Pre-insulated Pipes for Underground Hot Water Networks

ZPU MIĘDZYRZECZ Sp. z o.o. System

DESIGN GUIDELINES
PRE-INSULATED
TWIN SERVICE PIPE SYSTEM

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1. Introduction

1.1 Subject matter of study

The subject matter of the study comprises the principles of calculation and design of directly buried pre-insulated pipelines with two service pipes.

1.2 Scope of use

The principles of calculation and design shall be used while preparing technical documentation for the construction of pipelines made of pre-insulated pipes and fittings with two service pipes for a maximum temperature difference, between the heating medium of the supply pipe and the heating medium of the return pipe, of 90°C.

NOTE: in case of buying pre-insulated products with two service pipes, designed to work with a temperature difference of 90°C (between the heating medium of the supply pipe and the heating medium of the return pipe), the contactor is obliged to include this information in the materials order.

1.3 Building permit design

A building permit design shall be developed in accordance with the Construction Law, PN-EN13941 Standard and principles specified in these Guidelines.

2. Basic designations

2.1 Geometrical characteristics

A	Cross-sectional area of one service pipe – as active with respect to strength
DN	Service pipe nominal diameter
D_z	Service pipe outer diameter
D_{zp}	Casing pipe outer diameter
g	Service pipe wall thickness
g_p	Casing pipe wall thickness
H	Pipeline axis burial depth
L, C, D	Length of compensation arms
L	Pipeline section length
L_{max}	Pipeline installation length
ε	Pipeline unitary Expansion
ΔL	Expansion of pipeline, of length L, buried in ground
ΔL_n	Expansion of unburied pipeline, of length Ln, heated up to temperature [T_w], free Expansion
ΔL_z	Expansion of unburied pipeline, heated up to temperature [T_{max}]
L_n	Unburied pipeline section length
l_g	Pre-insulated pipe arch length
r	Bend radius of flexible pre-insulated pipes
β	Pre-insulated pipe bend angle

2.2 Loads, cross-sectional forces, load bearing capacity

V	Unitary earth pressure on casing pipe
F_T	Friction force at casing pipe side surface
N	Normal force
N_T	Normal force from thermal stresses in pre-insulated pipeline
N_z	Normal force from thermal stresses in supply service pipe
N_p	Normal force from thermal stresses in return service pipe
N_{PS}	Normal force acting on fixed point
N_{RC}	Design load-bearing capacity of twin service pipe cross section
p	Internal pressure in service pipe

2.3 Stresses and strength

σ	Normal stress
τ	Shear stress
R_e	Manufacturer's specified (standard) yield strength
R_m	Manufacturer's specified (standard) tensile strength
R_r	Breaking strength
R_s	Compression strength
σ_H	Hoop stress
σ_x	Axial stress
f_d	Reduced design strength of steel
$f_{d'}$	Design strength of steel

2.4 Material constants, coefficients and other designations

E	Longitudinal elasticity coefficient – Young's modulus
E_T	Longitudinal elasticity coefficient related to temperature
υ	Poisson's ratio
a	Linear thermal expansion coefficient
λ	Thermal conductivity coefficient
γ	Load factor
μ	Coefficient of friction between casing pipe and earth
ρ	Compacted backfill thickness
T_z	Supply pipeline operating temperature
T_p	Return pipeline operating temperature
T_o	Installation temperature
T_w	Preheat temperature
ΔT	temperature difference between supply pipe heating medium and return pipe
ρ_S	Steel density
ρ_{PE}	Casing pipe polyethylene density
ψ	Design load-bearing capacity reduction factor
k	Coefficient relating to activity of friction force between casing pipe and subsoil for unburied pipeline
K_o	Coefficient of earth pressure at rest on pre-insulated pipe

3. Materials and products

3.1 Service pipes

The service pipes comprise certified **seamless steel tubes** made of P235GH steel according to PN-EN 10216-2 or according to PN-EN 10216-1/A1, of P235TR1/P235TR2 steel or certified **welded steel tubes** according to PN-EN 10217-2/A1 and PN-EN 10217-5/A2 of P235GH steel or PN-EN 10217-1/A1, P235TR1/P235TR2 steel.

Mechanical properties according to PN-90/B-03200, PN-EN 10216-1/A1, PN-EN 10216-2, PN-EN 10217-1/A1PN-EN 10217-2\A1 and PE-EN 10217-5\A1

Product type	Steel grade	Mechanical properties			
		R_e	R_m	A_5	f_d'
		MPa	*MPa*	*%*	*MPa*
Spirally or longitudinally welded pipes	St 37.0 P235GH	235	350	25	210
Seamless rolled pipes	St 37.0 P235GH	235	345	25	210

Material constants of steel:

E = 210 GPa
ν = 0.3
$\alpha_t = 1.22 \cdot 10^{-5} / {}^oC$
ρ_s = 7,850 kg/m^3

3.2 Casing pipes

The casing pipe is manufactured in accordance with the requirements of the **PN-EN 253** standard, of high-density polyethylene (PEHD):

Product type	Mark	Mechanical properties		
		σ_H	R_r	R_s
		MPa	*MPa*	*MPa*
Casing pipe	PEHD	4.0	24.0	37.0

Material constants of PEHD:

E = 1.0 GPa
λ = 0.43 W/mK
$\alpha_t = 0.2 \cdot 10^{-5} / {}^oC$
ρ_{PE} = 950 kg/m^3

Coefficient of friction between casing pipe and earth: $\mu = 0.3 \div 0.5$

3.3 Rigid foam

The polyurethane rigid foam meets the requirements of the PN-EN 253 standard.

Uniform thickness: min 60 kg/m^3
Compression strength in radial direction:
At relative deformation of 10% — min 0.3 MPa
MDI index — min 130
Thermal conductivity coefficient for λ_{50}:
- For cyclopentane foam system — max. 0.029 W/mK

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3.4 Pipe assembly of two service pipes

The pre-insulated pipes and fittings of the twin service pipe system manufactured by ***ZPU Międzyrzecz Sp. z o.o.*** are a bonded structure comprising two service pipes placed within one casing pipe made of hard, high-density polyethylene (PEHD), where the space between them is filled evenly with rigid polyurethane foam (PUR). The pre-insulated pipes and fittings of the twin service pipe system manufactured by ***ZPU Międzyrzecz Sp. z o.o.*** are made offering "standard" and "plus" thermal insulation.

The steel service pipes, prior to the process of insulation with polyurethane foam, are permanently joined to each other by welding, by means of steel connectors. Therefore, the pre-insulated twin service-pipe single-casing system manufactured by ZPU Międzyrzecz Sp. z o.o. does not require making bare-end connections by welding steel flat end-caps or anchor plates on-site. All fittings manufactured by ZPU Międzyrzecz Sp. z o.o. made of two service pipes within one casing pipe also have inner connection so that there is no need to connect the join the steel pipes on-site by welding anchor plates or steel flat end-caps between the service pipes.

The pipe assembly - pre-insulated pipe meets the requirements of the PN-EN 253+A2 / EN253:2009+A2:2015 Standard.

Thermal conductivity coefficient at		max 0.029 W/mK
Expected life:		min 30 years
Shear strength:		
Radial	(temp. 20°C)	min 0.12 MPa
	(temp.140°C)	min 0.08 MPa
Circumferential	(temp. 20°C)	min 0.20 MPa

The pre-insulated twin service pipe system manufactured by *ZPU Międzyrzecz Sp. z o.o.* offers diameters 2×DN20 to 2×DN 200. Table No 1 provides geometrical dimensions of the pre-insulated pipes.

Dimensions of pre-insulated twin service pipes

Table 1

Steel service pipe				Casing pipe PEHD		Casing pipe PEHD	
2×DN	Dz	Welded	Seamless	"Standard" insulation		"Plus" insulation	
		min[g]	min[g]	Dzp	gp	Dzp	gp
mm	mm	mm	mm	mm	mm	Mm	mm
2x20	26.9	2.6	2.9	125	3.0	140	3.0
2x25	33.7	2.6	2.9	140	3.0	160	3.0
2x32	42.4	2.6	2.9	160	3.0	180	3.0
2x40	48.3	2.6	2.9	160	3.0	180	3.0
2x50	60.3	2.9	3.2	200	3.2	225	3.4
2x65	76.1	2.9	3.2	225	3.4	250	3.6
2x80	88.9	3.2	3.6	250	3.6	280	3.9
2x100	114.3	3.6	4.0	315	4.1	355	4.5
2x125	139.7	3.6	4.0	400	4.8	450	5.2
2x150	168.3	4.0	4.5	450	5.2	500	5.6
2x200	219.1	4.5	6.3	560	6.0	630	6.6

DN - steel pipe nominal diameter, Dz - steel pipe outer diameter, gp - service pipe wall thickness

4. Design input data

The following load values and material constants have been adopted to calculate the friction [F] between the sand bed/backfill and the casing pipe, the normal force of the service pipe cross-section [N], maximum installation length [L_{max}] and Expansion [ΔL] of pipelines of the system offered by *ZPU Międzyrzecz Sp. z o.o.*:

Pipeline axis burial depth	H	= 1m
Compacted backfill thickness	ρ	=1800 kg/m^3
Coefficient of friction between casing pipe and earth	μ	= 0.35
Coefficient of earth pressure at rest on pre-insulated pipe	K_o	= 0.6
Operating pressure in pipeline	p	= 1.6 MPa
Reduced design strength of steel	f_d	= 190 MPa
Operating temperature		
Supply (high parameter)	T_z	= 135°C
Return (high parameter)	T_p	= 70°C
Supply (high parameter)	T_z	= 100°C
Return (high parameter)	T_p	= 70°C
Supply (low parameter)	T_z	= 95°C
Return (low parameter)	T_p	= 70°C
Supply (low parameter)	T_z	= 95°C
Return (low parameter)	T_p	= 65°C
Installation temperature	T_0	= 8°C
Longitudinal elasticity coefficient related to temperature - Young's modulus	E_T	= 210 GPa
Linear thermal expansion coefficient		
For range 0÷100^{O}C	a_T	= 1.2·10^{-5}/°C
For range 0÷150^{O}C	a_T	= 1.22·10^{-5}/°C
Load factors:		
Load bearing capacity limit state	γ	= 1.1
Serviceability limit state	γ	= 1.0
Poisson's ratio	ν	= 0.3

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5. Principles of design of pre-insulated pipes with two service pipes

5.1 Dimensioning method

The dimensioning of a pipeline structure is made by the load bearing capacity and serviceability limit state method according to PN-76/B-03001, PN-EN 13941, demonstrating that the condition of pipeline load bearing capacity is fulfilled in the operational phase of the pipeline.

5.2 Loads

A directly buried pre-insulated pipeline is subjected to the following loads:

- Friction forces at the casing pipe side surface,
- Earth pressure forces on the casing pipe,
- Forces originating from the pressure in the service pipe,
- Forces from thermal stresses.

The permanent bonding of the supply service pipe with the return service pipe results in concurrent expansion of both pipes (geometric deformation continuity condition).

Due to the temperature difference of the heating medium between the supply pipe and the return pipe, as well as owing to the permanent bonding of the two service pipes, stresses will occur within the pipes: compressive ones on the supply side and tensile ones on the return side.

Thus, we have a static structure of a limited degree of free expansion in which, in case of a temperature increase or decrease, normal forces will occur dependent on the friction forces, the pressure inside the service pipe and on the difference in temperature of the heating medium in the supply pipe and the return pipe.

5.2.1 Earth pressure force on pipe

The unitary earth pressure at rest on the pipeline shall be determined according to PN-83/B-03010 in accordance with the formula below:

- Vertical component $V_z = \gamma \cdot H \cdot \rho \cdot g_z$ [N/m^2]
- Horizontal component $V_x = \gamma \cdot H \cdot \rho \cdot g_z \cdot K_0$ [N/m^2]

in which:

γ - *Load factor*

H - *Pipeline axis burial depth* [m]

ρ - *Compacted backfill thickness* [kg/m^3]

g_z - *Gravitational acceleration* [m/s^2]

K_O - *Coefficient of pressure at rest*

To determine the unitary earth pressure on the pipeline, as equally distributed around the circumference, a mean value is adopted and calculated from the following formula:

$$V = 0{,}5 \cdot (V_z + V_x)$$

5.2.2 Friction force at casing pipe surface

The friction force per pipe unit of length [F_T] is calculated from the following formula:

$$F_T = \mu \cdot V \cdot \pi \cdot D_{zp} \qquad [N/m]$$

Where:

μ - Coefficient of friction between casing pipe and earth

V - Unitary earth pressure on casing pipe [N/m^2]

Dzp - Casing pipe outer diameter [m]

5.2.3 Normal force [N] in service pipes from friction force load

The normal force [N] in service pipes, of length [L], from friction force load, is calculated from the following formula:

$$N = F_T \cdot L \qquad [N]$$

Where:

F_T - *Friction force per pipeline unit of length* [N/m]

L - *Pipeline section length* [m]

5.3 Forces related to internal pressure in service pipes

It is assumed that the load from the internal pressure exerted by the heating medium is taken by the service pipe, in which stresses occur:

- Circumferential $$\sigma_H = \frac{p \cdot (D_z - g)}{2 \cdot g} \qquad [N/m^2]$$

- Axial $$\sigma_x = \frac{p \cdot (D_z - g)}{4 \cdot g} \qquad [N/m^2]$$

Where:

p - Service pipe inner diameter [N/m^2]

D_Z - Service pipe outer diameter [m]

g - Service pipe wall thickness [m]

The nominal force from internal pressure in one service pipe - related to axial stress σ_x

$$N_x = \sigma_x \cdot A \qquad [N]$$

Where:

A - *Cross-sectional area of one service pipe* [m^2]

Hence the normal force from internal pressure in the service pipes equals, as follows:

$$2 \times N_x = 2 \times \sigma_x \cdot A \qquad [N]$$

5.4 Axial stresses resulting from difference in temperature between supply and return pipelines

As a result of the temperature difference of the heating medium in the service pipes and the geometric deformation agreement - expansion of both pipes, stresses occur:

- Compressive stresses - on the supply side

$$\sigma_z = \frac{N_z}{A} \qquad [N/m^2]$$

- Tensile stresses - on the return side

$$\sigma_p = \frac{N_p}{A} \qquad [N/m^2]$$

Where:

N_z – Normal force from thermal stresses in supply pipeline

$$N_z = \alpha_T \times (T_z - T_o) \times A \times E_T$$

N_p – Normal force from thermal stresses in supply pipeline

$$N_p = \alpha_T \times (T_p - T_o) \times A \times E_T$$

Hence the normal from thermal stresses in pre-insulated twin pipeline equals:

$$N_T = \alpha_T \times 2 \times A \times E_T \times \frac{(T_z - T_p)}{2}$$

Where:

A	- Cross-sectional area of one service pipe	[m^2]
σ_T	- Axial stresses in service pipes resulting from temperature difference in supply and return pipelines	[N/m^2]
N_T	- Normal force in pre-insulated pipeline from thermal stresses	[N]
a_t	- Linear expansion coefficient	[$1/^oC$]
T_z	- Supply pipeline design temperature	[^oC]
T_p	- Return pipeline design temperature	[^oC]
T_o	- Installation temperature	[^oC]
E_T	- Longitudinal elasticity coefficient – Young's modulus	[N/m^2]

5.5 Design load-bearing capacity of service pipe cross section

The basic load-bearing condition must be met – the normal force in service pipes must not exceed their design load-bearing capacity, that is:

$$N - 2N_X + N_p - N_z \leq N_{RC} \qquad [N]$$

Having substituted for

- Normal force in pre-insulated pipe from friction $N = F_T \times L$,
- Normal force from internal pressure $2 \times N_x = 2 \times \sigma_x \times A$,
- Normal force in pre-insulated pipe from thermal stresses

$$N_T = \alpha_T \times 2A \times E_T \times \frac{(T_z - T_p)}{2}$$

- Design load-bearing capacity of two service pipe's cross section $N_{RC} = \psi \cdot 2A \cdot f_d$

Hence:

$$F_T \times L - \sigma_x \times 2A + A \times E_T \times \alpha_T \times (T_z - T_p) \leq \psi \times 2A \times f_d \qquad [N]$$

Where:

F_T - Unitary friction force	[N/m]
L - Pipeline section length	[m]
ψ - Design load-bearing capacity reduction factor	
A - Cross-sectional area of service pipe	[mm^2]
f_d - Reduced design strength of steel	[MPa]
σ_x - Axial stresses	[N/m^2]
α_t - Linear expansion coefficient	[1/^{O}C]
T_z - Supply pipeline design temperature	[^{O}C]
T_p - Return pipeline design temperature	[^{O}C]
T_o - Installation temperature	[^{O}C]
E_T - Longitudinal elasticity coefficient – Young's modulus	[N/m^2]

6 Designing hot water network using system offered by ZPU Międzyrzecz Sp. z o.o.

The designing consists in determination of the following:

- The pipeline installation length [L_{max}], for which the maximum normal force in the service pipes [N_{max}] does not exceed the design load-bearing capacity of the service pipes [N_{RC}],

- The pipeline expansion [ΔL] and compensating for it in a natural way by changing the pipeline route (compensation systems).

6.1 Method I - Natural

The pipeline, following installation and testing, is buried.

6.1.1 Maximum installation length [L_{max}] of straight section of pipeline

According to 5.5, the condition for design load-bearing capacity of a service pipe's cross section is defined by the following formula:

$$F_T \times L - \sigma_x \times 2A + A \times E_T \times \alpha_T \times (T_z - T_p) \leq \psi \times 2A \times f_d$$

Where:

F_T - Unitary friction force	[N/m]
L - Pipeline section length	[m]
ψ - Design load-bearing capacity reduction factor	
A - Cross-sectional area of service pipe	[mm^2]
f_d - Reduced design strength of steel	[MPa]
σ_x - Axial stresses	[N/m^2]
α_t - Linear expansion coefficient	[1/^{o}C]
T_z - Supply pipeline design temperature	[^{o}C]
T_p - Return pipeline design temperature	[^{o}C]
E_T - Longitudinal elasticity coefficient	[N/m^2]

If $L = L_{max}$ and assuming $\psi = 1$ (Class 1 of cross section), the maximum installation length [L_{max}] equals:

$$L_{max} = \frac{2A \times \left[f_d + \sigma_x - E_T \times \alpha_T \times \left(\frac{T_z - T_p}{2}\right) \right]}{F_T} \quad \text{[m]}$$

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Tables No 2, 3, 4, 5, 6 and 7 provide maximum installation lengths $[L_{max}]$ of pre-insulated twin service pipe systems for the assumed pipeline axis depth $H = 1.0\ m$ and the assumed design input data as per Section 4.

High parameter ΔT=(135-70)=65ºC H=1.0m

Table 2

Seamless service pipes			Casing pipe	Friction force	Installation length
2×Dz	g	2×A	Dzp	F_T	L_{max}
mm	*mm*	*mm²*	*Mm*	*N/m*	*m*
2×26.9	2.9	437	125	2,135	22.5
2×33.7	2.9	561	140	2,391	26.0
2×42.4	2.9	719	160	2,732	29.5
2×48.3	2.9	827	160	2,732	34.2
2×60.3	3.2	1,147	200	3,415	38.2
2×76.1	3.2	1,465	225	3,842	44.2
2×88.9	3.6	1,928	250	4,269	52.5
2×114.3	4.0	2,771	315	5,379	60.7
2×139.7	4.0	3,409	400	6,831	60.0
2×168.3	4.5	4,629	450	7,685	73.1
2×219.1	6.3	8,419	560	9,563	105.9

High parameter ΔT=(100-70)=30ºC and low parameter ΔT=(95-65)=30ºC H=1.0m

Table 3

Seamless service pipes			Casing pipe	Friction force	Installation length
2×Dz	g	2×A	Dzp	F_T	L_{max}
mm	*mm*	*mm²*	*Mm*	*N/m*	*m*
2×26.9	2.9	437	125	2,135	31.8
2×33.7	2.9	561	140	2,391	36.7
2×42.4	2.9	719	160	2,732	41.5
2×48.3	2.9	827	160	2,732	48.0
2×60.3	3.2	1,147	200	3,415	53.5
2×76.1	3.2	1,465	225	3,842	61.5
2×88.9	3.6	1,928	250	4,269	73.0
2×114.3	4.0	2,771	315	5,379	84.1
2×139.7	4.0	3,409	400	6,831	82.7
2×168.3	4.5	4,629	450	7,685	100.4
2×219.1	6.3	8,419	560	9,563	145.9

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Low parameter ΔT=(95-70)=25ºC H=1.0m

Table 4

Seamless service pipes			Casing pipe	Friction force	Installation length
2×Dz	g	2×A	Dzp	F_T	L_{max}
mm	*mm*	*mm*^{2}	*Mm*	*N/m*	*m*
2×26.9	2.9	437	125	2,135	33.1
2×33.7	2.9	561	140	2,391	38.2
2×42.4	2.9	719	160	2,732	43.1
2×48.3	2.9	827	160	2,732	49.9
2×60.3	3.2	1,147	200	3,415	55.6
2×76.1	3.2	1,465	225	3,842	63.9
2×88.9	3.6	1,928	250	4,269	75.9
2×114.3	4.0	2,771	315	5,379	87.3
2×139.7	4.0	3,409	400	6,831	85.9
2×168.3	4.5	4,629	450	7,685	104.2
2×219.1	6.3	8,419	560	9,563	151.4

High parameter ΔT=(135-70)=65ºC H=1.0m

Table 5

Welded service pipes			Casing pipe	Friction force	Installation length
2×Dz	g	2×A	Dzp	F_T	L_{max}
mm	*mm*	*mm*^{2}	*Mm*	*N/m*	*m*
2×26.9	2.6	397	125	2,135	20.5
2×33.7	2.6	508	140	2,391	23.7
2×42.4	2.6	650	160	2,732	26.9
2×48.3	2.6	746	160	2,732	31.1
2×60.3	2.9	1,045	200	3,415	35.1
2×76.1	2.9	1,333	225	3,842	40.5
2×88.9	3.2	1,722	250	4,269	47.4
2×114.3	3.6	2,503	315	5,379	55.4
2×139.7	3.6	3,077	400	6,831	54.9
2×168.3	4.0	4,127	450	7,685	66.1
2×219.1	4.5	6,065	560	9,563	79.8

High parameter ΔT=(100-70)=30ºC and low parameter ΔT=(95-65)=30ºC H=1.0m

Table 6

Welded service pipes			Casing pipe	Friction force	Installation length
2×Dz	g	2×A	Dzp	F_T	L_{max}
mm	*mm*	*mm²*	*Mm*	*N/m*	*m*
2×26.9	2.6	397	125	2,135	29.0
2×33.7	2.6	508	140	2,391	33.4
2×42.4	2.6	650	160	2,732	37.7
2×48.3	2.6	746	160	2,732	43.5
2×60.3	2.9	1,045	200	3,415	49.0
2×76.1	2.9	1,333	225	3,842	56.3
2×88.9	3.2	1,722	250	4,269	65.7
2×114.3	3.6	2,503	315	5,379	76.5
2×139.7	3.6	3,077	400	6,831	75.4
2×168.3	4.0	4,127	450	7,685	90.6
2×219.1	4.5	6,065	560	9,563	108.6

Low parameter ΔT=(95-70)=25ºC H=1.0m

Table 7

Welded service pipes			Casing pipe	Friction force	Installation length
2×Dz	g	2×A	Dzp	F_T	L_{max}
mm	*mm*	*mm²*	*Mm*	*N/m*	*m*
2×26.9	2.6	397	125	2,135	30.2
2×33.7	2.6	508	140	2,391	34.7
2×42.4	2.6	650	160	2,732	39.2
2×48.3	2.6	746	160	2,732	45.2
2×60.3	2.9	1,045	200	3,415	50.9
2×76.1	2.9	1,333	225	3,842	58.5
2×88.9	3.2	1,722	250	4,269	68.3
2×114.3	3.6	2,503	315	5,379	79.5
2×139.7	3.6	3,077	400	6,831	78.2
2×168.3	4.0	4,127	450	7,685	93.9
2×219.1	4.5	6,065	560	9,563	112.6

The Installation length $L_{max}^{H_i}$ and unitary friction force F_T^{Hi} of a pipeline buried at the depth H_i can be determined from the following formulas:

$$L_{max}^{H_i} = \frac{L_{max}}{H_i} \qquad F_T^{\ Hi} = F_T \cdot H_i$$

e.g. for: $2\times D_z = 2\times 26.9\ mm$ $g = 2.9\ mm$ *(Welded)* *for* $\Delta T = (135°-70°)$
$L_{max} = 20.5\ m$ $F_T = 2.135 N/m$ -acc. To Table 5 for H=1.0m

for H_i = 0.6 m $L_{max}^{0.6} = \frac{20,5}{0.6} = 34,17m$ $F_T^{0.6} = 2.135 \cdot 0.6 = 1.281\ N/m$

In case of application of a steel service pipe of another sectional area (A) than provided in Tables No 2, 3, 4, 5, 6 and 7, L_{max} shall be adjusted on a pro-rata basis.

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6.1.2 Pipeline expansion

The expansion [ΔL] of a pre-insulated pipeline, buried, of installation length [L], is determined as the difference of free expansion from temperature increase and expansion relating to friction forces, from the following formula:

$$\Delta L = \alpha_t \left(\frac{T_z + T_p}{2} - T_0 \right) \cdot L - \frac{F_T^{Hi} \cdot L^2}{2 \cdot E_T \cdot 2A}$$

Where:

a_t - Linear expansion coefficient	[1/^{o}C]
T_z - Supply pipeline design temperature	[^{o}C]
T_p - Return pipeline design temperature	[^{o}C]
T_o - Installation temperature	[^{o}C]
L - Pipeline section length	[m]
F_T^{Hi} - Unitary friction force of pipeline buried at depth H_i	[N/m]
E_T - Longitudinal elasticity coefficient - Young's modulus	[N/m^2]
A - Cross-sectional area of one service pipe	[m^2]

Following substitution of the input data (as per Section 4), a simplified form of the expansion formula [ΔL] is obtained, as expressed in [mm]:

For $\Delta T = (\frac{135+70}{2} - 8)^{o}C$	$\Delta L = 1.1529\times L - W\times H\times L^2$	[mm]
For $\Delta T = (\frac{100+70}{2} - 8)^{o}C$	$\Delta L = 0.9240\times L - W\times H\times L^2$	[mm]
For $\Delta T = (\frac{95+70}{2} - 8)^{o}C$	$\Delta L = 0.8940\times L - W\times H\times L^2$	[mm]

Where:

1.1529; 0.9240 and 0.8940 - constants	[mm/m]
W - Coefficient relating to service pipe cross-section provided in Tables No 8 and 9	[mm/m^3]
H - Pipeline burial depth	[m]
L - Pipeline section length	[m]

"W" coefficient for determination of pipeline expansion

Table 8

Seamless service pipe			Coefficient	
			"Standard" insulation	*"Plus" insulation*
Dz	g	A	W	W
mm	*mm*	*mm²*	*mm/m³*	*mm/m³*
2×26.9	2.9	437	0.0116	0.0130
2×33.7	2.9	561	0.0101	0.0116
2×42.4	2.9	719	0.0090	0.0102
2×48.3	2.9	827	0.0079	0.0089
2×60.3	3.2	1,147	0.0071	0.0080
2×76.1	3.2	1,465	0.0062	0.0069
2×88.9	3.6	1,928	0.0053	0.0059
2×114.3	4.0	2,771	0.0046	0.0052
2×139.7	4.0	3,409	0.0048	0.0054
2×168.3	4.5	4,629	0.0040	0.0044
2×219.1	6.3	8,419	0.0027	0.0030

Table 9

Welded service pipe			Coefficient	
			"Standard" insulation	*"Plus" insulation*
Dz	g	A	W	W
mm	*mm*	*Mm²*	*mm/m³*	*mm/m³*
2×26.9	2.6	397	0.0128	0.0143
2×33.7	2.6	508	0.0112	0.0128
2×42.4	2.6	650	0.0100	0.0113
2×48.3	2.6	746	0.0087	0.0098
2×60.3	2.9	1,045	0.0078	0.0088
2×76.1	2.9	1,333	0.0069	0.0076
2×88.9	3.2	1,722	0.0059	0.0066
2×114.3	3.6	2,503	0.0051	0.0058
2×139.7	3.6	3,077	0.0053	0.0059
2×168.3	4.0	4,127	0.0044	0.0049
2×219.1	4.5	6,065	0.0038	0.0042

E.g. for: **$2 \times D_z = 2 \times 88.9$ mm g = 3.2 mm (Welded) for $\Delta T = (135° - 70°)$ and „Standard" insulation $W = 0.0059 mm/m^3$ *-acc. to Table 9***

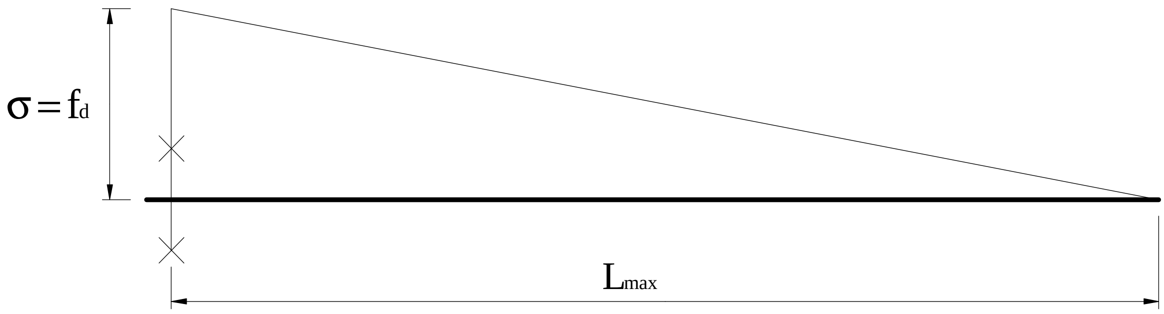
ΔL for L = 40m and H=0.6m

Equals

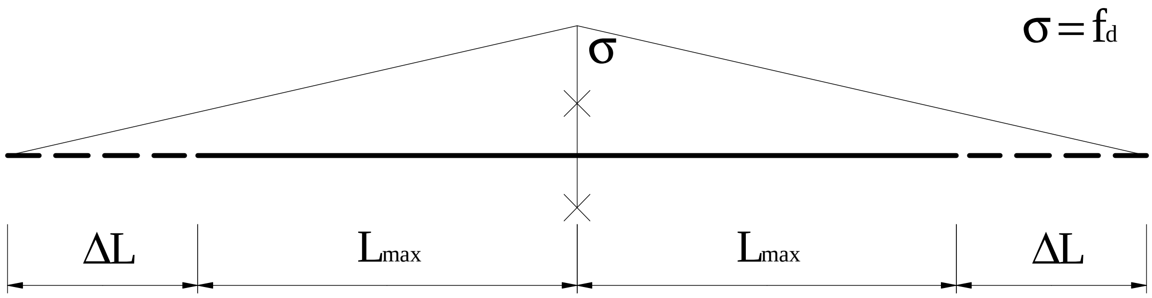
$$\Delta L = 1.1529 \times L - W \times H \times L^2 = 1.1529 \times 40 - 0.0059 \times 0.6 \times 40^2 = 40.452 mm$$

6.1.3 Expansion compensation

The normal stress state [σ] and expansion [ΔL] of a buried pipeline (at the installation temperature, without preheating), and then operated at maximum design temperature ($T_{max}=\frac{T_{z\max}+T_{p\max}}{2}$) of installation length [L_{max}], at which reduced design steel [f_d] of the service pipe's section is not exceeded, is illustrated by the below diagram:



Thus the length of straight sections of the pipeline should not exceed $2 \, x \, L_{max}$, wherein at the span centre expansion ΔL = *0* and a virtual (conventional) fixed point is determined – the pipe becomes ”fixed”, and at the free ends of the pipeline expansion [ΔL] will occur.



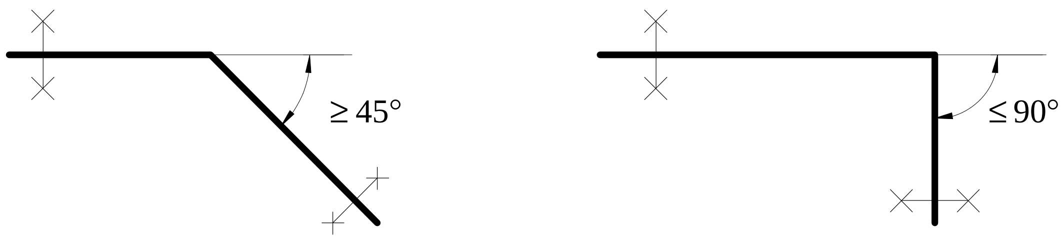
Expansions occurring in pipelines are compensated by changing the pipeline route (natural compensation).

Depending on the geometric shape of the route, natural compensation comprises, as follows:

- **L**-shape layout,
- **Z**-shape layout,
- **U**-shape layout.

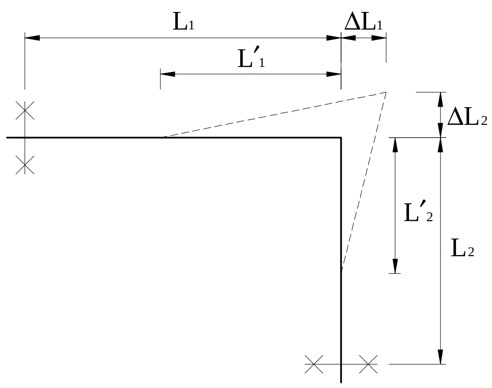
6.1.4 L-shape layout

The **L**-shape compensation layout includes rerouting at an angle from 45^{o} to 90^{o}.



Calculation of expansions and length of compensation arms

L90 compensation layout – rerouting by 90^{o}



$L_1 < L_{max}$
$L_2 < L_{max}$

The length of compensation arms [*L*'] is calculated from the following formulas:

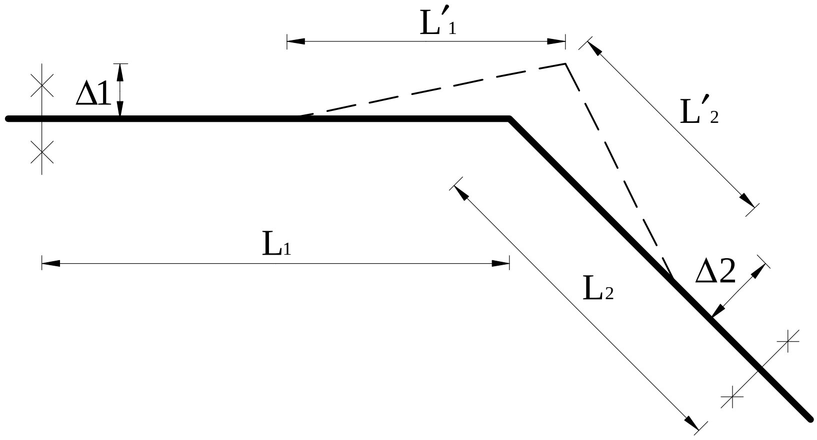
$$L'_1 = \sqrt{\frac{1{,}5 \times E_T}{f_d}} \times \sqrt{D_z \times \Delta L_2}$$

$$L'_2 = \sqrt{\frac{1{,}5 \times E_T}{f_d}} \times \sqrt{D_z \times \Delta L_1}$$

Where:

D_z	- Service pipe outer diameter	[m]
f_d	- Reduced design strength of steel	[MPa]
E_T	- Longitudinal elasticity coefficient	[MPa]
ΔL_1	- Expansion of section L_1 (to be calculated acc. to 6.1.2)	[m]
ΔL_2	- Expansion of section L_2 (to be calculated acc. to 6.1.2)	[m]

L≥45⁰ compensation layout – rerouting by ≥ 45⁰



The length of compensation arms [L'_1] and [L'_2] is calculated relating to the reduced expansions $\Delta 1$ and $\Delta 2$, from the following formula:

$$L'_1 = \sqrt{\frac{1{,}5 \times E_T}{f_d}} \times \sqrt{D_z \times \Delta 1}$$

$$L'_2 = \sqrt{\frac{1{,}5 \times E_T}{f_d}} \times \sqrt{D_z \times \Delta 2}$$

Where:

D_z - Service pipe outer diameter	[m]
f_d - Reduced design strength of steel	[MPa]
E_T - Longitudinal elasticity coefficient	[MPa]
$\Delta 1$ - reduced Expansion of section L_1	[m]
$\Delta 2$ - reduced Expansion of section L_2	[m]

The reduced expansion values are calculated from the following formula:

$$\Delta 1 = \frac{\Delta L_2}{tg\alpha} + \frac{\Delta L_1}{\sin\alpha} \quad [mm]$$

$$\Delta 2 = \frac{\Delta L_2}{\sin\alpha} + \frac{\Delta L_1}{tg\alpha} \quad [mm]$$

Where:

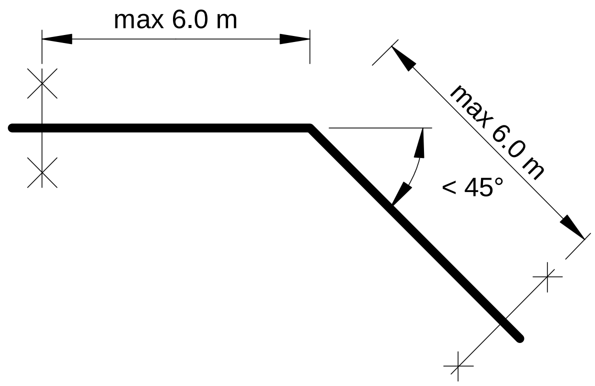
α - Flare angle

ΔL_1 - Expansion of section L_1 (calculated acc. to 6.1.2)	[m]
ΔL_2 - Expansion of section L_2 (calculated acc. to 6.1.2)	[m]

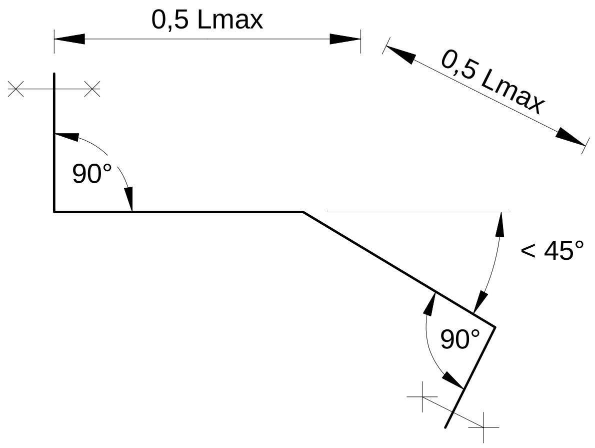
Specific requirements

A layout is not considered as a compensation one in case of changing the route a tan angle $8^{o} < \alpha < 45^{o}$. Such a layout should be overload-protected by means of a fixed point at a maximum distance of **L = 6.0** m or an L 90 compensation layout at a distance of no more than $0.5 \bullet L_{max}$. Rerouting by ≤ 7 ° comprises a pipe arch which should be regarded as a straight section of the pipeline.

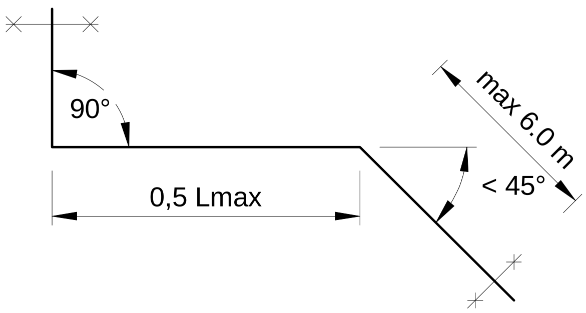
a)



b)



c)



L-shape layout

Table No 12 provides minimum lengths of compensation arms [*L'*] of the L-shape layout for thermal expansions [*ΔL*] originating in pipeline section L_{max} buried at a pipeline axis depth of H=1.0m.

E = 210 GPa

f_d = 190 MPa

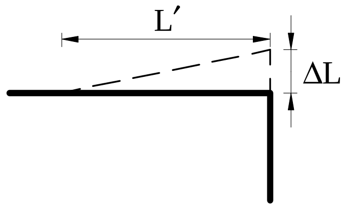
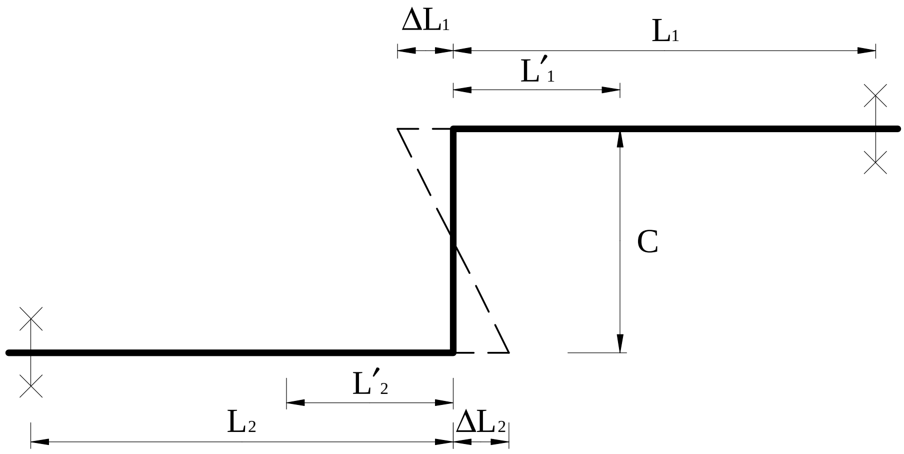


Table 12

Welded service pipes		Casing pipe	Installation length	Pipeline thermal expansion	Minimum length of compensation arm	Installation length	Pipeline thermal expansion	Minimum length of compensation arm	Installation length	Pipeline thermal expansion	Minimum length of compensation arm
			$\Delta T = (\frac{135+70}{2} - 8)^oC$			$\Delta T = (\frac{100+70}{2} - 8)^oC$			$\Delta T = (\frac{95+70}{2} - 8)^oC$		
2×Dz	g	Dzp	L_{max}	ΔL	L'	L_{max}	ΔL	L'	L_{max}	ΔL	L'
mm	*mm*	*Mm*	*m*	*mm*	*m*						
2×26.9	2.6	125	20.5	18.25	1.08	29.0	16.03	1.01	30.2	15.32	0.99
2×33.7	2.6	140	23.7	21.03	1.30	33.4	18.36	1.22	34.7	17.53	1.19
2×42.4	2.6	160	26.9	23.77	1.55	37.7	20.61	1.44	39.2	19.67	1.41
2×48.3	2.6	160	31.1	27.42	1.78	43.5	23.69	1.65	45.2	22.59	1.61
2×60.3	2.9	200	35.1	30.88	2.11	49.0	26.59	1.96	50.9	25.35	1.91
2×76.1	2.9	225	40.5	35.44	2.54	56.3	30.27	2.35	58.5	28.81	2.29
2×88.9	3.2	250	47.4	41.39	2.96	65.7	35.23	2.73	68.3	33.53	2.67
2×114.3	3.6	315	55.4	48.17	3.63	76.5	40.74	3.33	79.5	38.73	3.25
2×139.7	3.6	400	54.9	47.36	3.97	75.4	39.62	3.64	78.2	37.59	3.54
2×168.3	4.0	450	66.1	56.84	4.78	90.6	47.32	4.36	93.9	44.85	4.25
2×219.1	4.5	560	79.8	68.09	5.97	108.6	56.07	5.42	112.6	53.07	5.27

6.1.5 Z-shape layout

The length of compensation arm [*C*] of a Z-shape layout is calculated from the following formula:



$$C = \sqrt{\frac{1.5 \cdot E_T}{f_d}} \cdot \sqrt{D_z \cdot \Delta L} \quad \text{[m]}$$

Where:

D_z - Service pipe outer diameter [m]

f_d - Reduced design strength of steel [MPa]

E_T - Longitudinal elasticity coefficient [MPa]

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

ΔL_1 - Expansion of section L_1 (to be calculated acc. to 6.1.2) [m]

ΔL_2 - Expansion of section L_2 (to be calculated acc. to 6.1.2) [m]

Z-shape layout

Table No 13 provides minimum lengths of compensation arms [C] of the Z-shape layout for thermal expansions [ΔL] originating in pipeline section L_{max} buried at a pipeline axis depth of H=1.0m. The length of compensation arms [*C*] depending on expansion [ΔL].

E = 210 GPa

f_d = 190 MPa

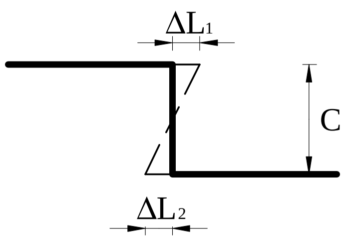


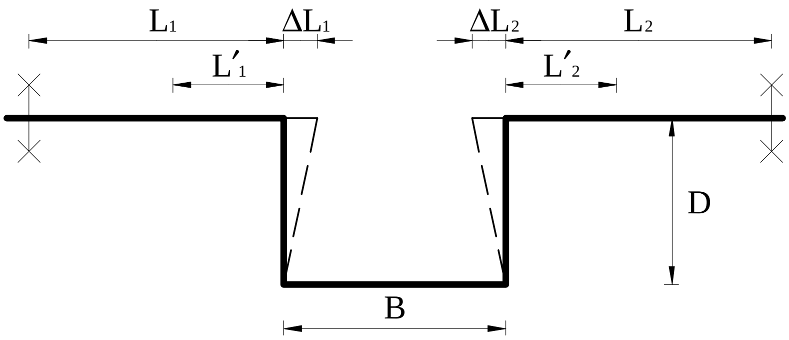
Table 13

Welded service pipes		Casing pipe	Installation length	Pipeline thermal expansion	Minimum length of compensation arm	Installation length	Pipeline thermal expansion	Minimum length of compensation arm	Installation length	Pipeline thermal expansion	Minimum length of compensation arm
			$\Delta T = (\frac{135+70}{2} - 8)^oC$			$\Delta T = (\frac{100+70}{2} - 8)^oC$			$\Delta T = (\frac{95+70}{2} - 8)^oC$		
2×Dz	g	Dzp	L_{max}	2xΔL	C	L_{max}	2xΔL	C	L_{max}	2xΔL	C
mm	*mm*	*Mm*	*m*	*mm*	*m*						
2×26.9	2.6	125	20.5	36.50	1.28	29.0	32.06	1.20	30.2	30.64	1.17
2×33.7	2.6	140	23.7	42.06	1.53	33.4	36.72	1.43	34.7	35.06	1.40
2×42.4	2.6	160	26.9	47.54	1.83	37.7	41.22	1.70	39.2	39.34	1.66
2×48.3	2.6	160	31.1	54.84	2.10	43.5	47.38	1.95	45.2	45.18	1.90
2×60.3	2.9	200	35.1	61.76	2.48	49.0	53.18	2.31	50.9	50.70	2.25
2×76.1	2.9	225	40.5	70.88	2.99	56.3	60.54	2.76	58.5	57.62	2.70
2×88.9	3.2	250	47.4	82.78	3.49	65.7	70.46	3.22	68.3	67.06	3.14
2×114.3	3.6	315	55.4	96.34	4.27	76.5	81.48	3.93	79.5	77.46	3.83
2×139.7	3.6	400	54.9	94.72	4.68	75.4	79.24	4.28	78.2	75.18	4.17
2×168.3	4.0	450	66.1	113.68	5.63	90.6	94.64	5.14	93.9	89.70	5.00
2×219.1	4.5	560	79.8	136.18	7.03	108.6	112.14	6.38	112.6	106.14	6.21

6.1.6 U-shape layout

A layout is regarded as a U-shape one whose length of arms [D] falls within the following limits:

$$B \le D \le 2 * B$$



The length of compensation arms [D] of a U-shape layout is calculated from the following formula:

$$D = 0.7 \cdot \sqrt{\frac{1.5 \cdot E_T}{f_d}} \cdot \sqrt{D_z \cdot \Delta L} \quad [m]$$

Where:

D_z - Service pipe outer diameter [m]
f_d - Reduced design strength of steel [MPa]
E_T - Longitudinal elasticity coefficient [MPa]

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

ΔL_1 - Expansion of section L_1 (to be calculated acc. to 6.1.2) [m]
ΔL_2 - Expansion of section L_2 (to be calculated acc. to 6.1.2) [m]

U-shape layout

Table No 14 provides minimum lengths of compensation arms [D] of the U-shape layout for thermal expansions [ΔL] originating in pipeline section L_{max} buried at a pipeline axis depth of H=1.0m. The length of compensation arms [D] depending on expansion [ΔL].

E = 210 GPa
f_d = 190 MPa

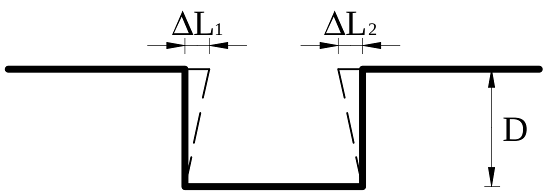


Table 14

Welded service pipes		Casing pipe	Installation length	Pipeline thermal expansion	Minimum length of compensation arm	Installation length	Pipeline thermal expansion	Minimum length of compensation arm	Installation length	Pipeline thermal expansion	Minimum length of compensation arm
			$\Delta T = (\frac{135+70}{2} - 8)^oC$			$\Delta T = (\frac{100+70}{2} - 8)^oC$			$\Delta T = (\frac{95+70}{2} - 8)^oC$		
2×Dz	g	Dzp	L_{max}	ΔL	L’	L_{max}	ΔL	L’	L_{max}	ΔL	L’
mm	mm	Mm	m	mm	m						
2×26.9	2.6	125	20.5	36.50	0.89	29.0	32.06	0.84	30.2	30.64	0.82
2×33.7	2.6	140	23.7	42.06	1.07	33.4	36.72	1.00	34.7	35.06	0.98
2×42.4	2.6	160	26.9	47.54	1.28	37.7	41.22	1.19	39.2	39.34	1.16
2×48.3	2.6	160	31.1	54.84	1.47	43.5	47.38	1.36	45.2	45.18	1.33
2×60.3	2.9	200	35.1	61.76	1.74	49.0	53.18	1.61	50.9	50.70	1.58
2×76.1	2.9	225	40.5	70.88	2.09	56.3	60.54	1.93	58.5	57.62	1.89
2×88.9	3.2	250	47.4	82.78	2.45	65.7	70.46	2.26	68.3	67.06	2.20
2×114.3	3.6	315	55.4	96.34	2.99	76.5	81.48	2.75	79.5	77.46	2.68
2×139.7	3.6	400	54.9	94.72	3.28	75.4	79.24	3.00	78.2	75.18	2.92
2×168.3	4.0	450	66.1	113.68	3.94	90.6	94.64	3.60	93.9	89.70	3.50
2×219.1	4.5	560	79.8	136.18	4.92	108.6	112.14	4.47	112.6	106.14	4.35

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Example

Data:

- *Service pipe outer diameters* $2{\times}D_z = 2{\times}88.9$ *mm,*
- *Service pipe (welded) wall thickness g = 3.2 mm,*
- *Maximum temperature in supply pipeline +135℃,*
- *Maximum temperature in return pipeline +70℃,*
- *Installation temperature +8℃,*
- *HDPE casing pipe diameter Dzp=250mm,*
- *Length of straight section of pipeline from virtual or actual fixed point to compensation elbow L = 40m,*
- *Pipeline burial depth from ground surface to pre-insulated pipeline axis H=0.6m;*

For: $2{\times}D_z = 2{\times}88.9$ *mm with wall g = 3.2 mm (welded pipes) for ΔT=(135°-70°) and "Standard" insulation, from Table No 9 – we take coefficient W= 0.0059mm/m*^{3}

For L = 40m and H=0.6m, using the formula acc. to 6.1.2 (simplified) – we calculate pipeline expansion

$\Delta L = 1{,}1529 \times L - W{\times}H{\times}L^2 = 1{,}1529{\times}40 - 0{,}0059{\times}0{,}6{\times}40^2 = 40{,}452mm$

In order to calculate the compensation arms of a twin pipeline for the L-, Z- and U-shape layout, the diameter of one service pipe must be considered, as for single steel pipe bending,

- *Hence for the L-shape layout, using the formula acc. to in 6.1.4, the length of the compensation arm L' equals:*

$$L' = \sqrt{\frac{1{,}5\times10^3\times210}{190}}\times\sqrt{0{,}0889\times0{,}040452} = 2{,}44m$$

- *For the Z-shape layout in 6.1.5, if* $L_1 = L_2 = 40m$

  ΔL=40.452mm+40.452mm=80.904mm - the length of the compensation arm C_{min} *equals:*

$$C_{\min} = \sqrt{\frac{1{,}5\times10^3\times210}{190}}\times\sqrt{0{,}0889\times0{,}080904} = 3{,}45m$$

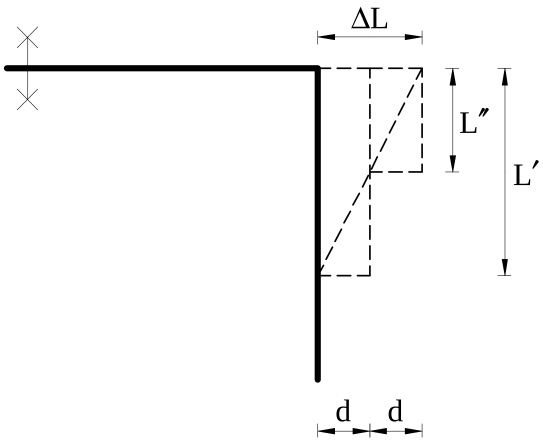
- *For the U-shape layout in 6.1.6, if* $L_1 = L_2 = 40m$

  ΔL=40.452mm+40.452mm=80.904mm - the length of the compensation arm D_{min} *equals:*

$$D_{\min} = 0{,}7\times\sqrt{\frac{1{,}5\times10^3\times210}{190}}\times\sqrt{0{,}0889\times0{,}080904} = 2{,}415m$$

6.1.7 Compensation zones

A compensation zone is to be understood as space in the ground at the pipe, limited by the length of the compensation arm [L'] and expansions [ΔL], as occurring, in which reduction of the load acting on the pipeline or elbow section is expected to occur from the pipeline pressure on the ground. It is recommended that the compensation zone be filled in along the section $L = 2/3L'$.



We recommend, as follows:

In order to fill a compensation zone with e,g, mineral wool mats or foam boards, the arrangement of individual layers should be graded, assuming that if one layer of the mat of the thickness [d] takes a part of the expansion [ΔL] along the length [L'], then the second mat should be of a length [L''], being:

$$L'' = \frac{\Delta L - d}{\Delta L} \cdot L' \quad \text{[m]}$$

6.2 Method II - Preload

The pipeline, following assembly, tightness tests and non-destructive testing of welded joints, prior to burying, is subjected to preheating. The pipeline, having achieved the required expansion, is buried.

The pipeline preheat temperature [T_w] is assumed at such a value that, having cooled the buried pipeline down to the installation temperature [T_o] and reheated up to the maximum operating temperature [$\frac{T_{z\max} + T_{p\max}}{2}$], axial stresses [$\sigma$] do not exceed the tensile and compressive design strength [f_d] of the steel pipe.

Expansion [ΔL_n] of unburied pipeline

Pipeline preheated to temperature [T_w], unburied:

The expansion [ΔL_n] of a pipeline of the length [L_n] heated up to the temperature [T_w] unburied - i.e. free expansion - is calculated from the following formula:

$$\Delta L_n = k \cdot \alpha_t \cdot (T_w - T_o) \cdot L_n \qquad [m]$$

Where:

$$T_w = 0,5 \times \left(\frac{T_{z\,max} + T_{p\,max}}{2} - T_o \right)$$

k - Coefficient relating to activity of friction force between casing pipe and subsoil for unburied pipeline — k=0.7÷0.8

α_t - Linear expansion coefficient — [1/°C]

T_w - Preheat temperature — [°C]

$T_{z\,max}$ - Supply pipeline maximum design temperature — [°C]

$T_{p\,max}$ - Return pipeline maximum design temperature — [°C]

T_o - Actual Installation temperature — [°C]

L_n - Length of unburied pipeline — [m]

The free expansion of a preheated pipeline may be determined as the product of the unitary expansion [ε] and the pipeline length [L_n]:

$$\Delta L_n = \varepsilon \cdot L_n \qquad [mm]$$

Pipeline unitary expansion:

$$\varepsilon = \alpha_t \cdot (T_w - T_o) \qquad [mm/m]$$

Having achieved the desired expansions, the pipeline is buried, and then cooled down to the installation temperature. Having reheated the pipeline up to the maximum operating temperature [$T_{max} = \frac{T_{z\,max} + T_{p\,max}}{2}$], expansions will occur on its free ends along the length of 1xLmax, which may be calculated from the following formula:

$$\Delta L_z = \alpha_t \left(\frac{T_{z\,max} + T_{p\,max}}{2} - T_w \right) \cdot L_{max} - \frac{F^{Hi} \cdot L_{max}^2}{2 \cdot E_T \cdot 2A}$$

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7 Pipeline rerouting

Pipeline rerouting may be executed by means of:

- prefabricated pre-insulated elbows,
- elastic bending of pipeline on site.

A bend in the rerouting direction by an angle $\alpha < 10^0$ is considered as a straight section of the pipeline.

7.1 Network rerouting by means of prefabricated pre-insulated elbows

Pipeline rerouting by means of pre-insulated elbows by the angles: **15°, 30°, 45°, 60°, 75°, 90°** is made for the entire diameter range

Table 10

Diameter	Steel grade	Bend radius (r)
2×DN20 to 2×DN40	R - 35 or P235GH	3 x Dz
2×DN50 to 2×DN200	St 37.0 or P235GH	2.5 x Dz

Dz - Service pipe outer diameter

7.2 Network rerouting by means of elastic bending of pipeline

A pipeline od pre-insulated pipes of the length of ***l* = 6,00** or ***12,00 m***, as assembled over the trench, is lowered into the trench and bent elastically. The minimum bend radius, as well as the corresponding pipe bend angle (β), as depending on the pipeline diameter and the lengths of the pre-insulated pipes used, are provided in the table.

Table 11

Steel service pipe		Casing pipe	Bend radius	Bend angle	
Diameter				Pipe length	
Nominal	Outer			6.00 m	12.00 m
DN	Dz	Dzp	r	β	β
mm	*mm*	*mm*	*m*	*Degree*	*Degree*
2×26.9	26.9	125	34.38	10.0	20.0
2×33.7	33.7	140	41.92	8.0	16.4
2×42.4	42.4	160	49.11	7.0	14.0
2×48.3	48.3	160	49.11	7.0	14.0
2×60.3	60.3	200	64.86	5.3	10.6
2×76.1	76.1	225	76.39	–	9.0
2×88.9	88.9	250	96.84	–	7.1
2×114.3	114.3	315	122.78	–	5.6
2×139.7	139.7	400	152.79	–	4.5
2×168.3	168.3	450	180.93	–	3.8
2×219.1	219.1	560	221.79	–	3.1

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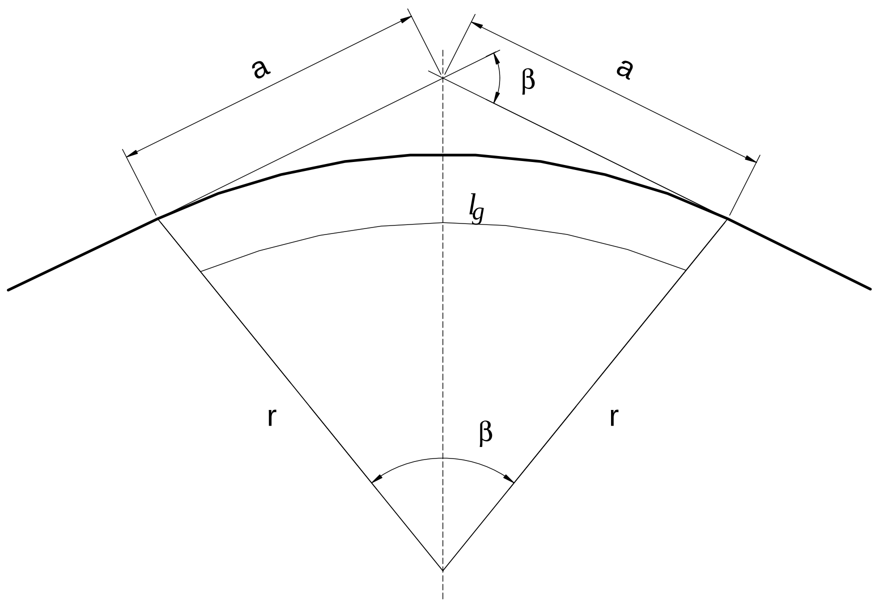
Auxiliary equations and guidelines for pipeline rerouting using elastic bending.

The pipeline rerouting direction angle (β) is determined from the design.

Length of tangent: $$a = r \cdot tg\frac{\beta}{2}$$ [m]

Bend radius: $$r = \frac{360 \cdot l_g}{2 \cdot \pi \cdot \beta}$$ [m]

The pipeline length (l_g) along the section of a bend is to be assumed as the multiple of pre-insulated pipe sections, respectively $l = 6.00\ m$ and $l = 12.00\ m$. In case of elastic bending, the bend length of the pipeline (l_g) is determined following determination of the rerouting direction angle in the design.



8 Pre-insulated fixed point - actual

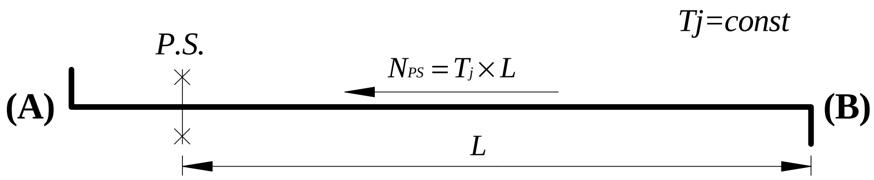
Pre-insulated fixed points on twin pre-insulated heat distribution networks are used in order to:

- Reduce loads on other pre-insulated elements which are not designed to transfer loads, i.e. e.g. pre-insulated T-connector branches, Y-adapter fittings, pipeline building entries, replacing the traditional heat network routing technology with the pre-insulated one;
- Shape desired heat network expansions, e.g. if the compensation arm of a pre-insulated elbow, as calculated based on the actual expansion, does not transfer this expansion due to terrain conditions.

8.1 Calculation of forces acting on fixed point

8.1.1 Reduced-load fixed point

A one-sidedly reduced-load fixed point is such a point on which the axial force acts one-sidedly. A one-sided load on a fixed point occurs if a straight section of the length L_{max} runs along one side of the fixed point, whereas on the other side of the fixed point there is a bend of the heat network, e.g. via a 90° elbow. It is important that the straight section between the 90° elbow **(A)** (the compensation one) and the fixed point is negligibly short. This situation is illustrated below.



The axial force [N_{PS}] acting on the fixed point is expressed by the following formula:

$$N_{PS} = T_j \times L_{\max} \quad [N]$$

Where:

T_j - Unitary earth friction force acting on twin pre-insulated pipe [N/m]

L_{max} - Maximum pipeline length from fixed point to compensation elbow **(B)** [m]

8.1.2 Partially reduced-load fixed point

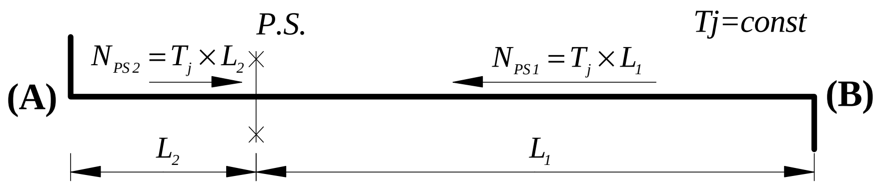
A partially-reduced-load fixed point is such a fixed point where the axial force caused by friction between the twin pre-insulated pipe casing and the sand backfill of the pipeline acting on the fixed point:

$$N_{PS1} = T_j \times L_1 \quad [N]$$

collected from the length L_1 between the fixed point and the compensation elbow at **(B)**, is partially reduced by the axial force acting in the opposite direction from the earth friction acting on the fixed point:

$$N_{PS2} = T_j \times L_2 \quad [N]$$

collected from the length L_2 between the fixed point and the compensation elbow at **(A)**. This situation is illustrated below:



The total axial force [N_{PS}], acting on the fixed point is expressed by the following formula:

$$N_{PS} = N_{PS1} - N_{PS2} \qquad [N]$$

$$N_{PS} = T_j \times (L_1 - L_2) \qquad [N]$$

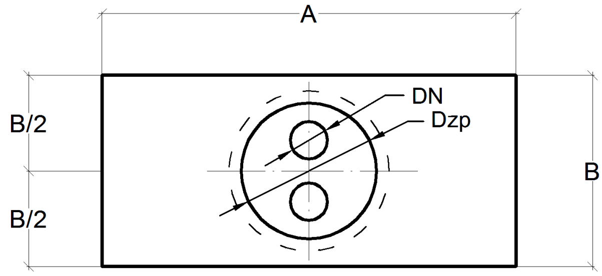
(For designations - see previous figure)

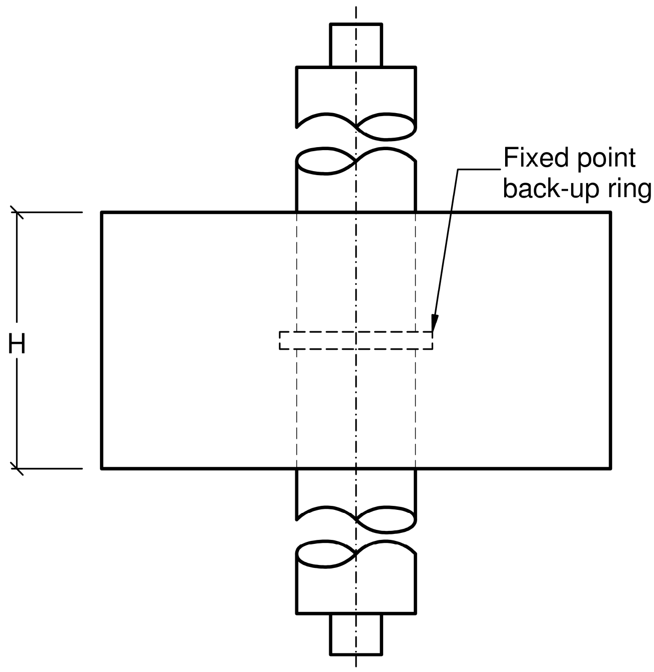
Table No 15 presents maximum sizes of fixed point concrete blocks. The axial forces acting on the fixed point have been calculated based on the following assumptions:

- Pipeline axis depth below ground level H=1,0 m;
- One-sidedly reduced-load fixed point;
- Length of section from which axial forces have been collected as acting on fixed point is L_{max} , Steel grade P235GH; "Standard" insulation;
- For concrete block dimensioning, unitary passive earth pressure 150 kPa has been adopted, as per PN-81/B-03020.

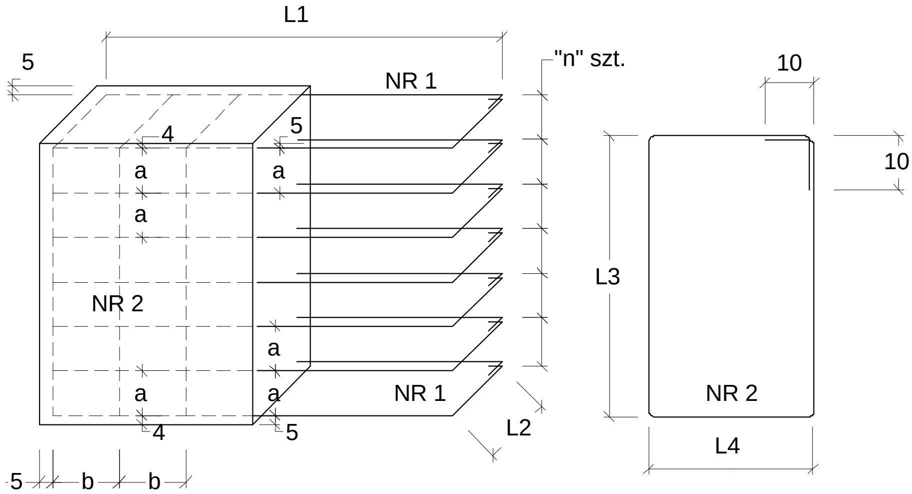
Fixed point footing blocks must be designed and made of concrete grade no less than C16/20 (concrete compression strength grade), reinforced with weldable steel rebar, grade B500SP or BSt500S (ribbed steel).

FIXED POINT CONCRETE BLOCK DIMENSIONS





CONCRETE BLOCK REINFORCEMENT



Reinforcement dimensions provided in [cm]

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MAXIMUM FIXED POINT CONCRETE BLOCK DIMENSIONS

Table 15

Diameter		Maximum force transferred by concrete block	Fixed point block dimensions			Fixed point concrete block reinforcement						
Steel pipe	Casing pipe											
Outer		[NPS] for Lmax for seamless pipes ΔT=25°C H=1.0m	A	B	H	Bar No	Diameter ∅	Quantity n	L1	L2	L3	L4
Dz/g	Dzp											
mm/mm	mm	dN	cm	cm	cm		mm	pcs	cm	cm	cm	cm
2x26.9/2.6	125	7067	110	50	30	1	8	4	100	20		
						2	6	5			42	22
2x33.7/2.6	140	9134	120	60	30	1	8	4	110	20		
						2	6	6			52	22
2x42.4/2.6	160	11775	130	70	30	1	8	4	120	20		
						2	6	5			62	22
2x48.3/2.6	160	13633	150	70	30	1	8	4	140	20		
						2	6	5			62	22
2x60.3/2.9	200	18987	180	80	40	1	10	5	170	30		
						2	6	6			72	32
2x76.1/2.9	225	24550	180	100	40	1	10	6	170	30		
						2	6	7			92	32
2x88.9/3.2	250	32402	200	120	50	1	10	8	190	40		
						2	6	7			112	42
2x114.3/3.6	315	46959	250	140	70	1	10	10	240	60		
						2	6	8			132	62
2x139.7/3.6	400	58678	320	140	100	1	12	10	310	90		
						2	8	11			132	92
2x168.3/4	450	80078	400	150	100	1	12	12	390	90		
						2	8	15			142	92
2x219.1/4.5	560	144784	680	170	120	1	1	12	670	110		
						2	8	15			162	112

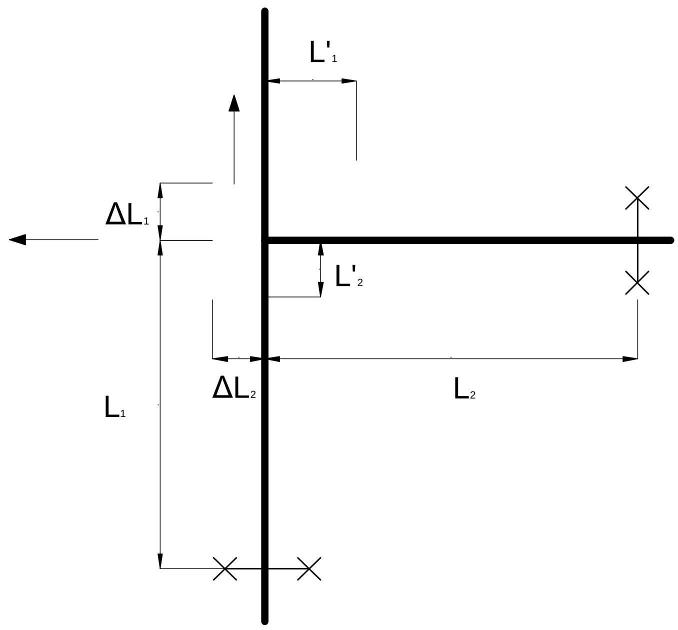
NOTE: Footing dimensions must be established on a case-by-case basis, considering the actual value of the normal force in the pipelines, checking the reference conditions for the limit state of the subsoil's passive pressure bearing capacity and the footing-subsoil stability, as per the PN-81/B-03020 Standard.

9 Pipeline branches, building entries and Y-adapter fittings.

Pipeline branches in the twin-pipe system by *ZPU Międzyrzecz Sp. z o.o.* should be executed using flat or riser T-pieces.

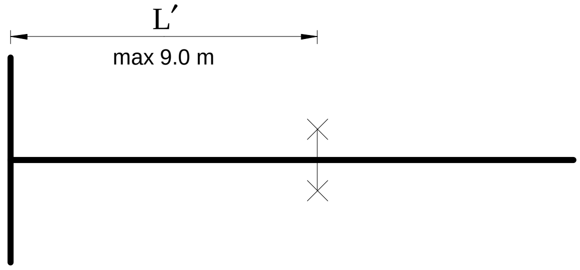
The branch will be subjected to the main pipeline's expansion ΔL_1 (as shown on the figure below); furthermore, the branch (side line) will also undergo thermal expansion ΔL_2, acting on the main pipeline.

A compensation zone [L_1'] must be made on the branch, to be calculated as for the compensation layout **L90**, using formula acc. to 6.1.4. In order to calculate the compensation arm [L_1'], the formula must include the expansion from the main pipeline [ΔL_1], as well as the branch diameter – for the compensation layout L90 (90° elbows), whereas on the main pipeline there will be the compensation zone [L_2'], which is also to be calculated from the formula, acc. to 6.1.4., taking the side line's expansion [ΔL_2], as well as the main pipeline diameter.

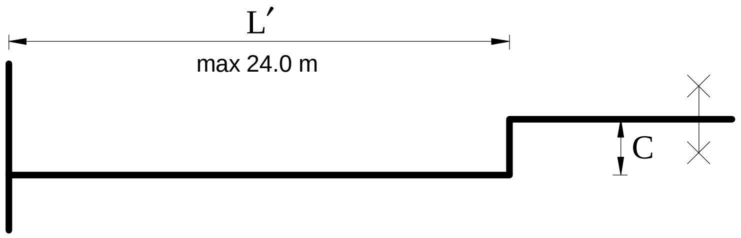


In case of T-pieces, the effect of the thermal expansion of the branch on the main pipeline can be balanced, by:

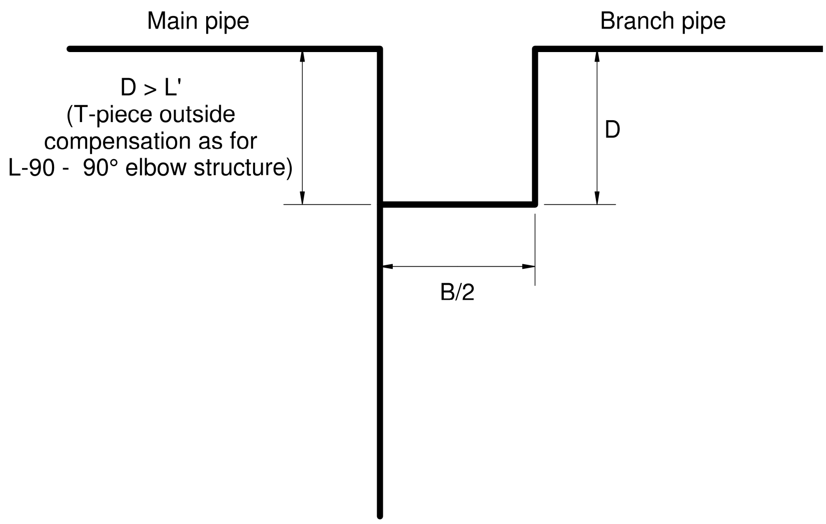
- Building into the riser T-piece's branch of an actual double fixed point at a distance of maximum 9.0 m from the main pipeline's axis:



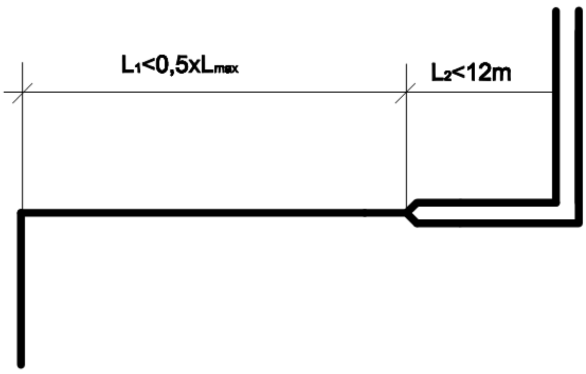
- Having the Z-shape compensation layout on the branch at a maximum distance of 24.0 m:



In case the branch is an extension to the mail pipe, one half of the U-shape compensation layout must be designed.



Pre-insulated cut-off, air-release, drain fittings as well as pre-insulated branches must not be installed within compensation zones.

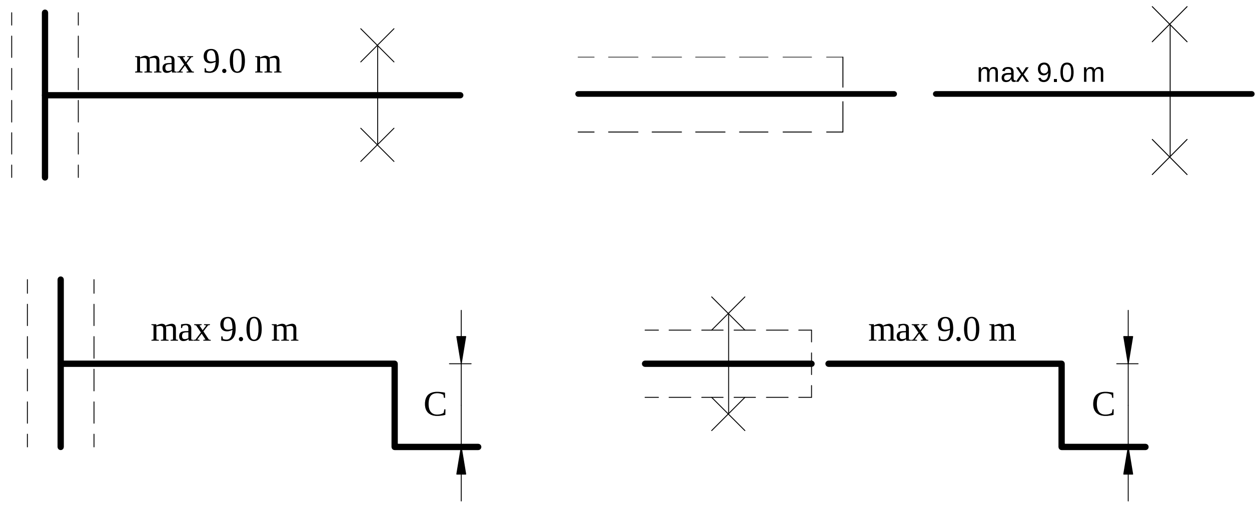


Y-adapter fittings, which are used on twin-single pipeline connections, should be located at a distance of less than 0.5xLmax from the compensation elbow on a twin-pipe system, and less than 12m from the compensation elbows on a single-pipe system.

10 Connection of twin pipes to traditional pipeline (channel network)

The effects of the expansion of the pre-insulated pipeline are balanced by building in of a fixed point or the Z-shape layout at a distance of max 9.0 m from the traditional pipeline's axis or connection

a) **b)**



11 Steel fittings

Designing pre-insulated steel fittings – cut-off fittings, cut-off fittings with one vent (drain) valve, drain and air-release cut-off fittings – one must:

- not locate the fittings within compensation zones (L-, Z-, U-type compensators),
- ensure access to the cut-off valve pin via the street box and casing pipe or executing a concrete-ring well of a diameter of at least 600 mm
- secure the cut-off valve pin situated in the ground by means of compensation mats of the dimensions 1000x250x40mm,
- place drain and air-release cut-off fittings in concrete-ring wells of a diameter of minimum1000 mm or concrete chambers.

Cut-off steel fittings are used to stop the flow of the medium within particular sections and devices of a heat network. Drain valves must be designed in the lowest, and the vent valves at the highest points of the heat network, and at cut-off valves for water drain and deaeration or aeration, respectively.

12 Technical information

Other catalogues and manuals of ZPU Międzyrzecz Sp. z o.o. System:

1.	Catalogue	Product Catalogue – Pre-insulated Twin Service Pipe System *ZPU Międzyrzecz Sp. z o. o. System*
2.	Manual	Pipeline Leak Detection. Impulse Warning System Connection (Wiring, Installation and Service Principles) *ZPU Międzyrzecz Sp. z o. o. System*
3.	Manual	Execution and Acceptance/ Installation, Pre-Commissioning and Commissioning *ZPU Międzyrzecz Sp. z o. o. System*
4.	Manual	Execution of Insulation and Hermetization of Coupling Unit *ZPU Międzyrzecz Sp. z o. o. System*
5.	Manual	Steel Pipe Welding [IS/01/06] *ZPU Międzyrzecz Sp. z o. o. System*
6.	Manual	Steel Pipe Welded Joint Quality Control [IK/01/06] *ZPU Międzyrzecz Sp. z o. o. System*
7.	Manual	Galvanized Pipe Braze Welding Technology *ZPU Międzyrzecz Sp. z o. o. System*
8.	Manual	Fusion Welded DX Couplings *ZPU Międzyrzecz Sp. z o. o. System*
9.	Manual	Fusion Welded DT-Type Heat Shrink Couplings *ZPU Międzyrzecz Sp. z o. o. System*
10.	Manual	NTX-Type Radiation Cross-linked Couplings *ZPU Międzyrzecz Sp. z o. o. System*

13 Commercial information

Manufacturer and Seller:

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