Typical outputs - steel pipes - single

Typical outputs - steel pipes - single						
at 100 Pa/m (10 mm water column/m) and medium temp. of 80°C						
Carrier pipe		Velocity	Mass flow	Output at Δt=30°C	Output at Δt=40°C	Output at Δt=50°C
DN	d outside mm	(m/s)	(m^3/h)	(kW)	(kW)	(kW)
20	26,9	0,35	0,47	15,8	21,1	26,4
25	33,7	0,41	0,86	29,3	39,1	48,8
32	42,4	0,50	1,97	67,0	89,3	112,0
40	48,3	0,56	2,92	99,2	132,0	165,0
50	60,3	0,65	5,45	185,0	247,0	309,0
65	76,1	0,77	10,70	364,0	485,0	606,0
80	88,9	0,85	16,34	555,0	740,0	925,0
100	114,3	0,97	27,73	1106,0	1475,0	1843,0
125	139,7	1,15	57,00	1937,0	2583,0	3229,0
150	168,3	1,29	94,07	3197,0	4263,0	5329,0

See section 1 on design calculations

Heat loss - steel pipes - single

4.2

Assumptions - heat loss

When comparing heat loss data, it is important to know the assumptions used in their calculation.

Several factors other than the properties of the pre-insulated pipe are of fundamental importance for heat loss.

The following parameters must be equal if a valid comparison of heat loss is to be made:

- Dimensions of carrier and jacket pipes
- Carrier pipe temperatures
- Soil lambda value
- Soil temperature
- Surface resistance
- Laying depth
- Distance between pipes

As it is in effect the lambda value of the insulation material that is compared, it is of course important that the correct lambda value be used. Below the lambda values is given as average values.

The following pages contain heat loss tables for pre-insulated pipes. Heat loss calculations are based on the following assumptions.

Depending on the mechanical properties of the foam, pipes can be produced with a variety of lambda values down to 0,0225 W/m°C.

Lambda$_{soil}$	1.2000	W/m°C
Lambda continuous production	0.024	W/m°C
Lambda discontinuous production	0.026	W/m°C
R_o	0.0685	m^2 °C/W
Laying depth H	800	mm
t_{flow}	80.0	°C
t_{return}	40.0	°C
t_{soil}	8.0	°C
Distance between pipes C	150	mm

Thermal conductivity - soil / sand
Values of 1.5-2.0 W/m°C are typical for moist soils.
Dry sand has a thermal conductivity of approx. 1.0 W/m°C.

Surface resistance
According to the EuHP District Heating Handbook, a value of 0.0685 m^2 °C/W is usually suitable.

Laying depth
Should be stated in mm from upper edge of jacket pipe to soil surface (unpaved areas) or lower surface of paving.

Heat loss - steel pipes - single

4.2.1

Heat loss - steel pipes - single - series 1 (calculated for pair of pipes)						
Steel pipe			Jacket pipe		Heat loss	U-value
DN	d outside mm	Wall thickness mm	D outside mm	Godstj. mm	W/m Φ_{total}	Φ_{total}
20	26,9	2,6	90	3,0	13,0	0,125
25*	33,7	3,2	90	3,0	14,7	0,141
32*	42,4	3,2	110	3,0	15,0	0,144
40*	48,3	3,2	110	3,0	17,1	0,164
50*	60,3	3,2	125	3,0	18,9	0,182
65*	76,1	3,2	140	3,0	22,2	0,213
80*	88,9	3,2	160	3,0	22,8	0,219
100*	114,3	3,6	200	3,2	24,4	0,234
125*	139,7	3,6	225	3,4	28,0	0,269
150*	168,3	4,0	250	3,6	32,7	0,314
200*	219,1	4,5	315	4,1	35,5	0,341
250	273,0	5,0	400	4,8	36,7	0,353
300	323,9	5,6	450	5,2	41,6	0,400
350	355,6	5,6	500	5,6	40,6	0,391
400	406,4	6,3	560	6,0	42,8	0,412
450	457,2	6,3	630	6,6	43,1	0,414
500	508,0	6,3	710	7,0	41,7	0,401
600	610,0	7,1	800	7,9	50,4	0,485

Heat loss is specified per metre trench.
U-values are specified per metre pipe.
*Continuously produced

Diffusion barrier

isoplus can produce pipes with jacket pipes in jacket pipe dimensions of ≤ ø355 mm as energy-saving, continuously produced pipes with a diffusion barrier inserted between the jacket pipe and the polyurethane foam.

For pipes with jacket pipes in dimension of >ø355 mm, the jacket pipe functions as a diffusion barrier due to its thickness.
The diffusion barrier secures isoplus pre-insulated pipes against ageing, and the heat loss is therefore constant throughout the pipe’s technical service life.

Series 1 pipes are normally supplied as traditionally produced pipes without an inserted diffusion barrier. However, dimensions with jacket pipes ≤ ø355 mm can be supplied as continuously produced on a special delivery – therefore the heat losses for these dimensions are indicated for energy-saving continuously produced pipes.

Heat loss - steel pipes - single 4.2.2

Heat loss - steel pipes - single - series 2 (calculated for pair of pipes)

Steel pipe			Jacket pipe		Heat loss	U-value
DN	d outside mm	Wall thickness mm	D outside mm	Wall thickness mm	W/m Φtotal	Φtotal
20	26,9	2,6	110	3,0	11,24	0,108
25*	33,7	3,2	110	3,0	12,28	0,118
32*	42,4	3,2	125	3,0	13,27	0,128
40*	48,3	3,2	125	3,0	14,91	0,143
50*	60,3	3,2	140	3,0	16,67	0,160
65*	76,1	3,2	160	3,0	18,56	0,179
80*	88,9	3,2	180	3,0	19,38	0,186
100*	114,3	3,6	225	3,4	20,59	0,198
125*	139,7	3,6	250	3,6	23,53	0,226
150*	168,3	4,0	280	3,9	26,65	0,256
200*	219,1	4,5	355	4,5	28,06	0,270
250	273,0	5,0	450	5,2	29,31	0,282
300	323,9	5,6	500	5,6	33,22	0,319
350	355,6	5,6	560	6,0	32,05	0,308
400	406,4	6,3	630	6,6	33,18	0,319
450	457,2	6,3	710	7,0	33,13	0,319
500	508,0	6,3	800	7,2	32,67	0,314
600	610,0	7,1	900	8,7	37,49	0,360

Heat loss is specified per metre trench.
U-values are specified per metre pipe.
*Continuously produced

Diffusion barrier

isoplus can produce pipes with jacket pipes in jacket pipe dimensions of ≤ ø355 mm as energy-saving, continuously produced pipes with a diffusion barrier inserted between the jacket pipe and the polyurethane foam.

For pipes with jacket pipes in dimension of >ø355 mm, the jacket pipe functions as a diffusion barrier due to its thickness.
The diffusion barrier secures isoplus pre-insulated pipes against ageing, and the heat loss is therefore constant throughout the pipe’s technical service life.

Heat loss - steel pipes - single 4.2.3

Heat loss - steel pipes - single - series 3 (calculated for pair of pipes)

Steel pipe			Jacket pipe		Heat loss	U-value
DN	d outside mm	Wall thickness mm	D outside mm	Wall thickness mm	W/m Φtotal	Φtotal
20	26,9	2,6	125	3,0	10,32	0,099
25*	33,7	3,2	125	3,0	11,11	0,107
32*	42,4	3,2	140	3,0	12,13	0,117
40*	48,3	3,2	140	3,0	13,49	0,130
50*	60,3	3,2	160	3,0	14,55	0,140
65*	76,1	3,2	180	3,0	16,26	0,156
80*	88,9	3,2	200	3,2	17,53	0,169
100*	114,3	3,6	250	3,6	18,08	0,174
125*	139,7	3,6	280	3,9	20,24	0,195
150*	168,3	4,0	315	4,1	22,23	0,214
200	219,1	4,5	400	4,8	24,90	0,239
250	273,0	5,0	500	5,6	24,90	0,239
300	323,9	5,6	560	6,0	27,25	0,262
350	355,6	5,6	630	6,6	26,31	0,253
400	406,4	6,3	710	7,0	26,95	0,259
450	457,2	6,3	800	7,2	27,17	0,261
500	508,0	6,3	900	7,9	26,71	0,257
600	610,0	7,1	1000	9,4	30,49	0,293

Heat loss is specified per metre trench.
U-values are specified per metre pipe.
*Continuously produced

Diffusion barrier

isoplus can produce pipes with jacket pipes in jacket pipe dimensions of ≤ ø355 mm as energy-saving, continuously produced pipes with a diffusion barrier inserted between the jacket pipe and the polyurethane foam.

For pipes with jacket pipes in dimension of >ø355 mm, the jacket pipe functions as a diffusion barrier due to its thickness.
The diffusion barrier secures isoplus pre-insulated pipes against ageing, and the heat loss is therefore constant throughout the pipe's technical service life.

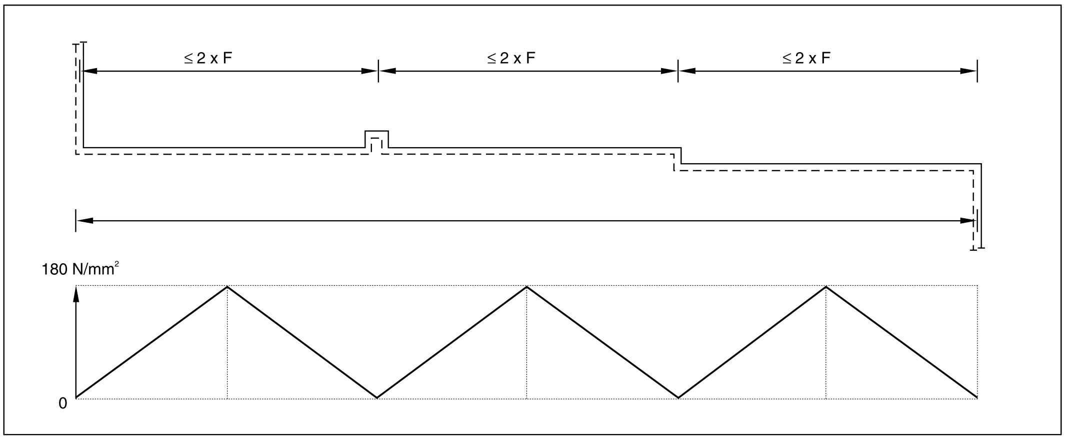
Laying method 1 - expansion bends

4.3

Exploiting "natural" expansion possibilities when laying pipelines provides a simple and relatively uncomplicated means of limiting axial stresses.

Basically, this laying method requires that the distance between two expansion possibilities - e.g. an L, Z or U bend - never exceeds 2 x F for the pipe type and size concerned (for F values, please refer to the table on page 4.5).

This can be illustrated as follows:



If a given section of pipeline exploiting natural changes in direction exceeds 2 x F, the section must be equipped with additional expansion zones and/or expansion components.

Laying method 2 - heat prestressing

4.3.1

Heat prestressing is suitable in situations where it is not possible to exploit natural expansion possibilities and/or the higher stress and other associated limitations of a cold-laid system arising where F (see page 4.5) is exceeded are unacceptable.

With this method, the pipes are laid and pre-heated before being covered. The pipes will thereby not be subjected to stress at the ”pre-heating temperature”.

The pipes can to a large extent be laid without restrictions or traditional expansion compensation in the form of bends, compensators, etc.

However, as a general rule, both ends of each section should be designed as an expansion zone (with L, Z or U bends) or one end of the section should be anchored.

Prior to heat prestressing, the trench may be filled with sand and compacted to a level no higher than the centre of the jacket pipe.

During heat prestressing, the pipes are allowed to expand freely (apart from the friction caused by the weight of the pipes) and, after being covered with compacted backfill material, remain stress free for the length of the friction fixated run. As a result, no special precautions need be taken when parallel excavation is subsequently required as long as the operating temperature is reduced to the same level as the preheating temperature.

A preheating temperature intermediate to the laying and operating temperatures is generally selected in order to reduce axial stresses in the flow and return pipes as much as possible.

Heat prestressing methods

District heating water

This method can be used if the section of pipeline to be preheated is connected to an existing network in operation and there is no need to drain the system before it is taken into use.

Steam

As heat prestressing is usually performed at temperatures of between 60°C and 75°C, the use of steam requires that the pressure in the pipeline is reduced from atmospheric pressure of approx. 1 bar to an underpressure of approx. 0.4 bar (i.e. the pressure at which water becomes steam at a temperature of 75°C).

At this temperature, steam has a heating power of 756 W/kg, which is approx. 15 times higher than that of water.

The main benefit of using steam is therefore the considerably reduced requirement for water in connection with preheating.

Electricity

Electric preheating is advantageous in certain circumstances, especially where long pipe runs are to be heated and district heating water from an existing supply is unavailable.

Electric preheating requires that the steel pipes have identical sizes and properties along the entire length of the section to be heated.

It is not possible to electrically preheat sections containing various sizes of steel pipe (e.g. sections containing one or more reducers) as the smaller pipes would be overheated. In such cases, the pipeline must be divided into separate sections of uniform pipe size and subsequently joined using single-use compensators and necessary reducers.

Electric preheating requires access to a 400 V power supply and/or a generator capable of providing the necessary output for preheating.

Laying method 3 - prestressing elements

4.3.3

Prestressing elements are suitable in situations where it is not possible to exploit natural expansion possibilities and/or the higher stress and other associated limitations of a cold-laid system are unacceptable.

In contrast to heat prestressing, which requires that the trench be left open, the use of prestressing elements allows the trench to be closed and the surface reestablished (with the exception of access holes) before prestressing is performed.

Prestressing is usually performed by means of district heating water from an existing network or using a mobile boiler.

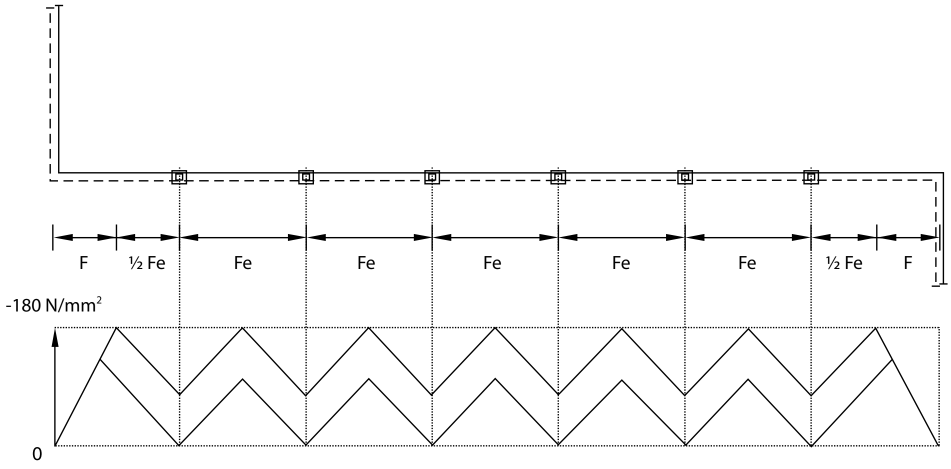
A prestressing element is a component that is welded into the pipeline and functions as an expansion unit during prestressing.

Prestressing elements are therefore designed to allow controlled expansion between two free pipe ends. Once the required expansion has occurred, the free pipe ends in the prestressing element meet and are then locked in position by welding.

This method thus has the same effect as heat prestressing in that the finished pipeline is stress-free at the preheating temperature while future temperature fluctuations will be absorbed as either tensile or compressive stresses over the length of the friction fixated run.

Similarly to the other methods, both ends of the prestressed section must as a general rule be formed as expansion zones (with L, Z or U bends).

The use of prestressing elements allows pipelines to be laid relatively quickly as the trench can be backfilled continuously. Similarly to heat prestressing, parallel excavations can also be performed without having to take special precautions.



Laying method 3 - prestressing elements 4.3.4

Design data

- Max. permissible operating temperature 149°C.
- Prestressing temperature must be at least 90% of max. operating temperature.
- System operating pressure must not exceed 16 bar.
  In certain situations, 25 bar is also permissible.
- The maximum permissible axial stress in friction fixated runs is 180 N/mm^2.
- Pipes in the entire section of prestressed pipeline must be uniformly covered.
- Trench backfill and compaction must be uniform throughout the length of the section.

The tables on pages 4.5 and 4.5.7 specify F and Fe values for a laying depth of 0.8 m and a max. permissible axial stress of 180 N/mm^2.

Laying method 4 - cold installation

4.3.5

With cold installation, the pipes can to a large extent be laid without restrictions or traditional expansion compensation in the form of bends, compensators, etc.

This manual covers the cold installation of pipes in dimensions up to DN 300. For larger pipe sizes, please contact isoplus for advice on optimising your system.

With cold installation, axial stress is allowed to exceed the yield point. The first time the pipeline is heated, slight deformation of the steel pipe therefore occurs, thus relieving stress.

During subsequent load fluctuations, straight pipes therefore remain in the so-called elastic zone.

Due to the higher stress levels and resulting forces affecting the steel pipe, initial heating results in significantly greater expansion of the pipe at its free ends. As a result, cold installation should always be combined with the use of expansion zones, i.e. broader, sand-filled trenches at bends and branches and/or foam pads (see pages 4.5.17, 4.5.18 and 4.5.20).

Cold installation is characterised by the following general conditions:

- Initial expansion which is typically twice as great as with heat prestressing.
- Expansion zones/foam pads must be used at bends/branches.
- Higher compressive stress in the insulation material at all changes of direction.
- Greater axial effects on pre-insulated valves.
- Branches must be reinforced due to the greater loads.
- Tapping into a cold-laid system in operation is not immediately possible.
- Excavation parallel to cold-laid pipelines is as a general rule not possible unless operating temperature is reduced and/or the pipe is prevented from bending outwards by supports or similar.
- Anchors cannot be used due to the high forces.
- Bevelled joints are not possible if $\Delta T \geq 120$ K.
- Bevelled joints only possible at $\Delta T \geq 100$ K with max. 3-degree bevel.
- Only single-step reducers can be used.

Several of these rules differ, depending on whether the run is friction fixated or friction restricted.

Laying rules for use of isosteelpress

4.3.6

Planning

isosteelpress can be used with single steel pipes and installation methods 1, 2, and 4. isosteelpress may only be used in projects where Δt does not exceed 70°C (the difference between installation temperature and max. operating temperature).

When using isosteelpress, the installation temperature may not exceed 50°C.
Installation depth: max. 1.0m.

Only preinsulated fittings may be used; reducers excepted.
Directional changes (bends) 80-100°. If directional changes with other angles are required, please contact isoplus' technical department.
Bends with leg lengths according to the tables on pages 5.4 and 5.5. Use of elastic bends is not allowed.

Handling

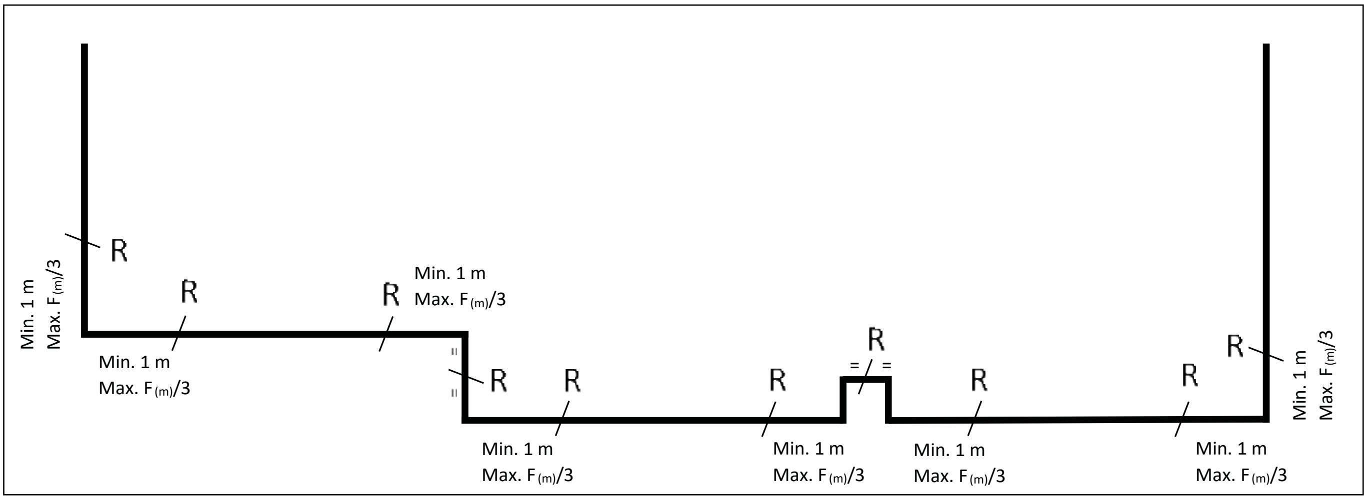
Pipes which are already assembled may not be lifted, i.e. the pipes must be assembled in the trench.

Reducers

The pressure on reducers must be relieved during the installation process. Se drawing below.

Placement of reducers

U bend: Centrally in the U bend
Z bend: Centrally in the Z bend
Bend: min. 1m and max. F(m)/3 (for the smallest dimension)



Design basis

The design and laying rules describe how expansion-related phenomena should be solved while ensuring optimum use of the pipeline system.

Design assistance

isoplus engineers are able to provide expert advice on all aspects of pipeline expansion systems and will be happy to review the drawings for any specific project.

System requirements

The design and laying rules are based on a foamed piping system in which the carrier pipe, insulation material and jacket pipe perform as an integrated sandwich construction.

When the steel pipe expands/contracts as a result of temperature fluctuations, the entire construction will move. In effect, therefore, such movement occurs between the jacket pipe and the surrounding backfill material.

Laying methods

The section on laying methods outlines four different methods and laying rules for isosteelpress:

Method 1 - Expansion bends

Method 2 - Heat prestressing

Method 3 - Prestressing elements

Method 4 - Cold installation

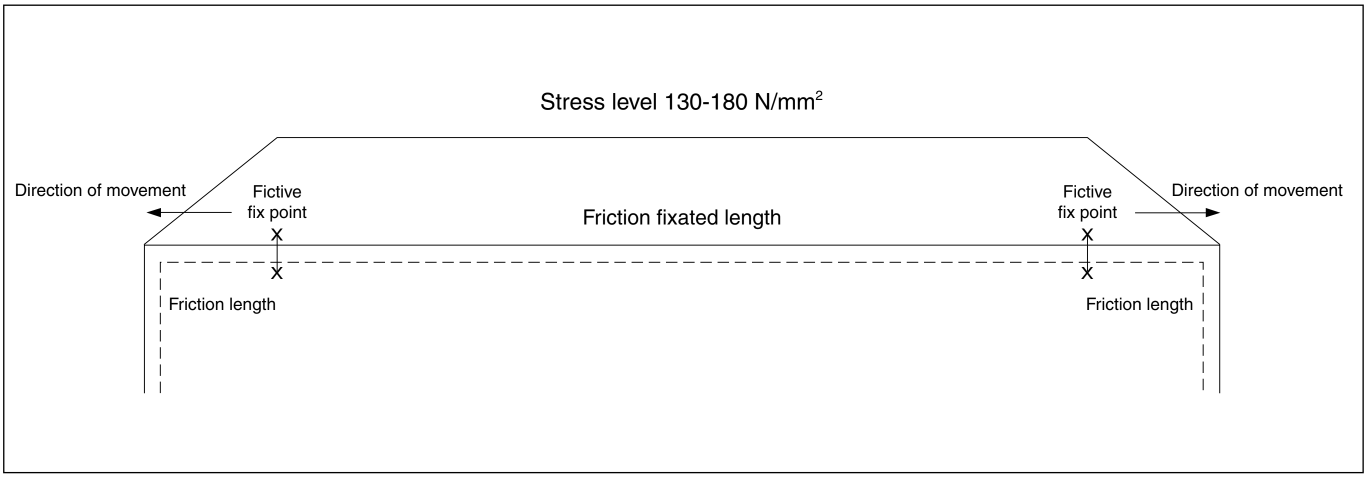
Laying rules for isosteelpress

In system design, the concepts of fictive fix points and friction restricted and friction fixated runs are used.

The friction restricted run (also known as the friction length) is the length of pipe (for a given pipe dimension) running from an expansion point (i.e. a bend) to a fictive fix point with a stress of 130-180 N/mm^2.

If cold installation is used, stress will theoretically exceed 300 N/mm^2.

Design basis



The calculations assume that the pipes are laid in sand in accordance with section 3 with a soil cover of max. 0.8 m and operating parameters of max. 16 bar and Δt max. 120°C.

Friction length

4.5

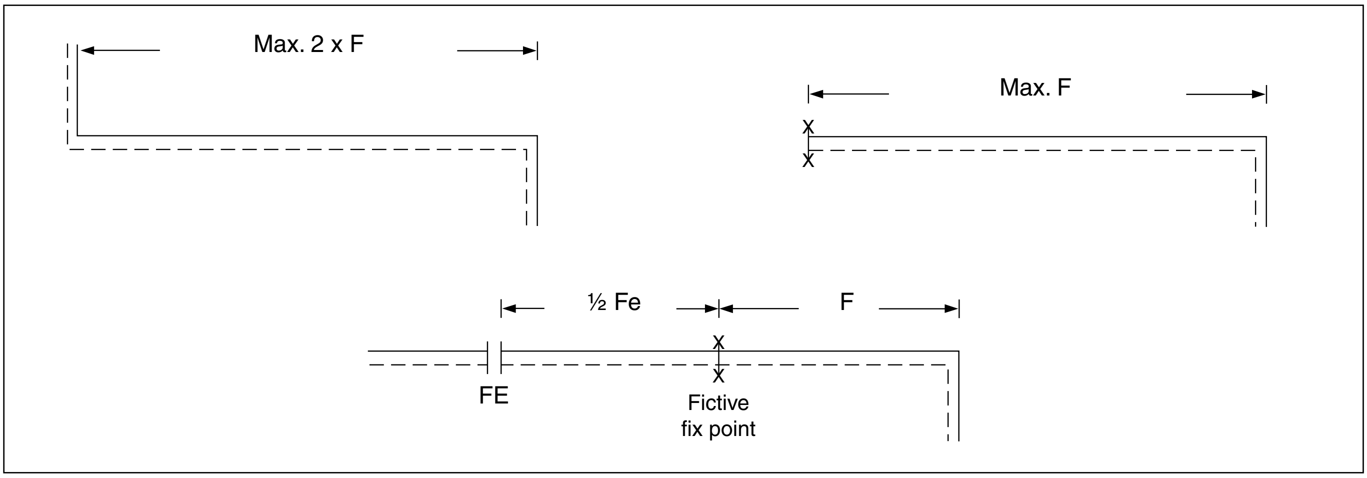
Friction length is the distance from a physical or fictive fix point to an expansion possibility in the form of a bend where sufficient movement can be absorbed to prevent the permissible stress level from being exceeded.

Friction length is used partly to calculate the maximum distance between two bends (where the max. distance without the use of expansion elements is 2 x F and partly to calculate when it is necessary to incorporate expansion elements in a given run.

The figures below illustrate the use of friction lengths (F).

The friction lengths stated in the table are average values based on the assumptions given in the design basis section.

The stated F values assume that expansion bends have an angle of 80-100°.



Series 1		Series 2		Series 3	
Dim	F (m)	Dim	F (m)	Dim	F (m)
26,9/90	23	26,9/110	19	26,9/125	17
33,7/90	36	33,7/110	29	33,7/125	26
42,4/110	37	42,4/125	33	42,4/140	29
48,3/110	43	48,3/125	38	48,3/140	34
60,3/125	48	60,3/140	42	60,3/160	37
76,1/140	54	76,1/160	47	76,1/180	42
88,9/160	55	88,9/180	49	88,9/200	44
114,3/200	63	114,3/225	56	114,3/250	50
139,7/225	68	139,7/250	61	139,7/280	55
168,3/250	81	168,3/280	73	168,3/315	64
219,1/315	89	219,1/355	82	219,1/400	73
273,0/400	94	273,0/450	86	273,0/500	79
323,9/450	105	323,9/500	97	323,9/560	88
355,6/500	103	355,6/560	94	355,6/630	86
406,4/560	112	406,4/630	103	406,4/710	93
457,2/630	111	457,2/710	101	457,2/800	92
508,0/710	108	508,0/800	99	508,0/900	90

11.10.2023

Expansion bends

4.5.1

When designing expansion bends, a distinction is made between bends of 80° - 100° and bends of less than 80°.

The movement a bend is subjected to depends partly on laying method and partly on the difference between the minimum and maximum temperatures of the system (Δt).

In the following, the necessary leg length is therefore specified for Δt 80°C and Δt 120° respectively for each of the four laying methods.

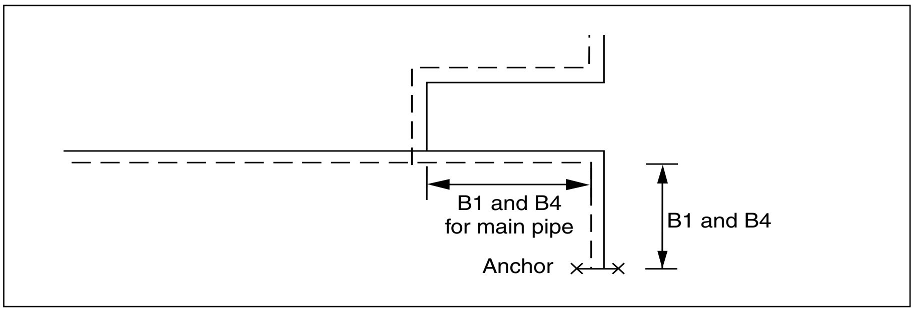
L bends 80° - 100°

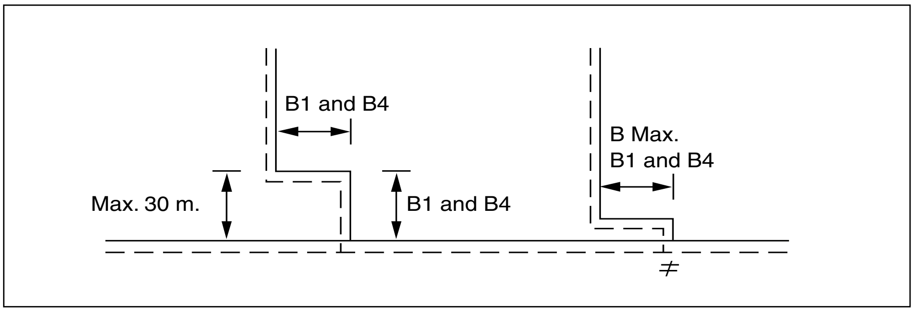
L-bends are expansion bends which (in contrast to Z-bends) are in effect only subjected to loads from the one side.

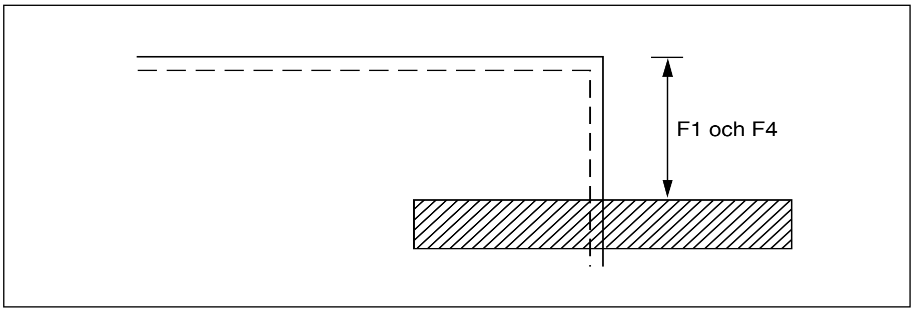
The specified lengths are minimum lengths for bends laid using methods 1, 2 and 3 (B1 and F1) or method 4 (B4 and F4) respectively.

The minimum lengths F1 and F4 ensure that wall lead-throughs are not subjected to excessive lateral force.

Laying method 4 should be used if the distance between two expansion bends is more than twice the friction length or if the distance between a cast anchor point and an expansion bend exceeds the friction length.







Max. lengths	
Jacket pipe branch	Max. B parallel branches
d outside mm	B Max. m
26,9	3,1
33,7	3,2
42,4	3,2
48,3	3,2
60,3	3,2
76,1	3,2
88,9	3,4
114,3	3,8
139,7	4,4
168,3	5,0
219,1	5,6
273,0	6,4
323,9	7,0
355,6	7,8
406,4	8,5
457,2	9,4
508,0	10,0
610,0	11,3

For laying method 1, 2 or 3, use B1 and F1.
For laying method 4, use B4 and F4.

Expansion bends 4.5.2

	Laying methods 1, 2 and 3 Δt 120°C		Laying method 4 Δt 120°C	
Steel pipe	B1	F1	B4	F4
d outside mm	m	m	m	m
26,9	1,0	1,0	1,1	1,1
33,7	1,2	1,2	1,4	1,4
42,4	1,3	1,4	1,5	1,7
48,3	1,5	1,7	1,8	2,0
60,3	1,8	2,0	2,1	2,3
76,1	2,1	2,8	2,4	3,3
88,9	2,3	3,3	2,6	3,7
114,3	2,6	4,2	3,1	4,7
139,7	3,1	5,0	3,5	5,7
168,3	3,5	5,9	4,1	6,9
219,1	4,0	6,9	4,6	7,9
273,0	4,6	7,9	5,4	9,1
323,9	5,1	9,4	5,9	10,7
355,6	5,7	9,4	5,9	10,7
406,4	6,2	11,4	7,2	12,9
457,2	6,8	12,3	7,9	14,3
508,0	7,3	12,9	8,4	14,9
558,8	7,6	13,3	8,8	15,8
610,0	8,4	14,9	9,7	17,3

	Laying methods 1, 2 og 3 Δt 80°C		Laying methods 4 Δt 80°C	
Steel pipe	B1	F1	B4	F4
d outside mm	m	m	m	m
26,9	0,7	0,8	0,7	0,9
33,7	0,8	1,0	1,0	1,2
42,4	0,9	1,2	1,0	1,3
48,3	1,0	1,3	1,2	1,6
60,3	1,2	1,6	1,4	1,9
76,1	1,4	2,2	1,6	2,7
88,9	1,5	2,7	1,8	3,1
114,3	1,8	3,4	2,1	3,9
139,7	2,1	4,0	2,3	4,7
168,3	2,3	4,8	2,7	5,7
219,1	2,6	5,7	3,1	6,5
273,0	3,1	6,5	3,6	7,5
323,9	3,4	7,6	4,0	8,7
355,6	3,8	8,1	4,4	9,3
406,4	4,1	9,3	4,8	10,5
457,2	4,5	10,1	5,3	11,7
508,0	4,8	10,5	5,6	12,1
558,8	5,1	10,9	5,9	12,9
610,0	5,6	12,1	6,5	14,1

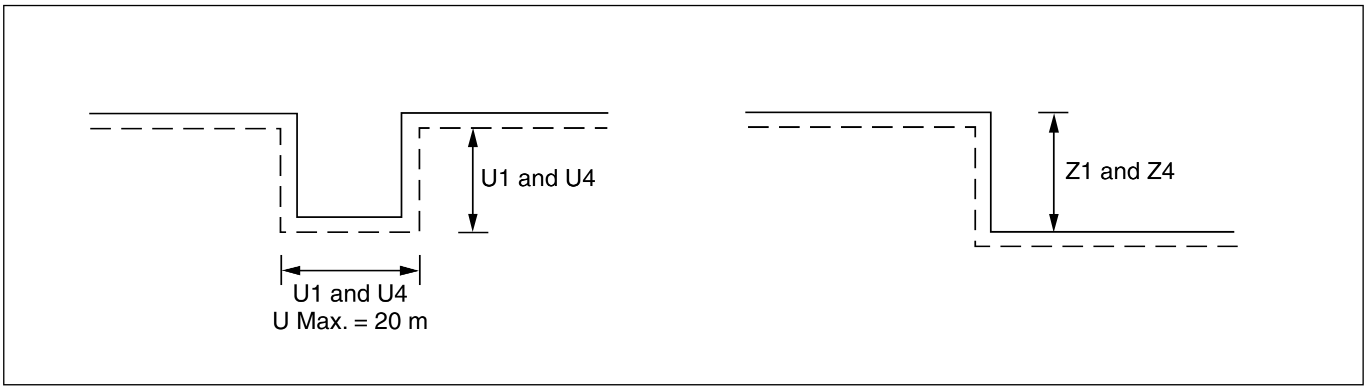
Z and U bends 80-90°

Thanks to the flexibility of their design, Z-bends are capable of absorbing greater displacement than L-bends.

As U-bends are only subjected to loads from the one side, the minimum leg length can be reduced in comparison to Z-bends.

The specified lengths are minimum lengths for bends laid using methods 1, 2 and 3 (Z1, U1) or method 4 (Z4, U4) respectively.

Laying method 4 should be used if the distance between two expansion bends is more than twice the friction length or if the distance between a cast anchor point and an expansion bend exceeds the friction length.



For laying method 1, 2 or 3, use U1 and Z1.
For laying method 4, use U4 and Z4.

Expansion bends 4.5.4

	Laying methods 1, 2 and 3 Δt 120°C		Laying method 4 Δt 120°C	
Steel pipe	Z1	U1	Z4	U4
d outside mm	m	m	m	m
26,9	1,2	0,8	1,4	0,9
33,7	1,5	1,0	1,8	1,1
42,4	1,7	1,1	1,9	1,2
48,3	1,9	1,2	2,2	1,4
60,3	2,2	1,4	2,6	1,7
76,1	2,6	1,7	3,0	1,9
88,9	2,9	1,8	3,3	2,1
114,3	3,3	2,1	3,9	2,5
139,7	3,9	2,5	4,4	2,8
168,3	4,4	2,8	5,1	3,3
219,1	5,0	3,2	5,8	3,7
273,0	5,8	3,7	6,7	4,3
323,9	6,3	4,0	7,4	4,8
355,6	7,2	4,6	8,3	5,3
406,4	7,7	4,9	8,9	5,7
457,2	8,5	5,5	9,9	6,3
508,0	9,1	5,8	10,5	6,7
558,8	9,5	6,1	11,0	7,0
610,0	10,5	6,7	12,1	7,7

	Laying methods 1, 2 and 3 Δt 80°C		Laying method 4 Δt 80°C	
Steel pipe	Z1	U1	Z4	U4
d outside mm	m	m	m	m
26,9	0,9	0,6	1,0	0,7
33,7	1,1	0,7	1,4	0,9
42,4	1,3	0,8	1,5	0,9
48,3	1,5	0,9	1,7	1,1
60,3	1,7	1,1	2,0	1,3
76,1	2,0	1,3	2,3	1,5
88,9	2,2	1,4	2,5	1,6
114,3	2,5	1,6	2,9	1,9
139,7	2,9	1,9	3,3	2,1
168,3	3,3	2,0	3,9	2,5
219,1	3,8	2,4	4,4	2,8
273,0	4,4	2,8	5,1	3,3
323,9	4,8	3,1	5,6	3,6
355,6	5,4	3,5	6,3	4,0
406,4	5,8	3,7	6,8	4,3
457,2	6,5	4,1	7,5	4,8
508,0	6,9	4,4	7,9	5,1
558,8	7,2	4,6	8,3	5,3
610,0	7,9	5,1	9,2	5,9

Expansion bends

Bends < 80°

Laying rules for expansion bends apply to bends of between 80° - 100°

For direction changes of less than 80°, max L should be calculated using the table below.

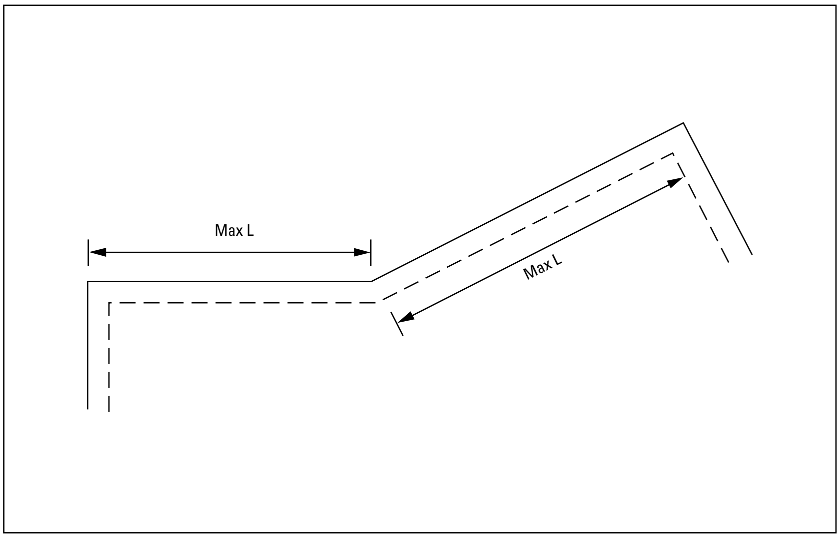
If other on-site conditions permit the use of curved pips, this may be a more suitable solution.

Curved pipes

See page 4.5.11.

Special bends

L = max. distance from a special bend of between 10° and 80° to an expansion bend.



α	Max. L as % of F
≤5°	1 x F
15°	40%
25°	30%
35°	30%
45°	35%
55°	50%
65°	65%
75°	85%
≥80°	2 x F

F should be found in the table on page 4.5.

Prestressing elements

4.5.6

When prestressing elements are used (laying method 3), axial stress is absorbed by the system in principle by means of thermal prestressing.

Prestressing elements are single-use compensators which are pre-set prior to installation.
Once the system is taken into use, the compensator is locked and subsequent temperature fluctuations are absorbed by the steel pipe as permissible axial stress.

After the system has been taken into use and the prestressing elements have been locked, movement will only occur on friction restricted sections while other sections will be held in place by soil friction and will be subjected to stress levels of max. +/- 180 N/mm^2.

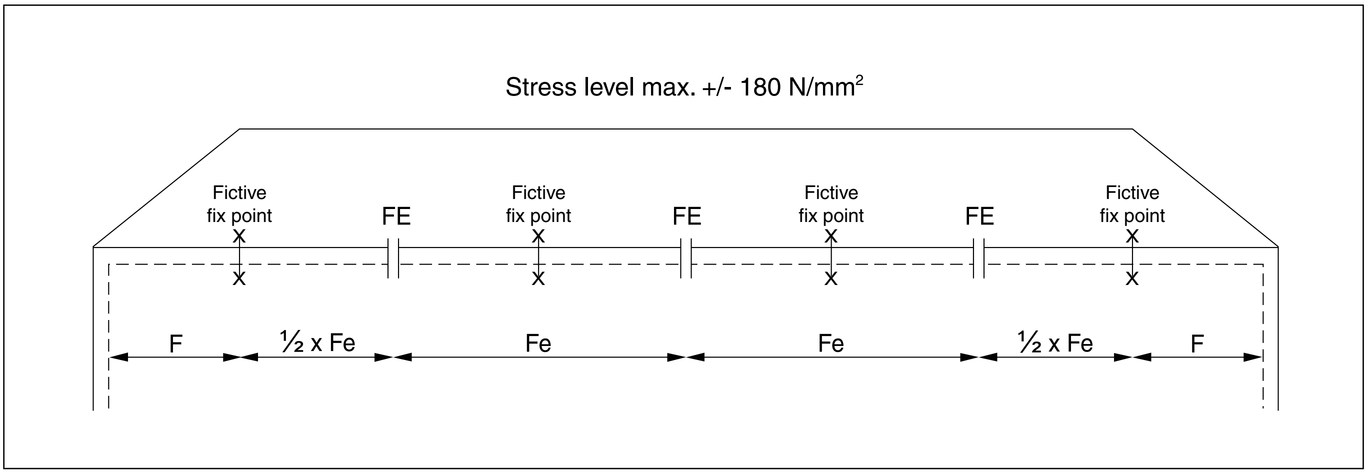
System design using prestressing elements

Prestressing elements must always be positioned between two fix points.

Such fix points may be either physical or fictive (i.e. friction length F from a bend). The type of fix point has no bearing on the design calculations.

The distance from a fix point to a prestressing element must not exceed ½ x Fe, while the distance between two prestressing elements must not exceed Fe.

The values for F and Fe are based on a soil cover of 0.8 m. See table on page 4.5.7.

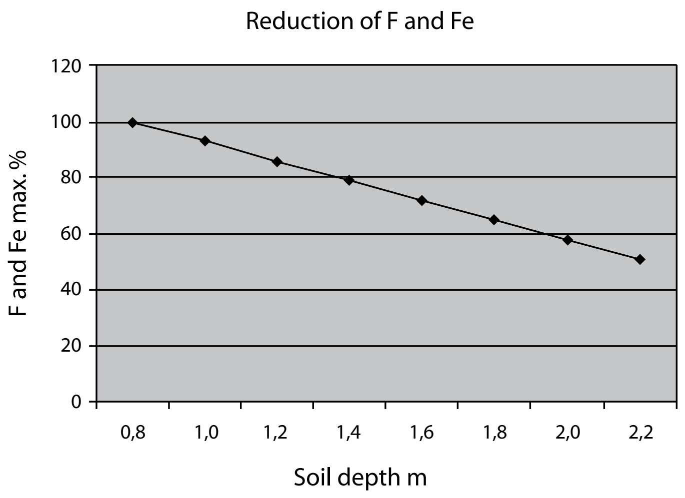


Prestressing elements 4.5.7

	Series 1		Series 2		Series 3	
Steel pipe	Fe	F	Fe	F	Fe	F
d outside mm	m	m	m	m	m	m
33,7	71	36	58	29	51	26
42,4	75	37	66	33	58	29
48,3	86	43	75	38	67	34
60,3	95	48	85	42	74	37
76,1	108	54	94	47	83	42
88,9	110	55	98	49	88	44
114,3	126	63	112	56	101	50
139,7	137	68	123	61	109	55
168,3	162	81	145	73	129	64
219,1	179	89	163	82	145	73
273,0	188	94	171	86	157	79
323,9	210	105	193	97	177	88
355,6	206	103	189	94	172	86
406,4	225	112	205	103	186	93
457,2	222	111	202	101	184	92
508,0	217	108	197	99	179	90

Reduction of F and Fe

The values given for F and Fe are based on a soil cover of 0.8 m.
If a pipeline is laid deeper than 0.8 m, the values should be reduced in accordance with the figure below.



Prestressing elements 4.5.8

Pre-setting of prestressing elements

Before welding the prestressing element between the two pipe ends, it must be pre-set to the correct prestressing length F_m.

The following parameters are used to calculate F_m

T_d = System operating temperature (°C) (On initial system start up, it may be necessary to achieve a temperature corresponding to approx. 90% of max. operating temperature in order to obtain the necessary expansion).

T_i = System installation temperature (°C)

Fe = The true Fe based on the actual distance between the planned prestressing elements.

The above parameters should be entered in the formula: F_m mm = $(T_d - T_i)$ x Fe x 0.005

The factor 0.005 is a constant, encompassing among other things soil friction, steel pipe expansion coefficient and permissible axial stresses.

Design example

Dimension = ø139,7/250 (Series 2)

Length = 482 m

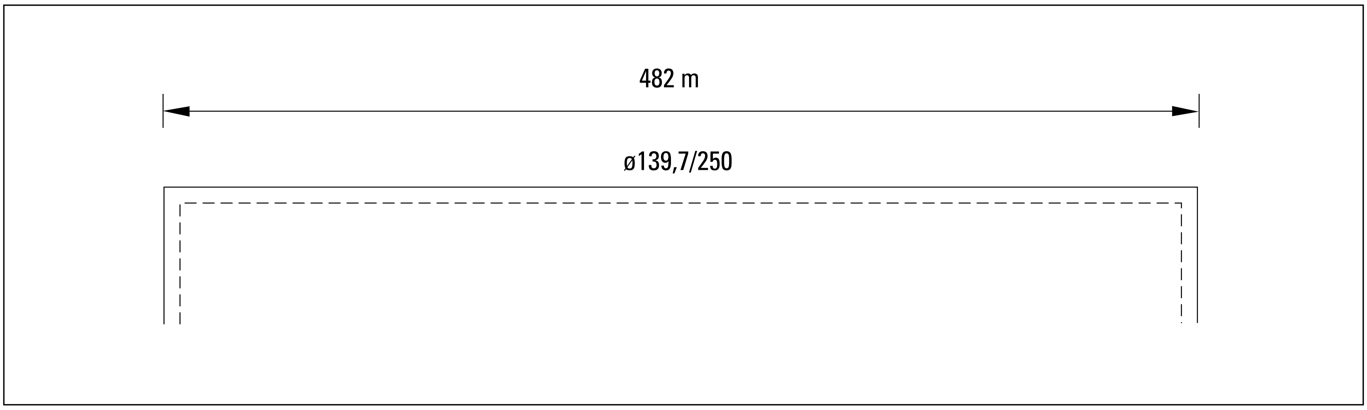
Soil covering = 0.8 m

Operating temperature = 90°C

Installation temperature = 10°C

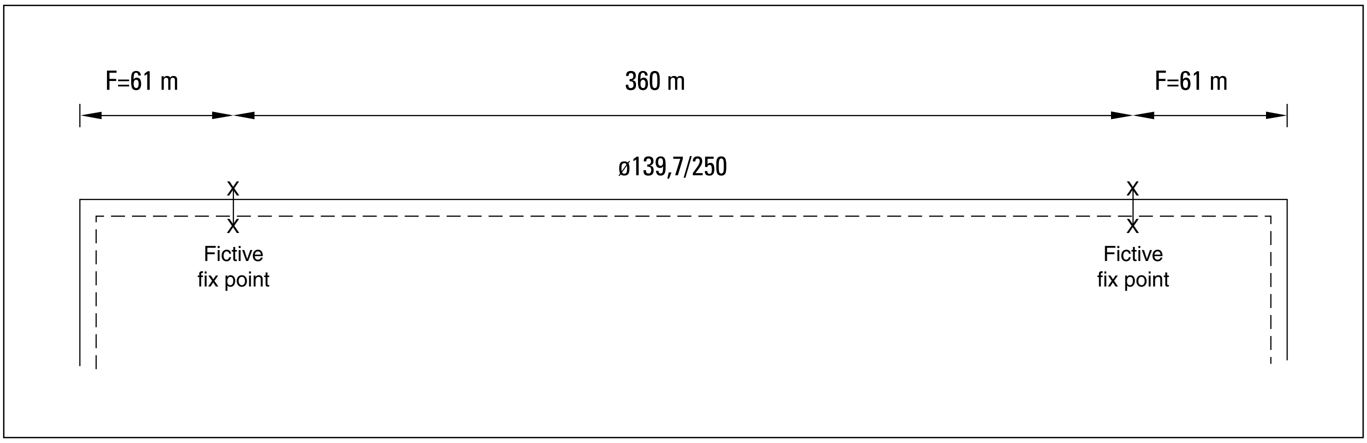
F = 61 m (see table on page 4.5.7)

Fe = 123 m (see table on page 4.5.7)



Prestressing elements

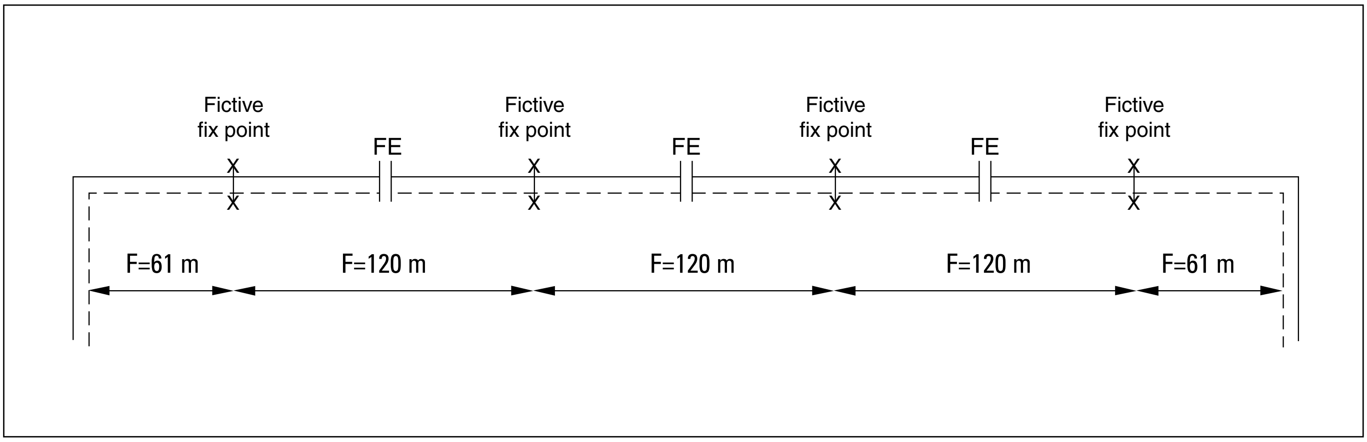
Fictive fix points are set F = 62 m into the run from the bend.



To calculate the number of prestressing elements required, the remainder of the run must be divided by Fe, see table on page 4.5.7.

Number of prestressing elements $\frac{360}{123} = 2.93$

This figure is rounded up to 3, resulting in a true Fe of $\frac{360}{3} = 120$ m



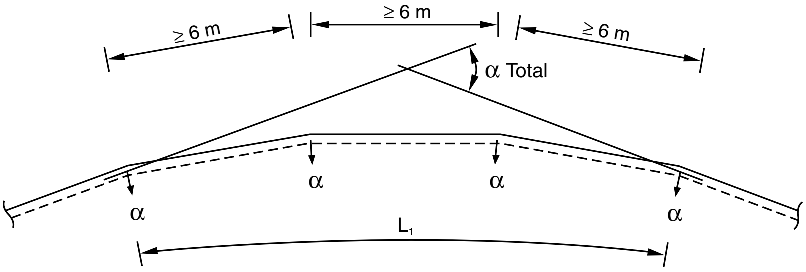
Prestressing length F_m = (90 - 10) x 120 x 0.005 = 48 mm

Prestressing elements should always be installed between two straight lengths of pipe without bevelled joints.

Bevelled joints - laying methods 1, 2 and 3

4.5.10

Bevelled joints may be used with laying methods 1, 2 and 3 for direction changes of max. 5° (2.5 + 2.5) per joint with a min. distance of 6 m between each successive bevelled joint.



Important:

The max. angle of a bevelled joint may be limited by the type of joint casing used.

Elastic curves

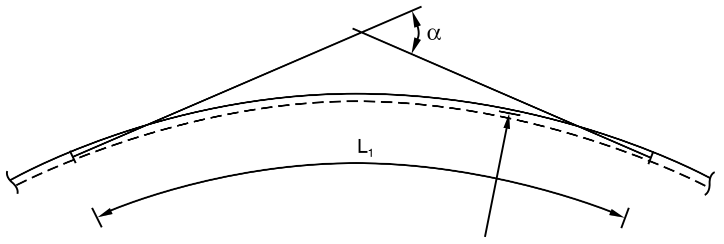
4.5.11

The concept of ”elastic curves” covers the bending of a given section of pipe without permanent deformation.

From a static analysis point of view, elastic curves can be considered as straight pipes.

In practice, elastic curves are created by welding/jointing the pipeline beside the excavated trench and then lowering the completed section into the trench and pulling it into the required position.

Because of differences in bending moments, the minimum permissible elastic bending radius (i.e. the largest bending angle) depends on the size of the pipe concerned.



Permissible bending radius (min.) and bending angle (max.) in relation to pipe size.

Steel pipe	Min. elastic bending radius	Max. elastic bending angle	Pipe length
d outside mm	m	per length in degrees	m
26,9	13	26,0°	6
33,7	17	20,0°	6
42,4	21	32,0°	12
48,3	24	28,0°	12
60,3	30	23,0°	12
76,1	38	18,0°	12
88,9	44	15,0°	12
114,3	57	11,0°	12
139,7	70	9,0°	12
168,3	84	7,0°	12
219,1	110	6,2°	12
273,0	137	5,0°	12
323,9	162	4,2°	12
355,6	178	3,9°	12
406,4	203	3,4°	12
457,2	229	3,0°	12
508,0	254	2,7°	12

Where changes in direction greater than those indicated in the table are needed, use prefabricated pipe bends, see catalogue section 5.2.

Curved pipes

The concept of ”curved pipes” covers pipes which are supplied pre-bent by isoplus or are bent to the required angle on-site using a special bending tool.

From a static analysis point of view, curved pipes can (in the same way as elastic curves) be considered as straight pipes. They are therefore suitable for use with any of the four laying methods.

By using curved pipes, the need for pre-insulated bends is reduced, thus allowing considerable savings on the costs of materials, excavation and subsequent reestablishment.

Curved pipes

4.5.13

The maximum bending angle depends on the length of the pipe and its dimensions, as given in the table below:

Curved pipes - single

Steel pipe		Design radius		Max. permissible angle α°	Max. permissible angle α°	Max. permissible angle α°
DN	d outside mm		r, m	6 m pipe lengths	12 m pipe lengths	16 m pipe lengths
20	26,9	For on-site bending	8,4	41°	-	-
25	33,7		12,8	27°	-	-
32	42,4		13,4	26°	52°	-
40	48,3		15,4	22°	44°	-
50	60,3		17,2	20°	40°	-
65	76,1		19,6	18°	36°	-
80	88,9		20,2	17°	34°	-
100	114,3	Pre-bent	22,9 (12m) 20,8 (16m)	-	30°	44°
125	139,7		22,9 (12m) 20,8 (16m)	-	30°	44°
150	168,3		25,5 (12m) 22,9 (16m)	-	27°	40°
200	219,1		28,6 (12m) 26,2 (16m)	-	24°	35°
250	273		32,7 (12m) 29,6 (16m)	-	21°	31°
300	323,9		36,2 (12m) 32,7 (16m)	-	19°	28°
350	355,6		68,8 (12m) 65,5 (16m)	-	10°	14°
400	406,4		76,4 (12m) 70,5 (16m)	-	9° (S1)	13° (S1)
400	406,4		105,8 (12m) 87,3 (16m)	-	6,5° (S2+S3)	10,5° (S2+S3)
450	457,2		137,5 (12m) 114,6 (16m)	-	5°	8°
500	508		171,9 (12m) 152,8 (16m)	-	4° (S1+S2)	6° (S1+S2)
550	558,8		171,9 (12m) 152,8 (16m)	-	4° (S1)	6° (S1)

When ordering curved pipes, please state:

- Bending angle (or corresponding bending radius)
- If the pipe is to be equipped with alarm, it is also necessary to state whether the pipe is to curve to the right or left or upwards or downwards.

If the required bending angle cannot be achieved using a single pipe, two or more pipes must be combined to achieve the correct angle.

Curved pipes

4.5.14

Example 1:

Pipe dimension ø114

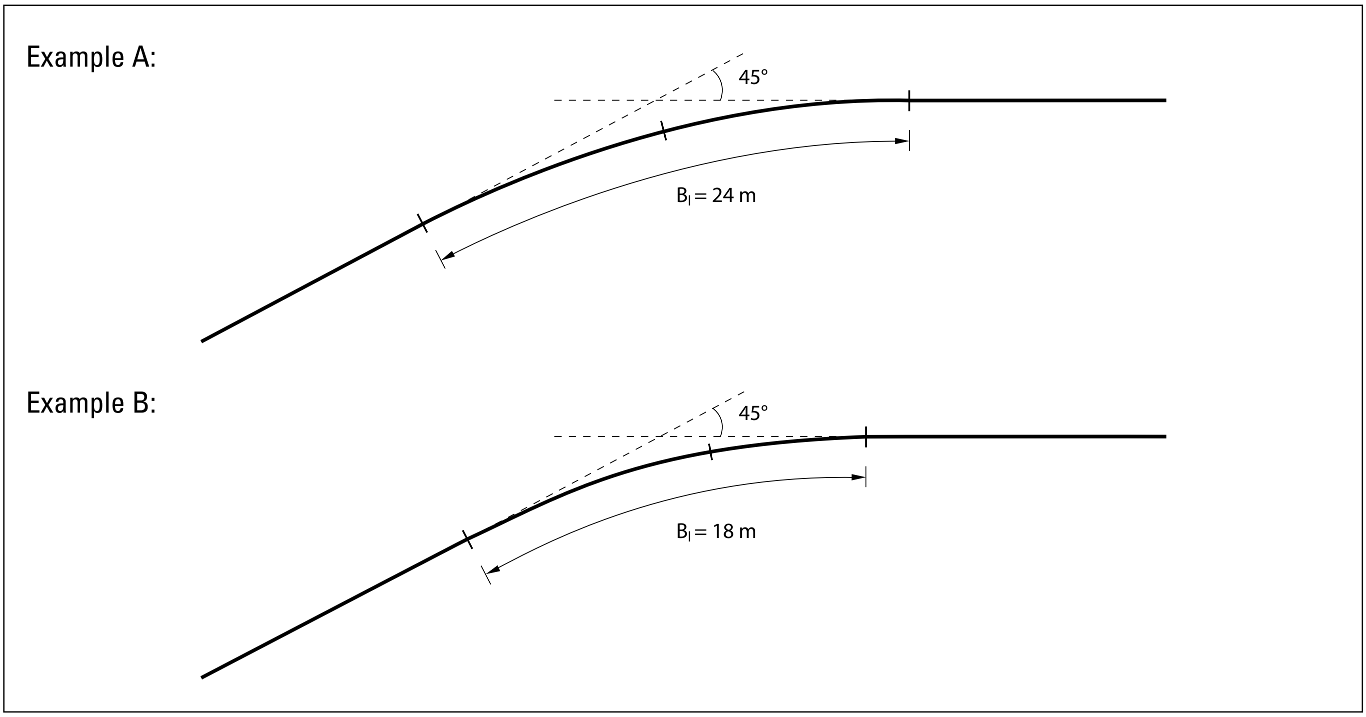
According to the table on the previous page, the max. permissible bending angle for ø114 pipes is 33°.

To obtain a 45° bend, two curved pipes must therefore be used, for example in one of the following ways:

A: 2 pipes of 12 m with bends of 22.5°

B: 1 pipe of 12 m with a bend of 33° + 1 pipe of 6 m with a 12° bend

Usually, solution A is preferable as the use of the longest possible pipes also reduces the number of necessary joints.



Curved pipes 4.5.15

The following formulas should be used to calculate the required number of curved pipes and the required trench dimensions:

Required number of curved pipes (n):

$$n = \frac{\alpha_{akt}}{\alpha_{max}}$$

Where α_{akt} is the required overall directional change and α_{max} is the maximum permissible bending angle for the pipe(s) used.

Bending radius (r):

$$r = \frac{B_l}{\pi \times \alpha_{akt}} \times 180 \text{ (m)}$$

B_l = total curve length

Tangent distance (T):

$$T = \frac{57{,}3 \times B_l}{\alpha_{akt}} \times \tan \frac{\alpha_{akt}}{2} \text{ (m)}$$

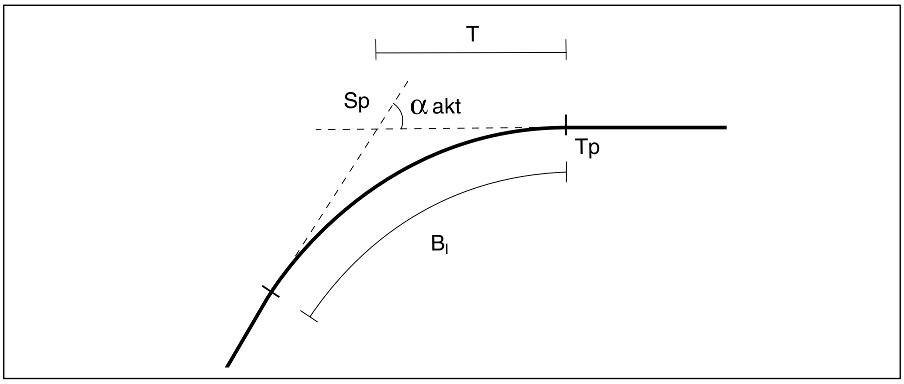
Displacement (Fs):

$$Fs = \frac{D + C \times \alpha_{akt}}{90}$$

D = jacket diameter in mm

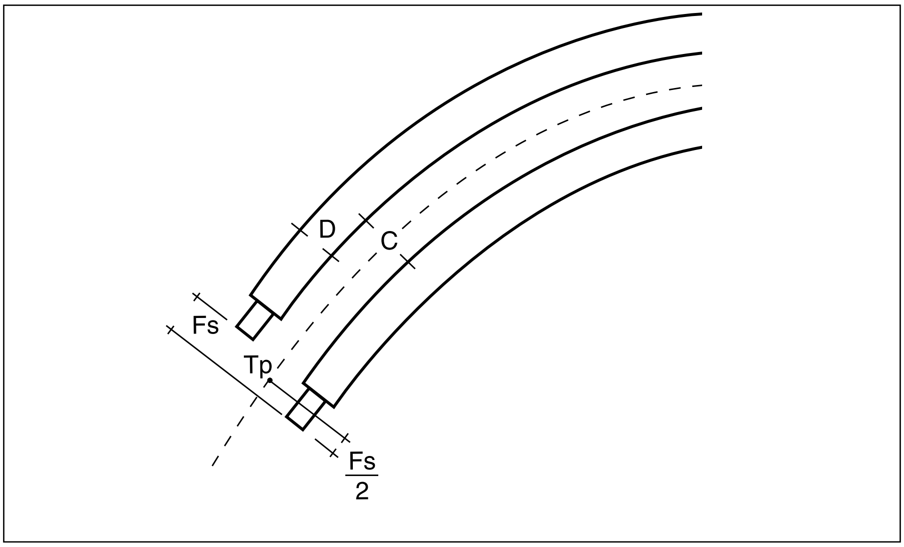
C = distance between pipes in mm

Example 2: To determine the trace of the curved pipe, the point of intersection of the straight pipe sections (Sp) must first be determined. The tangent point (Tp) is determined in relation to Sp.



The intersection and tangent point are always related to the trace centre-line.

When laying curved pipes, the ends of the two pipes will be slightly displaced from the tangent point (Tp).



Displacement is calculated as:

$$Fs = \frac{D + C \times \alpha_{akt}}{90}$$

Expansion zones 4.5.17

Expansion zones of sand

To prevent the insulating foam from becoming deformed as a result of lateral expansion movement at branches and bends, expansion zones of sand must be established around bends and branches on the friction length.

Requirements on compaction and materials

As the passive soil pressure must not exceed the long-term strength of the polyurethane foam, it is important that expansion zone compaction does not exceed the following limits:

$P_{max.}$:

- Standard proctor max. 98% with uniformity coefficient < 4
- Standard proctor max. 94% with uniformity coefficient < 8

$$\text{Uniformity coefficient} = \frac{\text{Grain size, 60\% passing}}{\text{Grain size, 10\% passing}}$$

- The material must be sand, free of clay and stones with sharp edges.

If laying method 1, 3, or 4 is used, the trench must be extended around bends and branches as specified in the table on page 4.5.18.

Where branches are concerned, distance C must be added to the side to which the branch will move.

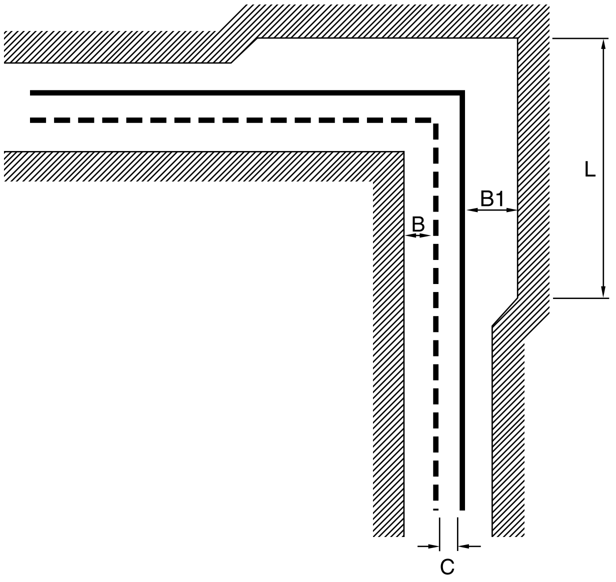
If laying method 2 is used, the trench must be extended around bends and branches as specified in the table on page 4.5.19.

Where sand fills are used at operating temperatures in excess of 80°, the stresses in the insulation foam cannot be expected to meet the requirements of EN 13941.

Expansion zones

4.5.18

Expansion zone design, laying methods 1, 3 and 4



Steel pipe	Width of sand in expansion zone			Expansion zone length
d outside mm	Jacket pipe to trench wall B mm	Jacket pipe to trench wall B1 mm	Between jacket pipes C mm	L m
26,9	100	140	150	0,8
33,7	100	140	150	0,8
42,4	100	140	150	1,0
48,3	100	190	150	1,0
60,3	140	190	150	1,1
76,1	140	190	150	1,2
88,9	140	240	150	1,4
114,3	140	285	250	1,7
139,7	190	330	250	1,9
168,3	190	330	250	2,1
219,1	240	430	250	2,6
273,0	285	525	285	2,9
323,9	330	570	335	3,3
355,6	380	620	335	3,4
406,4	380	665	380	4,1
457,2	430	760	430	4,5
508,0	475	810	475	4,8
558,8	570	905	475	4,9
610,0	620	1000	570	5,7

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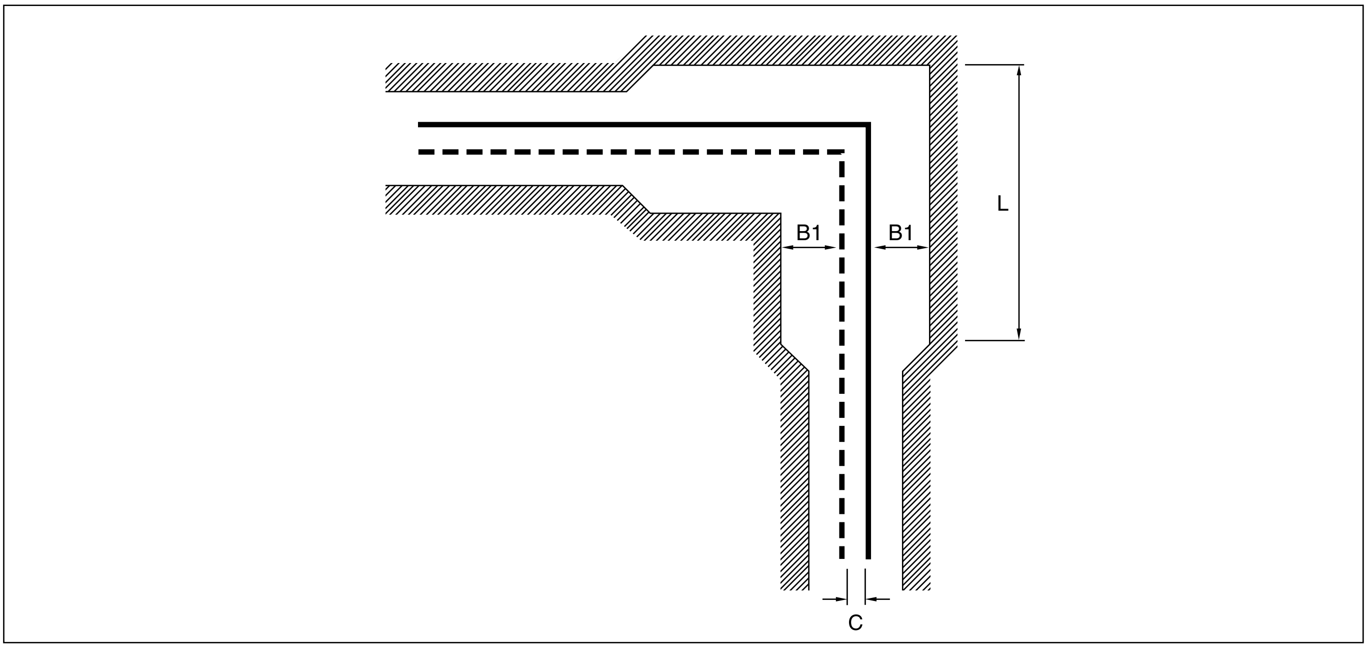
Expansion zones

Expansion zone design, laying method 2

If laying method 2 is used, the trench must be extended as specified in the table below.



Steel pipe	Width of sand in expansion zone		Expansion zone length
d outside mm	Jacket pipe to trench wall B1 mm	Between jacket pipes C mm	L m
26,9	100	150	0,8
33,7	100	150	0,8
42,4	100	150	1
48,3	100	150	1
60,3	140	150	1,1
76,1	140	150	1,2
88,9	190	150	1,4
114,3	190	250	1,7
139,7	240	250	1,9
168,3	240	250	2,1
219,1	285	250	2,6
273,0	380	250	2,9
323,9	430	250	3,3
355,6	475	300	3,4
406,4	475	300	4,1
457,2	525	300	4,5
508,0	570	300	4,8
558,8	665	335	4,9
610,0	760	380	5,7

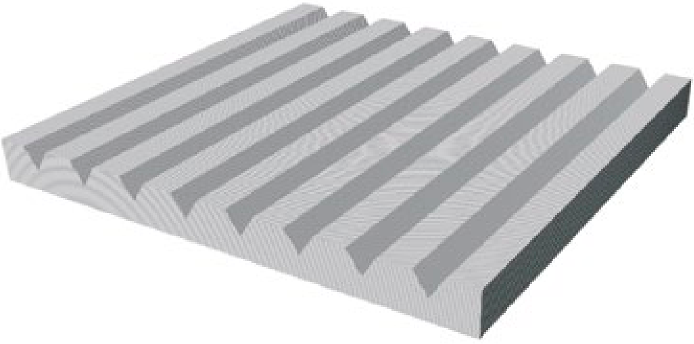
Foam pads

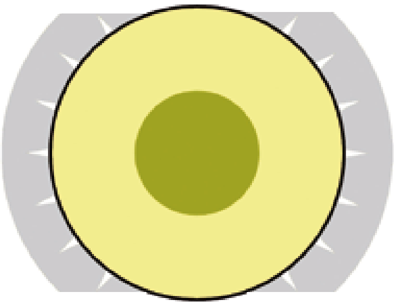
4.5.20

Foam pad for the absorption of expansions are only applied rarely in places where the requirements to sand and expansion zones are not observed.

Foam pads are produced in accordance with DS/EN 13941-1 and comply with the requirements for lifetime, rigidity, and labelling.

Foam pads are supplied in size 1000x2000x40 divided into rib sections that are cut off to match the pipe dimension.





Reducers - laying methods 1, 2 and 3

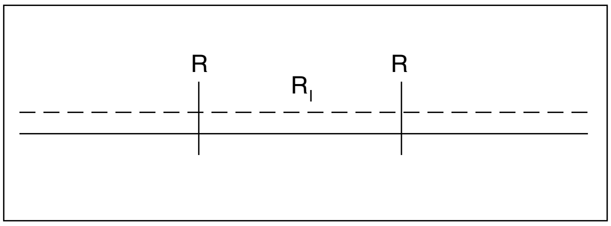
4.5.21

Reducers with up to two dimension changes require no special measures to be taken.

Greater dimensions are also possible if the pipe section is free from external forces.

Every effort should, however, be made to ensure that the largest dimension determines the course of the main trace (see the illustration below).

If more than two dimension changes are required, the following minimum ”reduction lengths” (R_l) between two successive reducers must be observed.



Dimension	R_l
ø26,9 - ø60,3	6
ø76,1-ø168,3	12
ø219,1-ø406,4	18

R_l values are the distance between two reducers on the friction fixated run where axial stress is greatest.

Reduction lengths located on friction lengths can therefore be reduced.

When the reducer is located in the immediate vicinity of an expansion bend, R_l can be reduced to R_l x 0.5.

Cold installation - laying method 4

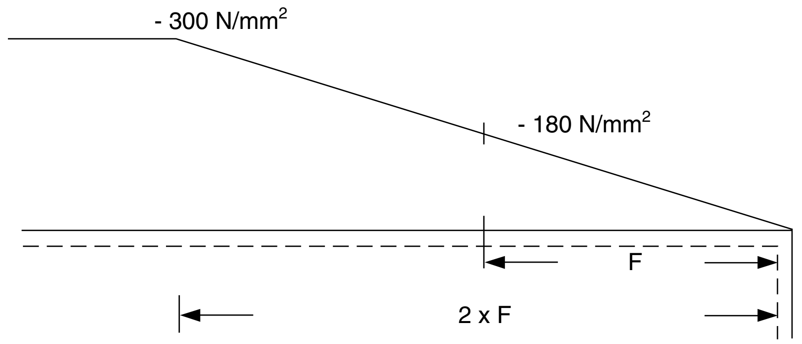
Cold installation involves several restrictions in relation to the general laying rules applicable to laying methods 1, 2 and 3.

The restrictions described in this section assume a Δt of 120°C.

As most systems operate at a Δt of approx. 60-80°C, actual restrictions will in such cases be less severe and, in effect, temperature parameters will often be such that cold installation can be used without restrictions.

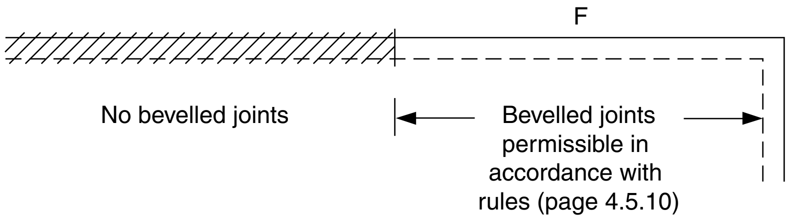
The advantages and disadvantages of cold installation are described on page 1.6.3.

With cold installation, the initial friction length will be 2 x F (where F = friction length). In response to subsequent temperature fluctuations, displacement will only occur on F.



Bevelled joints

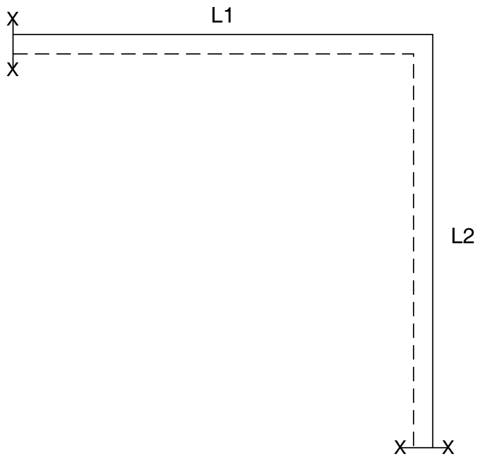
Bevelled joints may not be used on friction fixated runs.



Expansion bends

All bends must have an angle of between 80° - 100°.

For bends that are loaded from to directions, 5D bends should be used.



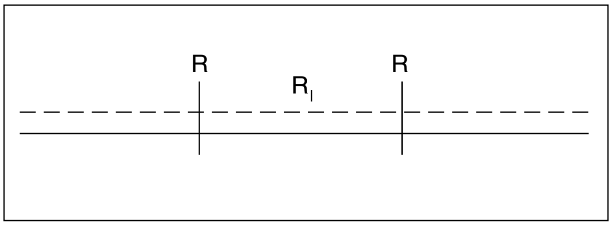
5D bends must be used if L1 + L2 is greater than F x 1.5.
3D (standard) bends can be used in all other cases.

Cold installation - laying method 4

Reducers

When cold installation is used, only reducers with a single dimension step may be established in friction fixated runs.

The distance between successive reducers (i.e. the ”reduction length”, R_l) can be found in the table below.



Dimension	R_l
ø26,9 - ø60,3	12
ø76,1-ø168,3	22
ø219,1-ø406,4	48

Permissible reduction lengths located on friction lengths are as described in the rules for laying methods 1, 2 and 3.

When cold installation is used, branches must not be established within a distance of R_l x 0.5 from a reducer.