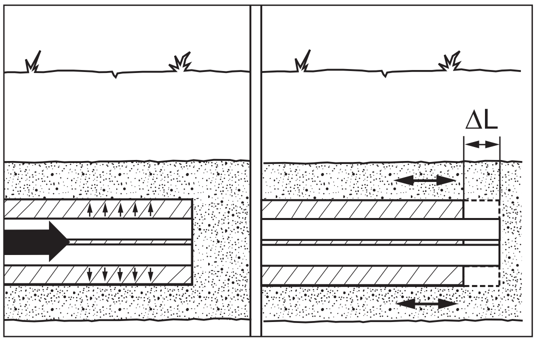
This means that
E · α = 2.52 MPa/°C

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

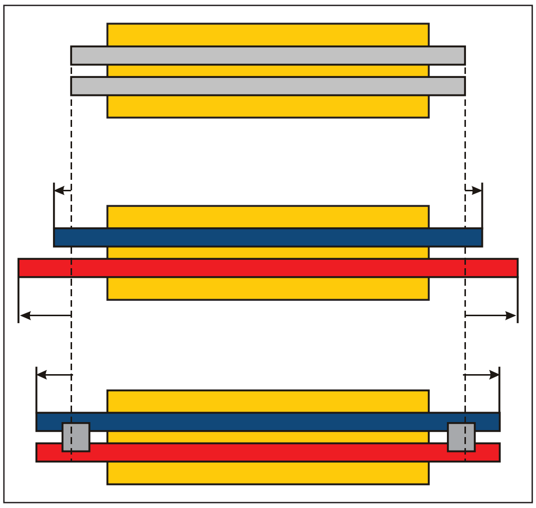
Bonded pipe system

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



In the TwinPipe system the flow and return service pipes have the same dimension and are embedded in the same casing. This means that the expansion or contraction occurring in the steel pipes 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 movements in the TwinPipe system are smaller than those in a corresponding single pipe system, because flow and return pipes are connected by means of fixing bars. The pipes thus move alike with a movement, corresponding the mean temperature betw-en flow and return.

Note! Fixing bars are not installed on straight pipes, only at bends.

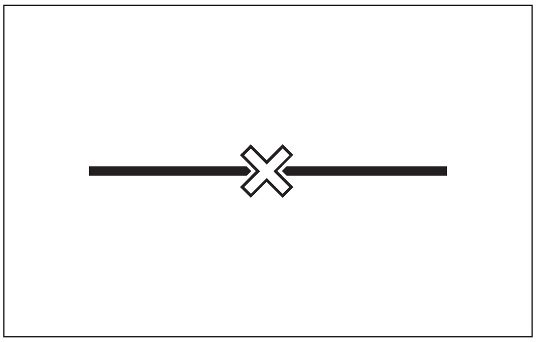
In a TwinPipe system the two pipes are installed on top of each other with the return at the top. This means that branch pipes are installed at the same level as the main pipe and perpendicular to it, so the total installation depth can be reduced correspondingly.

Anchors

An anchor in a TwinPipe system is defined as a virtual anchor where the movements of the pipe are controlled by the friction between the outer casing and the surrounding friction material.

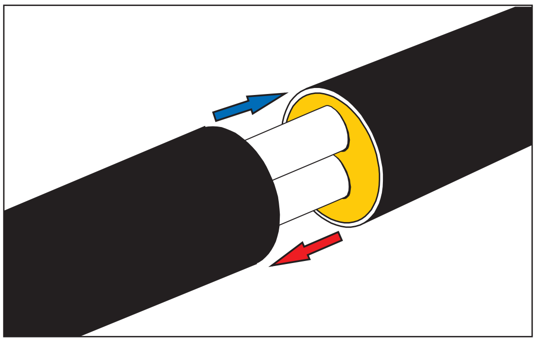
For this Design Manual a virtual anchor illustrates the center between two free expansion ends.

Cast anchor are not used in the TwinPipe system, because the movements are significantly reduced compared to movements in a similiar single pipe system.



Longitudinal expansion

As the two steel pipes are exposed to different temperature influences, this will usually result in a non-uniform longitudinal expansion of the two pipes.



Use of fixing bars

To ensure the pipe system against reciprocal movements between the steel pipes, these are connected by means of fixing bars, welded onto them:

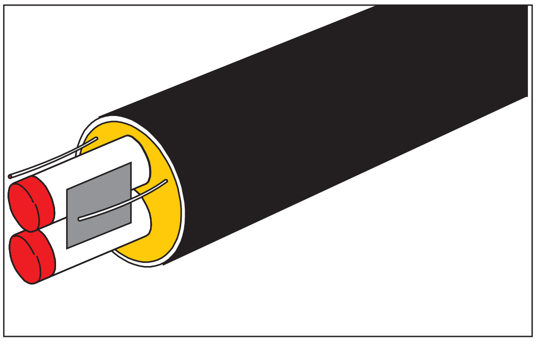
- At all directional changes
- On reductions (on the largest dimension)
- At ends of straight pipe runs
- At house connections

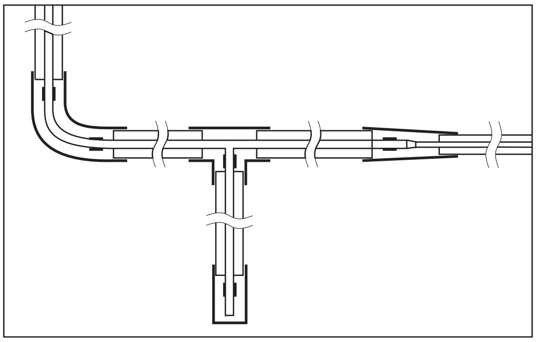
Fixing bars are designed for a maximum temperature difference of 60°C between flow and return.

Fixing bars are not necessary at short distances:

- Branches shorter than 6 m
- Bends with less than 12 m's distance between each other
- On flexible pipes: FlexPipe og FlextraPipe

Installation of fixing bars, see Handling & Installation the section "The Bonded TwinPipe".





System definitions

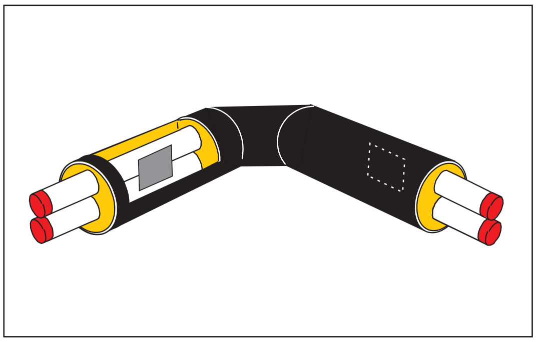
Preinsulated components

The TwinPipe system has embedded fixing bars in all preinsulated fitting components except for preinsulated venting valves.

On preinsulated branches there are only fixing bars on the branch pipes.

Straight pipes and curved pipes do not have embedded fixing bars.

If a straight TwinPipe run is terminated without connection to preinsulated components, fixing bars must always be welded on both sides of the pipe pair. See Handling & Installation the section "The Bonded TwinPipe".



Stress level and expansion calculation

Introduction

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

The formulas give the basis for being able to make the required calculations for a system, which according to EN 13941-1 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 maximum 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. flow temperature.

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.

Mean temperature

Due to the fixation between flow and return the the movements and friction lenghts differ from those of single pipes.

To calculate friction length and expansion movement an average temperature for flow and return is used:

$$T_{mean} = \frac{T_f + T_r}{2}$$

Where:
T_f = Design temperature for flow
T_r = Design temperature for return

This simplification is possible, as the two steel service pipes have the same dimension and cross sectional area.

As design temperature the maximum temperature, used to calculate a component or a pipe section, is applied.

Mean temperature difference

The mean temperature difference ΔT_{mean} is defined as the difference between the mean temperature and the temperature, at which the pipes are installed, T_{ins}:

$$\Delta T_{mean} = T_{mean} - T_{ins} = \frac{T_f + T_r}{2} - T_{ins}$$

Axial stress level

Friction length

The friction length L_F, which is the distance from the free end (bend) of a pipe section to the point, where the TwinPipe is fixed by soil friction is calculated as follows:

$$L_F = \Delta T_{mean} \cdot E \cdot \alpha \cdot \frac{A_s}{F}$$

Where:

ΔT_{mean} = The difference between the mean temperature and the temperature, where the pipe is covered

A_s = The total cross sectional area of the two steel pipes, which appears from the tables in the section "Straight pipes: Stress reduction with bends - Tables: Friction force".

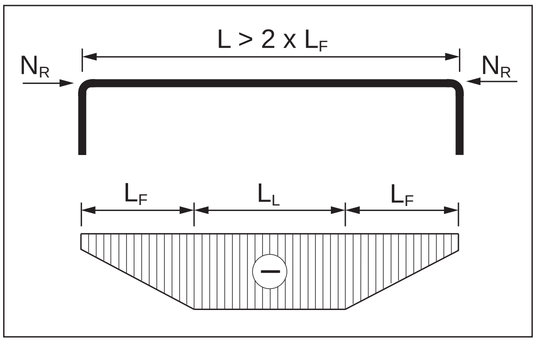
F = The friction force in the soil, i.e. the resistance against movements, transmitted by the soil to the preinsulated pipe. Appears from the tables in the section "Straight pipes: Stress reduction with bends - Tables: Friction force" or is calculated in accordance with the section "Stress level and expansion calculation: Fritction force".

The distance from the free end to max. axial stress is also named: 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

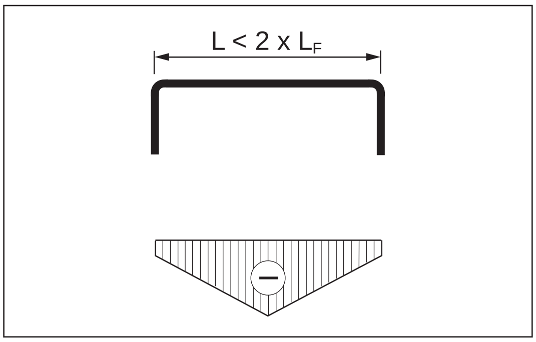
L_L = Section, locked by friction



Maximum axial stress L < 2 · L_F

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

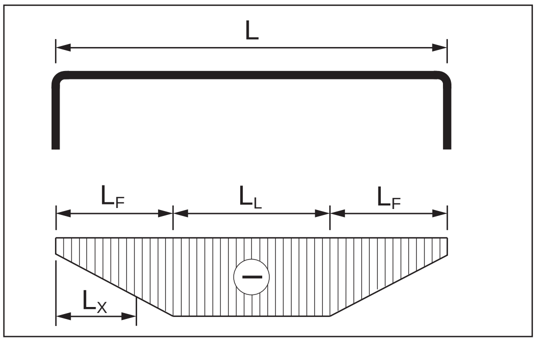
$$\sigma_{max} = \frac{1}{2} \cdot \left(E \cdot \alpha \cdot (T_f - T_r) + L \cdot \frac{F}{A_s}\right)$$



Axial stress level

Axial stress at any point

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



$L_x < L_F$

$$\sigma_x = \frac{1}{2} \cdot E \cdot \alpha \cdot (T_f - T_r) + L_x \cdot \frac{F}{A_s}$$

$L_x > L_F$

$$\sigma_x = \Delta T_{f,max} \cdot E \cdot \alpha$$

Where

$\Delta T_{f,max}$ = The difference between the flow design temperature and the temperature, where the pipe is covered.

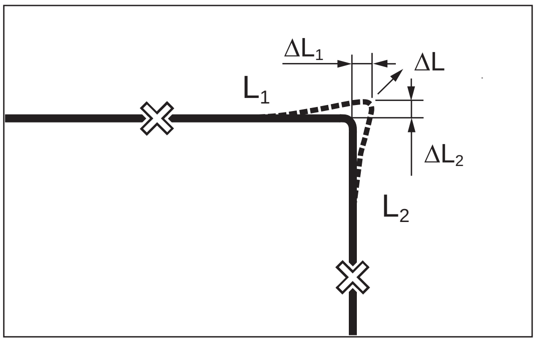
Expansion at bends

Expansion at free pipe end

The expansion at a bend can be calculated from

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

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



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. Further information, 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.

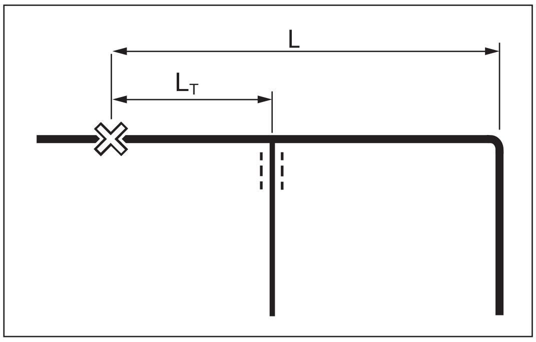
It is important to be aware of the axial expansion in the main pipe. This will lead to lateral movement of the same size at the branch pipe

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

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

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. See the section "Branches" for details.



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	Friction coefficient between sand and PE outer casing (0.4 is applicable)
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	Specific weight of soil (kN/m^3)
Z	Distance from centreline of the pipe to soil surface (Z = H + ½D)
H	Cover (measured from casing top to soil 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: Friction force" 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 13941-1 it appears, how to make this calculation.

Examples of stress level and expansion calculation

Introduction

The examples in this section are all calculated for the following temperatures:
T_f = 90°C
T_r = 50°C
T_{ins} = 10°C

On this basis the following is determined:
- Stress level
- Friction length
- Expansion movement

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

Contents

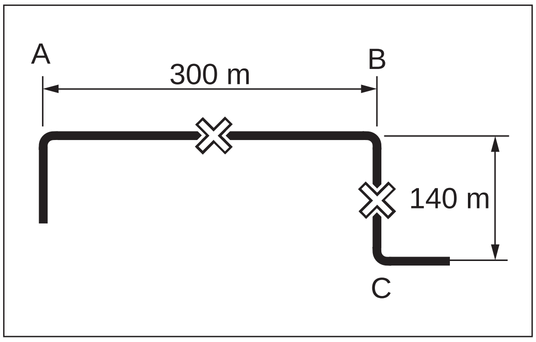
Axial stress level
Expansion at bends
Expansion at branches

1, Axial stress level

Conditions for example 1

ø 114.3 mm, TwinPipe series 2
Cover H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables: Friction force":
F = 4.22 kN/m
A_s = 2504 mm^2 (= total cross sectional area of the service pipes)



Maximum axial stress

Calculation of the maximum thermal axial stress level in a pipe system:
$\sigma_{max} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max} = (90 - 10) \cdot 2.52 = 202$ MPa

Section A-B

Calculation of friction length:

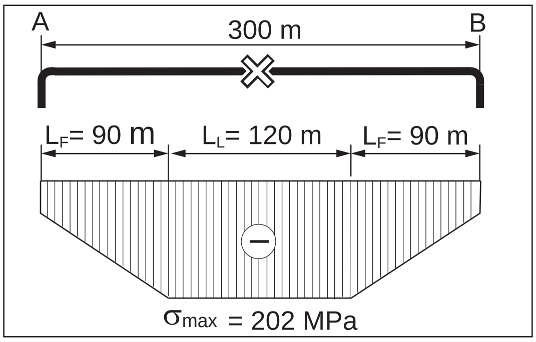
$$L_F = \Delta T_{mean} \cdot (E \cdot \alpha) \cdot \frac{A_S}{F}$$

$$L_F = \left(\frac{90 + 50}{2} - 10\right) \cdot 2.52 \cdot \frac{2504}{4.22 \cdot 1000} = 90 \text{ m}$$

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 90 m each.

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

$L_L = L - (2 \cdot L_F) = 300 - (2 \cdot 90) = 120$ m



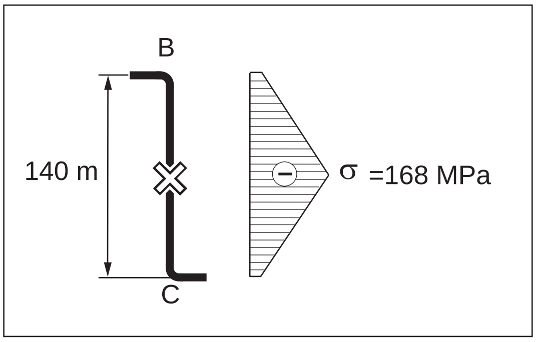
Section B-C

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:

$$\sigma_x = \frac{1}{2} \cdot \left((E \cdot \alpha) \cdot (T_f - T_r) + L \cdot \frac{F}{A_s}\right)$$

$$\sigma_x = \frac{1}{2} \cdot \left(2.52 \cdot (90 - 50) + 140 \cdot \frac{4.22 \cdot 1000}{2504}\right)$$
$$= 168 \text{ MPa}$$



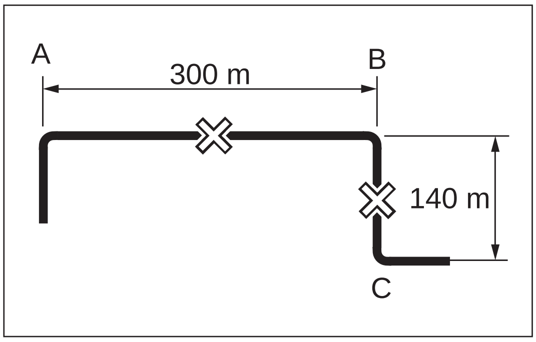
2, Expansion at bends

Conditions for example 2

ø 114.3 mm, TwinPipe series 2
Cover H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables: Frcktion force":

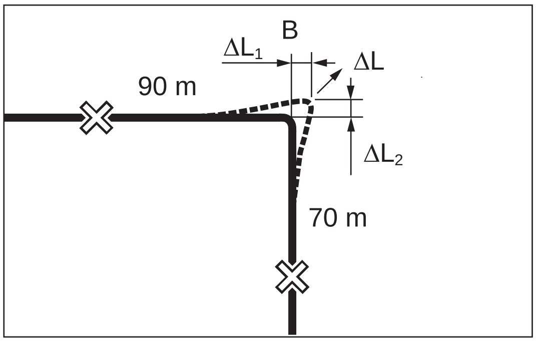
F = 4.22 kN/m
A_s = 2504 mm^2 (= total cross sectional area of the service pipes)



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 90 m (calculated in example 1).
L =90 m (< 150 m) is used for L_1 in the example.

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

$$\Delta L = 90000 \cdot 1.2 \cdot 10^{-5} \cdot \left(\frac{90 + 50}{2} - 10\right) - \frac{4.22 \cdot 90000^2}{2 \cdot 2504 \cdot 210000} = 32 \text{ mm}$$

From B-C:
The distance from the bend to the virtual anchor is ½ · 140 = 70 m.
L_F is 90 m (calculated in example 1).
L = 70 m (< 90 m) is used for L_2 in the example.

Calculation of ΔL_2:

$$\Delta L = 70000 \cdot 1.2 \cdot 10^{-5} \cdot \left(\frac{90 + 50}{2} - 10\right) - \frac{4.22 \cdot 70000^2}{2 \cdot 2504 \cdot 210000} = 31 \text{ mm}$$

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

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

$$\Delta L = \sqrt{32^2 + 31^2} = 45 \text{ mm}$$

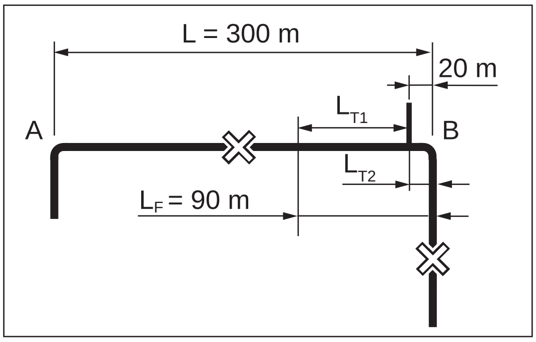
How to handle this expansion, see the section "Directional changes".

3, Expansion at branches

Conditions for example 3

ø 114.3 mm, TwinPipe series 2
Cover H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C

Values from the table in the section "Straight pipes: Stress reduction with bends - Tables: Frcktion force":
F = 4.22 kN/m
A_s = 2504 mm^2 (= total cross sectional area of the service pipes)



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 90m (calculated in example 1).
L = 90 m (< 150 m) is used in the example.

$L_{T1} = L - L_{T2} = 90 - 20 = 70$ m

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

$$\Delta L_1 = 1.2 \cdot 10^{-5} \cdot \left(\frac{90 + 50}{2} - 10\right) \cdot 70000 - \frac{4.22 \cdot (2 \cdot 90000 - 70000) \cdot 70000}{2 \cdot 210000 \cdot 2504} = 20 \text{ mm}$$

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

References

LOGSTOR Design Tool:

https://designtool.logstor.com/Tool/Form.aspx?ApplicationId=efd6607d-4f93-408e-a324-dc5f0febab5c

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 stress level
Stress level without stress reduction
Stress reduction with bends
Stress reduction with heat prestressing
Stress reduction with E-Comp

Determination of allowable axial stress level

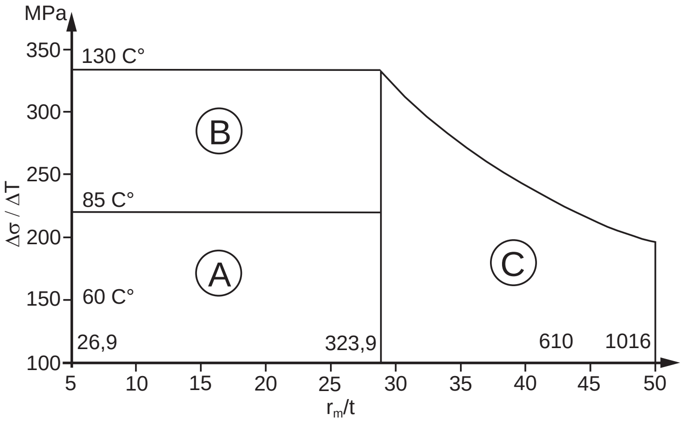
Allowable axial stress level

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.

In relation to local stability TwinPipe can be used with no risk at temperatures up to 140°C, as the maximum, axial stress level for the pipes will always be below the limit curve in below illustraion.



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
- Risk of buckling at miter joints
- Complexity of the pipeline and the trench
- Possible obstacles in the trench in connection with the construction work
- Reductions on straight pipe sections
- Position of valves
- Expansion size at bends

Determination of allowable axial stress level

Allowable axial stress level, ***continued***

EN 13941-1 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 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.

For further information on systems, carried out without stress reducing measures, see the section "Straight pipes: Without stress reduction".

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

- Bends
- Heat prestressing in open trench

These are described on the following pages and in detail in the sections: "Straight pipes: Stress reduction with bends" and "Straight pipes: Stress reduction by prestress-ing in open trench".

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 in the partly restrained section.

Low axial stress
Low design temperatures - below 95°C for flow (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 and medium-sized pipes.

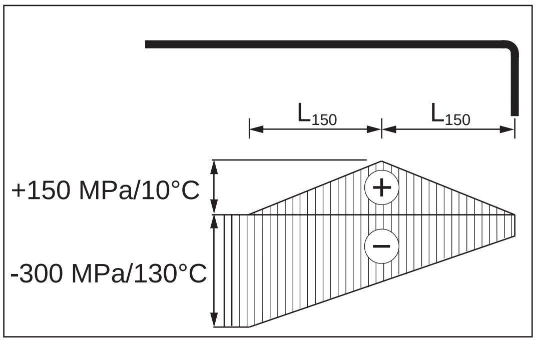
High axial stress
At high design temperatures the yield stress (R_e) of the steel is exceeded. This is called high axial stress and is defined in project class B for small and medium-sized pipes.

All TwinPipe systems can be used with high axial stress with due consideration to the global stability of the pipe system.

Straight pipe section without reduction

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

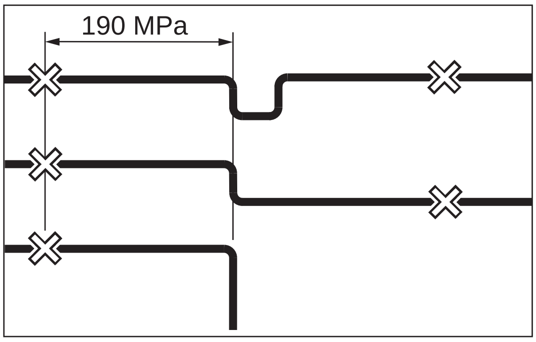
In a pipe system, installed at high axial stresses the maximum axial stresses will be -300 MPa when heating from 10° C to 130° C after backfilling.



Axial stress level reduction with bends

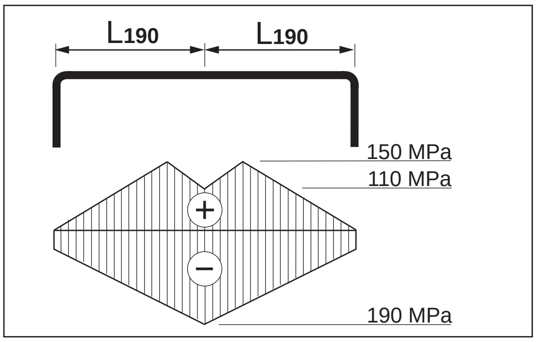
Expansion bends

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 in the flow.



All natural dircetional changes can absorb expansions, if the bend is suitable for this. Expansion bends are bulky and costly, so more expansion bends are usually only used, where there are not other possible solutions.

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 the flow of 130°C and a minimum temperature of 10°C, the maximum axial stress will be like in the illustration.

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

Axial stress level reduction with heat prestressing

Heat prestressing

When pipes are heated, before they are backfilled, they are stressfree at the pre-stressing termpature.

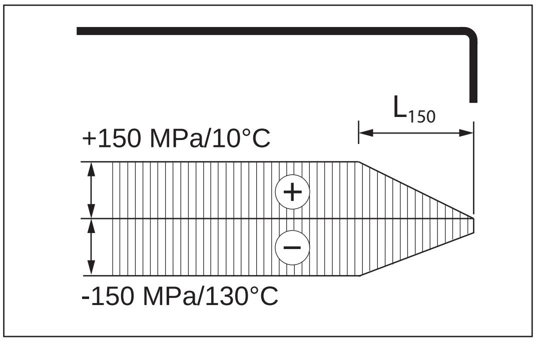
After backfilling at the prestressing temperature, at wich the pipeline has expanded longitudinally, the temperature changes will result in minor axial stresses, as they will occur as tensile as well as compressive stresses. Likewise the expansions at the ends will be minor and occur as expansion and contraction in relation to the prestressing temperature.

Thermal prestressing is done with water.

Note! During heating to the preheating temperature the flow and return tempera-ture may differ. There is therefore a risk of a minor rotation of the pipes in the open trench.

In a pipe system with a maximum operating temperature in the flow of 130°C and a minimum temperature after backfilling of 10°C the maximum axial stress in the flow will be ± 150 MPa, when the heat prestressing has been carried out at 70°C, a temperature dif-ference 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 not used in connection with the TwinPipe system.

Axial stress level - Advantages and disadvantages

Advantages and disadvantages

System	Advantages	Disadvantages
Without stress reduction Typical application: - Transmission pipelines - Distribution pipelines - House connections	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 Additional carefulness in connection with excavation and parallel excavation Limited use of miter joints
Stress reduction with bends Typical application: - Distribution pipelines - House connections	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 pre-stressing	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 (water) Heating source must be available before the trench is backfilled

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

References

Handling & Installation   The Bonded TwinPipe

Overview

Introduction

This section contains design rules for the trench as well as information about the backfill material and lifting TwinPipes.

Contents

Trench dimension and TwinPipe lifting
Backfill material
Soil cover
Excavating pipes

Trench dimension and TwinPipe lifting

Basis

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

Cross section

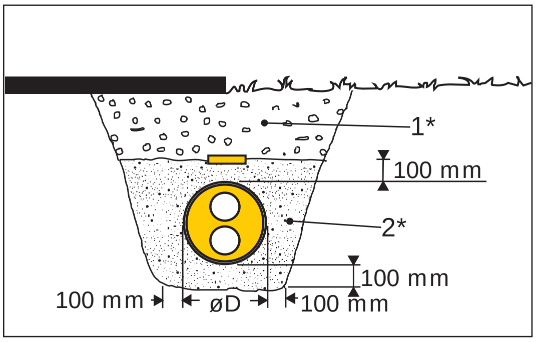
The cross section of the trench must as a rule be designed according to the requirements in EN 13941-1 as well as local rules and regulations as regards safety and work environment.

To ensure sufficient friction material around the pipes the measurements in the illustrated cross section must be complied with, see Handling & Installation "The Bonded TwinPipe".

Minimum 100 mm over the pipes place a warning tape or a warning net.

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.



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

TwinPipe lifting

TwinPipes are to be handled with caution in connection with any kind of lift. Compared to a single pipe the service pipes in a TwinPipe is much more exposed to overload, as they make out a relatively minor part of the pipe.

This is especially important on installation in a trench, where the pipe will bend around the "strong" axis (horizontal axis). Folding of the pipe wall can be avoided by ensuring that the pipes do not bend more than the allowable minimum bending radius (500 x d or 500 x H). As for the definition of "d" and "H", see the section "Directional changes: Elastic curves".

The section "Directional changes: Elastic curves" states the minimum bending radius as a function of the service pipe dimension in horizontal and vertical direction, respectively.

Backfill material

Friction material

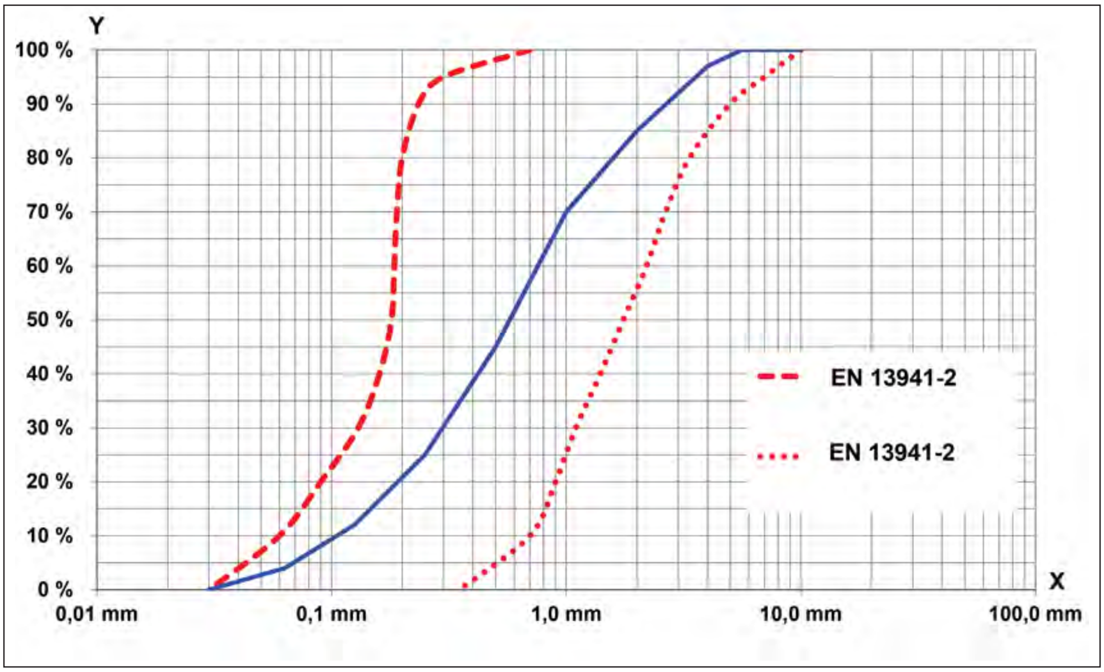
The backfill material in the friction zone (zone 2) must comply with below requirements, and a sieve analysis must lie e.g. like the blue curve between the two red limit curves according to EN 13941-2:

- 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.

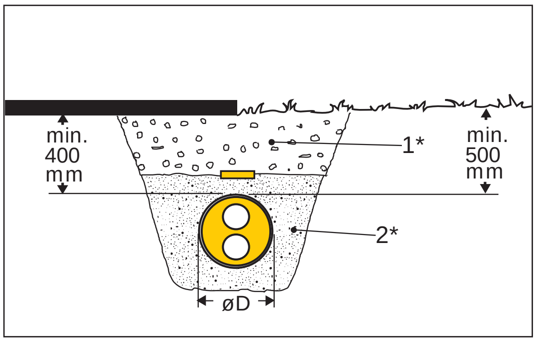
As regards expansion zones be aware of special requirements, see the section "Expansion absorption: Overview".

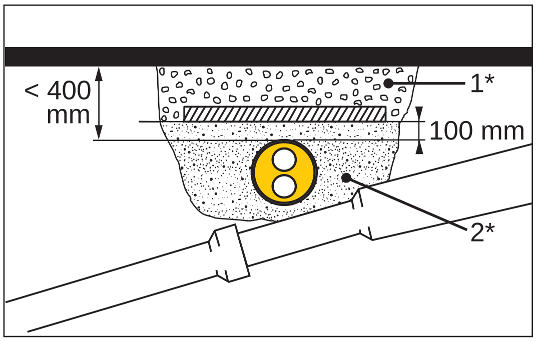
Soil cover

Minimum soil cover

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

In open terrain a minimum cover of 500 mm, measured from the top of the terrain to the top of the outer casing, is recommended.





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

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

For further information contact LOGSTOR.

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

Traffic load

If the minimum soil cover complies with the above recommendations, the pipes are secured against heavy traffic loads (100 kN wheel load).

If the soil cover is minor, it is necessary to use e.g. a steel plate or a reinforced concrete 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 13941-1.

In the zones, locked by friction the pipes can be installed deeper.

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	2.90	2.60	2.30
33.7	3.30	2.90	2.50
42.4	3.60	3.20	2.90
48.3	3.70	3.70	3.30
60.3	4.20	3.70	3.30
76.1	4.70	4.20	3.70
88.9	4.70	4.40	3.70
114.3	4.80	4.30	3.80
139.7	4.70	4.20	3.70
168.3	4.90	4.50	3.90
219.1	5.30	4.70	4.40
273	5.00	4.40	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.

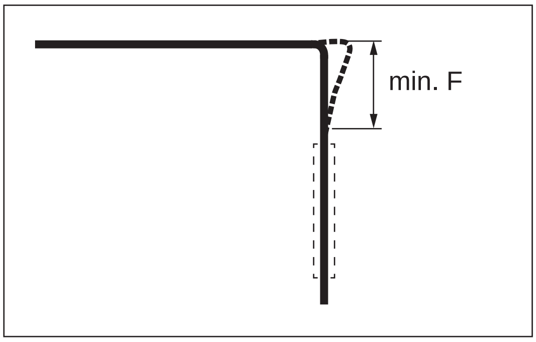
Branches in the zones, locked by friction shall be backfilled with friction material, see the section "Trench: Trench dimension and TwinPipe lifting".

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 (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 a free end/bend.

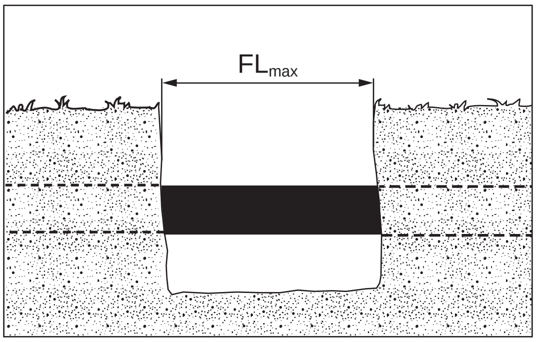
- If the pipe is exposed to lateral movement, i.e. near bends and branches, there must be sufficient space or it shall be ensured that the protective pipe is stopped where the lateral movement is zero.
  F-length, see the section "Directional changes: 80-90° bends with foam pads".



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, FL_{max} in 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 the stress level deviates from 190 MPa, 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

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

Steel pipe Ø mm	FL_{190} m	FL_{max} σ_{axial} > 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	8.1	5.5

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

The Bonded TwinPipe

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 pipe section without stress reduction
Stress reduction with bends
Stress reduction by prestressing in open trench

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.

Stress diagram

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

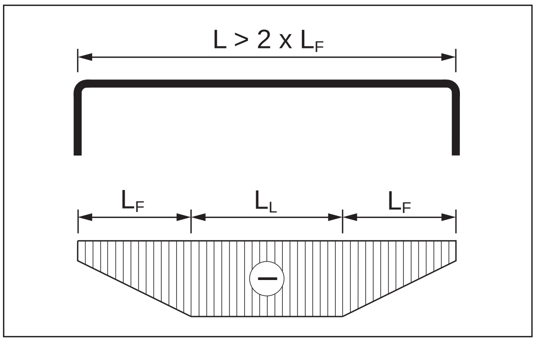
σ_{max}= (T_f – T_{ins}) · 2.52 [MPa]

From the bends the stress rises 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 · L_F.

For details see the section "Stress level and expansion calculation: Axial stress level".

L_L = section, locked by friction
L_F = friction length



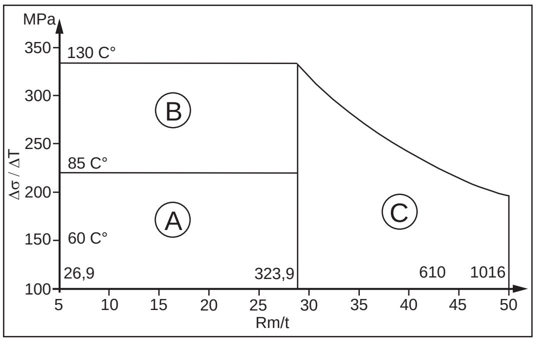
Maximum allowable temperature/axial stress level

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 reproduced from EN 13941.

From the horizontal axis the relation between the middle radius and wall thickness of the steel pipe appears.

The vertical axis is the maximum axial stresses and the temperature difference between installation and design temperature. See also EN 13941-1.



For TwinPipe-dimensions the allowable temperature difference is ΔT = 130°C, corresponding to an axial stress level of 334 MPa. TwinPipe-systems can therefore be installed without stress reductions, provided the global stability is secured.

The global stability must always be checked for all systems. As for detailed determination of stresses, see the section "Axial stress level: Detemination of allowable stresses".

Note:
The temperature difference between flow and return must always be less than 60°C.

Without stress reduction

Conclusion

Installation without stress reduction gives the lowest initial costs.

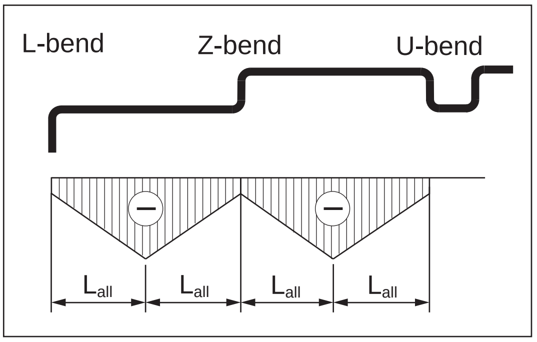
For systems, operating at low temperatures this installation method is absolutely preferable.

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

As for information about installation depths and excavation, see the section "Trench".

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 are adjusted so the distance between 2 bends does not result in axial stresses which exceed the determined stress level.

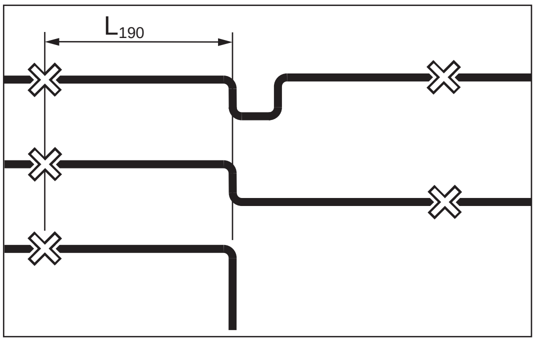
The distance from a bend to the point with the wanted stress level is called the installation length, and has the indices with the actual stress level.

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 for the TwinPipe systems.

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 is required in certain areas of the system due to the global stability.

Bends to be used can be L, Z, or U-bends. The angle must always be between 80 and 90°. Bends with minor angle must only be used, if they comply with the stated rules in the section "Directional changes".

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

Stress reduction - especially with U-bends - is an expensive method and should therefore only be used, when there are no other solutions.

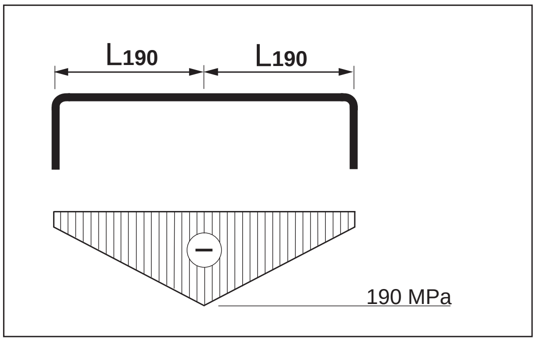
Stress reduction with bends

Installation length, calculation

To calculate the installation length for a random stress level the following formula can be used:

$$L_{all} = \left(\sigma_{all} - \frac{1}{2} \cdot E \cdot \alpha \cdot (T_f - T_r) \cdot \right) \frac{A_s}{F}$$

The cross-sectional area A_s and the friction force F are stated in the table in the section: "Straight pipes: Stress reduction with bends - Tables: Friction force" for the actual dimension, series, and cover.



Stress reduction with bends - Tables: Friction force

Conditions for the tables

From below tables the friction force from the soil (friction material) as a function of the cover appears.

The following conditions apply:

Internal friction angle of soil	$\varphi = 32{,}5°$
Specific weight of the soil	$\gamma = 19$ kN/m^3
Friction coefficient, between friction material and PE casing	$\mu = 0.40$

Series 1

d	D_c	A_s	Friction force. F		
			H = 0.60 m	H = 0.80 m	H = 1.00 m
ø mm	ø mm	mm^2	kN/m	kN/m	kN/m
26.9	125	397	1.37	1.80	2.23
33.7	140	508	1.54	2.02	2.51
42.4	160	650	1.77	2.33	2.88
48.3	160	747	1.78	2.33	2.89
60.3	200	1046	2.25	2.95	3.64
76.1	225	1334	2.57	3.35	4.13
88.9	250	1723	2.89	3.75	4.62
114.3	315	2504	3.72	4.82	5.91
139.7	400	3079	4.85	6.23	7.62
168.3	450	4129	5.57	7.13	8.70
219.1	560	6068	7.22	9.16	11.10
273	710	8419	9.57	12.04	14.50

A_s is the total cross sectional area of the two service pipes.

Series 2

d	D_c	A_s	Friction force. F		
			H = 0.60 m	H = 0.80 m	H = 1.00 m
ø mm	ø mm	mm^2	kN/m	kN/m	kN/m
26.9	140	397	1.53	2.02	2.50
33.7	160	508	1.77	2.32	2.88
42.4	180	650	2.00	2.63	3.25
48.3	180	747	2.01	2.63	3.26
60.3	225	1046	2.55	3.33	4.11
76.1	250	1334	2.86	3.73	4.60
88.9	280	1723	3.25	4.22	5.19
114.3	355	2504	4.22	5.45	6.69
139.7	450	3079	5.50	7.06	8.62
168.3	500	4129	6.24	7.97	9.71
219.1	630	6068	8.20	10.39	12.57
273	800	8419	10.92	13.70	16.47

A_s is the total cross sectional area of the two service pipes.

Stress reduction with bends - Tables: Friction force

Series 3

d	D_c	A_s	Friction force. F		
			H = 0.60 m	H = 0.80 m	H = 1.00 m
ø mm	ø mm	mm^2	kN/m	kN/m	kN/m
26.9	160	397	1.76	2.31	2.87
33.7	180	508	1.99	2.62	3.24
42.4	200	650	2.23	2.93	3.62
48.3	200	747	2.24	2.93	3.63
60.3	250	1046	2.84	3.71	4.58
76.1	280	1334	3.22	4.20	5.17
88.9	315	1723	3.67	4.77	5.86
114.3	400	2504	4.79	6.18	7.57
139.7	500	3079	6.16	7.89	9.63
168.3	560	4129	7.06	9.00	10.94
219.1	710	6068	9.36	11.82	14.28
273	900	8419	12.48	15.60	18.72

A_s is the total cross sectional area of the two service pipes.

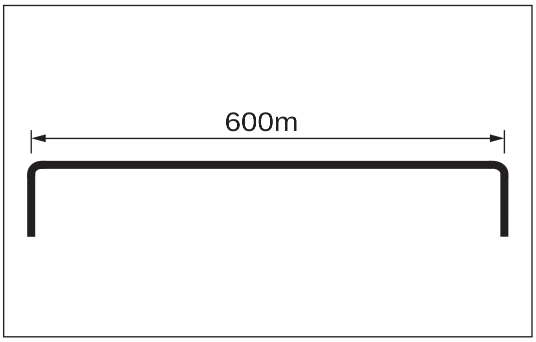
1, example of stress reduction with bends

Conditions for example 1

Straight pipe section:	600 m
Dimension:	ø 139.7 mm, TwinPipe series 2
Soil cover:	H = 0.6 m
Design temperature, flow:	T_f = 90°C
Design temperature, return:	T_r = 50°C
Installation temperature:	T_{ins} = 10°C

Maximum distance between bends

According to the section "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:

Soil friction and the cross sectional area of the steel pipes appear from the table in the section: "Straight pipes: Stress reduction with bends - Tables: Friction force" for DN125 in series 2:
F = 5.50 kN/m
A_s = 3079 mm^2 (total cross-sectional area of the service pipes)

The installation length for σ = 190 MPa is calculated.

$$L_{all} = \left(\sigma_{all} - \frac{1}{2} \cdot (E \cdot \alpha) \cdot (T_f - T_r)\right) \cdot \frac{A_s}{F}$$

$$L_{190} = \left(190 - \frac{1}{2} \cdot 2.52 \cdot (90 - 50)\right) \cdot \frac{3079}{5.50 \cdot 1000}$$

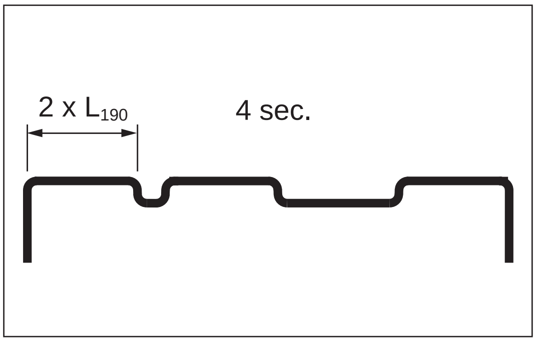
$$= 78 \text{ m}$$

The 600 m have to be divided into sections:

$$\text{Min No. of sections} = \frac{L}{2 \cdot L_{all}} = \frac{600}{2 \cdot 78}$$

$$= 3.8 \cong 4 \text{ sections (which are max } 2 \cdot L_{190})$$

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

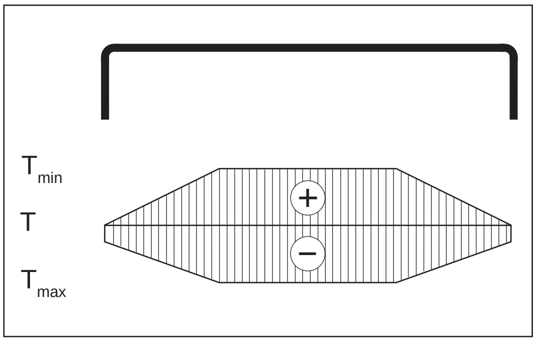


Stress reduction by prestressing in open trench

Definition

When pipes are heated, before they are backfilled, they are stressfree at the prestress termpature.

After backfilling at the prestressing temperature, at wich the pipeline has expanded longitudinally, the temperature changes will result in minor axial stresses, as they will occur as tensile as well as compressive stresse. Likewise the expansions at the ends will be minor and occur as expansion and contraction in relation to the prestressing temperature.



Note! During heating to the prestressing temperature the temperature in the flow and the return respectively may differ, resulting in a risk of a minor rotation of the pipes in the open trench.

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

The maximum temperature results in expansions, and the minimum temperatur results in contractions.

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

Heat prestressing can be carried out with water from the existing system.

Heating to the preheating temperature requires:
- Strict temperature control
- Heating in open trench
- Control of the linear expansion
- Securing the pipe longitudinally and transversely
- Checking the pipe rotation, if any, in the open trench

When the prestressing temperature has been reached and the pipes have expanded to 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 in the system is used when prestressing, which results in the compressive and tensile stresses in the flow 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:
$\sigma = (T_{Pre} - T_{Ins}) \cdot \alpha \cdot E$

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.

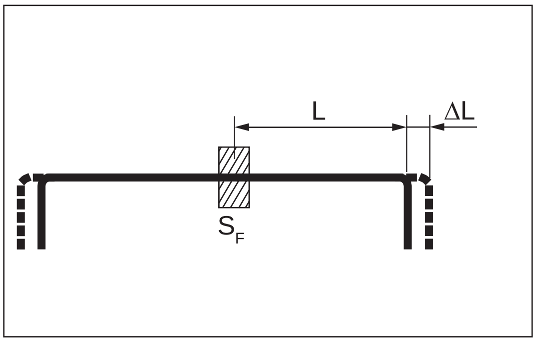
$\Delta L = (T_{Pre} - T_{Ins}) \cdot \alpha \cdot L$

$T_{Pre} = 0.5 \cdot (T_f + T_{Ins})$ = Heat prestressing temperature

T_f = Design temperature of the flow
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.



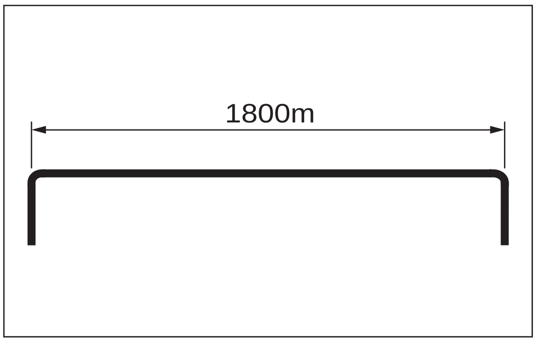
2, example of stress reduction by heat prestressing

Conditions for example 2

Straight pipe section:	1800 m
Dimension:	ø 139.7 mm, TwinPipe series 2
Soil cover:	H = 0.6 m
Design temperature, flow:	$T_f = 130°C$
Design temperature, return:	$T_r = 90°C$
Installation temperature:	$T_{ins} = 10°C$

Expansion and stresses

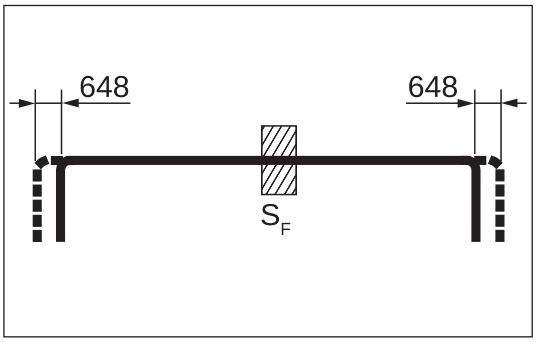
According to the section: "Straight pipes: Without stess reduction" the straight pipe section can be installed with high axial stresses without any stress reduction.



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

$T_{Pre} = 0.5 \cdot (T_f + T_{Ins}) = 0.5 \cdot (130 + 10) = 70°C$

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:

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

$\Delta L_1 = \Delta L_2 = (70 - 10) \cdot 1,2 \cdot 10^{-5} \cdot 900000 = 648$ mm.

In this example the prestressing temperature has been set to the half of the installation and the maximum temperature of the flow.

The axial stress for the flow will be:

$\sigma_{f,\,max} = (T_f - T_{Pre}) \cdot (E \cdot \alpha)$

$\sigma_{f,\,max} = (130 - 70) \cdot 2.52 = 151$ MPa (Compressive stresses, when heated)

$\sigma_{f,\,min} = (T_{Pre} - T_{Ins}) \cdot (E \cdot \alpha)$

$\sigma_{f,\,min} = (70 - 10) \cdot 2.52 = 151$ MPa (Tensile stresses, when cooled)

The axial stress for the return will be:

$\sigma_{r,max} = (90 - 70) \cdot 2.52 = 50$ MPa (Compressive stresses, when heated)

$\sigma_{r,min} = (70 - 10) \cdot 2.52 = 151$ MPa (Tensile stresses, when cooled)

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 nor the service pipe is exposed to excessive load in accordance with EN13941-1. If the design directions in the following are observed, the maximum loads will be on level with the requirements in EN 13941-1. 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.

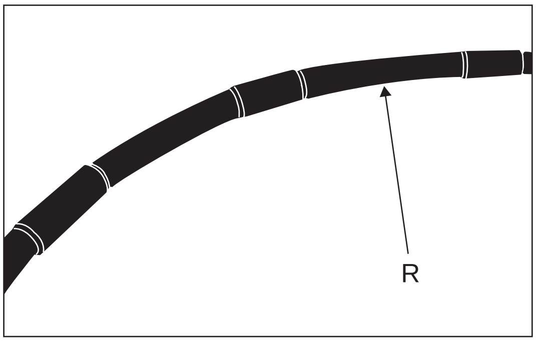
Contents

Elastic curve
Prefabricated curved pipe
Mitering
80-90° bend with foam pads
5-80° bend with foam pads

Elastic curves

General

With the LOGSTOR steel pipe system minor directional changes can be made by utilizing the elasticity of the pipes. This can be done horizontally, i.e. around the weak axis of the pipe and to a minor degree around its strong axis - i.e. vertically.

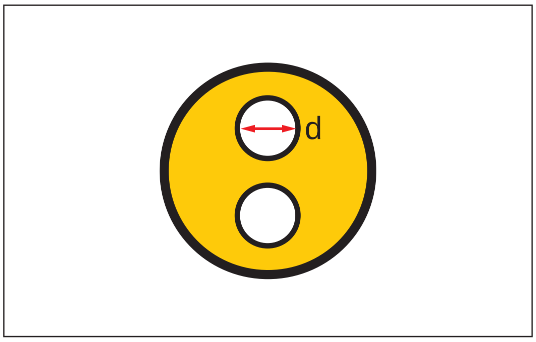


From a static point of view an elastic curve is regarded as a straight pipe. This means that an elastic curve does not result in stress concentrations like e.g. small angular deviations, arising when mitering the service pipe ends. It is therefore recommended to use elastic curves wherever possible.

The pipes are welded together in a straight section, installed in a curved trench by pulling the pipes in a soft curve. On installation it may be necessary to secure the position of the pipe e.g. by covering it partially or by means of sand sacks.

Application - horizontal

Elastic curves can be used on the horizontal level 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.

d mm	Min. allowable radius, horizontal m	Angle for 12 m °	Angle for 16 m °
26.9	13.5	51	68
33.7	16.9	41	54
42.4	21.2	32	43
48.3	24.2	28	38
60.3	30.2	23	30
76.1	38.1	18	24
88.9	44.5	15	21
114.3	57.2	12	16
139.7	69.9	9.8	13
168.3	84.2	8.2	11
219.1	110.0	6.3	8.4
273	137.0	5.0	6.7

Elastic curves

Apllication - vertical

Vertically, the TwinPipe system is more rigid due to the construction of the pipe.

The minimum bending radius is R = 500 · H, where H is the total, outside, vertical height of the service pipes.

R = 500 · H is also the minimum radius, which the pipes may be exposed to during handling on installation.

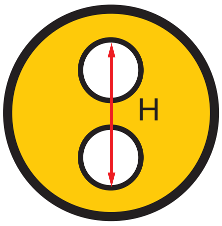
In practice this small radius should not be expected to be applicable during installation. TwinPipes are relatively rigid in vertical direction as compared to horizontal directional, so there is a risk of the pipes rotating. It is therefore recommended not to use the minimum radius on installation. As a rule of thumb, the pipes in the trench are installed with a radius of R = 750 · H.

From the table the bending radii corresponding to R = 750 · H valid for all series appear.

Elastic curves can be used for 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.

For further support please contact LOGSTOR.

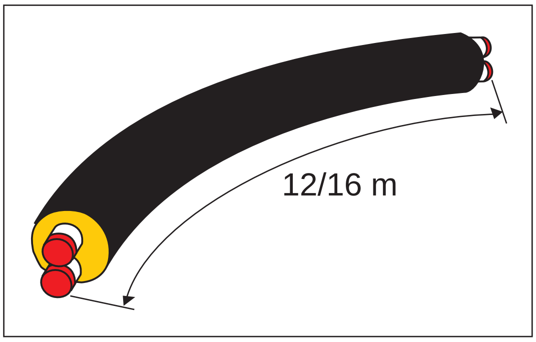


d mm	Recommended radius, 750 · H vertical m	Angle for 12 m °	Angle for 16 m °
26.9	55	13	17
33.7	65	11	14
42.4	78	8.8	12
48.3	87	7.9	11
60.3	105	6.5	8.7
76.1	129	5.3	7.1
88.9	152	4.5	6.0
114.3	190	3.6	4.8
139.7	232	3.0	4.0
168.3	282	2.4	3.2
219.1	362	1.9	2.5
273	443	1.6	2.1

Prefabricated curved pipes

General

Factory-made curved pipes are used with advantage when the required radius is less than the allowable, elastic radius of the pipe dimension. Curved pipes can only be bent horizontally.

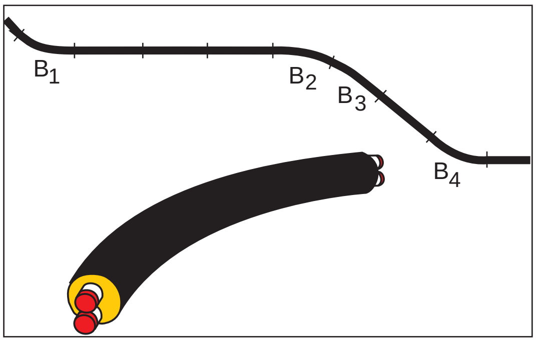


Application

Curved pipes are used for horizontal directional changes instead of traditional bend

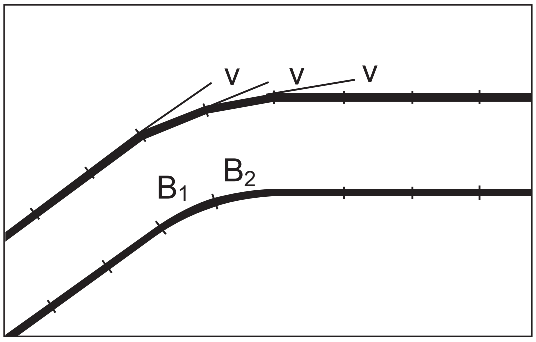
Fixing bars are not used in curved pipes.

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.

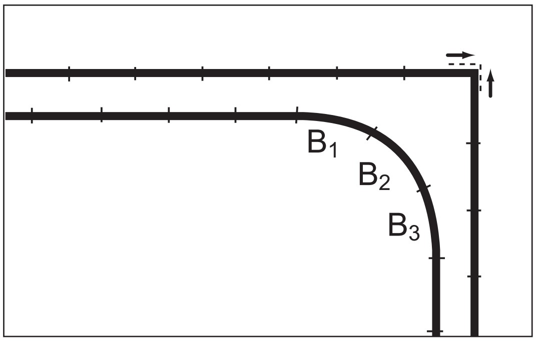


Possible solutions with curved pipes

- In replacement of directional changes, carried out by mitering



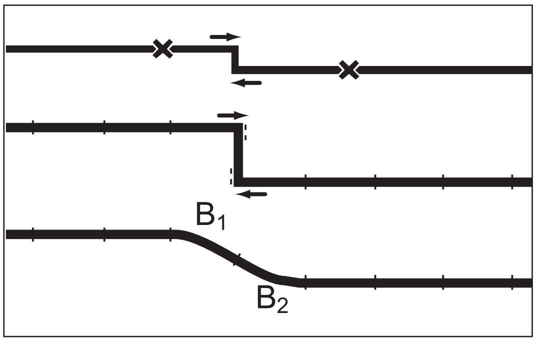
- For directional changes



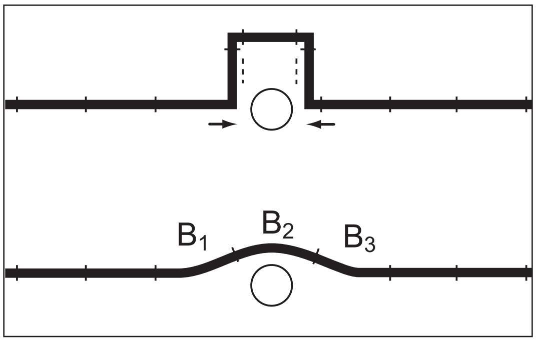
Prefabricated curved pipes

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



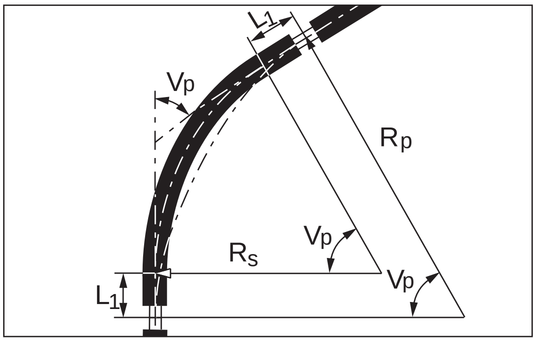
Prefabricated curved pipes

Designations of curved pipes

A factory-made curved pipe is delivered with a straight pipe piece at both ends (L_1), which has 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 Product Catalogue, the section "The Bonded TwinPipe: Curved TwinPipe").



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 or the right, see Product Catalogue, the section "The Bonded TwinPipe: Curved TwinPipe".

This must also be stated when ordering.

Max. angles and axial mean stresses

From the tables on the next page the maximum angle which a curved pipe can be delivered in as well as the mean 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.

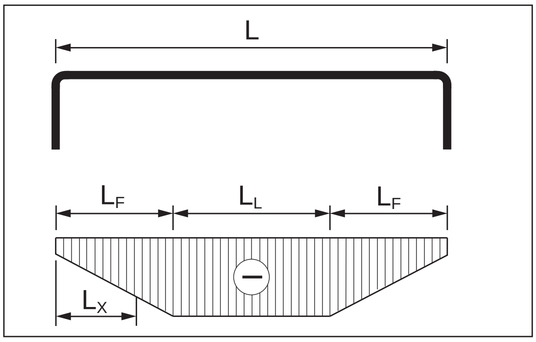
$V_{p,max}$:	Max. design angle which each dimension can be bent in.
$R_{p,min}$:	Min. design radius corresponding to maximum design angle.
L_1:	Length of the straight pipe piece at the ends of the curved pipe.
σ_{max}:	Max. axial mean stress at max. angle. In connection with higher axial mean stress the max. angle is reduced - see the section "Directional changes: Prefabricated curved pipes".
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 mean 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

Axial mean stress

The axial mean stress is a calculation unit like the mean temperature and is calculated as follows:



$L_x < L_F$

$$\sigma_x = L_x \cdot \frac{F}{A_s}$$

Where
A_s = The total cross-sectional area of the two steep pipes, which appears from the tables in the section "Straight pipes: Stress reduction with bends - Tables: Friction force".

$L_x > L_F$

$$\sigma_x = \Delta T_{mean} \cdot E \cdot \alpha$$

Where
ΔT_{mean} = The difference between the mean temperature of the flow and the return pipe and the temperature, at which the pipe is covered.

R_p at other angles

R_p is 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	$\sigma_{max, mean}$ MPa	Soil pressure MPa
60.3 x 2.9	16	43.0	0.60	334	0.036
76.1 x 2.9	25	27.5	0.60	334	0.067
88.9 x 3.2	33	20.8	0.60	334	0.091
114.3 x 3.6	38	18.1	0.56	334	0.109
139.7 x 3.6	43	16.0	0.63	190	0.105
168.3 x 4.0	45	15.3	0.67	180	0.112
219.1 x 5.0*	40	16.8	0.89	175	0.117

* When bending 219 x 219/710 the max degree for 12 m is 18°.

For further information, see Product Catalogue, the section "The Bonded TwinPipe: Directional changes - Curved TwinPipe".

16 m curved pipe

d x t mm	V_p, max °	R_p, min m	L_1 m	$\sigma_{max, mean}$ MPa	Soil pressure MPa
60.3 x 2.9	-	-	-	-	-
76.1 x 2.9	-	-	-	-	-
88.9 x 3.2	-	-	-	-	-
114.3 x 3.6	13	65.5	2.49	334	0.042
139.7 x 3.6	16	57.3	2.47	334	0.049
168.3 x 4.0	19	48.25	2.45	334	0.068
219.1 x 5.0	19	48.25	2.42	334	0.079

For further information, see Product Catalogue, the section "The Bonded TwinPipe: Directional changes - Curved TwinPipe".

Max. design angle at other stress levels

The design angle V_p must be reduced, if the actual mean stress level σ is higher than the stated level in the preceding tables.

The reduced design angle V_p is found as:

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

where $\sigma_{max,\ mean}$ is found in the table above, and σ is the actual mean stress level at the location where the curved pipe is to be installed.

$\Delta T_{mean} \leq 100°C$

For system with a mean temperature difference $\Delta T_{mean} \leq 100°C$ curved pipes with design angles/radii as stated in below table can be used. $\Delta T_{mean} = 100°C$ results in an axial mean stress of 252 MPa.

The table applies to horizontal directional changes in all insulation series with a soil cover of 0.6-1.5 m, where the groundwater table lies below the pipes.

In case the mean temperature and/or the actual mean stress level is lower than the stated values, where the curved pipe is installed, a curved pipe in a larger 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 sizes for 12 m curved pipes, stated on the previous page.

12 m curved pipes at max. axial mean stress

	$V_{p\ max}$	$R_{p\ min}$ m	L_1 m	$\sigma_{max, mean}$ MPa	Soil pressure MPa
60.3 x 2.9	15.0	45.8	0.7	334	0.03
76.1 x 2.9	24.0	28.6	0.7	334	0.06
88.9 x 3.2	32.0	21.5	0.6	334	0.082
114.3 x 3.6	38.0	18.1	0.6	334	0.109
139.7 x 3.6	36.5	18.8	0.6	252	0.105
168.3 x 4.0	34.0	20.2	0.7	252	0.111
219.1 x 5.0	24.0	28.7	0.9	252	0.094

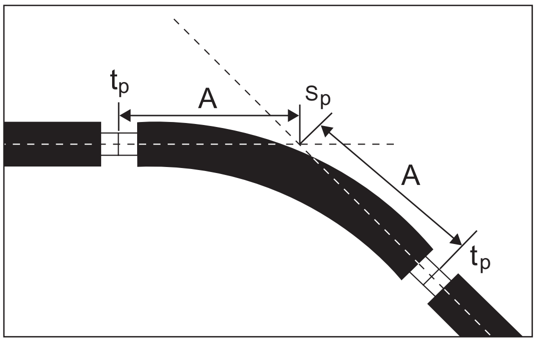
Prefabricated curved pipes

16 m curved pipe at max. axial mean stress

The table on the previous page can always be used, because 16 m curved pipes can be used at high axial mean stresses.

Marking curved pipe

To ensure that the trench of the pipe system is correctly marked 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

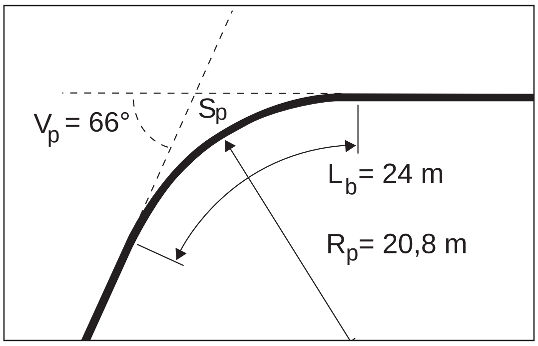
Vp: Design/bending angle

Prefabricated curved pipes - example

Conditions

Dimension ø 219.1/630 (series 2)
Soil cover H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C
Design angle V_p = 66°
Pipe length L_b = 24 m

The curved pipe is placed in the section, locked by friction.



From table earlier in this section the following values for ø 219.1 mm curved pipe appear:
- $V_{p,max}$ = 43° (Max. bending angle)
- $\sigma_{max,\ mean}$ = 140 MPa (Allowable stress level)

As the design angle V_p (66°) is larger than the allowable angle $V_{p,\ max}$ (43°), 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:

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

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

$$\sigma = 43 \cdot \frac{140}{33} = 182 \text{ MPa}$$

When calculating the axial mean stress it is established whether the stress level is below the allowable stress level of 182 MPa where the curved pipe is to be installed:

$L_x > L_F$

$\sigma_x = \Delta T_{mean} \cdot E \cdot \alpha$

$$\sigma_x = \left(\frac{90+50}{2} - 10\right) \cdot 2.52 = 150 \text{ MPa}$$

As the axial stress level is < 182 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 or the right due to the position of the alarm wires, see Product Catalogue, the section "The Bonded TwinPipe: Directional changes - Curved TwinPipe".

The A-measurement, which states the measurement from a weld to the points where the tangents of the curved pipe intersect, 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

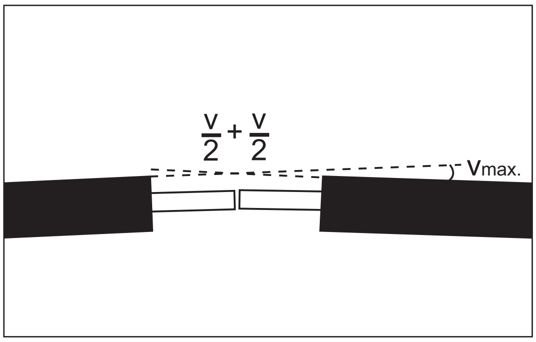
Mitering can be used for minor horizontal directional changes. The use of mitering should however be minimised as much as possible, as stress concentrations will occur in the mitre area, increasing the risk of weaknesses in the mitre.

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

Possible applications

Mitering is only allowed at horizontal directional changes - not at vertical directional changes.

Fixing bars are not installed at mitres.



Allowable mitering

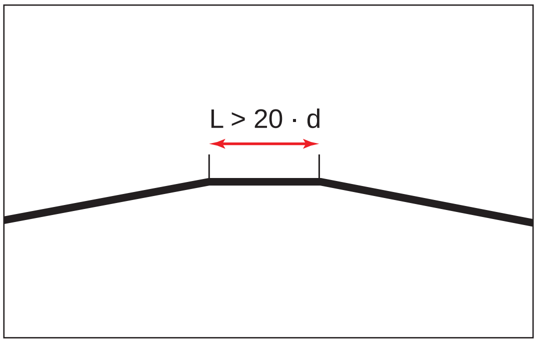
The allowable mitre dimension is defined on basis of the axial stress level of a pipe system, $\sigma_{a,max}$.

ΔT_{max} is the difference between the design temperature of the flow and the installation temperature.

ΔT_{max} °C	$\sigma_{a,max}$ MPa	V_{max} °
60	150	4
90	228	2
100	252	1
110	280	0,5
> 110	> 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 casing joint. This minimises the lateral movement, which may result in folding or fatigue failure 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 90-710 mm	ø 90-1000 mm	ø 90-1400 mm	ø 90-1400 mm
1	ø 90-630 mm	ø 90-710 mm	ø 90-1000 mm	ø 90-1400 mm	ø 90-1400 mm
2	ø 90-630 mm	ø 90-710 mm	ø 90-1000 mm	ø 90-1400 mm	ø 90-1400 mm
3	ø 90-630 mm	ø 90-710 mm	ø 225-1000 mm	ø 225-1000 mm	ø 90-710 mm
4	ø 90-630 mm	ø 90-630 mm	-	ø 225-500 mm	ø 90-500 mm
5	ø 90-630 mm	ø 90-630 mm	-	-	-

Steel service pipe must be checked statically.

Directional changes

80-90° bends with foam pads

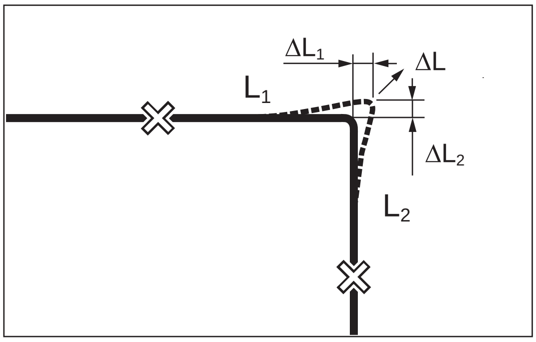
General

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 by absorbing the expansion in foam pads, see below.

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



Fatigue/ load cycles

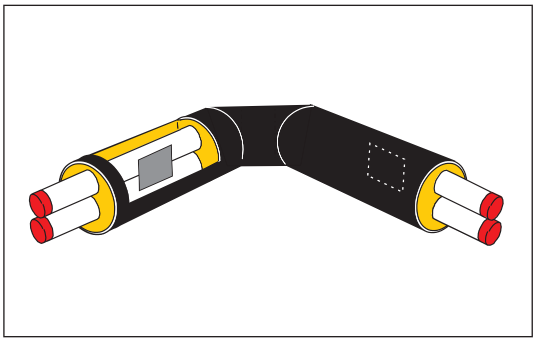
On basis of the actual temperatures and installation conditions the movement at the bend is calculated. All bends are secured against fatigue in accordance with EN13941 with the stated min. temperature variations, described in the section "General: Project classes".

Likewise all bends in this manual are calculated with safety factores for project class B.

Fixing bars

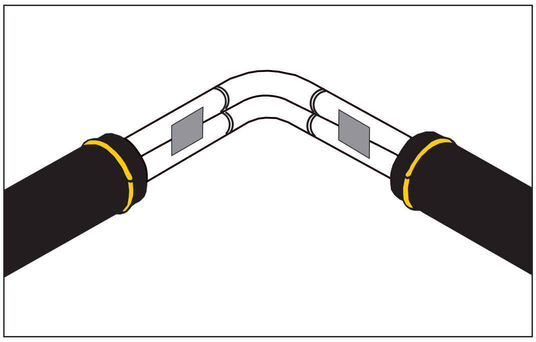
Fixing bars must be used for all directional changes.

All preinsulated bends are delivered with built-in fixing bars, so no additional measures are required when using preinsulated bends.



Bend fittings require that fixing bars are welded on to the straight pipe ends at both sides of the bend, see the section "General: System definitions". However, if the distance between two bends is less than 12 m, a fixing bar is not required on the leg with a distance to the next bend less than 12 m.

For installation of fixing bars, see Handling & Installation, the section "The Bonded TwinPipe: Expansion and anchoring - Fixing bars".



Possible applications

The guidelines in this section apply to horizontal directional changes.

Directional changes
80-90° bends with foam pads

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 "Stress level and expansion calculation: 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.

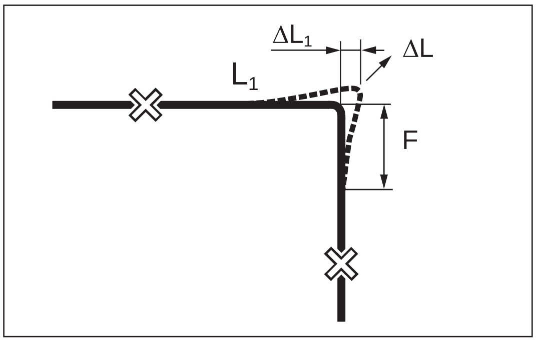
F = the length from the bend to be protected with foam pads to prevent the soil pressure from resulting in too high stresses in the PUR foam.

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

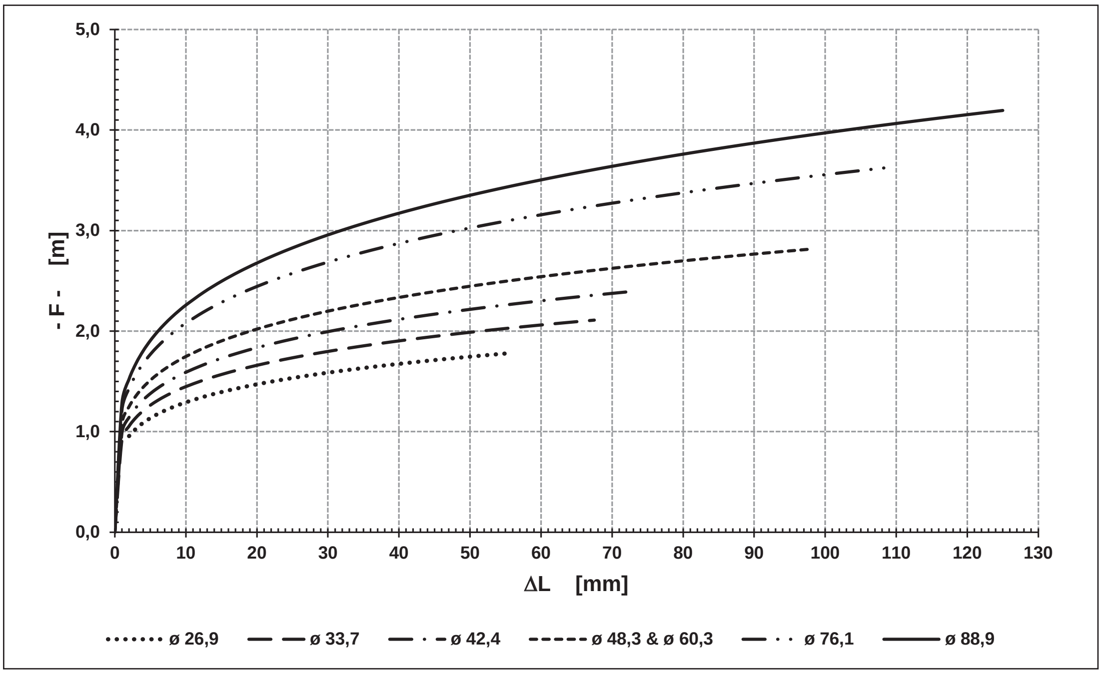
On the horizontal axis of the graph the actual ΔL is found.

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.

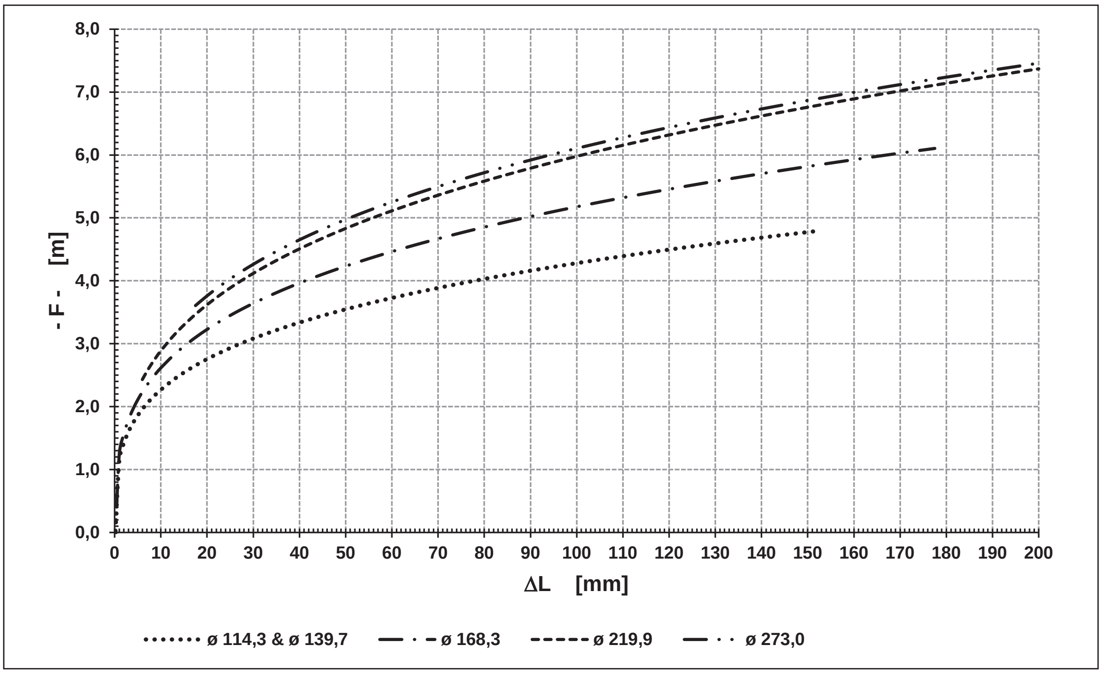


Expansion zone, F- length ø 26.9 – ø 114.3 Series 1, 2, and 3



80-90° bends with foam pads

Expansion zone, F- length ø 139.7 – ø 273 Series 1, 2, and 3



Foam pads

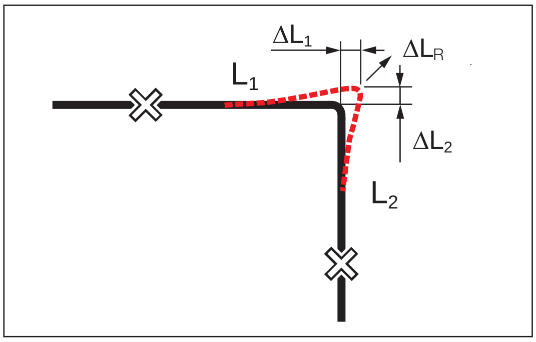
To detemine the number and thickness of the foam pads, required to absorb the expansion in the bend, the resulting expansion ΔL_R is calculated.

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

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".



80-90° bends with foam pads

Foam pad length

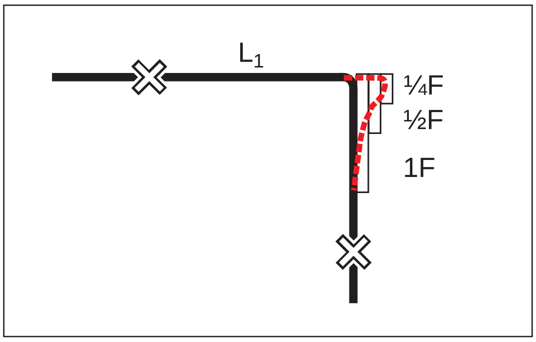
The length of the foam pad is minimum the F-length.

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.



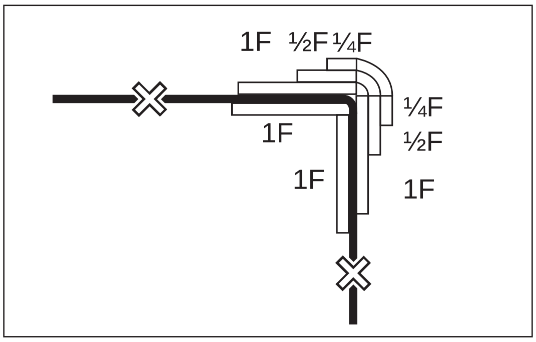
Position of foam pads

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.



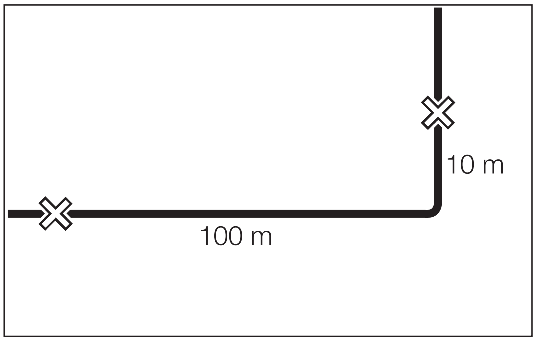
80-90° bends with foam pads - Example

Conditions for the example

ø 60.3, series 2
Soil cover, H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C
L_1 = 100 m
L_2 = 10 m

From table in the sectin "Straight pipes: Stress reduction with bends - Tables: Friction force" for ø 60.3 series 2:

F = 2.55 kN/m
A_s = 1046 mm² (= Total cross-sectional area of the service pipes)



Max. stress level

$\sigma_{max.} = \Delta T \cdot 2,52$ [MPa]
$\sigma_{max.} = (90 - 10) \cdot 2,52 = 202$ [MPa]

ΔT_{mean} is calculated:

$$\Delta T_{mean} = \left(\frac{T_f + T_r}{2} - T_{ins}\right) = \left(\frac{90 + 50}{2} - 10\right) = 60°C$$

The frictionlength L_F:

$$L_F = \Delta T_{mean} \cdot (E \cdot \alpha) \cdot \frac{A_s}{F}$$

$$L_F = 60 \cdot 2,52 \cdot \frac{1046}{2,55 \cdot 1000} = 62 \text{ m}$$

Expansion

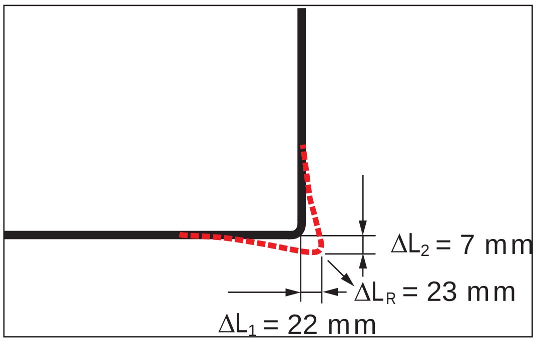
$$\Delta L = L_x \cdot \alpha \cdot \Delta T_{mean} - \frac{F \cdot L_x^2}{2 \cdot A_s \cdot E}$$

L_F, is used as L_x as it is shorter than the actual length.

$$\Delta L_1 = 62000 \cdot 1,2 \cdot 10^{-5} \cdot 60 - \frac{2,55 \cdot 62000^2}{2 \cdot 1046 \cdot 210000} = 22 \text{ mm}$$

The actual length = 10 mm is used as L_2.

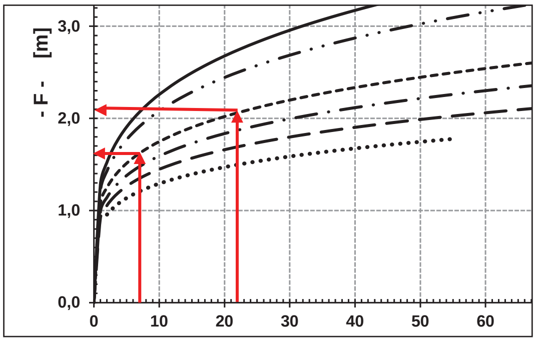
$$\Delta L_2 = 10000 \cdot 1,2 \cdot 10^{-5} \cdot 60 - \frac{2,55 \cdot 10000^2}{2 \cdot 1046 \cdot 210000} = 7 \text{ mm}$$

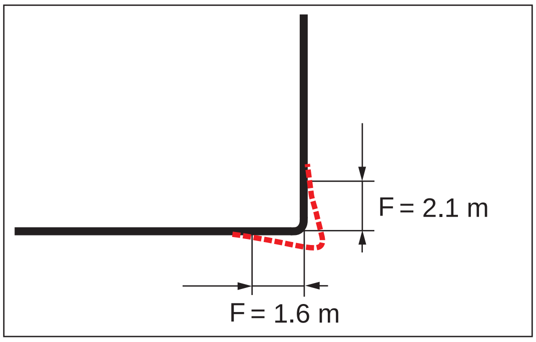


80-90° bends with foam pads - Example

F-length

From the table in the section "Directional changes: 80-90° bends with foam pads":
- 22 mm equals F = 2.1 m
- 7 mm equals F = 1.6 m





Foam pads

Radial expansion in bend:

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

$$\Delta L_R = \sqrt{22 + 7^2} = 23 \text{ mm}$$

Thickness of foam pads:
- Min. thickness:

$$t = \frac{\Delta L_R}{0.70} = \frac{23}{0.70} = 33 \text{ mm}$$

Number of layers of each 40 mm:

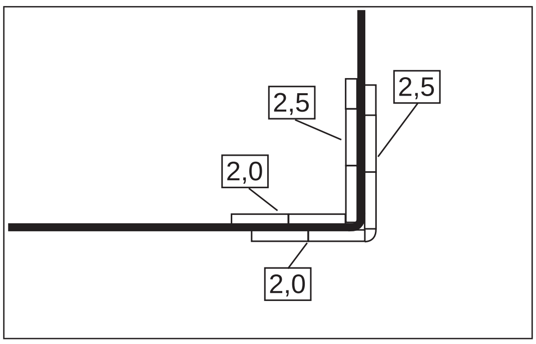
$$t = \frac{t}{40} = \frac{33}{40} = 1 \text{ layer}$$

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.

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:

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

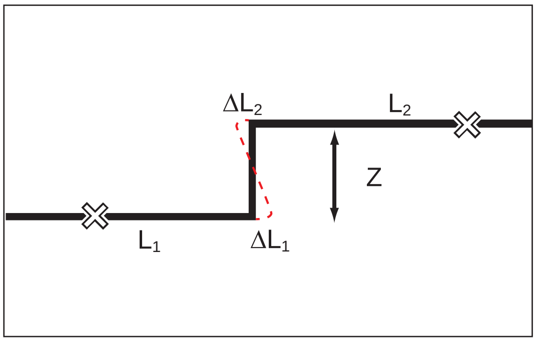
Where:

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". When calculating Z-bends the resulting expansion is set equal to the expansion from L_1 and L_2, respectively.

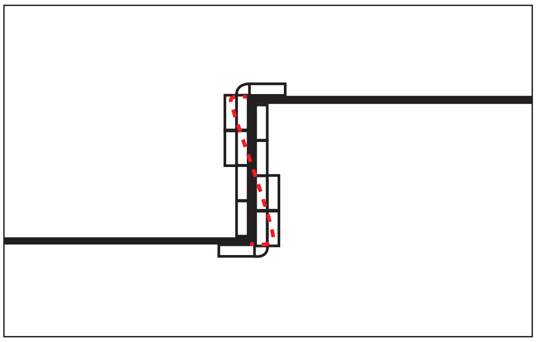


Length of foam pads

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) in the length 1 m is placed.



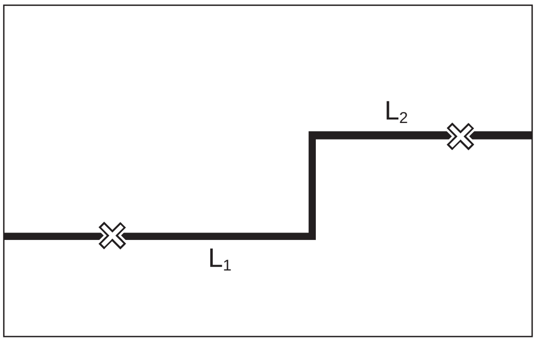
80-90° bends with foam pads - Z-bend - example

Conditions for the example

ø 114.3 series 2
Soil cover, H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C
L_1 = 83 m
L_2 = 21 m

From table in the section "Straight pipes: Stress redution with bends - Tables: Friction force" for ø 114,3 series 2:

F = 4.22 kN/m
A_s = 2504 mm² (= total cross-sectional area of service pipes)



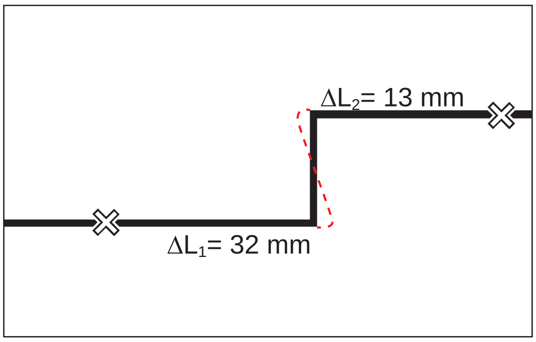
Expansion

$$\Delta T_{middel} = \left(\frac{T_f + T_r}{2} - T_{ins}\right) = \left(\frac{90 + 50}{2} - 10\right) = 60°C$$

$$\Delta L = L_x \cdot \alpha \cdot \Delta T_{middel} - \frac{F \cdot L_x^2}{2 \cdot A_S \cdot E}$$

$$\Delta L_1 = 83000 \cdot 1.2 \cdot 10^{-5} \cdot 60 - \frac{4.22 \cdot 83000^2}{2 \cdot 2504 \cdot 210000} = 32 \text{ mm}$$

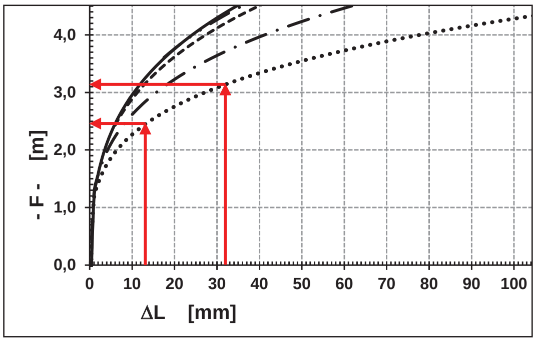
$$\Delta L_2 = 21000 \cdot 1.2 \cdot 10^{-5} \cdot 60 - \frac{4.22 \cdot 21000^2}{2 \cdot 2504 \cdot 210000} = 13 \text{ mm}$$



F-length

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

- L_1:
  ΔL = 32 mm equals F = 3.1 m
- L_2:
  ΔL = 13 mm equals F = 2.5 m

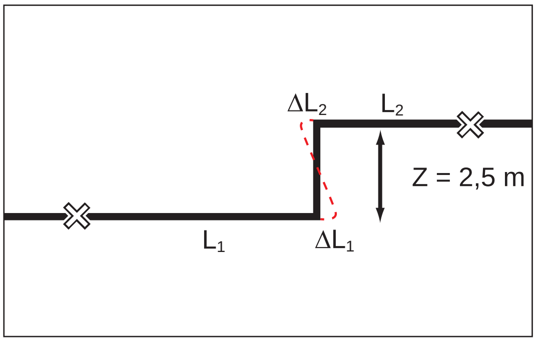


80-90° bends with foam pads - Z-bend - example

Required Z-length

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

$Z = 0.45 \cdot (3.1 + 2.5) = 2.5$ 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:

$$t_1 = \frac{\Delta L}{0.70} = \frac{32}{0.70} = 46 \text{ mm}$$

Number of layers of each 40 mm:

$$\frac{t_1}{40} = \frac{46}{40} = 2 \text{ layers}$$

For the expansion from L_2 it is found:

$$t_2 = \frac{\Delta L}{0.70} = \frac{13}{0.70} = 19 \text{ mm}$$

Number of layers of each 40 mm:

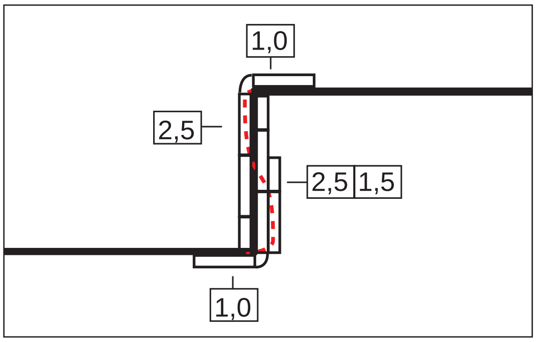
$$\frac{t_2}{40} = \frac{19}{40} = 1 \text{ layer}$$

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 full length and the next layer is ½ length.

On the axial part 40 mm foam pads are placed in 1 m length.



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

$U = 0.6 \cdot F_{max}$

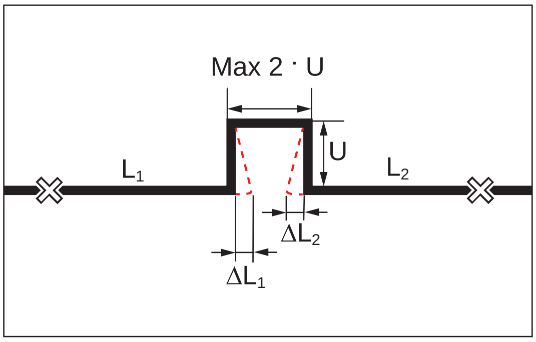
where F_{max} is the largest F-length for ΔL_1 or ΔL_2 for a 90° bend.

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 pcs. of 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.



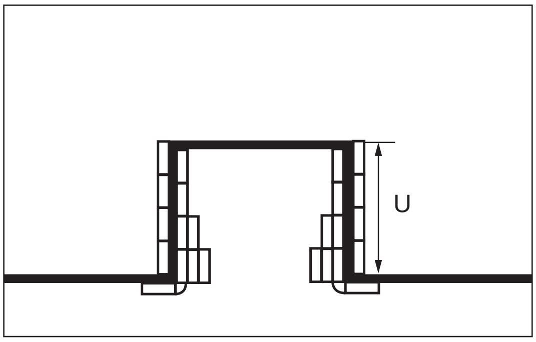
Length of foam pads

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 in 1 m length is placed.

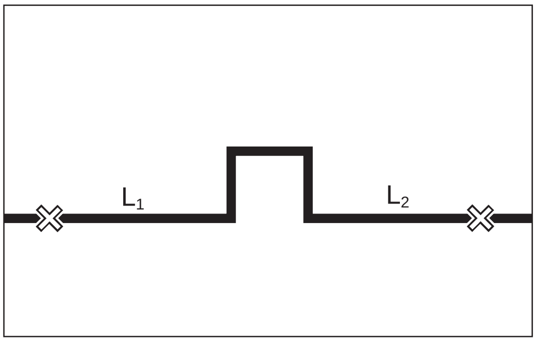


Directional changes

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

Conditions for the example

ø 114.3, series 1
Soil cover, H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°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: Friction force" ø 114.3 series 2:

F = 2,97 kN/m
A_s = 1252 mm² (= the total cross-sectional area of the service pipes)

Max. stress level

$\sigma_{max.} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max.} = (90 - 10) \cdot 2.52 = 202$ [MPa]

Mean temperature ΔT_{mean}:

$$\Delta T_{middel} = \left(\frac{T_f + T_r}{2} - T_{ins}\right) = \left(\frac{90 + 50}{2} - 10\right) = 60°C$$

Friction length L_F:

$$L_F = \Delta T_{middel} \cdot (E \cdot \alpha) \cdot \frac{A_S}{F}$$

$$L_F = 60 \cdot 2.52 \cdot \frac{2504}{4.22 \cdot 1000} = 90 \text{ m}$$

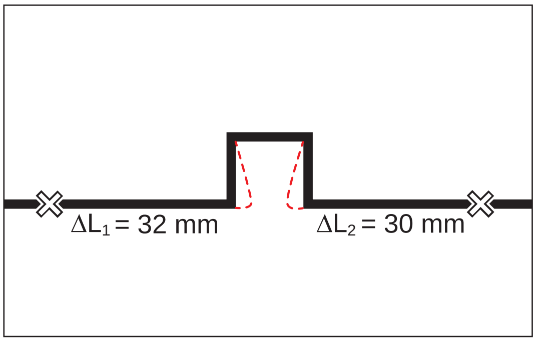
Expansion

$$\Delta L = L_x \cdot \alpha \cdot \Delta T_{mean} - \frac{F \cdot L_x^2}{2 \cdot A_S \cdot E}$$

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

$$\Delta L_1 = 90000 \cdot 1.2 \cdot 10^{-5} \cdot 60 - \frac{4.22 \cdot 90000^2}{2 \cdot 2504 \cdot 210000} = 32 \text{ mm}$$

$$\Delta L_2 = 65000 \cdot 1.2 \cdot 10^{-5} \cdot 60 - \frac{4.22 \cdot 65000^2}{2 \cdot 2504 \cdot 210000} = 30 \text{ mm}$$

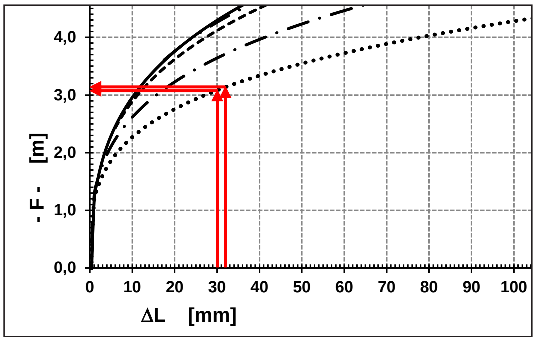


80-90° bends with foam pads - U-bend - Example

F-length

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

- L_1:
  ΔL = 32 mm equals F = 3.1 m
- L_2:
  ΔL = 30 mm equals F = 3.1 m



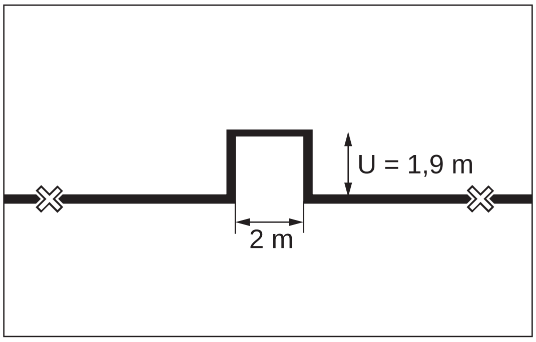
Required U-length

$U = 0.6 \cdot F_{max}$

$U = 0.6 \cdot 3.1 = 1.9$ m

The length of the bottom of the U-bend is max. 2 · U = 3,8 m.

Typically, 2 · leg length is used on a standard bend, here 2 · 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:

$$t_1 = \frac{\Delta L}{0{,}70} = \frac{32}{0{,}70} = 46 \text{ mm}$$

Number of layers of each 40 mm:

$$\frac{t_1}{40} = \frac{46}{40} = 2 \text{ layers}$$

For the expansion from L_2 it is found:

$$t_2 = \frac{\Delta L}{0.70} = \frac{30}{0.70} = 43 \text{ mm}$$

Number of layers of each 40 mm:

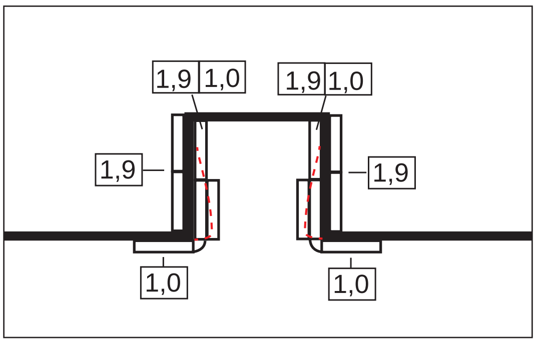
$$\frac{t_2}{40} = \frac{43}{40} = 2 \text{ layers}$$

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 and the next layer is ½ length.

On the axial part 40 mm foam pads in min. 1 m length is installed.



Directional changes
5-80° bends with foam pads

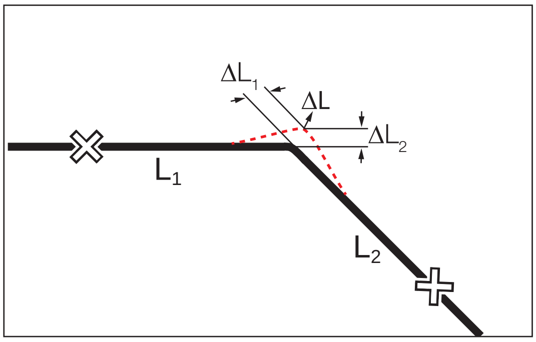
General

Axial expansion of straight TwinPipe 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 TwinPipe systems, installed traditionally, where the first time expansion is given by the difference between the mean temperature and the installation temperature of the system.

Directional changes are made by means of a 5-80° preinsulated bend or by welding in a bend segment. 5-80° 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.

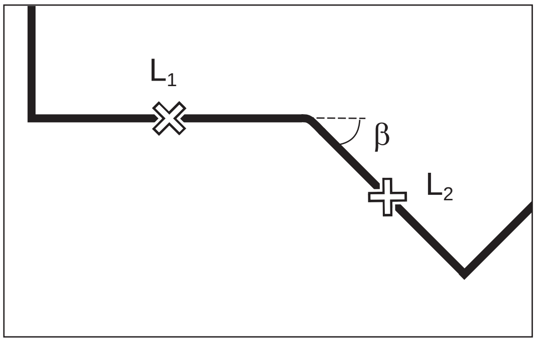
10-80° directional changes must be furnished with foam pads as described in this section.

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 TwinPipe 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.

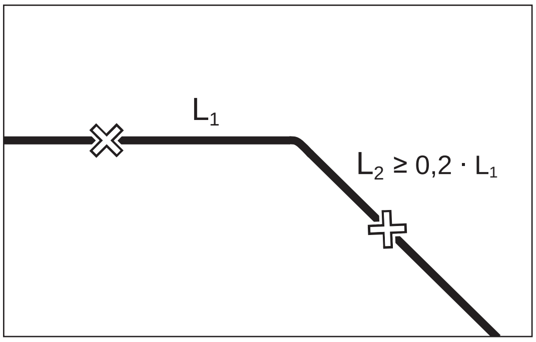


5-80° bends with foam pads

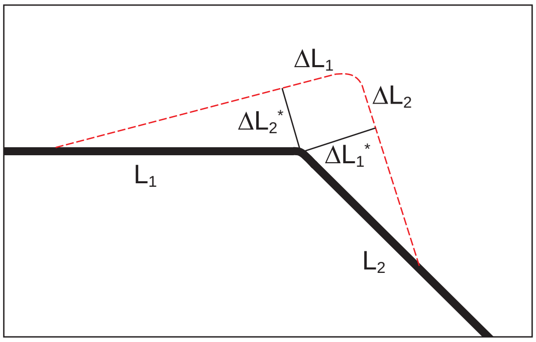
Application rules, ***continued***

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

$L_2 \geq 0.2 \cdot L_1$



For directional changes between 5-80° distinction is made between the axial movements ($\Delta L_1/\Delta L_2$) and the resulting movements (ΔL_1*/ΔL_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.

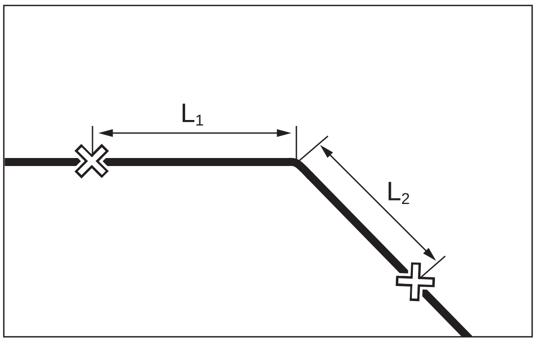
Max. lengths

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.



5-80° bends with foam pads

Axial movement

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

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

For further information about calculating the axial movement at a free pipe end, see the section "Stress level and expansion calculation: Axial stress level".

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.

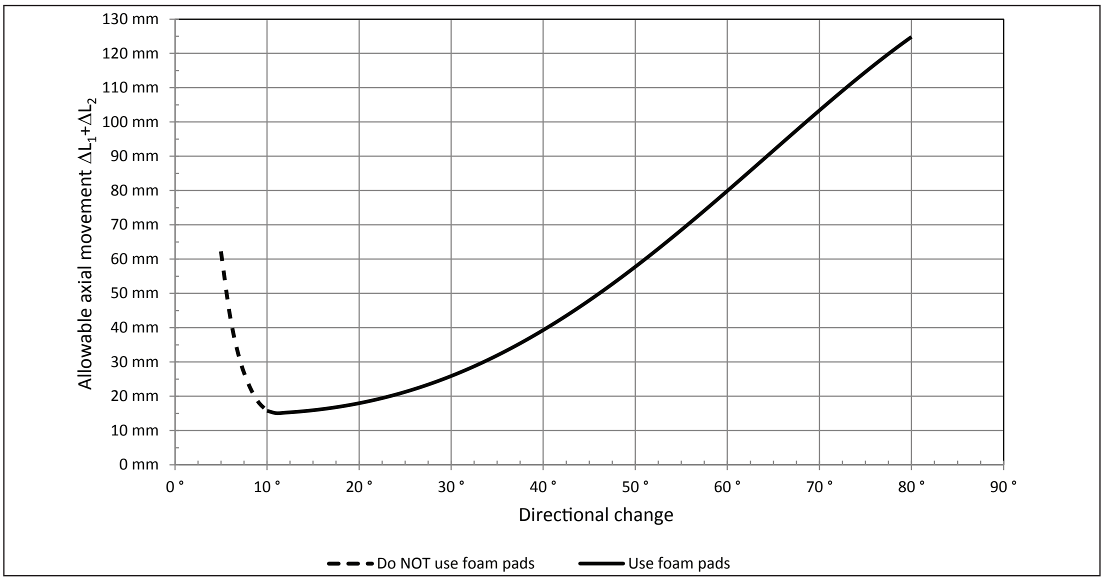
From the horizontal axis of the diagram the angle of the directional change is found.

This measurement is displaced upwards 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 DN 250 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 ø 26,9-ø 273, Series 1, 2, and 3 H = 0.6-1.5 m

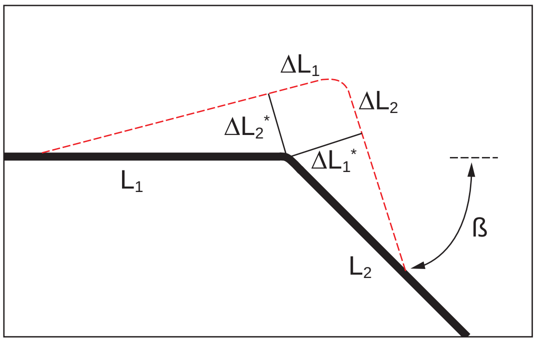


Length of the expansion zone

To establish the length of the expansion zone for 10-80° directional changes it is necessary to calculate the resulting movements in the bend.

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

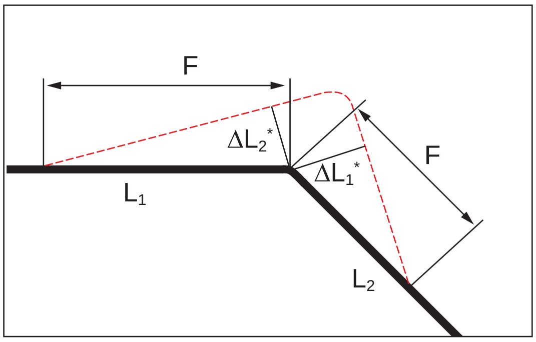
$$\Delta L_2^* = \frac{\Delta L_1}{\tan ß} + \frac{\Delta L_2}{\sin ß}$$



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.

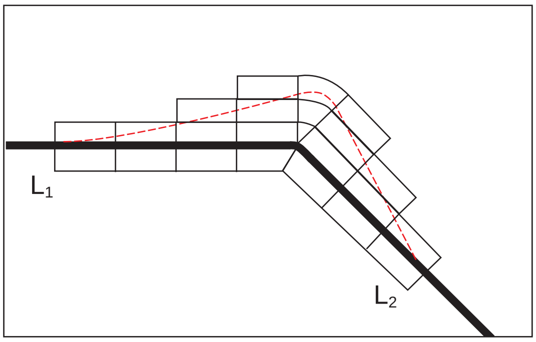
F = the length from the bend to be protected with foam pads to prevent the soil pressure from causing too high stresses in the PUR-foam.

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 the section "Directional changes: 80-90° bends with foam pads" as well as the following example.

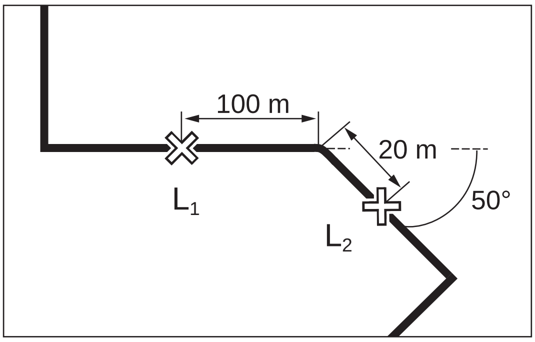
The inner side of the bend is furnished with 1 layer of foam pads in a length corresponding to the F-length.

5-80° bends with foam pads - Example

Conditions for the example

ø 60.3, series 2
Soil cover H = 0.6 m
Design temperature, flow T_f = 90°C
Design temperature, return T_r = 50°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: Friction force" for ø 60.3 series 2:
F = 2.55 kN/m
A_s = 1046 mm² (= total cross-sectional area of the service pipes)



Axial expansion

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

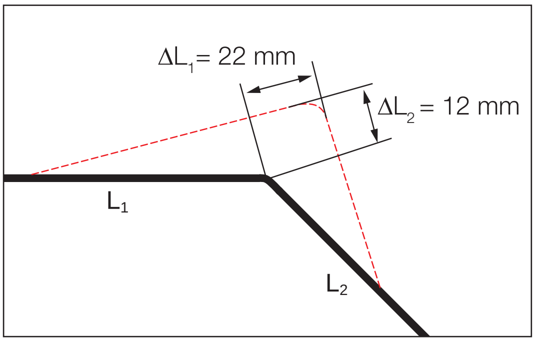
L_F (= 62 m) is used as L_1, as it is shorter than the actual length.

$$\Delta L_1 = 62000 \cdot 1.2 \cdot 10^{-5} \cdot \left(\frac{90 + 50}{2} - 10\right) - \frac{2{,}55 \cdot 62000^2}{2 \cdot 1046 \cdot 210000} = 22 \text{ mm}$$

As L_2 the actual length = 20 m is used.

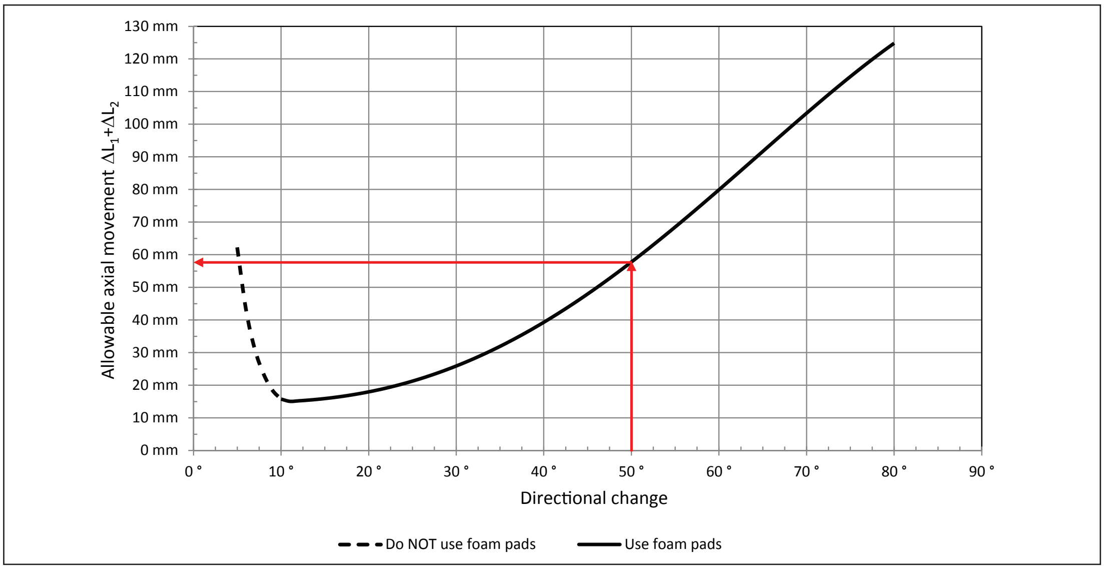
$$\Delta L_2 = 20000 \cdot 1.2 \cdot 10^{-5} \cdot \left(\frac{90 + 50}{2} - 10\right) - \frac{2{,}55 \cdot 20000^2}{2 \cdot 1046 \cdot 210000} = 12 \text{ mm}$$

The sum of the movements is:
$\sum \Delta L = \Delta L_1 + \Delta L_2$
$\sum \Delta L$ = 22 + 12 = 34 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

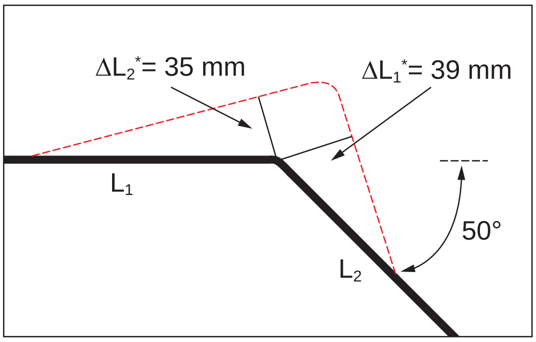
The resulting expansion is calculated for each leg:

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

$$\Delta L_1^* = \frac{12}{\tan 50} + \frac{22}{\sin 50} = 39 \text{ mm}$$

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

$$\Delta L_2^* = \frac{22}{\tan 50} + \frac{12}{\sin 50} = 35 \text{ mm}$$



Foam pads

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

Min. thickness:

$$t = \frac{\Delta L^*_{max}}{0.70} = \frac{39}{0.70} = 56 \text{ mm}$$

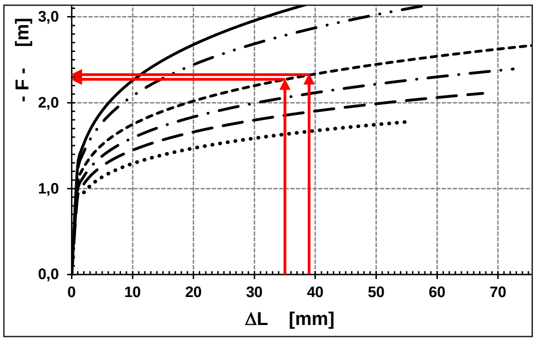
Number of layers of each 40 mm:

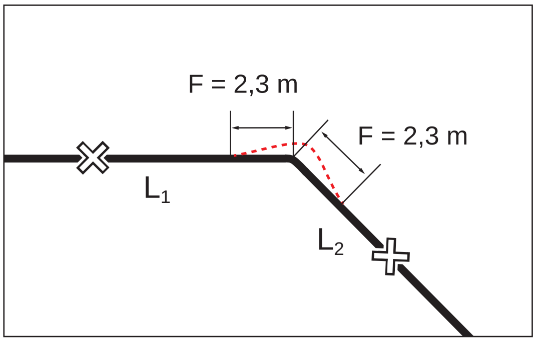
$$\frac{t}{40} = \frac{56}{40} = 2 \text{ layers}$$

5-80° bends with foam pads - Example

F-length

On basis of the resulting expansions the F-length for each leg is found in the diagram in the section "Directional changes: 80-90° bends with foam pads":
- 35 mm equals F = 2.3 m
- 39 mm equals F = 2.3 m





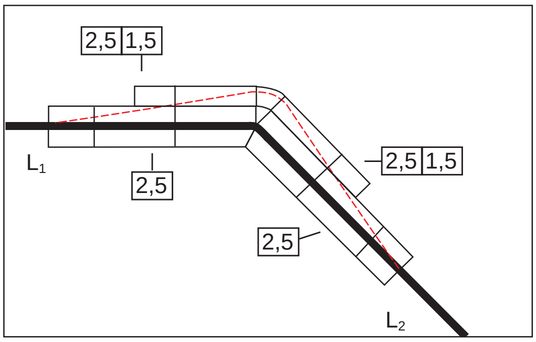
Positioning foam pads

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 full length and the next layer is half length.

The inner side of the 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

Product Catalogue:	"The Bonded TwinPipe: Directional changes - Curved TwinPipe"
Handling & Installation:	The Bonded TwinPipe: Expansion and anchoring - Fixing bar"

Branches
Overview

Introduction

This section contains guidelines for designing with branches in preinsulated TwinPipe 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 homepage supports and facilitates calculations of branches. The program is based on th directions in this section.

Contents

General
Application
Preinsulated branches and branch fittings
Reinforcement of branch fittings

Introduction

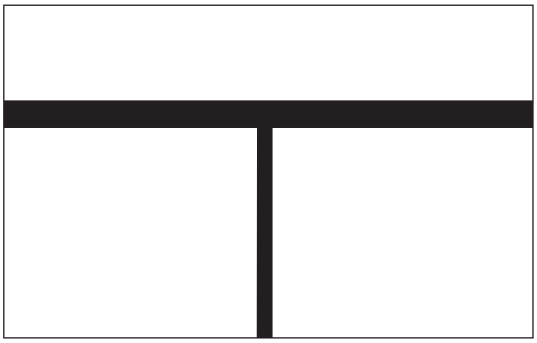
TwinPipe branches can be made as straight branches, where the branch pipes are on level with the main pipes.

This means that it is not necessary to dig deeper to ensure sufficient cover on the branch.

It is possible to branch to TwinPipes in all dimensions or two single pipes up to ø 110 outer casing (pipes from FlexPipe assortment). Further information about branching to the FlexPipe assortment, see the sections "PexFlextra", "PertFlextra", "AluFlextra" and "CuFlex".

For all branch types it must be ensured that the soil conditions around the branch are stable and that the main and branch pipes can absorb the movements, they are exposed to.

TwinPipe-branches can be made as branch fittings and preinsulated branches respectively, see Product Catalogue, the section "The Bonded TwinPipe: Branches".



Fixing bars

Preinsulated branches are delivered with fixing bars, built into the branch pipes.

When using branch fittings fixing bars must be welded onto both sides of the pipe pair of the branch. Installation of fixing bars, see Handling & Installation, the section "The Bonded TwinPipe: Expansion and anchoring - Fixing bar".

Stress level

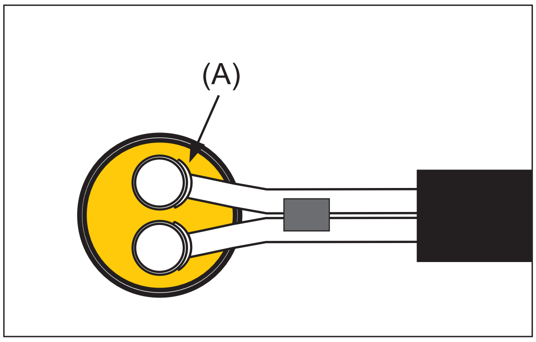
Generally, preinsulated TwinPipe branches can be used everywhere in systems with high axial stresses (systems without stress reduction, see the section "Straight pipes: Without reduction").

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.

Stress level, continued

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

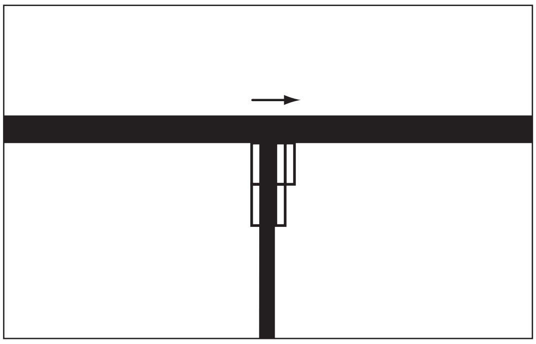
For branch fittings with the same main pipe and branch pipe dimension a weld T-piece must be used. This branch type can be used in systems with a stress level of up to 190 MPa.



Expansion

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

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 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 "Stress level and expansion calculation: Expansion at branches" 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".

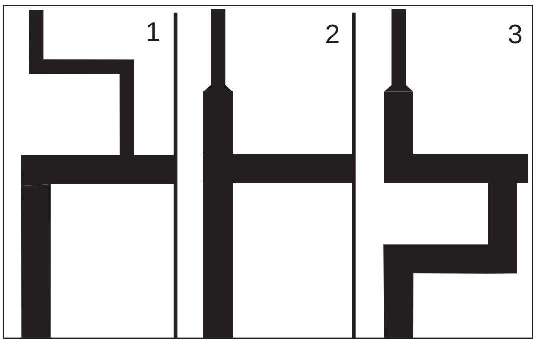
Also see examples in the section "Branches: Preinsulated branches - Example".

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.

Preinsulated branches and branch fittings

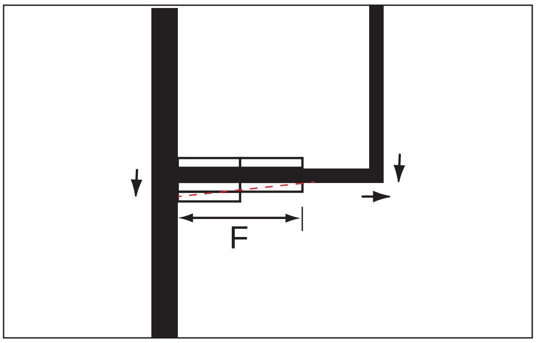
Axial movements and foam pads

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.

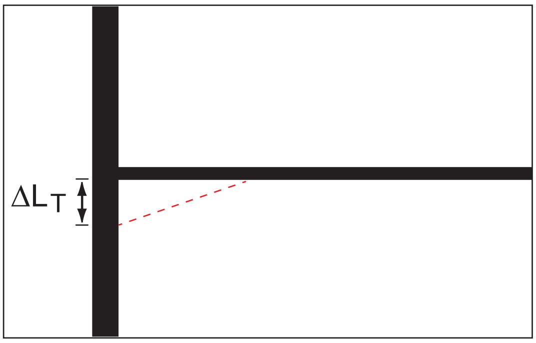
The length of the foam pads equals the F-length.

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



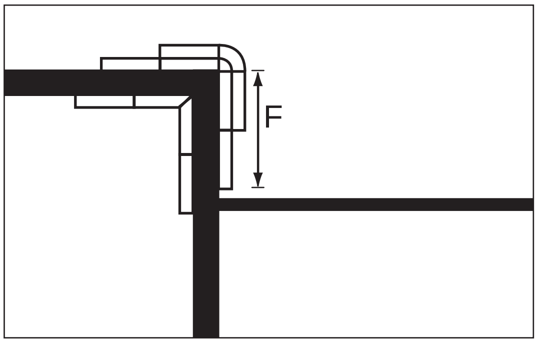
Position on main pipe

A TwinPipe branch may be placed where the expansion in the main pipe $\Delta L_T \leq 56$ mm, what corresponds to the movement, which can be absorbed by 2 layers of foam pads.



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

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



Length of branch pipe

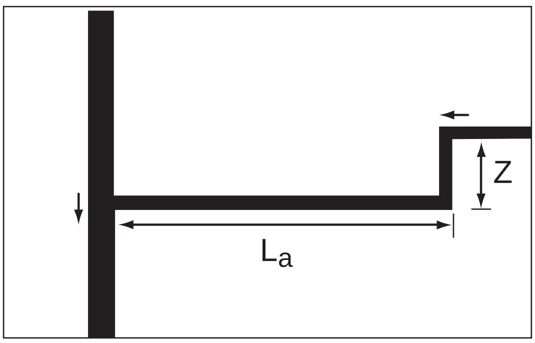
The length of the branch pipe is restricted by the loads, transmitted from the branch.
The maximum length of the branch pipe is defined on the basis of the installation length for 190MPa:

$$L_{a,max} = \frac{2}{3} \cdot L_{190}$$

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

This also applies to traditional heat prestressed systems.

The minimum length of the branch pipe equals the F-length for the main pipe movement.



Preinsulated branches and branch fittings

Branch pipe length for ∆T = 40°C

In TwinPipe systems with a temperature difference between flow and return of maximum 40°C, the maximum branch lengths in below tables can be used:

Series 1

DN	Max. branch length at ∆T = 40°C [m]			
	H = 0.6 m	H = 0.8 m	H = 1.0 m	H = 1.5 m
20	27	20	16	11
25	30	23	18	12
32	34	25	20	14
40	39	29	24	16
50	43	33	26	18
65	48	37	30	20
80	55	42	34	23
100	62	48	39	26
125	59	45	37	25
150	68	53	44	30
200	78	61	50	35
250	81	65	54	37

Series 2

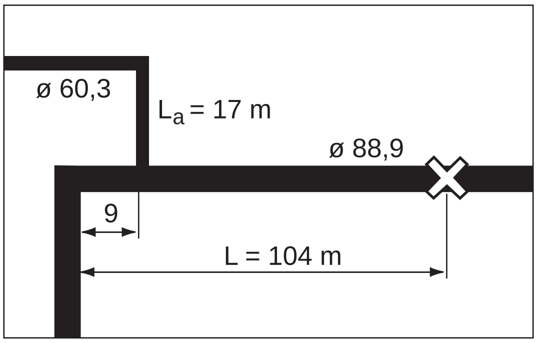
DN	Max. branch length at ∆T = 40°C [m]			
	H = 0.6 m	H = 0.8 m	H = 1.0 m	H = 1.5 m
20	24	18	14	9
25	26	20	16	11
32	30	23	18	12
40	34	26	21	14
50	38	29	23	16
65	43	33	27	18
80	49	38	30	21
100	55	42	34	23
125	52	40	33	22
150	61	48	39	27
200	68	54	44	31
250	71	57	47	33

Series 3

DN	Max. branch length at ∆T = 40°C [m]			
	H = 0.6 m	H = 0.8 m	H = 1.0 m	H = 1.5 m
20	20	15	12	8
25	23	18	14	9
32	27	20	16	11
40	31	23	19	12
50	34	26	21	14
65	38	29	24	16
80	43	33	27	18
100	48	37	30	21
125	46	36	29	20
150	54	42	35	24
200	60	47	39	27
250	62	50	41	29

Preinsulated branches - Example

Conditions



Soil cover H = 0.6 m
Design temperature, flowT_f = 90°C
Design temperature, return T_r = 50°C
Installation temperature T_{ins} = 10°C

D_h = ø 88.9/250 (Series 1)
L = 104 m

From the table in the section "Straight pipes: Stress reduction with bends - Tables: Friction force" the following is found for ø 88.9 at
H = 0.6 m
F = 2.89 kN/m
A_s = 1723 mm²

D_a = ø 60.3/200 (Series 1)
L_a = 17 m

From the table in the section "Straight pipes: Stress reduction with bends - Tables: Friction force" the following is found for ø88.9 at
H = 0,6 m
F = 2.25 kN/m
A_s = 1046 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:
  Calculate $L_{a,max}$. If $\Delta T \leq 40°C$, $L_{a,max}$ appears from the table in the section "Branches: Preinsulated branches and branch fittings".

Determination of friction length

To calculate the movement at the branch the following intermediate calculations must be made.

The maximum, axial stress level is calculated:
$\sigma_{max} = \Delta T \cdot 2.52$ [MPa]
$\sigma_{max} = (90 - 10) \cdot 2.52 = 202$ [MPa]

Determination of the friction length:

$$L_F = \Delta T_{mean} \cdot (E \cdot \alpha) \cdot \frac{A_s}{F}$$

$$L_F = \left(\frac{90 + 50}{2} - 10\right) \cdot 2.52 \cdot \frac{1723}{2.89 \cdot 1000} = 90 \text{ m}$$

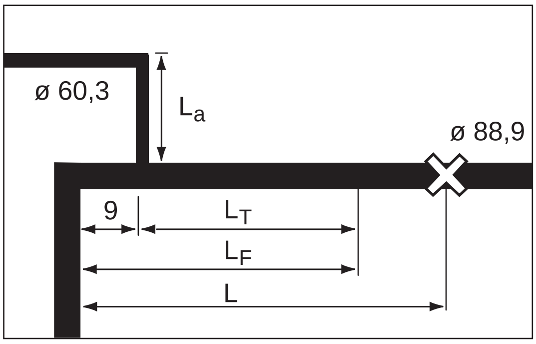
As $L > L_F$, $L = L_F$ is used in the calculation, because only L_F, contributes to the movement.

Preinsulated branches - Example

Calculating L_T

L_T is:

$L_T = 90 - 9 = 81$ m



Axial movement in the main pipe

The expansion in the main pipe at the branch is determined:

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

$$\Delta L_T = 1.2 \cdot 10^{-5} \cdot \left(\frac{(90 + 50)}{2} - 10\right) \cdot 81000 - \frac{2.89 \cdot (2 \cdot 90000 - 81000) \cdot 81000}{2 \cdot 210000 \cdot 1723} = 26 \text{ mm}$$

(formula in the section "Stress level and expansion calculation: Expansion at branches").

Allowable length of the branch

The instllaltion length of the branch for 190MPa is calculated:

$$L_{all} = \left(\sigma_{a,all} - \frac{1}{2} \cdot (E \cdot \alpha) \cdot (T_f - T_r)\right) \cdot \frac{A_s}{F}$$

$$L_{190} = (190 - \frac{1}{2} \cdot 2.52 \cdot (90 - 50)) \cdot \frac{1046}{2.25 \cdot 1000} = 65 \text{ m}$$

(formula in the section "Straight pipes: Stress reduction with bends")

The length of the branch must be:

$$L_{a,max} = \frac{2}{3} \cdot L_{190}$$

$$L_{a,max} = \frac{2}{3} \cdot 65 = 43 \text{ m}$$

The maximum length of the branch of 43 m also appears from the table in the section "Branches: Preinsulated branches and branch fittings", which applies to systems with a temperature difference between flow and return of maximum 40°C.

Check of branch

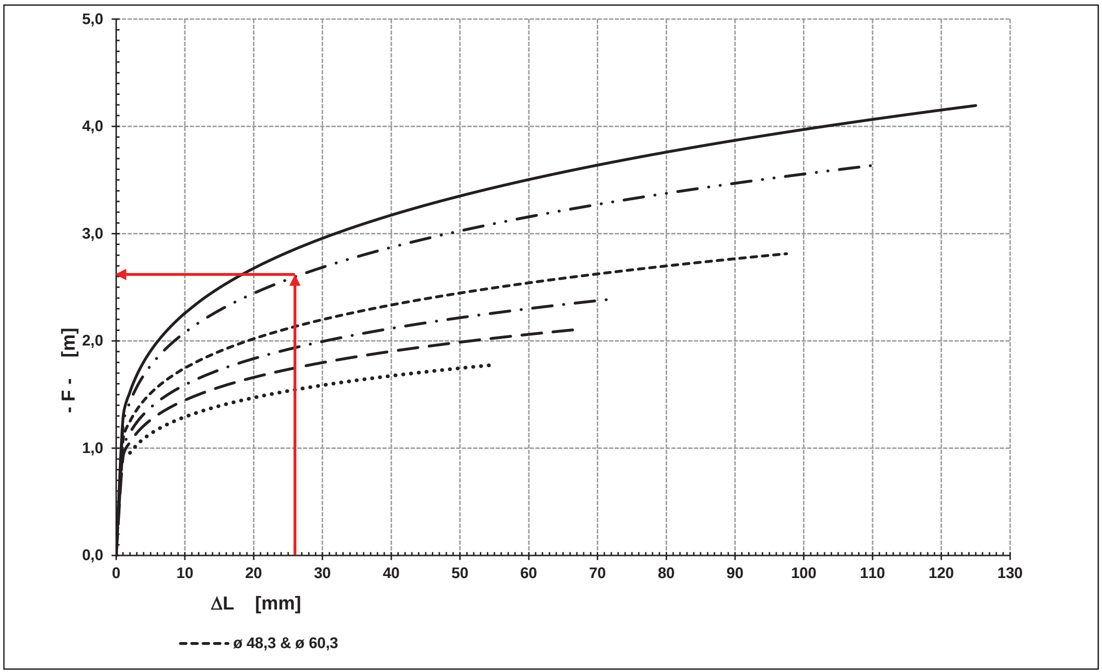
- Check of axial movement in the main pipe:
  $\Delta L_T \leq 56$ mm
  ΔL_T is calculated to be 26 mm - OK.
- Check of branch length:
  For a branch pipe in DN 50 $L_{a,max} = 43$ m.
  $L_a = 17$ m - OK.

Preinsulated branches - Example

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 = 26 mm for a ø60.3 gives F = 2.6 m



Foam pads

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

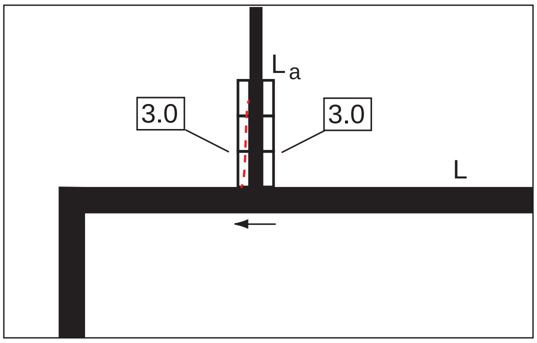
$$t = \frac{\Delta L_T}{0.70} = \frac{26}{0.70} = 37 \text{ mm}$$

Number of layers of 40 mm each:

$$t = \frac{t}{40} = \frac{37}{40} = 1 \text{ layer}$$

The length of the foam pads corresponds to the F-length, possibly rounded up to nearest half or whole metre.

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



Branch fittings - Example

Introduction

A TwinPipe branch fitting is determined in the same way as a preinsulated TwinPipe branch, because the same design rules apply.

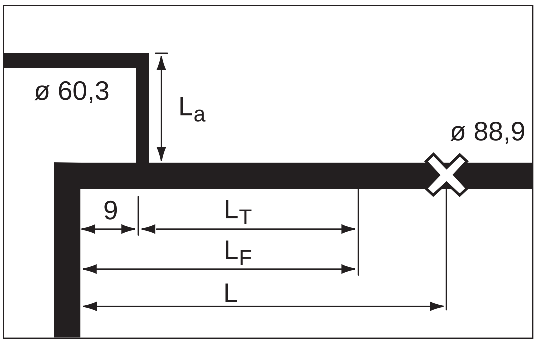
A branch fitting which is carried out with main pipe and pipe dimension, soil cover, operating temperatur, and in the same position as in example in the section "Branches: Preinsulated branches - Example" can therefore be carried out with foam pads as described in the example.

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 "Stress level and expansion calculation: Axial stress level":

$$\sigma_x = \frac{1}{2} \cdot (E \cdot \alpha) \cdot (T_f - T_r) + L_x \cdot \frac{F}{A_s}$$



$$\sigma_T = \frac{1}{2} \cdot (2.52) \cdot (90 - 50) + 9000 \cdot \frac{2.89}{1723}$$
$$= 65 \text{ MPa}$$

The branch fitting must be reinforced, as the stress level at the branch is > 150 MPa.

References

LOGSTOR Design Tool:

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

Reinforcement of branch fittings

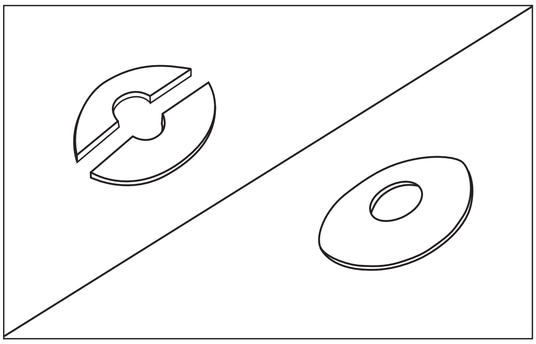
Application

In connection with branch fittings reinforcement plates 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 Product Catalogue, the section "The Bonded TwinPipe: Reinforcement plates".

Only reinforcement of the flow is required.

It is however recommended that reinforcement plates are installted on the main pipe at both branch pipes to avoid the risk of faults during installation.



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 ppe 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 Handling & Installation, the section "The Bonded TwinPipe: Expansion and anchoring - Fixing bar" for information on welding on reinforcement plates and on installing branch fittings.

Reinforcement of branch fittings

References	Product Catalogue:	The Bonded TwinPipe: Branches The Bonded TwinPipe: Reinforcement plate
	Handling & Installation:	The Bonded TwinPipe: Fixing bar Branches: Reinforcement plate

Reductions
Overview

Introduction

This section describes the design rules for establishing reductions, taking the actual, axial stress level of the pipe section into consideration.

Contents

Guidelines for use

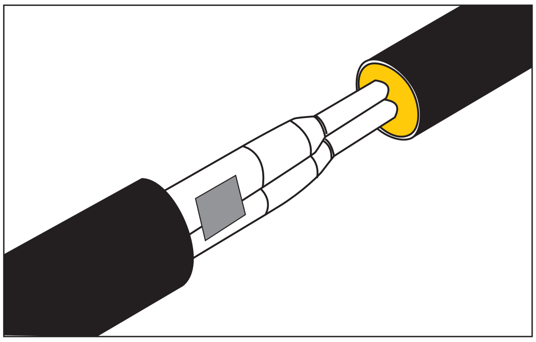
Guidelines for use

Fixing bars

Fixing bars must be used at all reductions.

All preinsulated reductions are delivered with built-in fixing bars on the largest dimension.

When using joints for reduction fixing bare must be welded on both sides of the pipe pair on the largest dimension. As regards installation of fixing bars, see Handling & Installation "The Bonded TwinPipe: Reductions".

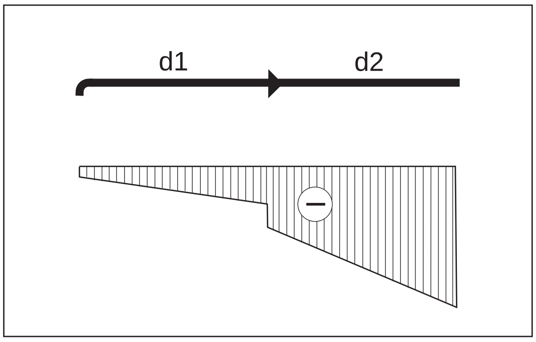


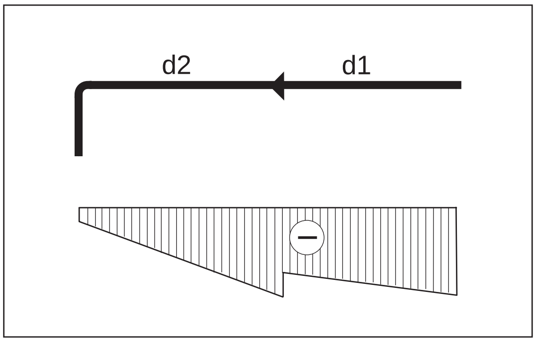
Stress diagram

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.

$$\sigma_2 = \sigma_1 \cdot \frac{A_1}{A_2}$$

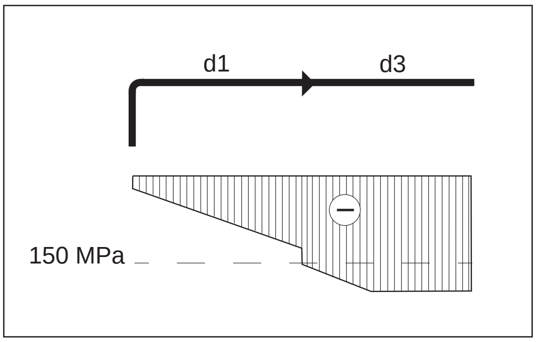
Dimensions:
d1 > d2





Stress level < 150 MPa

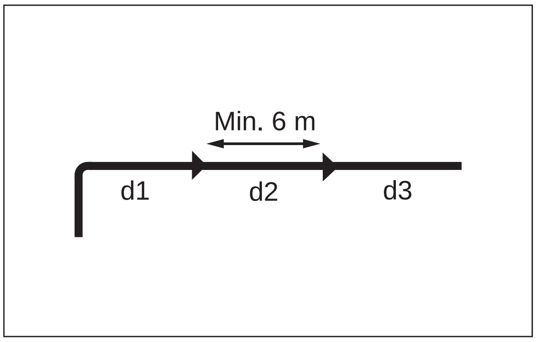
One reduction with 2 dimensional offsets can be placed where the stress level in the minor cross section (d3) is < 150 MPa.



Guidelines for use

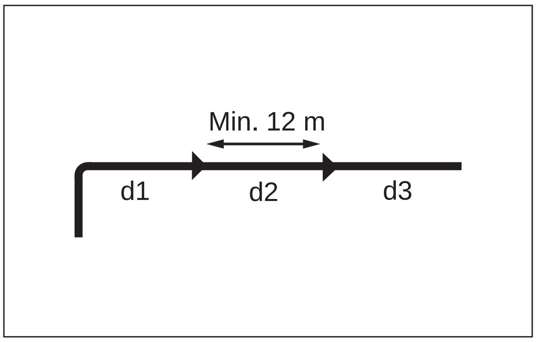
Stress level
< 150 MPa,
continued

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".

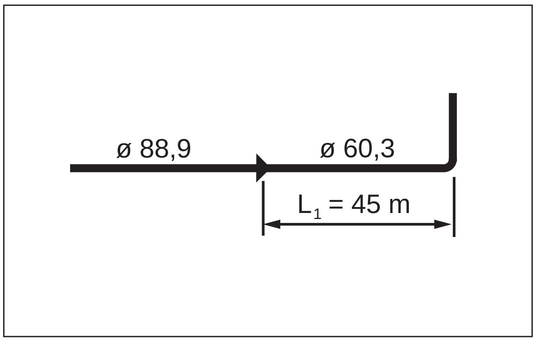
Guidelines for use - Example

Conditions

Dimension ø 88.9 series 2 to be reduced to ø 60.3. (2 dimensional offsets in 1 reduction)

Soil cover H = 0.6 m
Flow temperature T_f = 90°C
Return temperature T_r = 50°C
Min. design temperaturen T_{min} = 10°C
Installation temperature T_{ins} = 10°C
L_1 = 45 m

From the section "Straight pipes: Stress reduction with bends - Tables: Friction force":
ø 60.3:
F = 2.55 kN/m
A_s = 1046 mm² (= total cross-sectional area of the service pipes)



Determining the stress level

Determination of the stress level at the reduction:

$$\sigma_x = \frac{1}{2} \cdot (E \cdot \alpha) \cdot (T_f - T_r) + L_x \cdot \frac{F}{A}$$

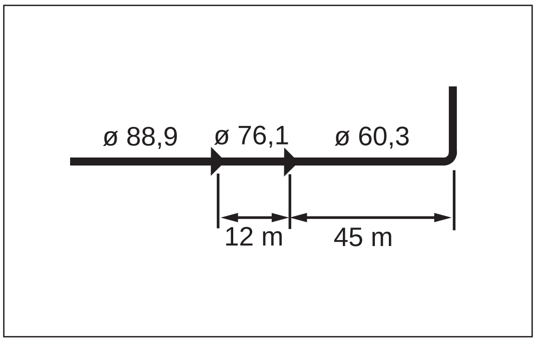
$$\sigma_{45m} = \frac{1}{2} \cdot 2.52 \cdot (90 - 50) + 45000 \cdot \frac{2.55}{1046}$$

$$= 160 \text{ MPa}$$

The stress level in the smallest dimension after the bend 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

Handling & Installation — The Bonded TwinPipe: Reductions

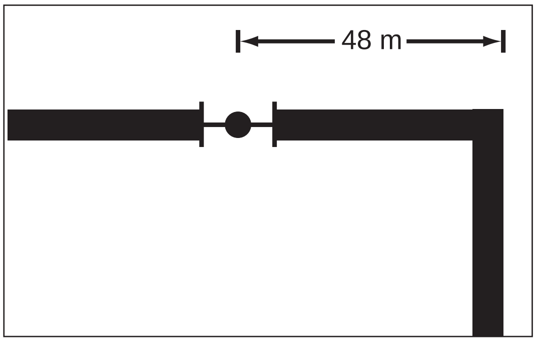
Transition pipes
General

Introduction

Due to bends with small angles installed in both TwinPipe valves and transition fittings as well as temperature variations and differences in temperature/stresses individual components must be placed in the TwinPipe system, so they are relieved.

Stop valves and service valves

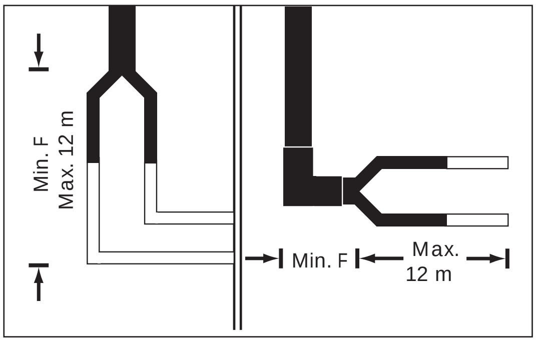
To ensure that the bends in the TwinPipe valves are not exposed to overload, they must be placed max. 48 m from an expansion relief.



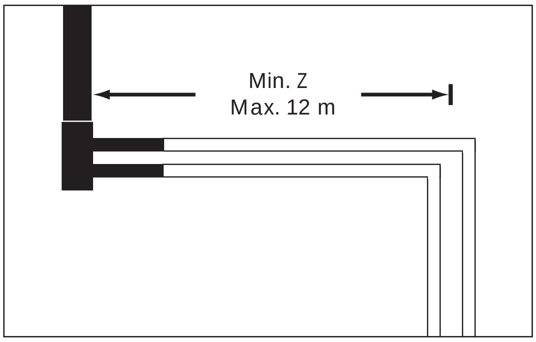
Transition pipes, TwinPipe - single pipe

Straight as well as 90° transition pipes are placed, so they are safe against overload from expansion and difference movements from the single pipe side.

Both must be installed, so they comply with the stated distances.



90° transition pipes, TwinPipe - single pipe



Isolation valves
Overview

Introduction

This section contains instructions for establishing valve arrangements, used in connection with isolating, venting and draining preinsulated TwinPipe systems.

Indhold

General
Venting/draining

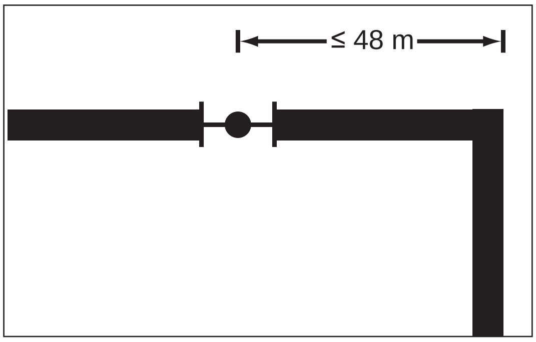
General

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 directly in the ground at the same time as the pipes are installed. The sand, used around the preinsulated valves, is the same type as the one used around the preinsulated pipes.

To ensure that the bends, positioned in the TwinPipe valve component, are not exposed to excessive stresses, the valve must be placed maximum 48 m from an expansion relief component like e.g. an expansion bend.



Preinsulated isolation valves are delivered with fixing bars, welded into the valve.

It is recommended to place TwinPipe isolation valves outside the expansion zones of the bend (the F-length), see the section "Directional changes: 80-90° bends with foam pads".

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.

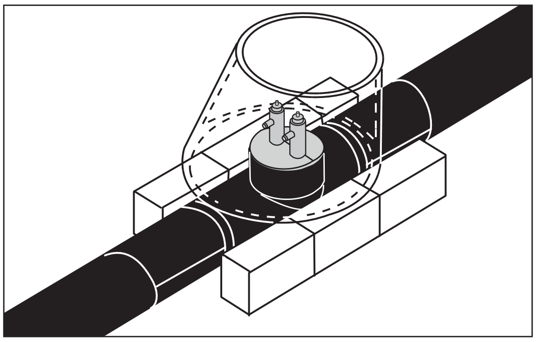
To ensure the correct functionality of the valve, it must be operated frequently, (i.e. 2 to 4 times per year dependent on the water quality).

The top is made of stainless steel which the spindles are welded onto. The top is bevelled, to keep the top of the valve free of water.

Return spindles and service valves are approx. 20 mm higher than flow spindles and service valves.

Installation instructions

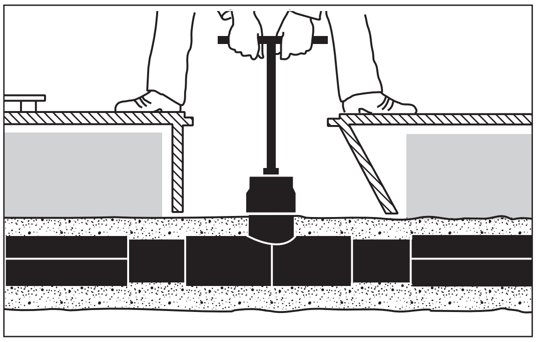
The valves must be installed, so the free movement of the spindle is ensured, when the pipe expands in the soil.
The simplest way to establish access to the valves is to place a concrete chamber on two rows of foundation bricks.
If there is a risk that groundwater can enter the concrete chamber, it must be ensured that the water can be drained away again.
The concrete chamber must not rest on the preinsulated pipe.



Installation instructions, *continued*

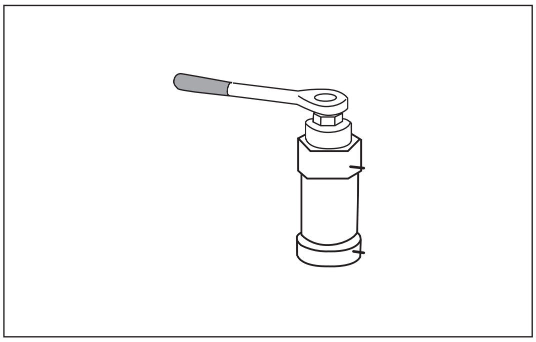
In this way the possible movement of the service pipe is ensured, and the tops of the spindles are kept free of sand.

Spindle tops must not be permanently under water.



Gear

For steel pipe dimensions ≥ ø 219.1 mm the valve must be operated with a gear - usually a portable planet gear.

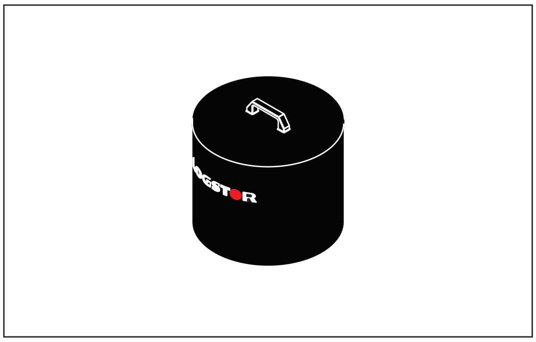


Cover

A PE cover can be used in flooded areas.

At periodic floodings the cover prevents water from penetrating into the spindle top and venting/draining valves which might result in corrosion.

The PE solution works by the PE cap sealing with the chamber cover.



Venting or draining

Application

A service valve for venting and draining can be carried out with preinsulated components.

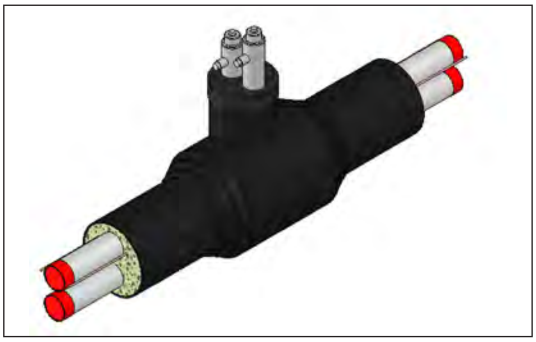
Preinsulated venting and draining solutions are applicable for all pipe systems with the following static conditions: Max. ΔT = 130°C and max. PN = 25.

Note! Preinsulated valves for venting or draining do not have built-in fixing bars.

If venting or draining valves are installed at the end of a pipepline wihtout e.g. a preinsualted bend, fixng bars must be applied, see Handling & Installation, the section "The Bonded TwinPipe: Valve arrangements".

Venting/draining arrangements

Venting/draining arrangements are available as preinsulated isolation valves with 2 or 4 stainless venting/draining valves or as a separate preinsulated component.

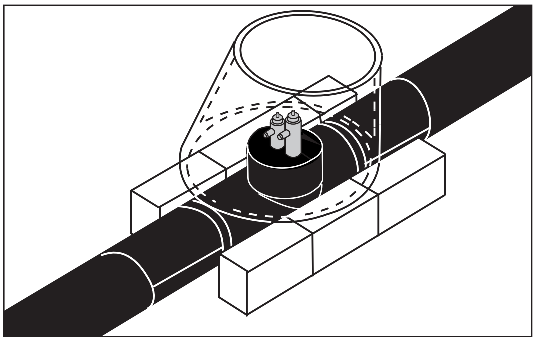


Positioning

Venting/draining arrangements are suitable to build-in everywhere in the system without any restrictions.

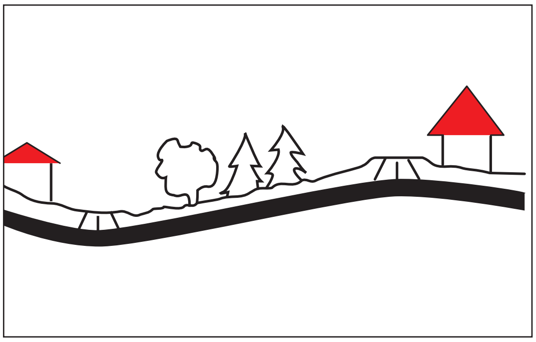
It is however recommended to keep them outside the F-length at bends.

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".



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/chambers at the lowest and highest points of the pipeline. This facilitates draining and venting, if needed.



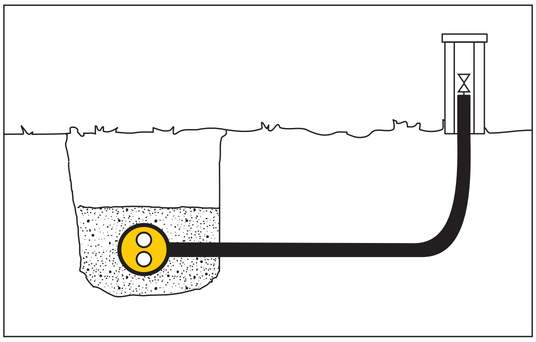
Experience shows that pipelines with a level difference < 3° do not result in air pockets. Air pockets which naturally build up at the highest points in the pipe system are carried along under normal flow.

Venting or draining

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

Handling & Installation

The Bonded TwinPipe: Valve arrangements

Terminations
Overview

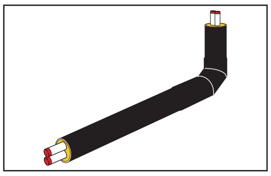
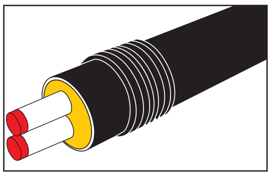
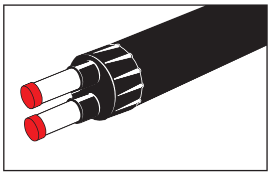
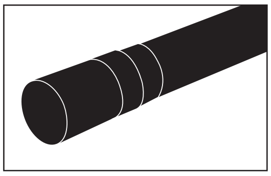
Introduction

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

Termination solutions in overview

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	

Terminations

House entry pipe

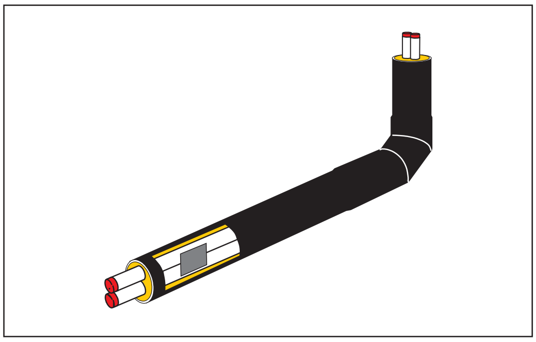
Application

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.

All preinsulated house entry pipes are delivered with built-in fixing bars on the leg, joined to the buried TwinPipe system.

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.



Wall entry sleeve

Application

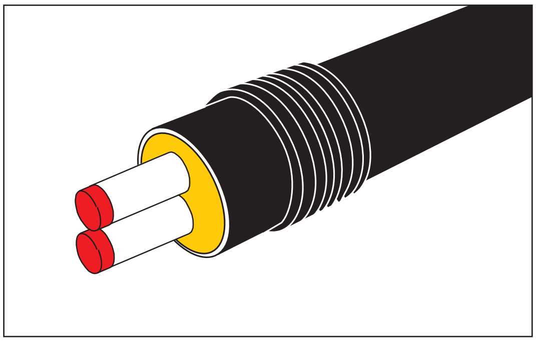
Where pipes are installed through masonry – at wells, foundations etc. – sealing rings are installed to prevent water ingress.

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.

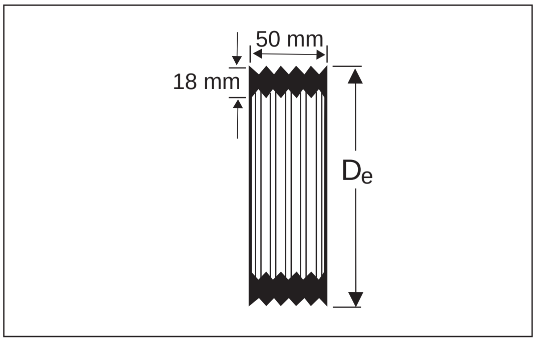


Description

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.

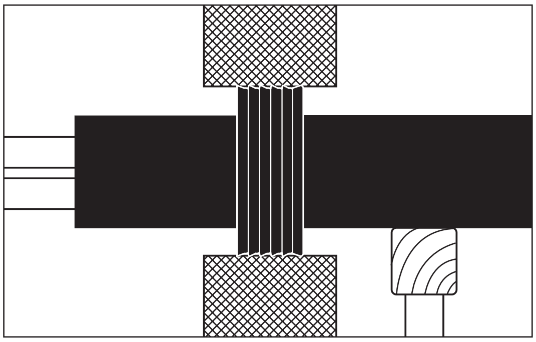
Note! The internal diameter is smaller than the nominal diameter of the casing, so the sleeve fits tightly around the outer casing.

For D_e please see Product Catalogue the section "The Bonded TwinPipe: Wall entry sleeve".



Bore in the base

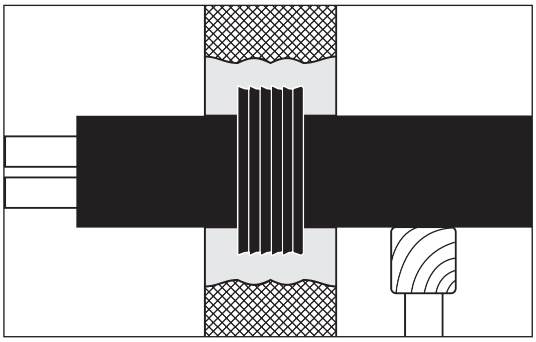
The bore diamter must be 1-3% smaller than D_e.



Wall entry sleeve

Concreting

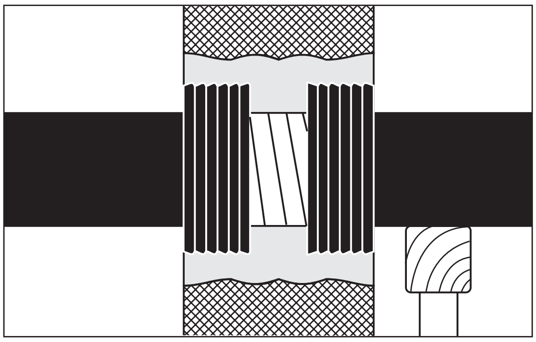
When encasing a pipe with wall entry sleeves in a core, the pipe should be supported, so the concrete can flow all the way around the wall entry sleeve.



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 movements.



Terminations
End-cap

Anvendelse

End-caps are used in connection with terminations in chambers, connections to concrete ducts, in cellars etc to prevent water ingress into the insulation.

Chambers and ducts must not be flooded, resulting in water around the end-cap.

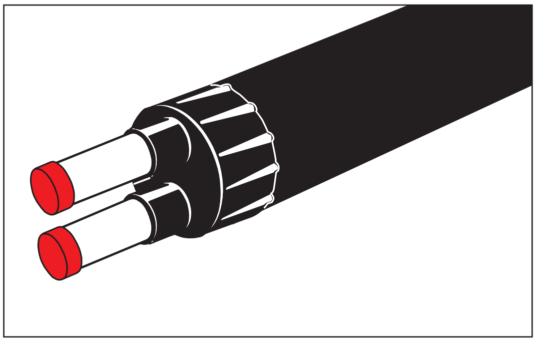
End-caps must not be used in the ground.

Description

The 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 further information and an overview of available dimensions, see Product Catalogue the section "The Bonded TwinPipe: End-cap".



End fitting

Application

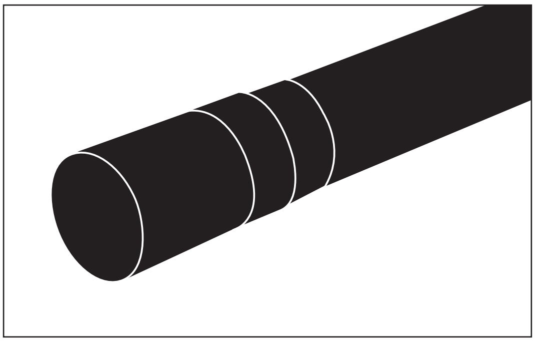
To terminate a pipe system in the ground a PE end fitting for foaming is used.

The outmost part of the fitting is shrinkable.

Description

If an end fitting is placed at the end of a section where it expands in the ground, the expansion must be absorbed by foam pads, placed at the end to avoid unintended impacts.

Fixing bars must be installed on both sides of the service pipes.



References

Product Catalogue	The Bonded TwinPipe: End-cap

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 13941-1, 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 13941-1, 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 13941-1, 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

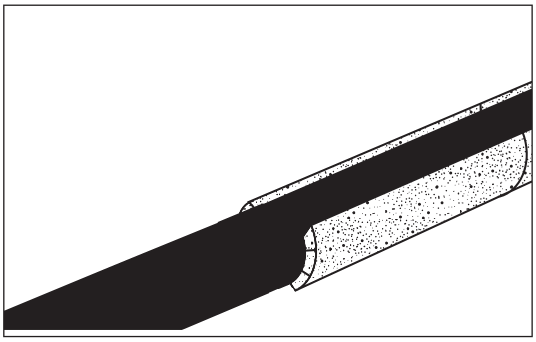
Application

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)

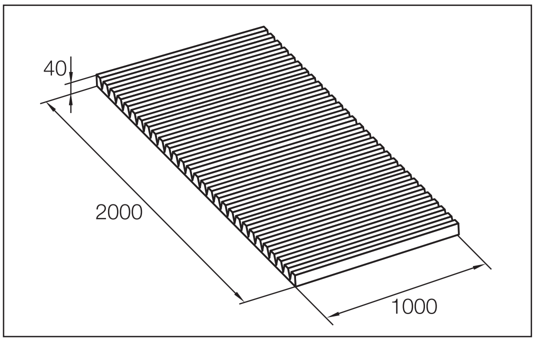
It is recommended not to use more than 3 layers of foam pads (120 mm) at a max. temperature of 130°C and normal varying operation. This ensures that the continuous surface temperature of the outer casing will not exceed 50°C, which is stated in EN 13941-1 as the upper limit.

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:

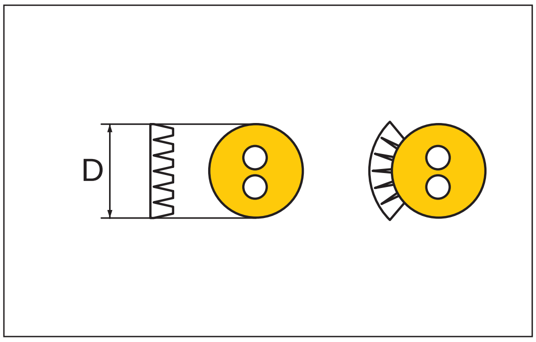
Deformation	Compressive stress
40%	0.06 MPa
50%	0.09 MPa
75%	0.275 MPa

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.

Actual foam pad measurement

The casing diameter determines the height of the foam pad.



Installing foam pads

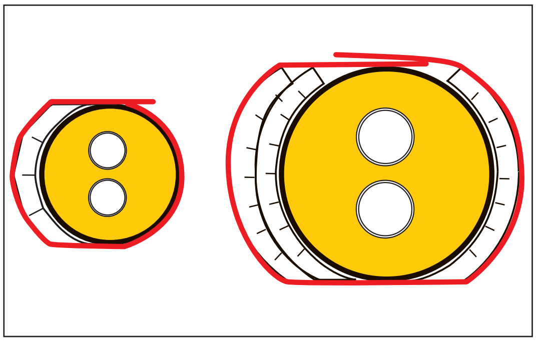
Install the pads on one or both sides of the outer casing in accordance with the project drawing.

Fix the pads with filament tape, min 3 pcs. per m foam pad.

To prevent sand from entering between the foam pads and the outer casing, the foam pads can be wrapped in e.g. geotextile or cross-linked foam foil laminate, which is secured by means of filament tape.

For major dimensions and several layers it is recommended to wrap the pads in geotextile or cross-linked foam foil laminate.

In systems with many large temperature cycles (e.g. solar panel plants) a geotextile or cross-linked foam foil laminate must always be used, ensuring that no backfill material comes between the pads and the outer casing.



Stating the number of foam pads

To determine the necessary number of foam pads, see the sections "Directional changes" and "Branches".

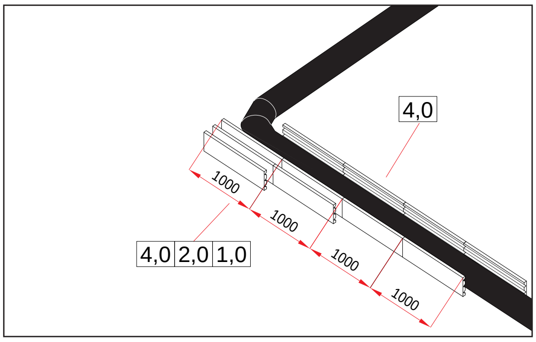
From the system drawing the necessary number of foam pads to absorb the expansion appears.

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.



Flexible TwinPipes
Overview

Introduction

The flexible TwinPipe systems consist of the Twin-FlexPipe with a smooth LDPE outer casing and the more flexible Twin-FlextraPipe with a corrugated HDPE outer casing. Both pipe systems are complete TwinFlex(tra) pipe systems for distribution networks and minor branch pipes.

The long flexbile TwinPipes 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 the flexible TwinPipe 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

General

Introduction

The flexible TwinPipes are available with 5 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

Read more under the different types of flexible Twinpipe or ask LOGSTOR, if in doubt.

Fields of application

FlexPipe system	Service pipe, material	Operating pressure, bar	Operating temperature, °C	Peak temperature, °C	Pipe type	Fields of application		Dimensional range ø mm	Surveillance
						District Heating	District Cooling		
PertFlextra	PE-RT	10	70-80	95 mal-function	Single pipe	x	x	25-63	
					TwinPipe	x	x	25-63	
PexFlextra	PEX	6	80-95	100 mal-function	Single pipe	x	x	20-110	
					TwinPipe	x	x	20-63	
AluFlextra	pe-rt/ aluminium/ PE-RT	10	80-95	100 mal-function	Single pipe	x	x	20-32	
					TwinPipe	x	x	20-32	
					Double pipe	x		26/20	
SteelFlex	Steel	25	120	140	Single pipe	x	x	20-28	x
CuFlex	Copper *	16	120	140	Single pipe	x		15-35	x
					TwinPipe	x		18-28	x

* PN 16 is calculated at max. 120°C (the Swedish District Heating Association D 213).

Installation methods

The flexible TwinPipes are installed in trenches or by means of tunnelling techniques in accordance with the illustrations and below minimum measurements.

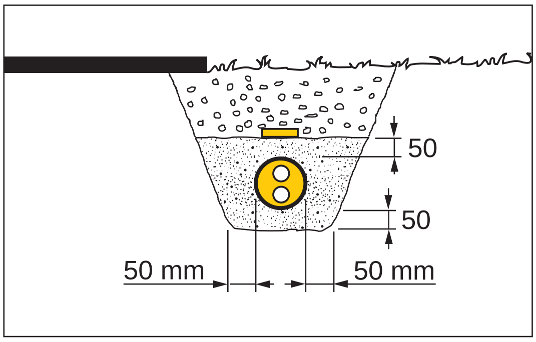
FlextraPipes are installed in trenches like FlexPipes, but FlextraPipes can only be used in connection with tunnelling, if they are pulled through a conductor pipe.

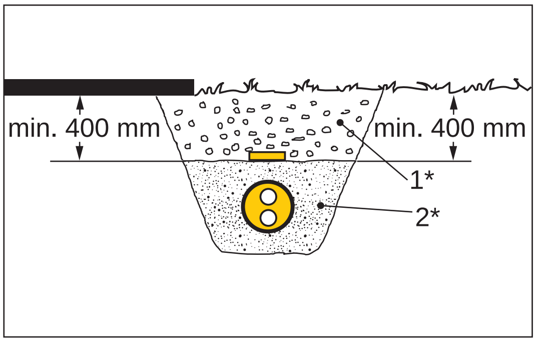
When installed in trenches, the pipes must be surrounded by 50 mm backfill material with properties as described below.

1* Backfill material.
2* Friction material.

Use min. 400 mm soil cover, measured from the bottom of the asphalt/concrete or from the top of the grass or gravel layer.

In connection with directional changes the trench is adapted to the actual





Bending radius

Generally a minimum bending radius R = 10 x outer casing diameter can be used for temperatures down to 5°C.

For higher flexibility at higher ambient temperatures: See bending radius under 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.

Connection to main pipe

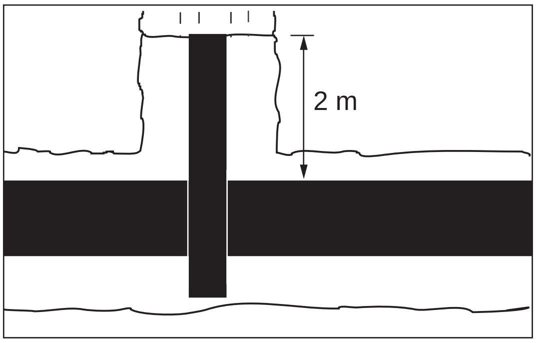
Perpendicular connection

The best way to obtain a faultless installation between a flexible TwinPipe 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.

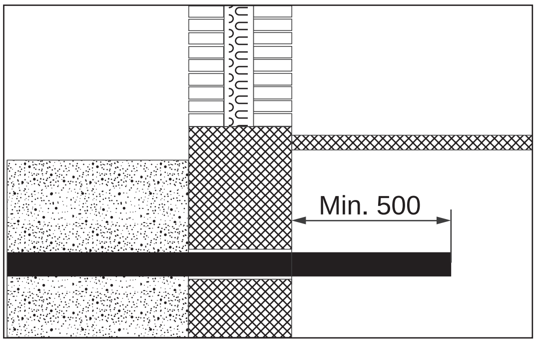
In case of perpendicular connection to a main pipe min. 2 m of the branch pipe trench must remain uncovered to provide room for later installation of press couplings/welding and casing joint.

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 TwinPipe section.

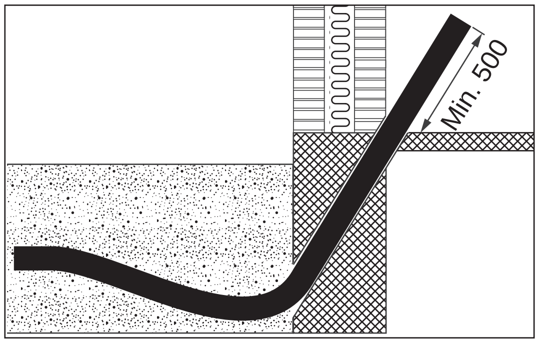


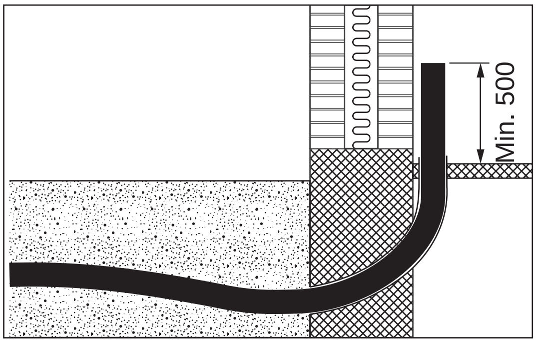
Termination in house

For house connections through a cast inlet pipe or straight/tilted bore in the base make sure that the flexible TwinPipe is led through the base in the same working process as installation and backfilling.



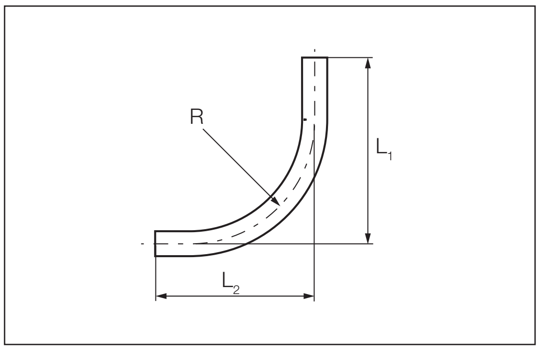
The flexible TwinFlexPipe is terminated min. 500 mm from the indoor base/ above the floor to ensure sufficient length to prepare the pipe end.





Inlet pipe

For house entry it may be advantageous to use an inlet pipe in accordance with below table.



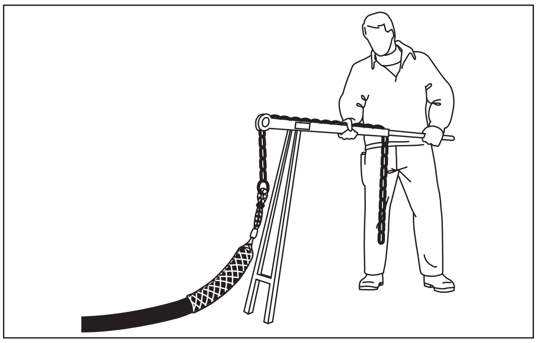
Outer casing D, mm	125	140	160	180
FlexPipe D, mm	90	110	125	140
Radius R, mm	800	800-900	900-1000	1000-1100
L_1, mm	1050	1250	1350	1400
L_2, mm	900	1000	1100	1250

The diameter of the inlet pipe must be minimum 2 dimensional offsets larger than the relevant outer casing diameter.

Inlet pipe, *continued*

It is recommended to use a pulling sleeve and a pulling tool when pulling the flexible TwinPipe through the inlet pipe.

The pulling tool may be manual as illustrated here or with an electric winch.

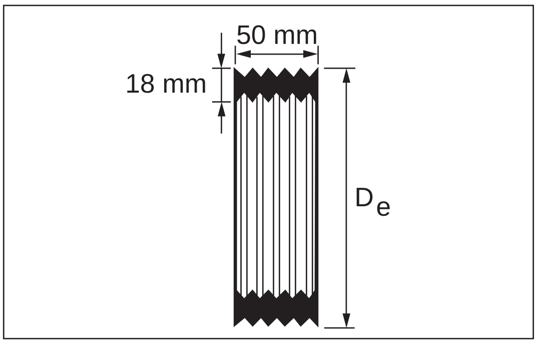


Bore in the base

For bore in the base the hole diameter must be 1-3% minor than the wall entry sleeve diameter.

The stated bore diameters are recommended for bore in the base using wall entry sleeve.

For constructions with a high hydrostatic pressure, wall entry sleeve which are fixed to the internal or external wall and squeezes the PE casing are recommended.



PertFlextra TwinPipes
Overview

Introduction

PertFlextra TwinPipe is acomplete flexible pipe system.

PertFlextra TwinPipe has a corrugated casing.

The wide dimensional range makes PertFlextra TwinPipe applicable for house entries as well as distribution pipelines.

Contents

Design rules
Examples of installation combinations

Design rules

General

PertFlextra TwinPipes have a service life of minimum 50 years at below temperature profile and pressure:

- Operating temperature:	70°C for 49 years
- Maximum operating temperature:	80°C for 7760 hours
- Malfunction:	95°C for 100 hours
- Maximum operating pressure:	10 bar

Bending radius

PertFlextra TwinPipes can be bent on site to a minimum bending radius R.

The flexibility of the FlextraPipe depends on the temperature of the pipe.

At temperatures below 10°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

Branching from steel to PertFlextra

In some cases it is necessary to reinforce the steel main pipe, when branching with a connecting piece or a steel/Pex connecting coupling, welded directly onto the steel service pipe, to a PertFlex(tra) branch. The criteria are given based on a combination of the max. system temperature and the dimension.

Max. temperature	**Reinforcement plate is required, when:**
All temperatures	Main pipe is 1 dimension larger than connecting piece dimension
	Reinforcement plate is required at axial stress σ > 150 MPa in main pipe, when:
T ≤ 80 C°	Main pipe is 1 or 2 dimensions larger than connecting piece dimension
T ≤ 85 C°	Main pipe is 1, 2, 3 or 4 dimensions larger than connecting piece dimension
T > 85 C°	All main pipe dimensions

It is a condition that T_{ins} = 10°C.

Note: If the main pipe dimension and connecting piece dimension are the same, it is recommended to use weld Tee.

Design rules

Expansion

It is a flexible pipe system which do not require special measures to be taken for installation in the ground. It is self-compensating, and due to the properties of the PE-RT service pipe it is not necessary to pay attention to the expansion in buried systems.

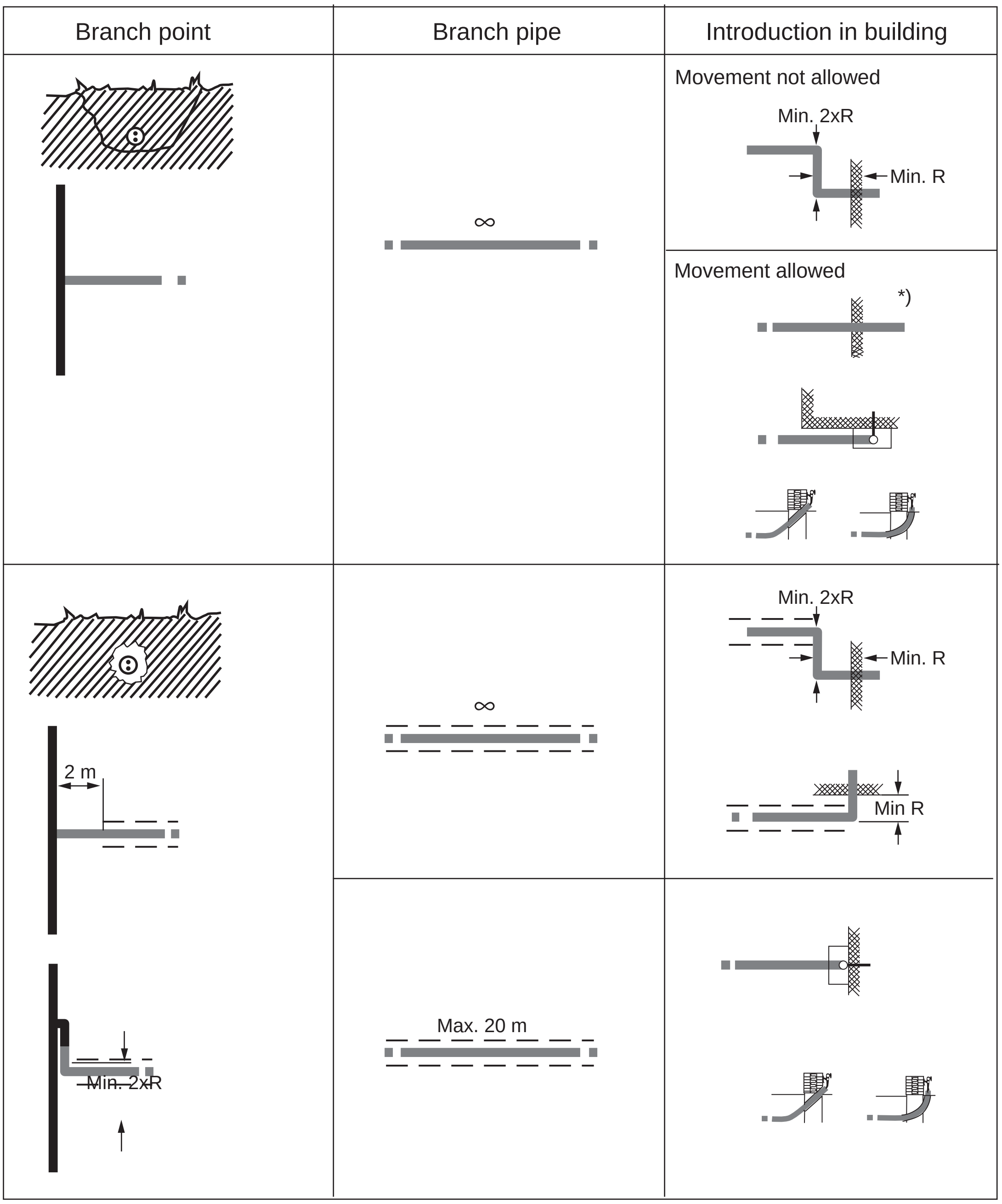
When connecting a PertFlextra TwinPipe and a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the PertFlextra TwinPipe system.

This is ensured by establishing the connection from the steel pipe to the PertFlextra TwinPipe 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, measured from the nearest expansion bend.

When branching from a steel main pipeline with a PertFlextra TwinPipe make sure that movements in the main pipeline is not transferred to the branch pipe. For details, see illustration on the next page.

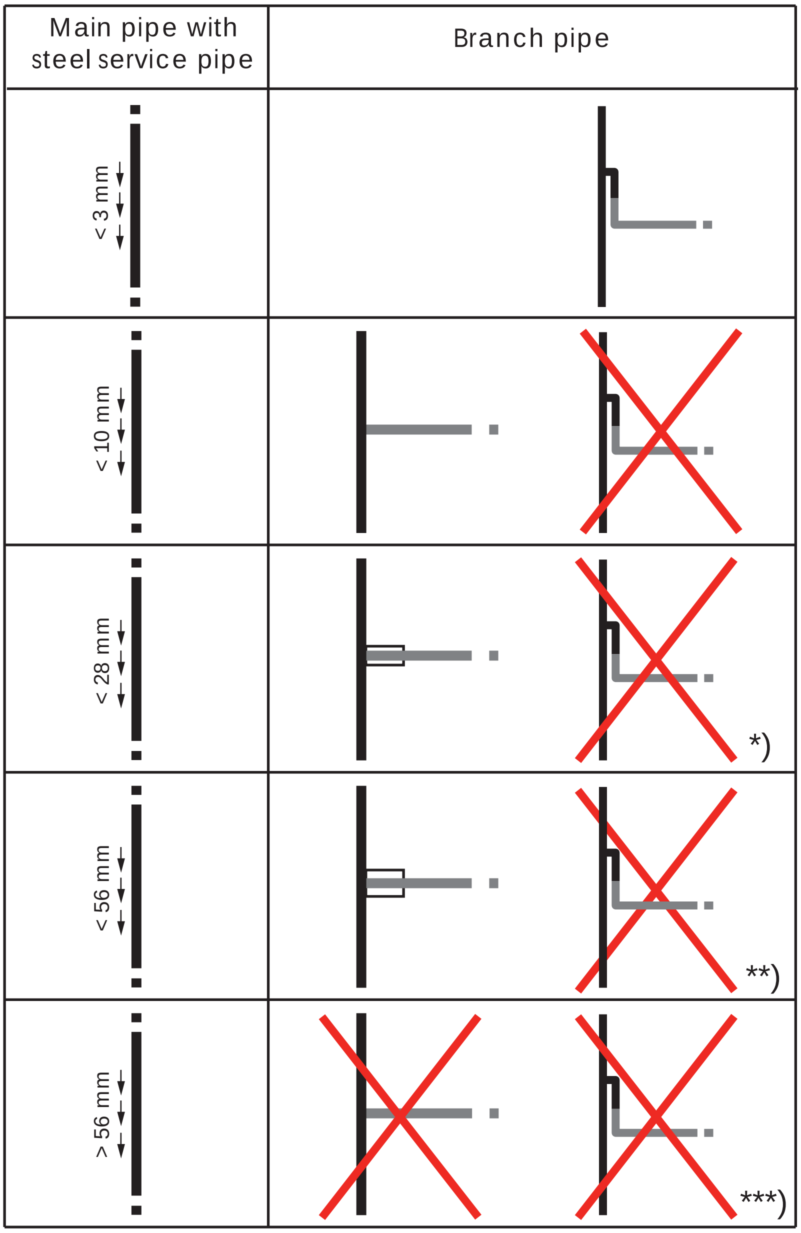
Examples of installation combinations

Branch pipe lengths and introduction in houses



*) Movement is not allowed when using mounting immediately inside the wall.

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 FlexPipe must not be carried out.

Overview

Introduction

PexFlextra TwinPipe is a complete flexible pipe system.

PexFlextra TwinPipe has a corrugated casing.

The wide dimensional range makes PexFlextra TwinPipe applicable for house entries as well as minor distribution pipelines.

Contents

Design rules
Examples of installation combinations

PexFlextra TwinPipes
Design rules

General

PexFlextra TwinPipes have a service life of minimum 30 years at below temperature profile and pressure:

- 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

Bending radius

PexFlextra TwinPipes can be bent on site to a minimum bending radius R.

The flexibility of the FlextraPipe depends on the temperature of the pipe.

At temperatures below 10°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

Branching from steel to PexFlextra

In some cases it is necessary to reinforce the steel main pipe, when branching with a connecting piece or a steel/Pex connecting coupling, welded directly onto the steel service pipe, to a PexFlex(tra) branch. The criteria are given based on a combination of the max. system temperature and the dimension.

Max. temperature	**Reinforcement plate is required, when:**
All temperatures	Main pipe is 1 dimension larger than connecting piece dimension
	Reinforcement plate is required at axial stress σ > 150 MPa in main pipe, when:
T ≤ 80 C°	Main pipe is 1 or 2 dimensions larger than connecting piece dimension
T ≤ 85 C°	Main pipe is 1, 2, 3 or 4 dimensions larger than connecting piece dimension
T > 85 C°	All main pipe dimensions

It is a condition that T_{ins} = 10°C.

Note: If the main pipe dimension and connecting piece dimension are the same, it is recommended to use weld Tee.

Design rules

Expansion

It is a flexible pipe system which do 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.

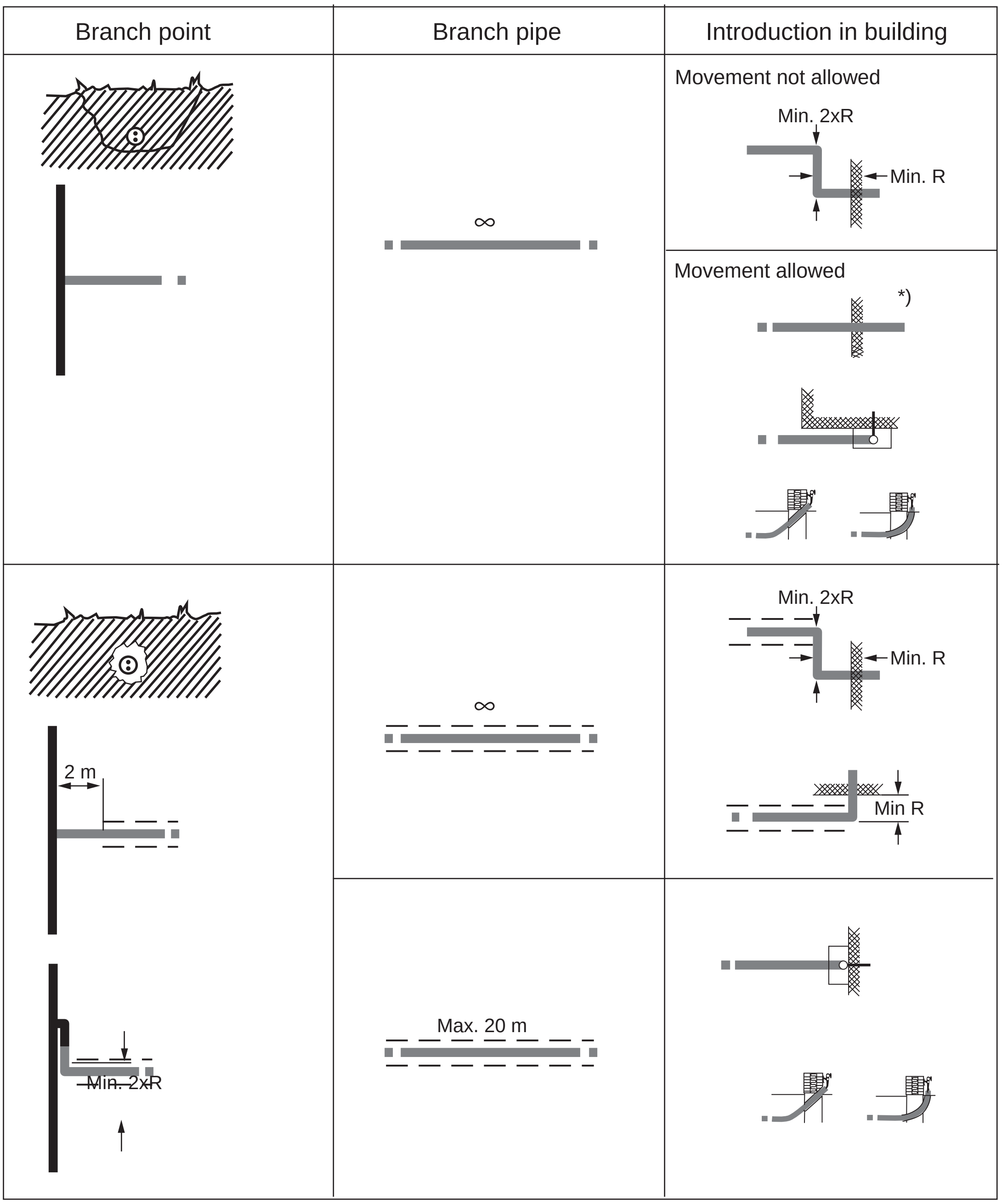
When connecting a PexFlextra TwinPipe and a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the PexFlextra TwinPipe system.

This is ensured by establishing the connection from the steel pipe to the PexFlextra TwinPipe 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, measured from the nearest expansion bend.

When branching from a steel main pipeline with a PexFlextra TwinPipe 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

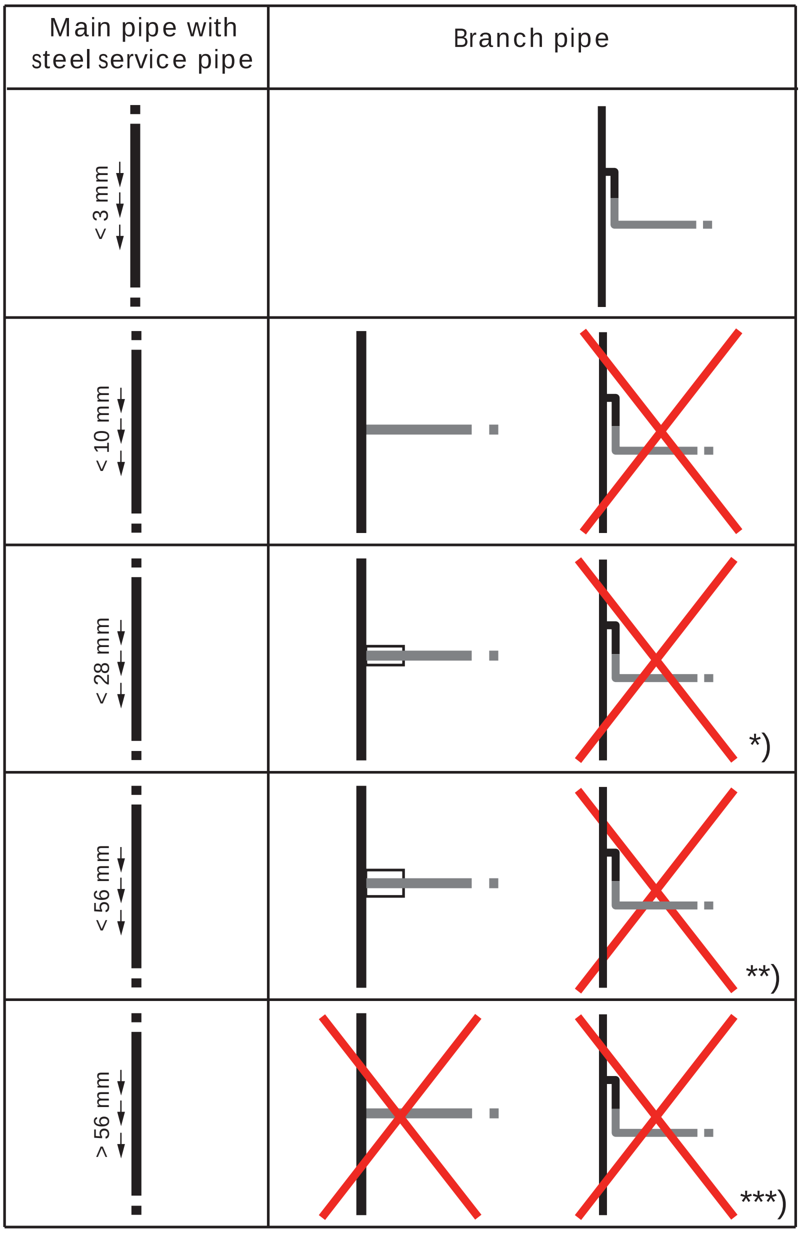
Branch pipe lengths and introduction in houses



*) 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 FlexPipe must not be carried out.

AluFlextra TwinPipes
Overview

Introduction

AluFlextra TwinPipe is a complete flexible pipe system.

AluFlextra TwinPipe has a corrugated casing.

AluFlextra TwinPipe is applicable for house entries as well as minor distribution pipe-lines.

Contents

Design rules
Examples of installation combinations

Design rules

General

AluFlextra TwinPipes have a service life of minimum 30 years at below temperature profile and pressure:

- 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 (type MP)
- A high flexibility when bending the pipe in the required curve

Bending radius

AluFlextra TwinPipes can be bent on site to a minimum bending radius R.

The flexibility of the FlextraPipe depends on the temperature of the pipe.

At temperatures below 10°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	1.4

Branching from steel to AluFlextra

In some cases it is necessary to reinforce the steel main pipe, when branching with a connecting piece or a steel/Alu connecting coupling, welded directly onto the steel service pipe, to a AluFlextra branch. The criteria are given based on a combination of the max. system temperature and the dimension.

Max. temperature	**Reinforcement plate is required, when:**
All temperatures	Main pipe is 1 dimension larger than connecting piece dimension
	Reinforcement plate is required at axial stress σ > 150 MPa in main pipe, when:
T ≤ 80 C°	Main pipe is 1 or 2 dimensions larger than connecting piece dimension
T ≤ 85 C°	Main pipe is 1, 2, 3 or 4 dimensions larger than connecting piece dimension
T > 85 C°	All main pipe dimensions

It is a condition that T_{ins} = 10°C.

Note: If the main pipe dimension and connecting piece dimension are the same, it is recommended to use weld Tee.

Examples of installation combinations

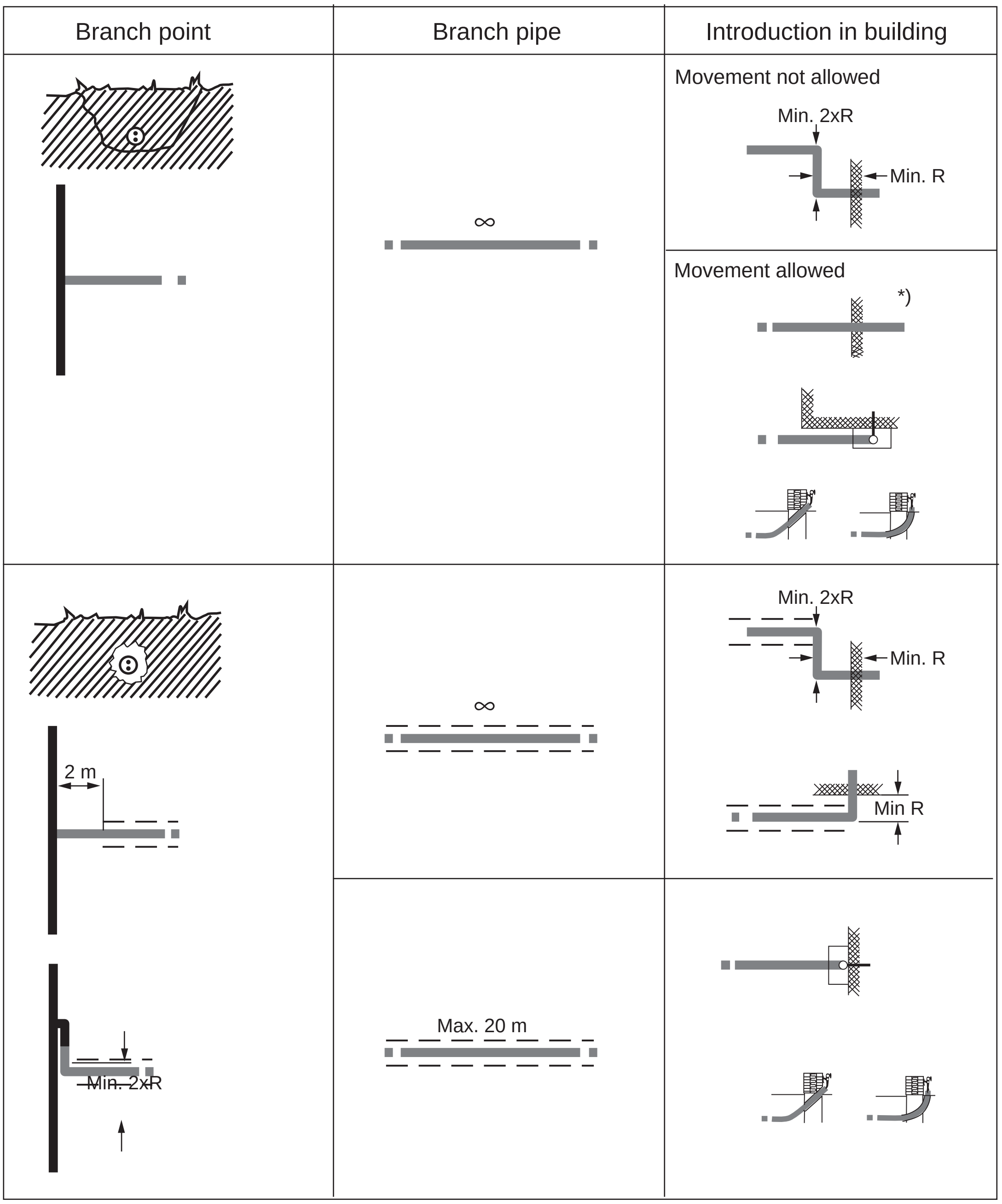
Expansion

It 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 an AluFlextra TwinPipe and a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the AluFlextra TwinPipe system.This is ensured by establishing the connection from the steel pipe to the AluFlextra TwinPipe 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 an AluFlextra TwinPipe make sure that movements in the main pipeline is not transferred to the branch pipe. For details, see below illustration.

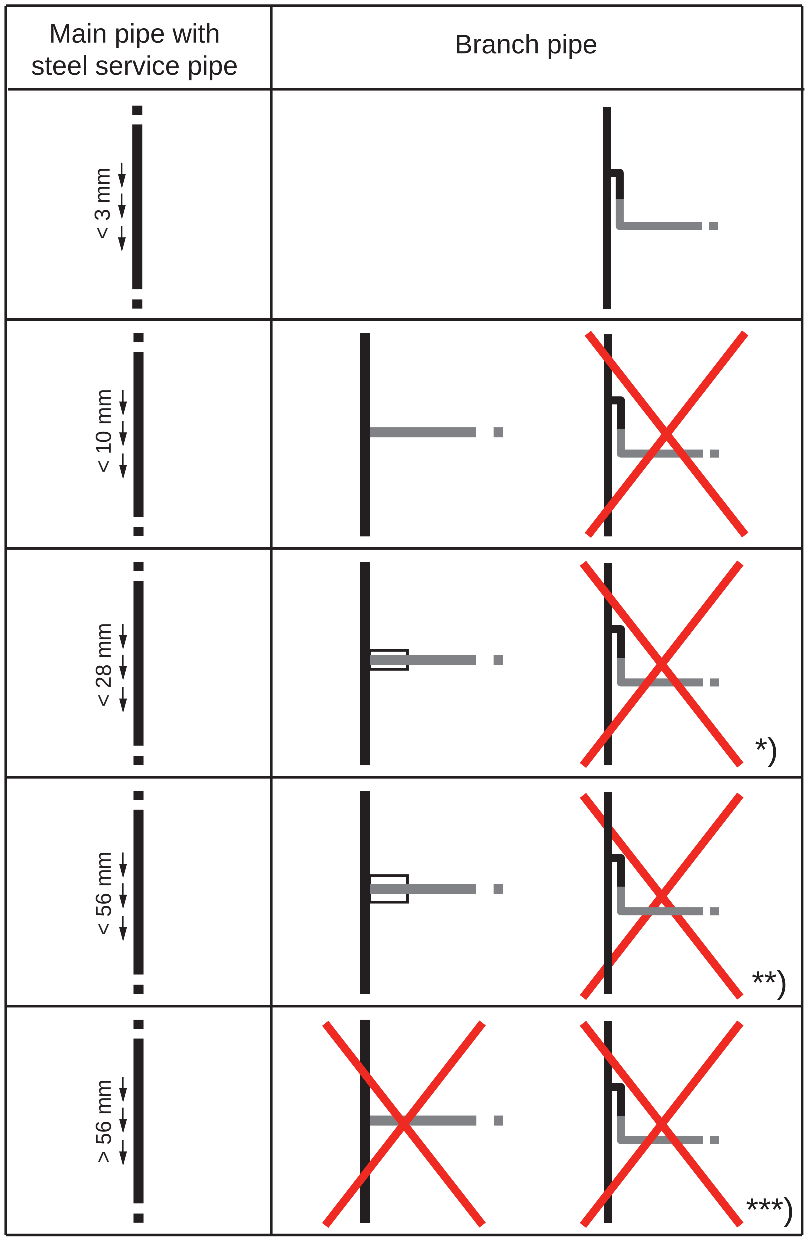
Branch pipe lengths and introduction in houses



*) 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 FlexPipe must not be carried out.

CuFlex TwinPipes
Overview

Introduction

CuFlex TwinPipes form a complete flexible pipe system for distribution networks and minor house connections.

Contents

Design rules
Examples of installation combinations

Design rules

General

The pipe system complies with the requirements in EN15632-2 for a minimum design service life of 30 years at the following operational conditions:

Continuous operation with hot water at up to 120°C and at individual time intervals with a peak temperature up to 140°C. The sum of these individual time intervals shall not exceed 300 hours a year.

Operating pressure max.: 16 bar.

Bending radius

CuFlex TwinPipes can be bent on site to a minimum bending radius R.

The flexibility of the CuFlex TwinPipe depends on the temperature of the pipe.

At temperatures below 10°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 adius, R m
90	0.9
110	1.1

Branching from steel to CuFlex

In some cases it is necessary to reinforce the steel main pipe, when branching with a connecting piece or a steel/Cu connecting coupling, welded directly onto the steel service pipe, to a CuFlex branch. The criteria are given based on a combination of the max. system temperature and the dimension.

Max. temperature	**Reinforcement plate is required, when:**
All temperatures	Main pipe is 1 dimension larger than connecting piece dimension
	Reinforcement plate is required at axial stress σ > 150 MPa in main pipe, when:
T ≤ 80 C°	Main pipe is 1 or 2 dimensions larger than connecting piece dimension
T ≤ 85 C°	Main pipe is 1, 2, 3 or 4 dimensions larger than connecting piece dimension
T > 85 C°	All main pipe dimensions

It is a condition that T_{ins} = 10°C.

Note: If the main pipe dimension and connecting piece dimension are the same, it is recommended to use weld Tee.

Examples of installation combinations

Expansion

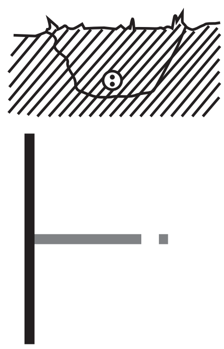
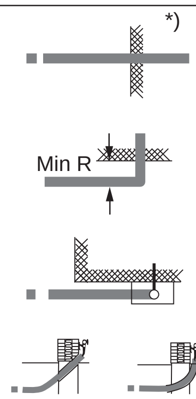
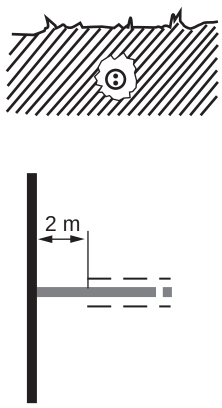
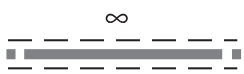
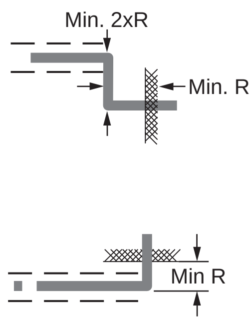
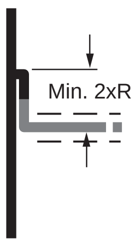
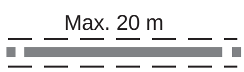
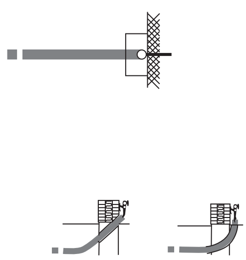
CuFlex TwinPipe is a flexible pipe which does not require special measures when installed in the ground.

It is a self-compensating system, and due to the properties of the service pipe of the CuFlex TwinPipe it is not necessary to pay attention to expansion in CuFlex Twinipes, installed in the ground.

When connecting a CuFlex TwinPipe to a preinsulated steel pipe make sure that too large movements from the steel pipe are not transferred to the CuFlex TwinPipe system.
This is ensured by establishing the connection from steel to CuFlex TwinPipe 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 TwinPipe make sure that the movements in the main pipeline are not transferred to the branch.

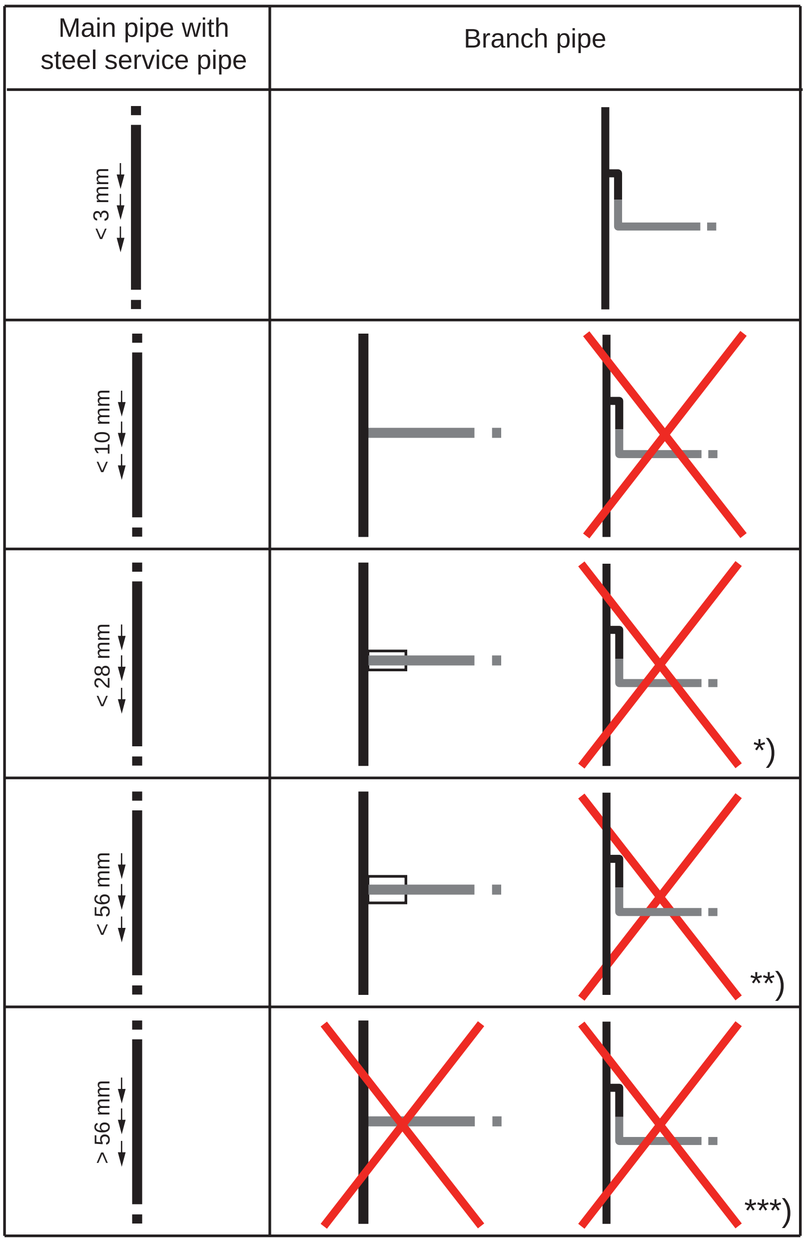
Branch pipe lengths and introduction in houses

Branch point	Branch pipe	Introduction in building
		
		
		

*) 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.

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 13941-1
- Advanced calculations, taking the influence of the temperature on the lambda (λ) 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

General

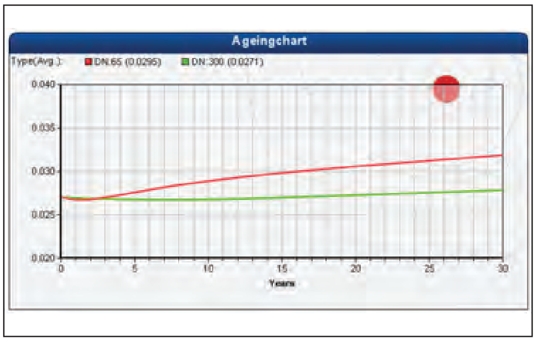
Calculation of heat loss

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 13941-1
- Advanced

Standard calculation according to EN 13941

When calculating the heat loss in accordance with EN 13941-1 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.

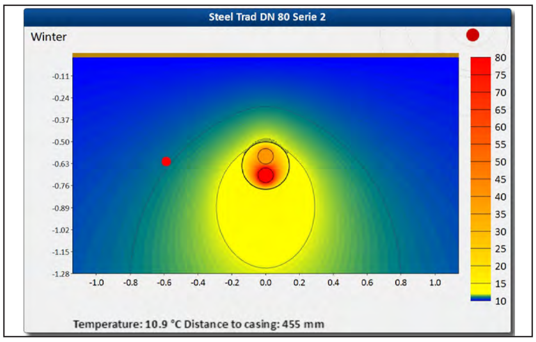
As for production methods, see Product Catalogue the section "The Bonded Single Pipe: General".

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

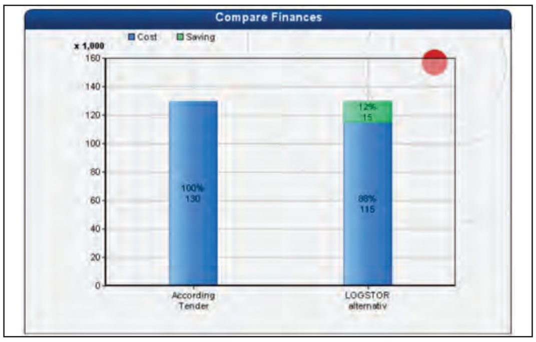
In addition to the ageing of the PUR-foam due to diffusion the advanced calculation method also takes the influence of the temperature on the λ-value of the materials into account.
These variables are included in the advanced calculation method, resulting in a more precise heat loss calculation.
The 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.



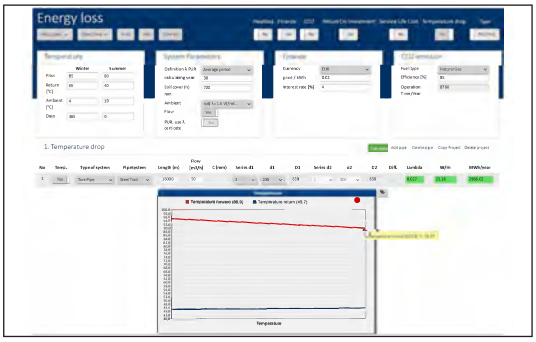
Economy calculation

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.



Return on Investment (ROI)

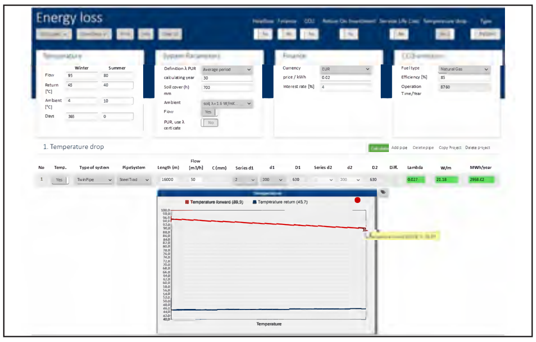
When comparing 2 projects, it is possible to calculate a simple payback time on basis of the difference in the energy loss in the pipelines.
To make the calculation the energy price in kWh and the difference in costs between the 2 projects, i.e. material and installation costs, must be known. If the 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.

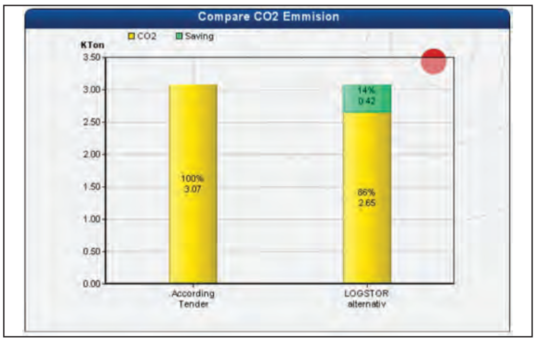


Emission

The program can also show the approximate size of the emission, resulting from producing the energy for 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.



Life cycle costs

To assess which type of pipe is most economical to invest in, a calculation of the life cycle costs have to be made. This calculation includes investments in the pipe system, excavation and installation costs as well as operational costs during the entire service life.

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 operational costs are calculated in present value, i.e. the amount of money to deposit at the bank today to cover all operational costs during the service life. Costs due to heat loss are also included in the operational costs and can be calculated in LOGSTOR Calculator.

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

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

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 %

ϕ = Heat loss in the pipeline, W

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: $s = 0.62 + \dfrac{0.38}{n}$

Hot domestic water: $s_\Delta = \dfrac{1.0 \cdot n^{-0.5} \cdot (51 - n)}{50}$

n being the number of houses

For more than 50 houses the factor s_Δ for hot domestic water is = 0

Pressure loss

Pressure loss in a straight pipe section is calculated according to the following fomula: $\Delta P = \frac{1}{2} \cdot P \cdot c^2 \cdot \zeta$

Where
P = water density
C = average velocity of water over the cross section [m/s]
ζ = pressure loss coefficient for straight pipes

To calculate the pressure loss coefficient the following roughnesses are used dependent on the service pipe material:

Service pipe material	Roughness, k mm
Steel	0.1
PEX	0.01
Multilayer (Alu)	0.01
Cu	0.01
PE-RT	0.01

General

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 Calculator program http://calc.logstor.com

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For the product offering in other markets please contact your local sales representative or visit www.logstor.com

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