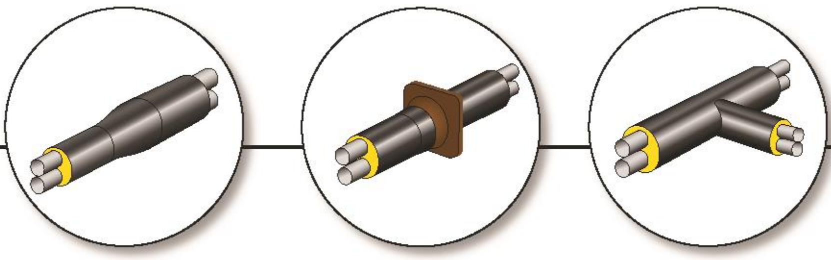
PRE-INSULATED PIPE SYSTEMS – TWIN PIPES

DESIGNER'S GUIDE



1. Introduction

This guide gives general principles for designing pre-insulated heat networks made using **RADPOL** technology, and the tips included in the study are intended to simplify selected stages of design work and facilitate making certain related decisions.
Advice and tips have been developed on the basis of the standards used in the process of implementation of heat networks made of pre-insulated elements, primarily:

- **PN-EN 13941-1** District heating pipelines – Design and construction of underground district heating networks from single- and twin-pipe pre-insulated composite systems – Part 1: Design.
- **PN-EN 13941-2** District heating pipelines – Design and construction of underground district heating networks from single- and twin-pipe pre-insulated composite systems – Part 2: Assembly.
- **PN-EN 15698-1** – District heating networks – System of pre-insulated composite pipes for water district heating networks laid directly in the ground – Part 1: Two-pipe assembly of steel line pipe, polyurethane thermal insulation and polyethylene jacket.
- **PN-EN 15698-2** – District heating networks – System of pre-insulated composite twin pipes for water district heating networks laid directly in the ground – Part 2: Fittings and the valve assembly of steel line pipes, polyurethane thermal insulation and polyethylene jacket.
- **PN-EN 253** – District heating networks – System of pre-insulated composite pipes for water district heating networks laid directly in the ground – Pipe assembly of steel line pipe, polyurethane thermal insulation and polyethylene jacket.
- **PN-EN 489** – District heating networks – System of pre-insulated composite pipes for water district heating networks laid directly in the ground – Joint assembly for steel line pipes with polyurethane thermal insulation and polyethylene jacket.
- **PN-EN 14419** – District heating networks – System of pre-insulated composite pipes for water district heating networks laid directly in the ground – Emergency control and signalling system.
- **PN-EN 10217-2** – Welded steel pipes for pressure applications – Technical conditions of delivery – Part 2: Electrically welded non-alloy and alloy steel pipes with required elevated temperature properties.
- **PN-EN 10220** – Seamless and seamed steel pipes – Dimensions and weights per unit of length.
- **PN-B-10405** – District heating – District heating networks – Acceptance requirements and tests.
- **prEN 17248** – District heating and district cooling pipe systems – Terms and definitions.
- **PN-C-04601** – Water for energy purposes – Requirements and tests of water quality for water boilers and closed heating circuits.

- **PN-EN 10253-2** – Pipe fittings for butt welding – Part 2: Non-alloy and ferritic alloy steels with specific inspection requirements.
- **PN-EN 1990** – Eurocode – Basis of structural design.
- **PN-76/M-34034** – Pipelines. Principles of pressure loss calculations.

and "Rules for the structure and drafting of CEN/CENELEC Publications."

The study presents the general guidelines of the **TWIN PIPE** system concerning:

- design class specification,
- calculation of friction force,
- calculation of friction length,
- axial stresses,
- hydraulic calculations,
- heat loss calculations,
- the use of compensating pads,
- construction of heat networks using twin pipes.

2. General comments

1. All pre-insulated elements of the **RADPOL** system are made in accordance with the requirements of the standards in question, and this means that they can also be used for the construction of heat networks designed based on the design requirements of other manufacturers and suppliers of pre-insulated systems, provided that these requirements have been developed in accordance with the philosophy and assumptions of the **PN-EN 13941** standard.
2. For more complex cases that go beyond these guidelines, please contact the **RADPOL** Design and Technical Consulting Team.
3. Relevant from the point of view of regulations, standardisation documents and requirements are the interpretations of the language phrases used. According to the document "Rules for the structure and drafting of CEN/CENELEC Publications"
    1. **Requirement** – an expression in the body of the document that conveys the criteria that should be met to state compliance with the document and from which no deviation is allowed (3.3.1). The corresponding verbal form in Polish: *powinien*, *należy* ("should") *(Table H.1)*.
    2. **Recommendation** – an expression in the body of the document conveying that, among several possibilities, one is recommended as particularly useful, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or (in negative form) that a certain possibility or course of action is not recommended but at the same time not prohibited (3.3.2). The corresponding verbal form in Polish: *zaleca się*, *jest zalecane* ("is recommended") (*Table H.2*).
4. According to the guidelines of **PN-EN 13941-1**, due to the range of diameters used below **up to = 355.6×5.6** and the range of axial stresses **σ_{MAX}< ReT**, it can be assumed that designs for heat networks made of pre-insulated elements of the **TWIN PIPE** system are designs eligible for "**class A**".

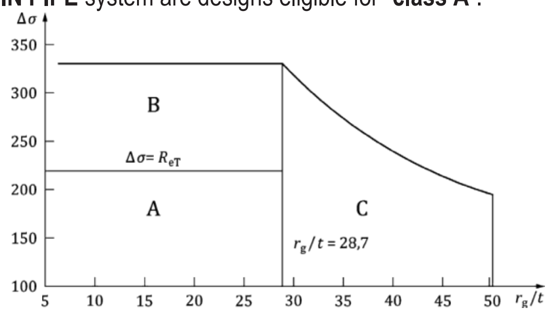


Figure 1: Definition of design classes – for pipes made of steel with yield strength Re (23°C) = 235 N/mm².

This means that the design can be carried out on the basis of catalogues and design guides of manufacturers and suppliers of pre-insulated elements, provided that they are made on the basis of the requirements of this standard.

5. According to the standard's guidelines, a designer can upgrade the design class to "**Class C**" as long as all the requirements for designs in that class are met.
6. For the purpose of developing auxiliary tables, parameters of **125°C/65°C** were assumed for a high-parameter heat network, and **90°C/55°C** for consumer installations. The specific gravity of the sand bed material $\gamma_S = 18\ kN/m^3$ and the installation temperature $T_{INST} = 10°C$ were also assumed.

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3. Symbols used

The following are the symbols used in figures, tables and formulae.

Symbol	Name	Unit
A_{MIN}	elongation at break	%
A_S	ring surface of a single steel pipe	mm²
B_K	width of the fixing anchor	mm
C	distance between pipe axes in TWIN PIPE elements	mm
d	PUR cell dimension in the radial direction	mm
d_i	inside diameter of the steel pipe	mm
d_n	nominal diameter of the steel pipe	mm
d_O	outside diameter of the steel pipe	mm
D_C	outside diameter of the polyethylene jacket	mm
D_i	inside diameter of the polyethylene jacket	mm
D_P	thickness of compensating pads of medium hardness	mm
E	linear deformability modulus – Young's modulus	N/mm² = MPa
E_{PUR}	flexibility modulus	N/mm² = MPa
E_T	linear deformability modulus – Young's modulus at the assumed temperature	N/mm² = MPa
F	force due to friction between the HDPE jacket and the sand bed	kN/m
g	gravitational acceleration	m/s²
G	weight of pre-insulated element	kN/m
G_{HDPE}	weight of the polyethylene jacket in 1 m of the pre-insulated element	kN/m
G_{PUR}	weight of the thermal insulation in 1 m of the pre-insulated element	kN/m
G_{ST}	weight of line pipes in 1 m of the pre-insulated element	kN/m
G_W	weight of water inside the line pipes	kN/m
H	pipeline cover	m
h_a	antisymmetric coefficient for heat loss calcu-	–

	lations	
H_K	(in the drawing part) height of the fixing anchor type A	mm
h_S	symmetric coefficient for heat loss calculations	–
H_W	depression of the groundwater table level	m
k	roughness of the tube	mm or m
K_O	at-rest earth pressure coefficient	–
L	length of the friction section	m
l	length of the pipeline section under consideration (also L_1, L_2, L_{ODG})	
L_{MAX}	mounting length for the pipe assembly	m
L_O	maximum distance between adjacent free ends	m
L_P	distance between line pipes in TWIN PIPE elements	mm
M_1	distance between pre-insulated pipelines acc. to PN-EN 253	mm
M_2	distance between the HDPE jacket and the trench wall	mm
N_X	axial force	N or kN
N_F	component of the axial force due to passive soil resistance	N or kN
N_P	component of the axial force due to internal pressure	N or kN
N_R	force due to compensation and due to lateral ground reaction	N or kN
N_T	component of the axial force due to the temperature difference	N or kN
q	heat loss of the pipe assembly	W/m
q_A	component of the antisymmetric system in heat loss calculations	W/m
q_F	heat loss of the supply pipeline	W/m
q_R	heat loss of the return pipeline	W/m
q_S	component of the symmetric system in heat loss calculations	W/m
Re	(in hydraulics) Reynolds number	–

Re_T	yield strength at the assumed temperature	N/mm²
Re_{MIN}	minimum yield strength	N/mm²
R_i	linear flow resistance	Pa/m
R_O	coefficient accounting for heat exchange between ground and air	m²K/W
R_{MIN}	minimum radius of flexible bending of the pipe assembly	m
s	wall thickness of the steel line pipe	mm
s_C	jacket wall thickness	mm
T	(in anchor calculations) fixing anchor thick-ness	mm
T	temperature	°C
T_A	temperature for the antisymmetric system	°C
T_F or t_F	temperature of the medium in the supply pipeline	°C
T_{INST}	installation temperature	°C
T_R or t_R	temperature of the medium in the return pipeline	°C
t_S	temperature of undisturbed ground at the pipeline level	°C
T_S	temperature for the symmetric system	°C
T±	steel pipe wall thickness tolerance	mm
in	heating medium flow velocity	m/s
W_1, W_2	(in route geometry) conversion elongation	mm
Z, Z_1 Z_2	pipe assembly axis depression	m
Z	(in hydraulics) local resistance	Pa/m
Z_C	substitute pipe assembly axis depression	m

Greek symbols

α	coefficient of linear expansion of steel	1/K
α	(in route geometry) angle of pipeline axis deviation	°
α_{HDPE}	coefficient of linear expansion of HDPE polyethylene	1/K
α_T	coefficient of linear expansion at the assumed temperature	1/K
γ	(in heat loss calculations) auxiliary variable	–
γ_m	safety coefficient	–
γ_S	specific gravity of the backfill	kN/m³
γ_{ST}	specific gravity of steel	kN/m³
γ_{SW}	specific gravity of the sand skeleton	kN/m³
γ'_{SW}	specific gravity of wet sand	kN/m³
γ_W	specific gravity of water	kN/m³
δ	friction angle between the ground and the pipeline	°
δ	displacement of the free end of the pipeline	mm
δ_W	resultant displacement of the free end of the pipeline	mm
δ_{MAX}	elongation of the free end for the maximum placement length LMAX	mm
Δp	pressure loss	Pa
ΔT	temperature difference or rise	K
ΔT_T	temperature rise for the pipe assembly	K
ε	relative roughness of the tube	–
ε_{gr}	relative boundary roughness of the tube	–
λ	(in hydraulics) local resistance coefficient	–
ζ	local resistance coefficient	
λ_{50}	thermal conductivity coefficient for PUR at 50°C	W/mK
λ_{HDPE}	thermal conductivity coefficient of HDPE polyethylene	W/mK
λ_i	thermal conductivity coefficient of the insulating material – PUR	W/mK

λ_S	thermal conductivity coefficient of the backfill – sand	W/mK
μ	friction coefficient	–
ν	in strength – Poisson’s ratio for steel = 0.3	–
ν	in hydraulics – dynamic viscosity	m^2/s
π	3.14…	–
$\rho_{ŚR}$	minimum density of PUR foam at pipe ends – average density	kg/m^3
ρ_{HDPE}	minimum density of HDPE polyethylene	kg/m^3
σ	(in heat loss calculations) auxiliary variable	–
$\sigma_{10\%}$	compressive strength in the radial direction	N/mm^2
$\sigma_{\Delta T}$	axial stress due to the use of fixing anchors	N/mm^2
σ_{DOP}	permissible axial stresses	N/mm^2
σ_F	axial stress in the supply pipe	N/mm^2
σ_{MAX}	maximum permissible axial stresses	N/mm^2
σ_P	peripheral stress due to hypertension	N/mm^2
σ_R	axial stress in the return pipe	N/mm^2
σ_X	average axial stress due to temperature deviation	N/mm^2
τ_{ax}	axial shear strength of PUR foam	N/mm^2
τ_{tan}	tangential shear strength of PUR foam	N/mm^2
φ or φ’	angle of internal friction of the ground	°
ψ	adjusted value of external cells	%

4. Description of the TWIN PIPE system

The pre-insulated **TWIN PIPE** system is another proposal for the construction of heat networks from pre-insulated elements prepared in advance under factory conditions for direct laying in the ground.

4.1. Structure

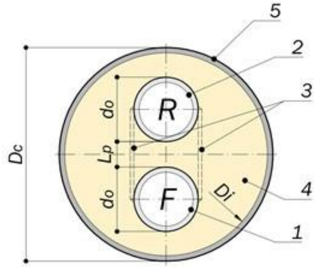

Figure 2: Structure of a pre-insulated element – made in the TWIN PIPE system.
(1) supply steel pipe, (2) return steel pipe, (3) fixing anchors,
(4) PUR thermal insulation, (5) polyethylene jacket

The pre-insulated element, the cross-section of which is shown in the figure, consists of two steel line pipes (1) and (2) laid in parallel one above the other in a polyethylene jacket (5) filled with insulating material – rigid polyurethane foam (4).

In sensitive areas, steel pipelines are connected by specially selected fixing anchors (3).

4.2. Line pipes

Steel pipes made of **P 235 GH** steel in accordance with **PN-EN 10217-2** are used as line pipes.

The series of steel pipes used by **RADPOL** is presented in Table 1.

Table 1: Characteristic parameters of used steel pipes.

dn	d_0 [mm]	S [mm]	T± [mm]	A_S [mm]	G_S [kN/m]
20	26.9	2.6	0.3	198.5	0.0153
25	33.7	2.6	0.3	254.0	0.0196
32	42.4	2.9	0.3	359.9	0.0277
40	48.3	2.9	0.3	413.6	0.0319
50	60.3	2.9	0.3	522.9	0.0403
65	76.1	2.9	0.3	666.9	0.0514
80	88.9	3.2	0.3	861.6	0.0663
100	114.3	3.6	0.4	1252.0	0.0964
125	139.7	3.6	0.4	1539.3	0.1185
150	168.3	4.0	0.5	2064.7	0.1590
200	219.1	4.5	0.5	3033.8	0.2336

In the diameter range from **dn 20 mm** to **dn 40 mm**, steel pipe walls thickened in relation to **PN-EN 253** are used.

The steel parameters depending on the temperature are shown in Table 2.

Table 2: Characteristic parameters of P 235 GH steel (γ = 78.5 kN/m³).

Parameter	Values of the presented parameters at temperature:									
	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C	140°C
E_T N/mm²	211143	210571	210000	209429	208857	208286	207714	207143	206571	206000
α_T mm/(mK)	1.18	1.19	1.19	1.20	1.21	1.22	1.23	1.23	1.24	1.25
α E N/(mm²K)	2.49	2.51	2.5	2.51	2.53	2.54	2.55	2.55	2.56	2.58
Re_T N/mm²	227.0	224.0	221.0	219.0	216.0	213.0	210.0	207.0	205.0	202.0
σ_{DOP} N/mm²	206.0	204.0	201.0	199.0	196.0	194.0	191.0	188.0	186.0	184.0

To aid design calculations using spreadsheets, steel parameters can be calculated using the following formulae:

- yield strength of steel

$$R_{eT}=227-0{,}28\cdot(T-50) \quad \text{in the} \quad T\leq140^{o}C \quad \frac{N}{mm^2} \tag{1}$$

- Young's modulus

$$E_T=\left(21{,}4-\frac{T}{175}\right)\cdot10^4 \quad \frac{N}{mm^2} \tag{2}$$

- coefficient of linear expansion

$$\alpha_T=\left(11{,}4+\frac{T}{129}\right)\cdot10^{-6} \quad \frac{1}{K} \tag{3}$$

The symbols used in the formulae are in accordance with Chapter **3**.

4.3. PUR thermal insulation

The requirements for the thermal insulation used are shown in the table below.

Table 3: Characteristic parameters of PUR thermal insulation.

Itemisation	Symbol	Unit of measure	Requirements acc. to PN-EN 253
Thermal conductivity coefficient for PUR at 50°C	Λ_{50}	W/(mK)	≤ 0.029
Minimum density at pipe ends	$\rho_{ŚR}$	kg/m3	≥ 55
Compressive strength in the radial direction	$\sigma_{10\%}$	N/mm2	0.3
Axial shear strength at room temperature (23 ±2)°C	τ_{ax}	N/mm2	0.12
Axial shear strength at (140 ±2)°C	τ_{ax}	N/mm2	0.08
Tangential shear strength	τ_{TAN}	N/mm2	0.2
Cell dimension in the radial direction	d	mm	≤ 0.5
Corrected closed cell content in PUR	ψ	%	≥ 88
Water absorption by PUR – after boiling	WA	%	≤ 10%
Modulus of elasticity at room temperature (23 ±2)°C	E_{PUR}	N/mm2	10.0
Modulus of elasticity at room temperature (140 ±2)°C	E_{PUR}	N/mm2	6.5
Safety coefficient with spacing of adjacent elbows up to 20 m	γ_m		2.0
Safety coefficient with spacing of adjacent elbows over 20 m	γ_m		3.0

In connection with the declared durability of polyurethane foam at a continuous operating temperature of 140°C, the material is suitable for use in heat networks with a design life of 50 years in accordance with PN-EN-13941-1 and PN-EN 1990.

4.4. Polyethylene jacket

The jacket is made in the form of high-density HDPE polyethylene pipe that meets the requirements of **PN-EN 253**.

Table 4: Characteristic parameters of polyethylene jackets.

Itemisation	Symbol	Unit of measure	Size
Thermal conductivity coefficient for HDPE	λ_{HDPE}	W/(mK)	≤ 0.43
Minimum density	ρ_{HDPE}	kg/m3	≥ 944
Yield strength	Re_{MIN}	N/mm2	19.0
Coefficient of linear expansion	α_{HDPE}	1/K	0.00018
Elongation at break	A_{MIN}	%	350.00
Impact resistance	-	°C	> -50

4.5. Fixing anchors

In the sensitive areas of the heat network, which are mainly fittings, the line pipes are connected to each other with fixing anchors, which are steel plates appropriately designed at the system production stage.

The **TWIN PIPE** system manufactured using **RADPOL** technology uses "**type A**" fixing anchors designed in accordance with **PN-EN 13941-1**.

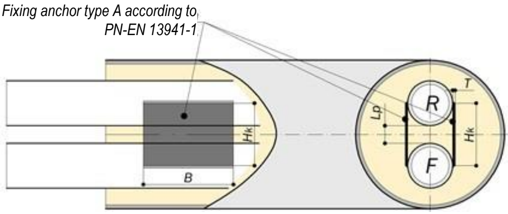

Figure 3: Fixing anchors in pre-insulated elements made in the twin pipe system.

The following table shows the sizes of the anchors used.

Table 5: The size of the fixing anchors used.

dn	d_0 [mm]	No. [mm]	B [mm]	H [mm]	g [kN/m]
20	26.9	19.0	50.0	46.0	4.0
25	33.7	19.0	50.0	53.0	4.0
32	42.4	19.0	50.0	61.0	4.0
40	48.3	19.0	50.0	67.0	4.0
50	60.3	20.0	70.0	80.0	4.0
65	76.1	20.0	90.0	96.0	4.0
80	88.9	25.0	110.0	114.0	6.0
100	114.3	25.0	140.0	139.0	6.0
125	139.7	30.0	170.0	170.0	6.0
150	168.3	40.0	200.0	208.0	6.0
200	219.1	45.0	260.0	264.0	8.0

The dimensions of the weld used and the size of the fixing plates were selected so that the weld surface would transfer the shear forces caused by the temperature difference between the supply and return pipelines, and so that the fixing plate would not cause deformation of the pipe.

4.6. TWIN PIPE assemblies

Pipe assemblies manufactured using **RADPOL** technology meet the requirements and conditions of the **PN-EN 15698-1** and **PN-EN 15698-2** standards. The basic series, defined as **SERIES 1** in **PN-EN 15698-1**, with standard insulation, is as follows:

Table 6: Overview and method of labelling of pre-insulated SERIES 1 – STANDARD insulation elements.

Steel pipes						Series 1 STANDARD INSULATION		
dn	d_0 [mm]	S [mm]	T± [mm]	No. [mm]	A_S [mm³]	Da [mm]	s [mm]	designation [-]
20	26.9	2.6	0.3	19.0	198.5	125	3.0	DN (2x20)/125
25	33.7	2.6	0.3	19.0	254.0	140	3.0	DN (2x25)/140
32	42.4	2.9	0.3	19.0	359.9	160	3.0	DN (2x32)/160
40	46.3	2.9	0.3	19.0	413.6	160	3.0	DN (2x40)/160
50	60.3	2.9	0.3	20.0	522.9	200	3.2	DN (2x50)/200
65	76.1	2.9	0.3	20.0	666.9	225	3.4	DN (2x65)/225
80	88.9	3.2	0.3	25.0	861.6	250	3.6	DN (2x80)/250
100	114.3	3.6	0.4	25.0	1252.0	315	4.1	DN (2x100)/315
125	139.7	3.6	0.4	30.0	1539.3	400	4.8	DN (2x125)/400
150	168.3	4.0	0.5	40.0	2064.7	450	5.2	DN (2x150)/450
200	219.1	4.5	0.5	45.0	3033.8	560	6.0	DN (2x200)/560

For a table on the series designated as **SERIES 2** and **SERIES 3** in **PN-EN 15698-1**, see Chapter **11.** Auxiliary tables**.**

5. Loads acting on the pipe assembly

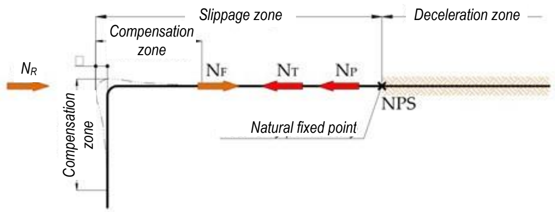

Figure 4: Diagram of the loads acting on the pre-insulated pipeline.
N_T – force due to temperature, N_P – force due to pressure, N_F – force due to friction,
N_R – force from the compensating arm

Figure 4 shows the loads that have a direct effect on the working pre-insulated pipeline made in the **TWIN PIPE** system. The peculiarity of the pipe assembly design is the transfer of loads occurring in the line pipes, through the rigid polyurethane foam insulation, to the polyethylene jacket (internal forces to the outside), and the transfer of loads occurring "from the outside" on the polyethylene jacket, through the insulation, to the line pipes (external forces to the inside).

In addition, within the **TWIN PIPE** system, forces are generated as a result of the stresses caused by the permanent connection of two pipes with different operating temperatures. These stresses affect the strength of individual pipes, but due to their nature do not have direct effects on the outside of the pipe assembly.

The figure also shows:

- **slippage zone** – also known as the friction section – the section along the length of which the movement of the pre-insulated network in the ground is observed,
- **deceleration zone** – a section or a place called the natural fixed point (NFP) where force balancing occurs,
- **compensation zones** – sections of the network adjacent to the elbow top that are subject to lateral deformation.

5.1. Force due to temperature N_T

In pre-insulated pipelines, one of the components of the force due to temperature is the force caused by stresses induced by temperature rise, which in the TWIN PIPE system can be calculated as:

$$\Delta T_T = \frac{T_F + T_R}{2} - T_{inst} \tag{4}$$

axial stresses take the value:

$$\sigma = E \cdot \alpha \cdot \Delta T_T \tag{5}$$

while the axial force:

$$N_T = 2 \cdot A \cdot (E \cdot \alpha \cdot \Delta T_T) \tag{6}$$

5.2. Force due to internal pressure N_P

In pipelines subjected to internal pressure, stresses develop, tending to increase its diameter – the so-called circumferential (meridional) stresses. Their value can be calculated based on:

$$\sigma_P = \frac{p \cdot d_i}{2 \cdot s} \tag{7}$$

If the pipe is terminated with a bottom (or, for example, an elbow) axial (parallel) stresses will also arise, the value of which can be calculated from:

$$\sigma_X = \frac{p \cdot d_i}{4 \cdot s} \tag{8}$$

as you can see

$$\sigma_X = 0{,}5 \cdot \sigma_P \tag{9}$$

In addition, according to Hooke's law, the circumferential stresses will cause the pipeline to shorten by creating additional axial stresses of

$$\sigma_X = -\nu \cdot \sigma_P \tag{10}$$

hence, in the pipeline axis of interest, we will obtain axial stresses induced by the pressure of the medium with a value of

$$\sigma_X = (0{,}5 - \nu) \cdot \sigma_P \tag{11}$$

The axial force resulting from these stresses will reach a value of

$$N_P = 2 \cdot A \cdot (0{,}5 - \nu) \cdot \sigma_P \qquad (12)$$

5.3. Force due to friction N_F

With the occurrence of movement of the pipe assembly in the ground caused by the deformation of the line pipes under the influence of temperature rise, there will also be passive soil resistance, the magnitude of which will depend on:

- coefficient of friction between the polyethylene jacket and the backfill

$$\mu = tg\delta \qquad (13)$$

where the angle of friction between the ground and the pipeline

$$\delta = \frac{2}{3} \cdot \varphi \qquad (14)$$

- effective ground stresses at the pipeline axis level calculated from the formula

$$\sigma_V = \gamma_S \cdot Z \; for \; (H_W \geqslant Z) \qquad (15)$$

if the groundwater level is below the axis of the pipe assembly or from the formula

$$\sigma_V = \gamma_S \cdot H_W + \gamma_{SW} \cdot (Z - H_W) \; for \; (H_W < Z) \qquad (16)$$

where

$$\gamma_{SW} = \gamma'_{SW} - \gamma_W \qquad (17)$$

and

$$Z = H + \frac{D_C}{2} \qquad (18)$$

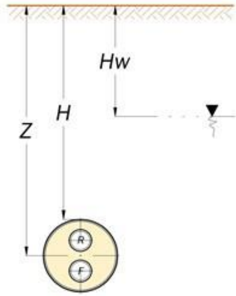

Figure 5: Diagram for calculating the force due to friction.

As can be seen in the figure, the upper component of the polyethylene jacket is loaded only by the weight of the ground and paving (usually omitted in the tabular calculations). The lower component is additionally loaded with the weight of the pipe assembly along with water.

$$G = G_{ST} + G_W + G_{PUR} + G_{HDPE} \tag{19}$$

whose individual components can be calculated from the formulae:

$$G_{ST} = 2 \cdot \{\pi \cdot (d_O - s) \cdot s \cdot \gamma_{ST}\} \tag{20}$$

weight of steel,

$$G_{PUR} = \left\{\frac{\pi \cdot D_i^2}{4} - 2 \cdot \frac{\pi \cdot d_O^2}{4}\right\} \cdot \gamma_{PUR} \tag{21}$$

weight of thermal insulation,

$$G_{HDPE} = \pi \cdot (D_C - s_C) \cdot s_C \cdot \gamma_{HDPE} \tag{22}$$

weight of the polyethylene jacket and

$$G_W = 2 \cdot \left\{\frac{\pi \cdot (d_O - 2 \cdot s)^2}{4} \cdot \gamma_W\right\} \tag{23}$$

weight of water.

Referring the calculations to the effective ground stresses at the pipeline axis level, it is also necessary to take into account:

- the diameter of the DC pipe assembly jacket,
- its weight and
- make an adjustment related to replacing part of the ground with a pipe assembly.

Then, the force due to friction per unit of length of the pipeline can be calculated from the formula:

$$F = \mu \cdot \left(\frac{(1+K_o)}{2} \cdot \gamma_S \cdot Z \cdot \pi \cdot D_C + G - \gamma_S \cdot \pi \cdot \left(\frac{D_C}{2} \right)^2 \right) \; for \; (H_W > Z) \quad (24)$$

for laying above groundwater and

$$F = \mu \cdot \left(\frac{(1+K_o)}{2} \cdot \left(\gamma_S \cdot H_W + \gamma_{SW} \cdot (Z - H_W) \right) \cdot \pi \cdot D_C + G - \gamma_S \cdot \pi \cdot \left(\frac{D_C}{2} \right)^2 \right) \; for \; (H_W < Z) \quad (25)$$

otherwise.

Ultimately, the force due to friction acting on the section will be:

$$N_F = F \cdot l \quad (26)$$

where l is the distance of the section under consideration, from the free end of the pipeline.

The table below shows the unit frictional force for the **basic SERIES 1 – standard insulation**. For **SERIES 2** and **SERIES 3**, tables of values are included in the chapter: Auxiliary tables.

Table 7: Values of frictional force – basic SERIES 1 – STANDARD insulation.

SERIES 1 STANDARD insulation	Steel pipes				Jacket	F – frictional force per unit of length [kN/m] for cover H:						
	dn	d_o [mm]	s [mm]	A_s [mm²]	Dc [mm]	H=0.8	1.0 m	1.2 m	1.4 m	1.6 m	1.8 m	2.0 m
DN (2x20)/125	20	26.9	2.6	198.5	125	1.75	2.17	2.59	3.01	3.44	3.86	3.44
DN (2x25)/140	25	33.7	2.6	254.0	140	1.97	2.44	2.91	3.39	3.86	4.33	3.86
DN (2x32)/160	32	42.4	2.9	359.9	160	2.27	2.81	3.35	3.88	4.43	4.96	4.43
DN (2x40)/160	40	48.3	2.9	413.6	160	2.27	2.81	3.35	3.89	4.43	4.97	4.43
DN (2x50)/200	50	60.3	2.9	522.9	200	2.87	3.54	4.22	4.89	5.57	6.24	5.57
DN (2x65)/225	65	76.1	2.9	666.9	225	3.26	4.02	4.78	5.53	6.30	7.05	6.30
DN (2x80)/250	80	88.9	3.2	861.6	250	3.65	4.50	5.34	6.18	7.03	7.87	7.03
DN (2x100)/315	100	114.3	3.6	1252.0	315	4.69	5.75	6.82	7.88	8.95	10.01	8.95
DN (2x125)/400	125	139.7	3.6	1539.3	400	6.08	7.43	8.77	10.12	11.48	12.83	11.48
DN (2x150)/450	150	168.3	4.0	2064.7	450	6.96	8.47	9.99	11.51	13.04	14.55	13.04
DN (2x200)/560	200	219.1	4.5	3033.8	560	8.94	10.83	12.72	14.60	16.51	18.40	16.51

5.4. Force from the "compensating arm" N_R

An additional load occurring in pre-insulated heat networks that induces stresses in the cross-section of the pipe assembly is the reaction of the transverse compensating arm, which is a component of the loads coming from the deformation of the line pipe and, or rather, first and foremost, from the pressure of the ground on the jacket of the transverse arm.

PN-EN 13941-1 specifies that this force causes a reduction in friction length or a reduction in free displacement of up to 25% of the design value of these quantities.

This reaction is difficult to calculate without the use of specialised software simulating a pipeline laid on an elastic foundation, but for the purpose of preliminary calculations, it can be assumed that with the use of compensating pads, its value can amount to:

$$N_R = 0{,}1 \cdot F \cdot l \qquad (27)$$

5.5. Stresses from the use of fixing anchors

In the **TWIN PIPE** system, additional stresses in the line pipes are caused by the use of fixing anchors permanently connecting pipes of different temperatures and depend on the temperature difference between the supply and return pipelines.

These stresses will be:

$$\sigma_{\Delta T} = E \cdot \alpha \cdot \frac{T_F - T_R}{2} \qquad (28)$$

Considering the axial stresses in the steel pipe section for the deceleration zone

$$\sigma_X = -(E \cdot \alpha \cdot \Delta T_T - \nu \cdot \sigma_P) \qquad (29)$$

or the slippage zones

$$\sigma_X = -\frac{F \cdot l}{2 \cdot A} + \frac{1}{2} \cdot \sigma_P - \frac{N_R}{2 \cdot A} \qquad (30)$$

we obtain axial stresses in the supply pipe:

$$\sigma_F = \sigma_X - \sigma_{\Delta T} \qquad (31)$$

and the return pipe

$$\sigma_R = \sigma_X + \sigma_{\Delta T} \qquad (32)$$

5.6. Stresses within the pipe assembly

The next four figures show stress diagrams, with an indication of the forces responsible for their formation, arising in the supply and return pipelines.

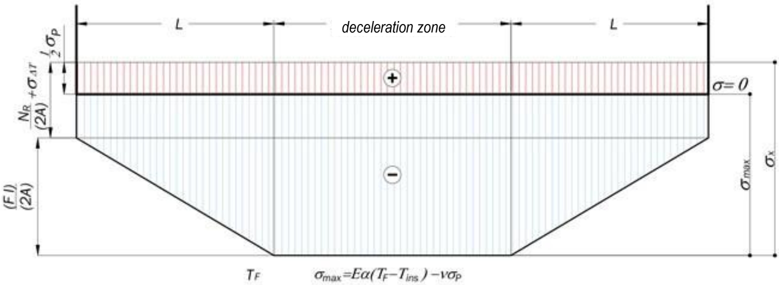

Figure 6: Diagram of axial stresses in the supply pipe – without limiting the level of stress.

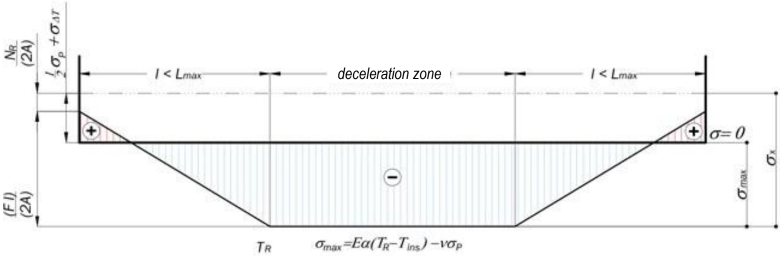

Figure 7: Diagram of axial stresses in the return pipe – without limiting the level of stress.

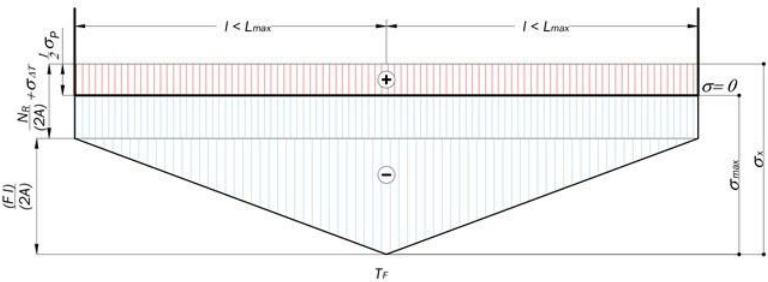

Figure 8: Diagram of axial stresses in the return pipe – length $l \leq L_{MAX}$ limited by the allowable stress σ_{MAX}.

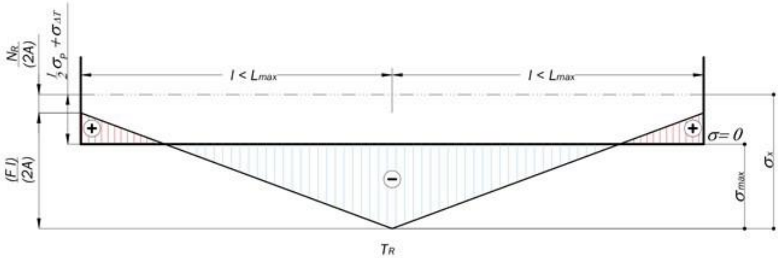

Figure 9: Diagram of axial stresses in the return pipe – length l ≤ L_{MAX} limited by the allowable stress $σ_{MAX}$.

6. Laying technique

In pipelines, as the temperature increases, the stresses reach a maximum value at a level that we can calculate from the formula:

$$\sigma_{max} = E \cdot \alpha \cdot (T_F - T_{inst}) - \nu \cdot \sigma_P \quad (33)$$

In **TWIN PIPES**, the maximum stresses develop in the supply pipeline at TF temperature and occur in the deceleration zone.

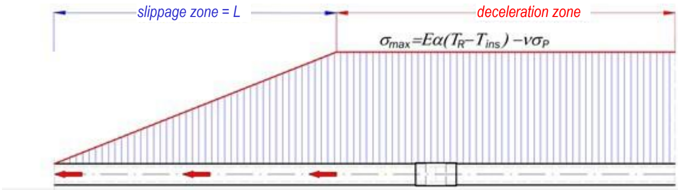

Figure 10: Maximum stresses in the deceleration zone.

If the maximum stresses exceed the allowable stresses calculated from the formula,

$$\sigma_{MAX} > \sigma_{DOP} = \frac{R_{eT}}{\gamma_m} \quad (34)$$

then, when designing the geometry of the route of the heat network, it is necessary to keep the stress level below the level of allowable stress.

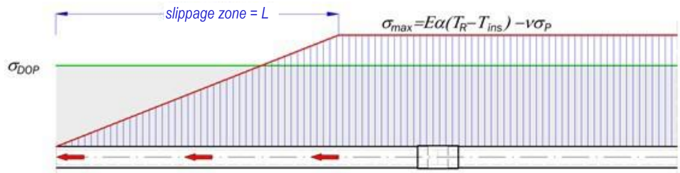

Figure 11: Maximum stresses in relation to allowable stresses.

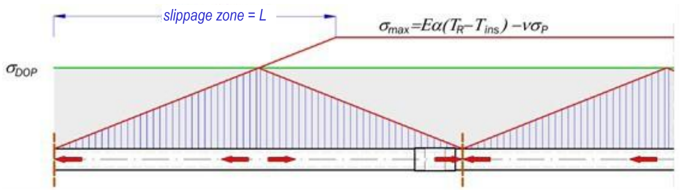

Figure 12: Required stress distribution in the pipeline.

To achieve this, it is necessary to locate free ends at appropriate points to allow the pipeline to “unload” deformations. Since the TWIN PIPE technique lacks axial expansion joints that could be used as free ends in the straight line of the network route, it is necessary to use diversion of the route with compensating elbows.

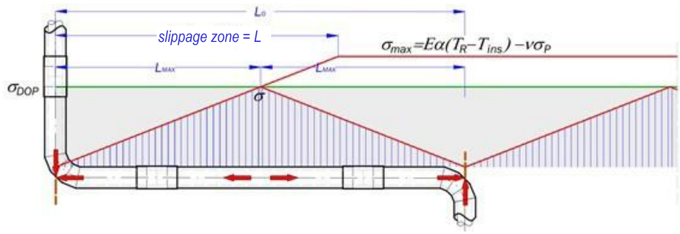

Figure 13: The use of compensating elbows as free ends of the pipeline.

The maximum spacing of compensating elements (free ends) in this technique of laying pre-insulated pipelines is:

$$L_O = 2 \cdot l_{max} \quad (35)$$

and in the case of a smaller distance between free ends, the stresses will be lower.

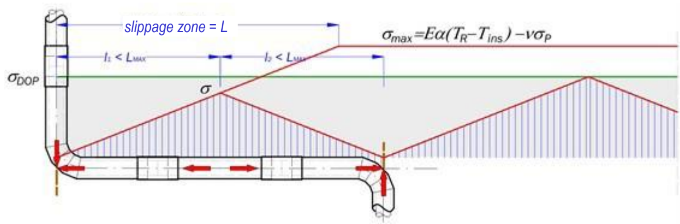

Figure 14: Keeping stresses lower than allowable stresses.

6.1. Permissible stresses

The maximum axial stress depends on the yield strength of the steel at elevated temperatures and the safety coefficient. They can be determined by the formula:

$$\sigma_{DOP} = \frac{R_{eT}}{\gamma_m} \qquad (36)$$

In the attached tables for the adopted temperature range:

- of **125°C/65°C** network, on the basis of calculations, the maximum stresses (for $\gamma m = 1.1$)
- were assumed to be at the level of $\boldsymbol{\sigma_{DOP} = 187}$ **N/mm²**,
- and for **90°C/55°C** consumer installations, the maximum stresses were assumed to be at the
- level of $\boldsymbol{\sigma_{DOP} = 196}$ **N/mm²**.

Depending on the temperature of the medium in the supply pipeline and its rise relative to the installation temperature, we distinguish between two diagrams of stresses arising in line pipes:

- when we can design pipelines without the limit of allowable stresses or when the maximum axial stresses developed in the pipelines will not exceed the allowable stresses,
- when the maximum axial stresses developed in the pipelines exceed those specified as permissible.

Recognising that, according to the preliminary assumptions, the designs of networks in the **TWIN PIPE** system are classified as **Class A** designs, it should be observed that the axial stresses do not exceed the permissible stresses.

6.2. Length of the slippage zone L and elongation of the section

Thermal networks, where the temperature rise in the supply pipeline relative to the installation temperature does not exceed about **75°C**, can be classified as networks laid without stress limit. In this case, the length of the slippage zone (friction section) can be determined from the formula:

$$L = \frac{2 \cdot A}{F} \cdot (E \cdot \alpha \cdot \Delta T_T + (0{,}5 - \nu) \cdot \sigma_P) - \frac{N_R}{F} \tag{37}$$

In this case, the displacement of the free end of the pipe assembly (elongation of the section) is determined from the formula:

$$\delta = \frac{F \cdot L^2}{4 \cdot E \cdot A} \tag{38}$$

6.3. Permissible installation length L_{MAX} and section elongation

If the temperature rise in the supply pipeline relative to the installation temperature exceeds about **75°C**, we are required to limit the installation length to the value calculated from the formula:

$$L_{MAX} = \frac{2 \cdot A}{F} \cdot \left(\sigma_{DOP} + \frac{1}{2} \cdot \sigma_P - \frac{N_R}{2 \cdot A} - \sigma_{\Delta T}\right) \tag{39}$$

In this case, the displacement of the free end of the pipe assembly (elongation of the section) is determined from the formula:

$$\delta = \frac{l}{E}\left(E \cdot \alpha \cdot \Delta T_T - \frac{F \cdot l}{4 \cdot A} + (0{,}5 - \nu) \cdot \sigma_P - \frac{N_R}{2 \cdot A}\right) \tag{40}$$

6.4. Summary of permissible installation lengths

The tables on the following page show the permissible installation lengths and section elongations for **125°C/65°C** network, for **90°C/55°C** consumer installations and for the basic **SERIES 1 – standard insulation**.

For **SERIES 2** and **SERIES 3**, tables of values are included in the chapter: Auxiliary tables.

Table 8: Calculations for 125°C/65°C network – SERIES 1.

SERIES 1 Insulation STANDARD	Steel pipes				Jacket	Heat network with parameters of 125°C/65°C – installation temperature of 10°C. Backfill density of 18 kN/m³. Frictional force per unit of length *F* – [kN/m], Installation length L_{MAX}, – [m] and its elongation δL_{MAX} – [mm] for the corresponding cover H:																				
	dn	d_O [mm]	s [mm]	A_s [mm]	Dc [mm]	0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m		
						F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}
DN (2x20)/125	20	26.9	2.6	198.5	125	1.75	23.0	18	2.17	18.5	14	2.59	15.5	12	3.01	13.5	10	3.44	11.5	9	3.86	10.5	8	4.28	9.5	7
DN (2x25)/140	25	33.7	2.6	254.0	140	1.97	26.5	20	2.44	21.5	16	2.91	18.0	14	3.39	15.5	12	3.86	13.5	10	4.33	12.0	9	4.80	11.0	8
DN (2x32)/160	32	42.4	2.9	359.9	160	2.27	33.0	25	2.81	26.5	20	3.35	22.5	17	3.88	19.0	15	4.43	17.0	13	4.96	15.0	12	5.50	13.5	10
DN (2x40)/160	40	48.3	2.9	413.6	160	2.27	38.0	29	2.81	31.0	24	3.35	26.0	20	3.89	22.0	17	4.43	19.5	15	4.97	17.5	13	5.51	15.5	12
DN (2x50)/200	50	60.3	2.9	522.9	200	2.87	39.0	30	3.54	31.5	24	4.22	26.5	20	4.89	22.5	17	5.57	20.0	15	6.24	17.5	14	6.92	16.0	12
DN (2x65)/225	65	76.1	2.9	666.9	225	3.26	44.5	34	4.02	36.0	27	4.78	30.0	23	5.53	26.0	20	6.30	23.0	17	7.05	20.5	16	7.81	18.5	14
DN (2x80)/250	80	88.9	3.2	861.6	250	3.65	51.5	39	4.50	41.5	32	5.34	35.0	27	6.18	30.5	23	7.03	26.5	20	7.87	24.0	18	8.71	21.5	16
DN (2x100)/315	100	114.3	3.6	1252.0	315	4.69	59.0	45	5.75	48.0	36	6.82	40.5	31	7.88	35.0	27	8.95	31.0	23	10.01	27.5	21	11.07	25.0	19
DN (2x125)/400	125	139.7	3.6	1539.3	400	6.08	57.0	43	7.43	47.0	35	8.77	39.5	30	10.12	34.5	26	11.48	30.0	23	12.83	27.0	20	14.18	24.5	19
DN (2x150)/450	150	168.3	4.0	2064.7	450	6.96	68.0	51	8.47	55.5	42	9.99	47.0	36	11.51	41.0	31	13.04	36.0	27	14.55	32.5	24	16.07	29.0	22
DN (2x200)/560	200	219.1	4.5	3033.8	560	8.94	79.0	60	10.83	65.5	49	12.72	55.5	42	14.60	48.5	36	16.51	43.0	32	18.40	38.5	29	20.29	35.0	26

Table 9: Calculations for 90°C/55°C network – SERIES 1.

SERIES 1 Insulation STANDARD	Steel pipes				Jacket	Heat network with parameters of 90°C/55°C – installation temperature of 10°C. Backfill density of 18 kN/m³. Frictional force per unit of length *F* – [kN/m], Installation length L_{MAX}, – [m] and its elongation δL_{MAX} – [mm] for the corresponding cover H:																				
	dn	d_O [mm]	s [mm]	A_s [mm]	Dc [mm]	0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m		
						F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}
DN (2x20)/125	20	26.9	2.6	198.5	125	1.75	31.5	11	2.17	25.5	9	2.59	21.5	8	3.01	18.5	7	3.44	16.0	6	3.86	14.0	5	4.28	13.0	5
DN (2x25)/140	25	33.7	2.6	254.0	140	1.97	36.5	13	2.44	29.0	11	2.91	24.5	9	3.39	21.0	8	3.86	18.5	7	4.33	16.5	6	4.80	15.0	5
DN (2x32)/160	32	42.4	2.9	359.9	160	2.27	45.0	16	2.81	36.0	13	3.35	30.5	11	3.88	26.0	9	4.43	23.0	8	4.96	20.5	7	5.50	18.5	7
DN (2x40)/160	40	48.3	2.9	413.6	160	2.27	52.0	19	2.81	42.0	15	3.35	35.0	13	3.89	30.0	11	4.43	26.5	10	4.97	23.5	9	5.51	21.0	8
DN (2x50)/200	50	60.3	2.9	522.9	200	2.87	52.5	19	3.54	42.5	15	4.22	35.5	13	4.89	30.5	11	5.57	27.0	10	6.24	24.0	9	6.92	21.5	8
DN (2x65)/225	65	76.1	2.9	666.9	225	3.26	59.5	21	4.02	48.5	17	4.78	40.5	15	5.53	35.0	13	6.30	31.0	11	7.05	27.5	10	7.81	25.0	9
DN (2x80)/250	80	88.9	3.2	861.6	250	3.66	69.0	25	4.50	56.0	20	5.34	47.0	17	6.18	40.5	15	7.03	36.0	13	7.87	32.0	11	8.72	29.0	10
DN (2x100)/315	100	114.3	3.6	1252.0	315	4.70	79.0	28	5.76	64.0	23	6.82	54.0	19	7.88	47.0	17	8.95	41.5	15	10.01	37.0	13	11.07	33.5	12
DN (2x125)/400	125	139.7	3.6	1539.3	400	6.08	76.0	27	7.43	62.5	22	8.78	52.5	19	10.12	45.5	16	11.48	40.0	14	12.83	36.0	13	14.18	32.5	12
DN (2x150)/450	150	168.3	4.0	2064.7	450	6.96	90.0	32	8.48	74.0	26	10.00	62.5	22	11.51	54.5	19	13.04	48.0	17	14.56	43.0	15	16.07	39.0	14
DN (2x200)/560	200	219.1	4.5	3033.8	560	8.95	104.5	37	10.84	86.0	30	12.72	73.5	26	14.61	64.0	22	16.52	56.5	20	18.41	50.5	18	20.29	46.0	16

7. Hydraulic calculations

7.1. Use of spreadsheets

The use of properly prepared spreadsheets makes it possible to carry out hydraulic analysis of the entire network system under consideration. Linear and local losses should be calculated, for example, according to **PN-76/M-34034**.

The difficulty of the task is to determine the linear resistance coefficient λ. The calculation should take into account the variability of flows characterised by the Reynolds number Re.

$$Re = \frac{w \cdot d_i}{\nu} \qquad (41)$$

- for the range Re ≤2300

$$\lambda = \frac{64}{Re} \qquad (42)$$

- for the range 2300 < Re ≤ 4000, in the critical zone, we can determine the resistance coefficient with sufficient accuracy from the Walden formula:

$$\lambda = \frac{1}{\left(-2 \cdot log\left(\frac{6,10}{Re^{0,916}} + \frac{0,268 \cdot k}{d_i}\right)\right)^2} \qquad (43)$$

for the range Re > 4000, the **Walden** formula can also be used, but on closer analysis it is necessary to check that the relative roughness ε meets the condition:

$$\varepsilon = \frac{k}{d_i} > \varepsilon_{gr} = \frac{23}{Re} \qquad (44)$$

if not, the coefficient of linear resistance should be determined from the **Prandtl-Karman** formula:

$$\lambda = \left(2 \cdot log\frac{\sqrt{(\lambda)} \cdot Re}{2,51}\right)^{-2} \qquad (45)$$

and otherwise from the **Colebrook-White** formula:

$$\lambda = \frac{1}{\left(-2 \cdot log\left(\frac{2{,}51}{Re \cdot \frac{1}{\sqrt{\lambda}}} + \frac{\varepsilon}{3{,}71}\right)\right)^2} \qquad (46)$$

In both cases, due to the complexity of the formulae, the first approximation should be made using the **Walden** formula. Sufficient accuracy is obtained after 4–6 approximations.

Taking the linear resistance coefficient calculated in this way, the unit linear resistance can be determined from the following relationship:

$$Ri = \frac{\lambda \cdot w^2 \cdot \varrho}{2 \cdot d_i} \qquad (47)$$

while local resistances based on the relationship:

$$Z = \Sigma\xi \cdot \frac{\varrho \cdot w^2}{2} \qquad (48)$$

the total pressure loss can be calculated from the relationship:

$$Z = \Sigma\xi \cdot \frac{\varrho \cdot w^2}{2} \qquad (48)$$

7.2. Graphic method

For the purpose of estimating the required diameter of the pipeline, the chart in the figure can be used.

Using the chart involves connecting two selected parameters with a straight line and extending it so that you can read the other parameters.

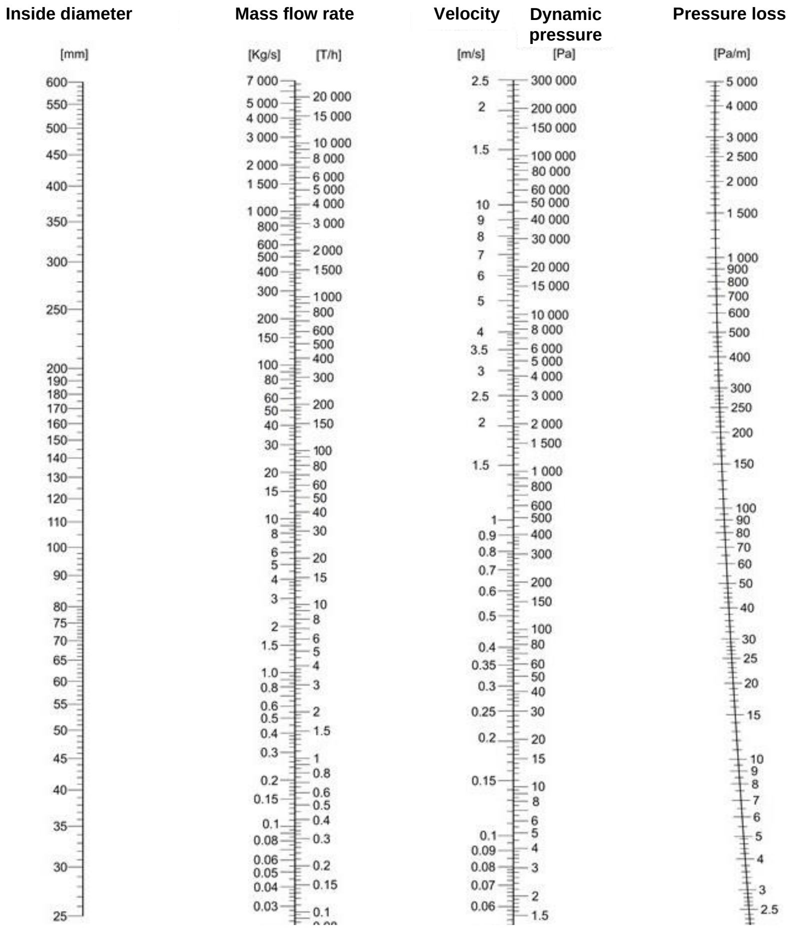

Figure 15: Nomogram of flow, diameter selection and pressure loss.

8. Heat loss calculation of the TWIN PIPE assembly

The computational model is shown in the figure below.

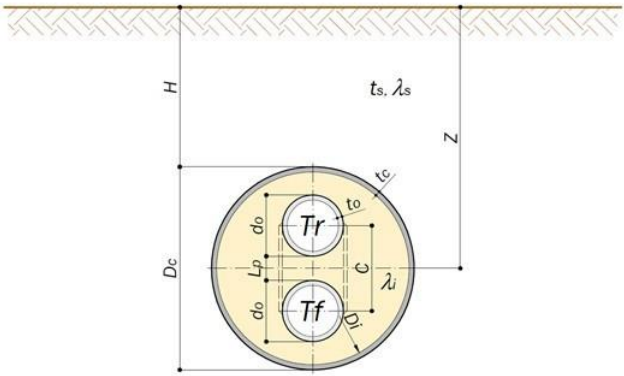

Figure 16: Model for calculating heat loss in twin pipes.

Currently, the superposition method is the preferred method for calculating heat loss in pre-insulated pipelines according to **PN-EN 13941-1**.

In this method, we create two systems (see figure) – symmetric and antisymmetric. We calculate each of these systems separately, and then add up the calculations.

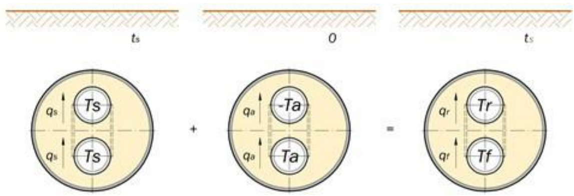

Figure 17: Diagram of assumptions for calculating heat loss by the superposition method.

For each system, we calculate the required temperature:

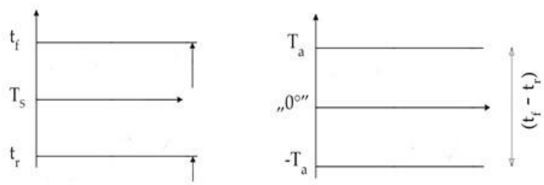

Figure 18: Temperature in symmetric (TS) and antisymmetric (Ta) systems.

For the symmetric system, the temperature is:

$$T_S = \frac{T_F + T_R}{2} \quad (50)$$

and for the antisymmetric system it is:

$$T_A = \frac{T_F - T_R}{2} \quad (51)$$

By introducing two auxiliary variables:

$$\sigma = \frac{\lambda_i - \lambda_S}{\lambda_i + \lambda_S} \quad (52)$$

and

$$\gamma = \frac{2 \cdot (1 - \sigma^2)}{1 - \sigma \cdot \left(\frac{D_i}{4 \cdot Z_C}\right)^2} \quad (53)$$

we proceed to calculate the coefficients: – symmetric coefficient

$$h_S^{-1} = 2 \cdot \frac{\lambda_i}{\lambda_S} \cdot ln\left(\frac{4 \cdot Z_C}{D_i}\right) + ln\left(\frac{D_i^2}{2 \cdot C \cdot d_O}\right) + \sigma \cdot ln\left(\frac{D_i^4}{D_i^4 - C^4}\right) - \frac{\left(\frac{d_O}{2 \cdot C} - \frac{2 \cdot \sigma \cdot d_O \cdot C^3}{D_i^4 - C^4}\right)^2}{1 + \left(\frac{d_O}{2 \cdot C}\right)^2 + \sigma \cdot \left(\frac{2 \cdot d_O \cdot D_i^2 \cdot C}{D_i^4 - C^4}\right)^2} \quad (54)$$

and antisymmetric coefficient

$$h_a^{-1} = ln\left(\frac{2 \cdot C}{d_O}\right) + \sigma \cdot ln\left(\frac{D_i^2 + C^2}{D_i^2 - C^2}\right) - \frac{\left(\frac{d_O}{2 \cdot C} - \gamma \cdot \frac{C \cdot d_O}{16 \cdot Z_C^2} + \frac{2 \cdot \sigma \cdot d_O \cdot D_i^2 \cdot C}{D_i^4 - C^4}\right)^2}{1 - \left(\frac{d_O}{2 \cdot C}\right)^2 - \gamma \cdot \frac{d_O}{4 \cdot Z_C} + 2 \cdot \sigma \cdot d_O^2 \cdot D_i^2 \cdot \frac{(D_i^4 + C^4)}{(D_i^4 - C^4)^2}} - \gamma \cdot \left(\frac{C}{4 \cdot Z_C}\right)^2 \quad (55)$$

where:

$$C = Lp + d_o \; [m] \qquad (56)$$

$$Z_C = Z + R_O \cdot \lambda_S \; [m] \qquad (57)$$

$$R_O = 0{,}0685 \; \frac{m^2 \cdot K}{W} \qquad (58)$$

while the thermal conductivity coefficient for the backfill should be taken from the following values:

$$\lambda_S = 1{,}0 \; \frac{W}{m \cdot K} - dry\ sand$$
$$\lambda_S = 1{,}6 \; \frac{W}{m \cdot K} - medium\ damp\ sand \qquad (59)$$
$$\lambda_S = 2{,}0 \; \frac{W}{m \cdot K} - damp\ sand$$

The heat loss through the supply pipeline in the twin system is calculated from the formula:

$$q_F = q_S + q_A \; \frac{W}{m} \qquad (60)$$

and the heat loss through the return pipeline in the twin system is calculated from the formula:

$$q_F = q_S - q_A \; \frac{W}{m} \qquad (61)$$

We determine the individual components needed for these calculations from the formulae:

$$q_S = (T_S - t_S) \cdot 2 \cdot \pi \cdot \lambda_i \cdot h_S \; \frac{W}{m} \qquad (62)$$

$$q_A = T_a \cdot 2 \cdot \pi \cdot \lambda_i \cdot h_a \; \frac{W}{m} \qquad (63)$$

and the total heat loss through the pipe assembly of the **TWIN PIPE** system is:

$$\Sigma q = q_F + q_R = 2 \cdot q_S \; \frac{W}{m} \qquad (64)$$

The table shows symmetric and antisymmetric coefficients for use in calculating the heat loss of pipelines laid at different depths.

Table 10: Symmetric and antisymmetric coefficients for heat loss calculations – STANDARD insulation.

SERIES 1 - STANDARD insulation	Symmetric and antisymmetric heat loss coefficients for calculation of heat loss in pre-insulated TWIN PIPE pipelines by the superposition method, for t_s = 8°C; λ_s = 1.6 W/mK; λ_i = 0.029 W/mK and pipeline cover H =															
	0.60 m		0.80 m		1.00 m		1.20 m		1.40 m		1.60 m		1.80 m		2.00 m	
	h_s [-]	h_a [-]	h_s [-]	h_a [-]	h_s [-]	h_a [-]	h_s [-]	h_a [-]	h_s [-]	h_a [-]	h_s [-]	h_a [-]	h_s [-]	h_a [-]	h_s [-]	h_a [-]
DN (2x20)/125	0.5377	0.9108	0.5353	0.9108	0.5334	0.9108	0.5317	0.9108	0.5304	0.9108	0.5291	0.9108	0.5280	0.9107	0.5271	0.9107
DN (2x25)/140	0.5306	0.9749	0.5877	0.9749	0.5854	0.9749	0.5834	0.9749	0.5818	0.9749	0.5803	0.9749	0.5790	0.9749	0.5778	0.9749
DN (2x32)/160	0.6416	1.0509	0.6382	1.0508	0.6355	1.0508	0.6332	1.0508	0.6313	1.0508	0.6296	1.0508	0.6280	1.0508	0.6267	1.0508
DN (2x40)/160	0.7707	1.0816	0.7659	1.0816	0.7620	1.0816	0.7587	1.0816	0.7559	1.0816	0.7534	1.0816	0.7513	1.0816	0.7493	1.0816
DN (2x50)/200	0.7496	1.1215	0.7451	1.1214	0.7415	1.1214	0.7384	1.1214	0.7358	1.1214	0.7335	1.1214	0.7315	1.1214	0.7296	1.1214
DN (2x65)/225	0.9015	1.1718	0.8951	1.1717	0.8899	1.1717	0.8856	1.1716	0.8818	1.1716	0.8786	1.1716	0.8756	1.1716	0.8730	1.1716
DN (2x80)/250	1.0322	1.1397	1.0239	1.1396	1.0172	1.1396	1.0116	1.1396	1.0068	1.1396	1.0026	1.1396	0.9988	1.1395	0.9954	1.1395
DN (2x100)/315	1.0343	1.2066	1.0263	1.2065	1.0197	1.2064	1.0142	1.2064	1.0095	1.2063	1.0053	1.2063	1.0016	1.2063	0.9982	1.2063
DN (2x125)/400	0.9518	1.2006	0.9452	1.2005	0.9399	1.2004	0.9353	1.2003	0.9314	1.2003	0.9279	1.2003	0.9248	1.2002	0.9220	1.2002
DN (2x150)/450	1.1683	1.1587	1.1587	1.1586	1.1508	1.1585	1.1441	1.1584	1.1383	1.1584	1.1332	1.1583	1.1287	1.1583	1.1245	1.1583
DN (2x200)/560	1.3132	1.1875	1.3017	1.1872	1.2922	1.1871	1.2841	1.1870	1.2770	1.1869	1.2708	1.1869	1.2652	1.1868	1.2601	1.1868

The following shows the maximum heat loss of pipelines with a cover of **H = 0.6 m** and the minimum heat loss with a cover of **H = 1.6 m**, both for **125°C/65°C** network and for **90°C/55°C** consumer installations and for the basic **SERIES 1 – standard insulation**.

For **SERIES 2** and **SERIES 3**, tables of values are included in the chapter: Auxiliary tables.

Table 11: Heat loss for 125°C/65°C network – SERIES 1 STANDARD insulation.

SERIES 1 STANDARD insulation	Steel pipes		Jacket	Heat loss under design conditions for 125°C/65°C network					
				Cover H = 0.6 m λs = 2.0 W/(mK); ts=0°C			Cover H = 1.6 m λs = 1.6 W/(mK); ts=8 °C		
	dn	d_0 [mm]	Dc [mm]	q_F W/m	q_R W/m	Σq W/m	q_F W/m	q_R W/m	Σq W/m
DN (2x20)/125	20	26.9	125	14.4	4.4	18.8	13.4	3.4	16.8
DN (2x25)/140	25	33.7	140	15.7	5.0	20.7	14.5	3.9	18.4
DN (2x32)/160	32	42.4	160	17.0	5.5	22.5	15.7	4.2	19.9
DN (2x40)/160	40	48.3	160	19.5	7.7	27.2	17.9	6.0	23.9
DN (2x50)/200	50	60.3	200	19.3	7.0	26.3	17.8	5.5	23.3
DN (2x65)/225	65	76.1	225	22.3	9.5	31.8	20.3	7.5	27.8
DN (2x80)/250	80	88.9	250	24.5	12.0	36.5	22.1	9.7	31.8
DN (2x100)/315	100	114.3	315	24.8	11.6	36.4	22.5	9.3	31.8
DN (2x125)/400	125	139.7	400	23.3	10.2	33.5	21.3	8.1	29.4
DN (2x150)/450	150	168.3	450	26.9	14.3	41.2	24.3	11.6	35.9
DN (2x200)/560	200	219.1	560	29.7	16.7	46.4	26.6	13.7	40.3

Table 12: Heat loss for 90°C/55°C network – SERIES 1 STANDARD insulation.

SERIES 1 - STANDARD insulation	Steel pipes		Jacket	Heat loss under design conditions for 90°C/55°C network					
				Cover H = 0.6 m λs = 2.0 W/(mK); ts=0°C			Cover H = 1.6 m λs = 1.6 W/(mK); ts=8°C		
	dn	d_0 [mm]	Dc [mm]	q_F W/m	q_R W/m	Σq W/m	q_F W/m	q_R W/m	Σq W/m
DN (2x20)/125	20	26.9	125	10.1	4.3	14.4	9.1	3.3	12.4
DN (2x25)/140	25	33.7	140	11.0	4.8	15.8	9.9	3.7	13.6
DN (2x32)/160	32	42.4	160	11.9	5.2	17.1	10.7	4.0	14.7
DN (2x40)/160	40	48.3	160	13.8	6.9	20.7	12.3	5.4	17.7
DN (2x50)/200	60	60.3	200	13.6	6.5	20.1	12.2	5.0	17.2
DN (2x65)/225	65	76.1	225	15.9	8.4	24.3	14.1	6.6	20.7
DN (2x80)/250	80	88.9	250	17.5	10.3	27.8	15.4	8.1	23.5
DN (2x100)/315	100	114.3	315	17.8	10.1	27.9	15.7	8.0	23.7
DN (2x125)/400	125	139.7	400	16.6	8.9	25.5	14.7	7.1	21.8
DN (2x150)/450	150	168.3	450	19.4	12.0	31.4	17.0	9.6	26.6
DN (2x200)/560	200	219.1	560	21.5	13.9	35.4	18.7	11.2	29.9

Due to the fact that the pipelines are laid in the frost zone, for the calculation of SERIES 1 pipelines – standard insulation, with a cover of H = 0.6 m, the thermal conductivity coefficient of the backfill was adopted as for wet sand, i.e. $\boldsymbol{\lambda_S = 2.0}$ **W/mK** , and the temperature of the undisturbed ground at the level of the pipeline axis $\boldsymbol{t_S = 0}$**°C**. For pipelines buried deeper, $\boldsymbol{\lambda_S = 1.6}$ **W/mK** and $\boldsymbol{t_S = 8}$ **°C** were adopted, respectively.

9. Design indications

9.1. Pipeline laying

The way in which the elements of the **TWIN PIPE** system are laid in the trench is of great importance. As shown in the figure, the pre-insulated elements should be laid in the trench so that the steel pipelines are in a vertical position (one above the other), with the supply pipeline (**F**) laid below the return pipeline **(R**). Such an arrangement increases the vertical stability of the laid section of the heat network and reduces heat loss.

A major limitation of such an arrangement is the difficulty of making corrections to the longitudinal profile of the laid heat network. Hence, the designer's task is to comprehensively assess the required depth of laying pre-insulated pipelines in relation to the existing underground utilities of the entire area where the proposed investment will be implemented.

It is not permissible to arrange the pre-insulated elements so that the steel pipelines are laid horizontally – one next to another.

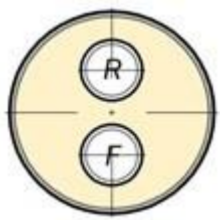

Figure 19: TWIN PIPE element arrangement.

9.2. Trenches

The minimum trench dimensions (minimum width) should be adapted to the diameters of the pipe assemblies used and the spacing distances in the trench, which are shown in the table below.

In addition, the width of the trench should take into account the need for workers to walk in the trench along the pipelines on one or both sides depending on the diameter of the pipelines.

Table 13: Distances in the trench.

Minimum distances in the trench		
DC jacket diameter (mm)	Distance between pipe jackets M [mm]	Distance between the jacket and the trench wall N [mm]
Dc ≤ 225	150	150
225 < Dc ≤ 560	250	250
Dc >560	300	300

In networks run with a steep slope or located on slopes, it is necessary to take into account the possibility of the drainage effect of the trench profile.

For the needs of the welder and the person making the connections, a stand shall be provided at the connection points of the pre-insulated elements, which must meet the following requirements:

- minimum length: **1.5 m**
- minimum distance between the line pipe and the bottom of the trench **0.4 m**,
- minimum distance between the wall of the line pipe and the trench wall **0.5 m**.

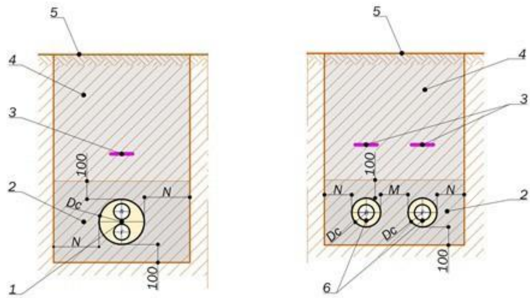

Figure 20: Comparison of minimum trenches for double and single pipelines of the same diameter, laid with the same cover.
(1) pre-insulated TWIN PIPE element, (2) sand bed, (3) marker tape,
(4) backfill, (5) paving, (6) pre-insulated element in accordance with PN-EN 253

Comparing the minimum trench cross-sections for the **TWIN PIPE** system and the system compliant with **PN-EN 253** (single pipes), it can be concluded that, while meeting the requirements of **PN-EN 13941-1**, the reduction in trench volume for the **TWIN PIPE** system compared to the system according to **PN-EN 253** can be up to **30%**, especially for small diameter pipelines.

Table 14: Minimum trench dimensions for the TWIN PIPE system.

dn	System according to PN-EN-15698-1 – TWIN PIPE system SERIES 1 – STANDARD insulation						
	DC [mm]	designation [-]	Horizontal distance [mm]	Minimum bed height [m]	Minimum bed width [m]	Bed volume l=1.0 m [m³]	Min. volume of 1.0 m length of trench H=0.8 m [m³]
20	160	DN (2x20)/160	150	0.36	0.46	0.17	0.49
25	180	DN (2x25)/180	150	0.38	0.48	0.18	0.52
32	200	DN (2x32)/200	150	0.40	0.50	0.20	0.55
40	200	DN (2x40)/200	150	0.40	0.50	0.20	0.55
50	250	DN (2x50)/250	150	0.45	0.55	0.25	0.64
65	280	DN (2x65)/280	150	0.48	0.58	0.28	0.69
80	315	DN (2x80)/315	250	0.52	0.82	0.42	0.99
100	400	DN (2x100)/400	250	0.60	0.90	0.54	1.17
125	500	DN (2x125)/500	250	0.70	1.00	0.70	1.40
150	560	DN (2x150)/560	250	0.76	1.06	0.81	1.55
200	710	DN (2x200)/710	250	0.91	1.21	1.10	1.95

Table 15: Minimum trench dimensions for the system according to PN-EN 253 – single pipes.

dn	System according to PN EN 253 - SERIES 1						
	Dc [mm]	Designation [-]	Horizontal distance [mm]	Minimum bed height [m]	Minimum bed width [m]	Bed volume l=1.0 m [m³]	Min. volume of 1.0 m length of trench H = 0.8 m [m³]
20	90	DN 20/90	150	0.29	0.63	0.18	0.62
25	90	DN 25/90	150	0.29	0.63	0.18	0.62
32	110	DN 32/110	150	0.31	0.67	0.21	0.68
40	110	DN 40/110	150	0.31	0.67	0.21	0.68
50	125	DN 50/125	150	0.33	0.70	0.23	0.72
65	140	DN 65/140	150	0.34	0.73	0.25	0.76
80	160	DN 80/160	150	0.36	0.77	0.28	0.82
100	200	DN 100/200	150	0.40	0.85	0.34	0.94
125	225	DN 125/225	150	0.43	0.90	0.38	1.01
150	250	DN 150/250	250	0.45	1.25	0.56	1.44
200	315	DN 200/315	250	0.52	1.38	0.71	1.68

9.3. Sand bed and backfill

The sand bed is the space in close proximity to pre-insulated pipelines with a layer thickness of **min. 0.1 m** and width according to the table of distances in the trench.

This space should be filled with non-cohesive sand of medium to coarse granulation with the following parameters:

- granularity – **0÷4 mm**,
- grains with round edges,
- grading curve according to **PN EN 13941-2**.

It is unacceptable to use materials with variable properties (such as self-stabilising sand mixtures known and used in road construction) and sands with stone content within the sand bed.

If, due to unfavourable ground or weather conditions, there is a risk that the bed sand will be washed out during the operation of the network (e.g. by rainwater), the bed zone should be covered with geotextile.

No “foreign” utilities may pass through the sand bed.

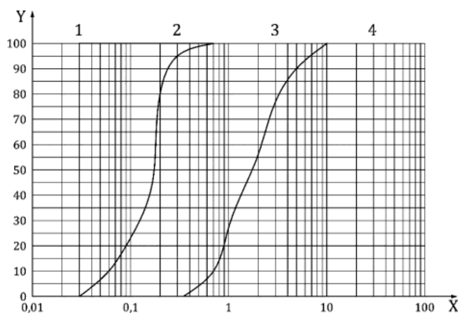

Figure 21: Limits of grading curves for sand bed according to PN-EN 13941-2.
(1) silt, (2) sand, (3) gravel, (4) stones

According to **PN-EN 13941-1**, the material for the sand bed should be sand. According to Appendix E of the said standard, the calculations assumed medium compacted sand with a weight of **γ_S = 18 kN/m^3** with an angle of internal friction of **φ = 32.5°**.

9.4. Minimum coverage of the pipe assembly

The minimum size of cover for pre-insulated elements and pipelines where the value of axial stresses does not exceed **190 MPa** is **0.4 m**.

When crossing paved surfaces with pre-insulated pipelines, this size is the depression of the top of the pipeline jacket in relation to the underside of the paved surface substructure. This means that if the road surface including the substructure is (for example) 60 cm thick, the cover of the pipelines should be at least **H = 1.0 m**. Laying pipelines with less cover in this situation will require additional solutions (e.g. casing pipes, pressure relief plates, etc.)

Avoid laying pipelines using minimal cover. Such a solution is only allowed in exceptional cases, after consultation with the network manager.

It is recommended to lay pre-insulated pipelines with a cover of at least **0.8-1.0 m**. This helps to avoid many collisions with power and telecommunications cables.

9.5. Maximum coverage of the pipe assembly

The table shown gives the maximum coverage of pre-insulated pipelines depending on the designed spacing of adjacent elbows (the so-called free ends).

The calculation of the limit states of PUR foam is carried out in accordance with the provisions of **PN-EN 13941-1** and **PN-EN 253**, taking into account the required variation of safety coefficients. A safety coefficient for the specific gravity of the backfill was also applied in accordance with the recommendations of **PN-EN 13941-1**.

Table 16: Maximum coverage of pipelines.

dn	d_0 [mm]	Maximum coverage of pre-insulated pipelines – TWIN PIPE system					
		elbow spacing ≤ 20.0 m (γm=2.0)			elbow spacing > 20.0 m (γm=3.0)		
		SERIES 1 [m]	SERIES 2 [m]	SERIES 3 [m]	SERIES 1 [m]	SERIES 2 [m]	SERIES 3 [m]
20	26.9	2.9	2.5	2.2	1.90	1.70	1.50
25	33.7	3.2	2.8	2.5	2.10	1.80	1.60
32	42.4	3.5	3.1	2.8	2.30	2.10	1.90
40	48.3	4.0	3.6	3.2	2.70	2.40	2.10
50	60.3	4.0	3.5	3.2	2.60	2.30	2.10
65	76.1	4.5	4.0	3.6	3.00	2.70	2.40
80	88.9	4.7	4.2	3.7	3.10	2.80	2.50
100	114.3	4.8	4.2	3.7	3.20	2.80	2.50
125	139.7	4.6	4.1	3.6	3.00	2.70	2.40
150	168.3	4.9	4.4	3.9	3.20	2.90	2.60
200	219.1	5.1	4.5	4.0	3.40	3.00	2.60

9.6. Compensating pads

In order to protect the pre-insulated pipe assembly, where there is lateral movement of the pipelines, it is necessary to design the covering of the pipelines with flexible materials that allow the pipelines to move in the ground.

PN-EN 13941 requires that the pads be made of foamed and cross-linked, closed-cell polyethylene **PE**. The stiffness of the compensating pads used must be in accordance with the stiffness values used in the calculations, which are shown in the table.

Compensating pads should be designed on both sides of the pipelines. Any deviation from covering pre-insulated pipelines with compensating mats should be documented in the design with calculation, checking the polyurethane foam limit states for each such location.

Table 17: Compensating pad requirements.

Normative designation of types of compensating pads according to PN-EN 13941-1	Required compressive stress value for pad compression;		
	40% [kPa]	50% [kPa]	75% [kPa]
Type 1: HARD	85 ±15%	120 ±15%	480 ±15%
Type 2: MEDIUM HARD	60 ±15%	90 ±15%	275 ±15%

The compensation zone should also be designed wherever there is a lateral impact of the ground on the surface of the pre-insulated pipe jacket, that is, at:

- compensating bends,
- non-compensating bends,
- side branches from the main pipeline,
- the main pipeline at the side branch,
- changes in the diameter of the pipeline,
- shut-off valve stems,
- vent and vertical drain stubs.

Compensating pads should be designed in different layers depending on the desired thickness. In addition, they should be wrapped with a suitable protective cover. Protective covers can consist of either geotextile with filament tape or foam film made of cross-linked polyethylene.

According to **PN-EN 13941-1** and **PN-EN 13941-2**, the use of compensating pads without a protective cover is not permitted.

9.7. Fixing anchors

The figure below shows the locations of the fixing anchors used to fuse the supply and return pipelines in the pre-insulated **TWIN PIPE** heat network installed.

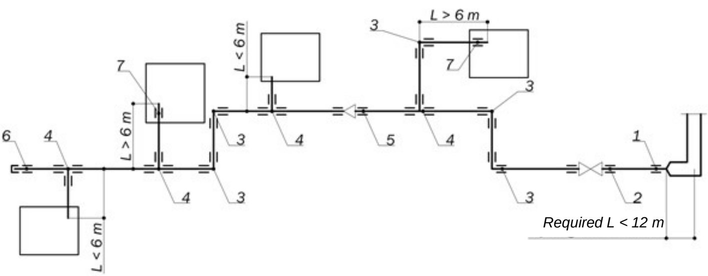

Figure 22: Locations where anchors are required in the twin pipe system.
(1) transition fittings (2) assemblies of shut-off, vent and drainage fittings, (3) elbows, (4) tees, (5) diameter reductions,
(6) completion of the construction phase, (7) entry into buildings,

RADPOL uses anchors in all factory-produced fittings in the following quantities:

- transition fitting – **2 sets**
- valve assemblies – **2 sets**
- vent assemblies – **2 sets**
- drainage assemblies – **2 sets**
- reducers – **2 sets**
- elbows – **2 sets**
- tees – **3 sets**

It is the designer's task to anticipate the need for fixing anchors at building entrances if the section in front of the building is longer than **6.0 m** and the entrance to the building is through a straight pipe.

The use of anchors should also be provided for:

- at the site of possible construction staging – **1 set**
- at the site where installation work is interrupted – **1 set**
- at the site of application of the reducer in the reduction coupler – **1 set**
- at the site of elbow installation in the elbow coupler – **2 sets**
- at the site where the heat network pipelines should be cut in order to insert an additional tee – **2 sets**

9.8. Change of direction

9.8.1. Elbows

To change the direction of the network route, bends (elbows) with angles from **5° to 90°** (selected in **5°** increments) or arrangements of these bends are used.

In places where natural compensations are expected, it is recommended to use bends with angles of **90°** or angles in the range of **75°÷90°**.

It is allowed to design changes in the direction of the heat network route with the use of bends with a range of bending angles from **5°÷75°**, provided that:

- the displacement of the top of the bend is checked and a coefficient is applied to increase the size of the compensation zone,
- a comparison is made with the limit values in the table opposite.

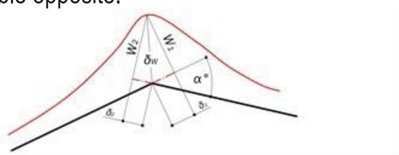

Figure 23: Displacement of the pipeline top and conversion elongations.

Table 18: Elongations allowed.

Angle of deviation of the network axis	$(W_1+W_2)_{DOP}$ mm
≤ 5°	straight
10°	16.0
15°	17.0
20°	18.0
25°	22.0
30°	26.0
35°	32.0
40°	39.0
45°	48.0
50°	57.0
55°	68.0
60°	80.0
66°	92.0
70°	104.0
75°	115.0

The values of W1 and W2 can be calculated from the formulae:

$$W_1 = \frac{\delta_1}{tg\alpha} + \frac{\delta_2}{sin\alpha} \quad (65)$$

$$W_2 = \frac{\delta_2}{tg\alpha} + \frac{\delta_1}{sin\alpha} \quad (66)$$

$$\delta_W = \sqrt{W_1^2 + W_2^2} \quad (67)$$

The values of the maximum permissible distances between adjacent bends for intermediate angles should be determined by interpolation.

It is desirable that the sections on both sides of the bend have similar lengths in the considered range of **5°÷75°**, and if this is not possible, then the quotient of the lengths of the sections should not be greater than **3**.

If there are bends with an angle of deviation of the network route from **5°÷75°**, they should be treated as non-compensating.

The most advantageous solution is to use a substitute layout.

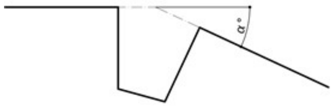

Figure 24: A substitute layout using a U-shape.

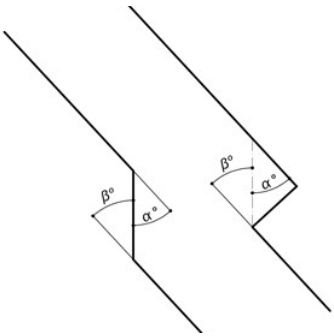

Figure 25: A substitute layout using Z-shape.

The value of thermal elongations of pipelines on both sides of such a bend should be specified in the design.

All bends should be covered with compensating pads.

9.8.2. Bevel

Due to the difficulty of implementation, it is not recommended to design small angular deviations of the pipeline axis using bevelling. The main problem is the need for preparatory and welding work on two independent steel pipelines. Slight vertical deflection during the course of the work can result in poor weld performance.

If such an operation is necessary, the maximum bevel angle must not exceed 3° for each diameter of the pipe assembly.

The distance between two consecutive bevels must not be less than 20 outside diameters of the line steel pipe.

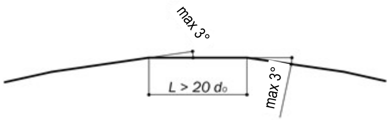

Figure 26: Bevelling requirements.

9.8.3. Flexible bent pipes

Instead of performing the difficult bevelling process, it is more advantageous to design and perform flexible bending of the pre-insulated pipe.

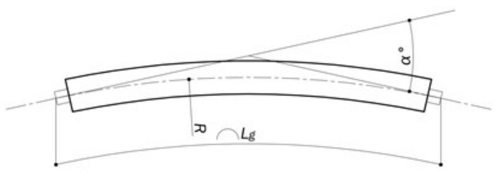

Figure 27: Characteristic parameters of a flexible bent pipe.

To calculate the minimum bending radius of the pipe, use the formula:

$$R_{MIN} = \frac{E \cdot d_o}{1{,}3 \cdot R_e} \quad (68)$$

and from there, we can determine the angle by which we can change the direction of the pipeline axis:

$$\alpha = \frac{180 \cdot L}{\pi \cdot R_{MIN}} \quad (69)$$

We can also determine what the required bending radius is for a given pipeline axis deviation angle.

$$R = \frac{180 \cdot L}{\pi \cdot \alpha} \geq R_{MIN} \qquad (70)$$

9.9. Cascades

Due to the difficulties associated with overcoming significant differences in terrain, it is recommended to use cascades (changing the ordinate of the axis of the pipeline vertically). Cascades should only be designed with bends with an angle of 75°-90° and their minimum height must not be less than 2.0 m ("bend to bend").

The design of cascades should take into account the additional slope (backfill) load, and the elbows should be covered with compensating mats. In addition, a check should be made to ensure that the maximum allowable coverage of the pipelines is not exceeded.

The distance between the nearest adjacent bends and the bends of the cascade should not exceed 20 m.

It is essential that the location of cascades is marked and described on the site plan and installation diagram.

Cascades should be made using vertical elbows that allow for changes of direction in the vertical plane.

9.10. Branches

In the network built with pre-insulated elements made in the **TWIN PIPE** system, branches are made in the plane of the main pipeline. It is important to maintain the required permissible length of the branch, which is shown in the presented relations and the figure.

$$L_{ODG} = 0{,}5 \cdot L_{MAX} \leqslant 12m \qquad (71)$$

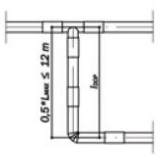

Figure 28: Branch length requirements.

In the network built with pre-insulated elements made in the TWIN PIPE system, branches are made in the plane of the main pipeline – see the figure.

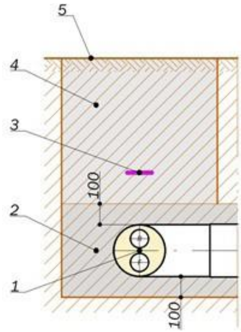

Figure 29: Branch in the plane of the pipelines.
(1) TWIN PIPE system tee, (2) sand bed, (3) marker tape,
(4) backfill, (5) paving

9.11. Shut-off valves

The fitting of the valve assembly is a rather complicated steel piping system inside the jacket, so it is not recommended to install it at the point of maximum axial stress. It is recommended that it be mounted no further than 1/3 of the LMAX from the free end.

The location of the valve stems in the fitting allows them to be installed in a common manhole with a Φ600 hatch.

Due to the height location of the valves, which is related to the position of the steel piping in the fitting, it is recommended to use stem extenders.

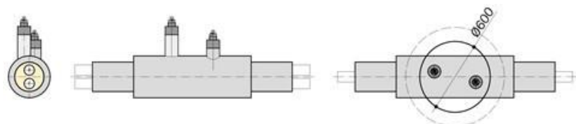

Figure 30: Shut-off valve DN (2x80) /160 with hatch clearance Φ600 marked.

It is not allowed to use street boxes to house valves. The stem insulation depends on the diameter of the valve:

- dn 20 and 25 – 90 mm
- dn 32, 40, 50, 65 and 80 – 110 mm
- dn 100, 125, 150 – 140 mm
- dn 200 – 200 mm

9.12. Vents

All vent fittings are equipped with vent valves with a diameter of **dn 25 mm**.

The vents are equipped with service valves, whose body is made of stainless steel and the spigot is made of black steel pipe.

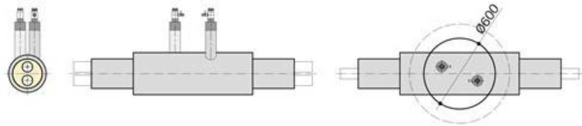

Figure 31: Venting at DN (2×80) /160 with hatch clearance Φ600 marked.

The location of the spigots in the fitting allows them to be installed in a common manhole with a Φ600 hatch.

It is not allowed to use street boxes to house valves.

9.13. Vertical drains

Drainage fittings are equipped with valves with diameters:

- dn 20, 25, 32 and 40 – 25 mm
- dn 50, 65, 80 and 100 – 32 mm
- dn 125, 150 and 200 – 50 mm

The drains are equipped with service valves, whose body is made of stainless steel and the spigot is made of black steel pipe.

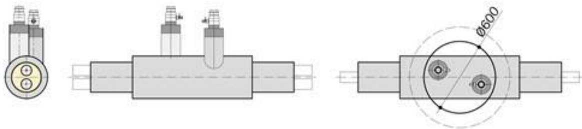

Figure 32: Drainage at DN (2×80) /160 with hatch clearance Φ600 marked.

The location of the spigots in the fitting allows them to be installed in a common manhole with a Φ600 hatch.

It is not allowed to use street boxes to house valves.

9.14. Reduction of diameters

The reducers should be designed downstream of the branches and downstream of future planned locations of branches from the network.

When designing diameter reduction on pre-insulated pipelines, it is essential to analyse the stress spike in the smaller diameter steel pipe, which is proportional to the ratio of the cross-sectional areas of the pipes.

Due to the above, these assemblies may be subject to displacement, and as a result, compensating matting is required around these elements. The thickness of the mats should be adjusted to the design displacement of the pipeline at the reduction point during the first heating.

The following requirements should be observed when designing a reduction in pipeline diameter:

- do not design a reduction in pipeline diameter by more than two dimensions on a single pre-insulated reducer,
- in the case of a reduction at the point where stresses of ≤ 150 MPa will occur on the smaller diameter pipeline, a reduction of two dimensions is allowed;
- the distance between two reducers at the point where stresses of ≤ 150 MPa will occur on the smaller diameter pipeline must not be less than 6.0 m,
- in the case of a reduction at the point where stresses of > 150 MPa will occur on the smaller diameter pipeline, a reduction of one diameter is allowed. A larger diameter change should be achieved by using several single-stage reducers.

9.15. Connections to pre-insulated networks according to PN-EN 253

The **TWIN PIPE** system can be combined with pre-insulated pipelines made in accordance with **PN-EN 253** – single pipelines.

The connection requires a specialised fitting. At present, "**Y-type**" fittings are available.

The "Y-type" fitting is made in two variants that differ in the mutual arrangement of the supply and return pipelines on the side of the single pipe system.

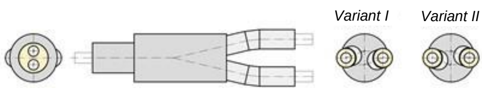

Figure 33: Transition fitting from TWIN PIPE to single pipe system – Y type.

A “**type F**” fitting, shown in figure below, which will also be made in two variants, is under development.

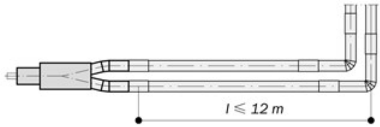

Figure 34: The condition of connecting TWIN PIPE pipelines to pipelines according to PN-EN 253.

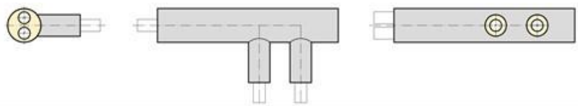

Figure 35: Transition fitting from TWIN PIPE to single pipe system – F type.

9.16. Passages through building partitions

A passage through building partitions (buildings, chambers or wells), can be made using a typical rubber ring.

If groundwater is present, additional sealing should be provided in the form of sealing elements (e.g. type WGC).

If the section of the heat network outside the building is longer than **6.0 m**, use fixing anchors inside the building (see figure).

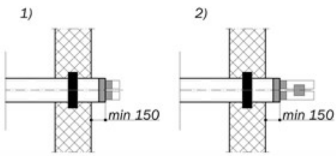

Figure 36: Passages through building partitions using a rubber ring.

(1) length of straight pipe outside the building < 6.0 m
(2) length of straight pipe outside the building > 6.0 m with fixing anchor

The building wall can also be passed using a vertical elbow, which is a specialised elbow that allows you to change direction in the vertical plane (see figure).

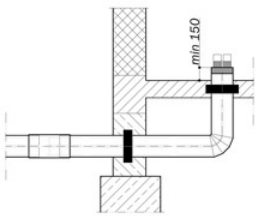

Figure 37: Passing through a wall using a vertical elbow.

9.17. Real fixed points

In the design of pre-insulated pipelines, including the **TWIN PIPE** system, the use of real fixed points should be avoided due to the size and difficulty of locating them in a built-up area.

If necessary, the size and shape of the concrete block of the fixed point should be determined by the design engineer, adapting it to the existing situation on site.

9.18. Insulation of joints

The type of couplers used to insulate the joints of pre-insulated elements under construction conditions should be specified in detail in the design.

In the range of polyethylene jacket diameters up to Dc = 560 mm, heat shrinkable couplers should be designed. Above this diameter, electrofusion couplers should be used. Electrofusion couplers should also be used at the connection points of two pre-insulated fittings, where it is not possible to install a

heat shrinkable coupler before welding.

The length of the coupler should depend on the length of the bare ends of the pre-insulated elements.

Under no circumstances should heat shrinkable couplers be shortened.

9.19. Heat shrinkable end seals

At the ends of the pre-insulated elements, where the pre-insulation is in contact with the outside air, heat shrinkable ends adapted to the existing diameters of the line pipes and polyethylene jackets should be installed.

9.20. Installation in the field with underground utilities

9.20.1. Parallel installation

The heat network should be designed in a way that the recommended minimum distances between the heat network gauge and the gauge of other objects listed below are maintained.

- Sewerage – basic distance of at least 1.2 m with the possibility of change with the consent of the owner.
- Water supply – basic distance of at least 0.9 m with the possibility of change with the consent of the owner.
- Cables up to 30 kV – basic distance of at least 0.5 m.
- Cables over 30 kV – basic distance of at least 1.0 m.
- Gas pipeline – basic distance of at least 1.0 m with the possibility of change based on the Regulation of the Minister of Economy of 26 April 2013 on the technical conditions to be met by gas networks and their location.
- Telecommunications networks – basic distance of at least 1.0 m with the possibility of change with the consent of the owner and based on the Regulation of

the Minister of Infrastructure of 26 October 2005 on the technical conditions to be met by telecommunications construction facilities and their location.

In justified cases, upon agreement with the manager of underground utilities, it is allowed to reduce the distances indicated above, after applying additional safety solutions agreed with the managers of these networks. In addition, the design should provide technical solutions for the protection of the adjacent underground infrastructure.

The distance between the gauge of the heat network and the building, its foundations (due to the risk of ground bearing capacity failure), as well as the outline of the building above ground level (due to operational requirements, including the possible work of equipment during repairs or failure removal) depends on the diameter of the heat network.

9.20.2. Crossings

Irrespective of possible ground or pipeline displacements, all crossing pipelines should be laid no closer than 150 mm from the jacket.

If this minimum distance cannot be maintained, the casing pipe must be protected by an additional HDPE pipe over a length equal to five times the diameter of the casing pipe, but not less than 1.5 m.

The crossing pipe must also be protected by a casing pipe.

In the vicinity of couplers, branches or valves, a minimum distance of 150 mm also applies.

Crossings resulting from the laying of district heating pipelines over or under the equipment of other underground infrastructure must be marked in the design, which should also include detailed solutions to the collision, agreed or accepted by the owner or manager of the underground utilities.

In the case of crossing the heat network with these facilities, the minimum (vertical) distances between pre-insulated pipelines and other utilities (or the protective pipe of other utilities) should be:

- telecommunication networks – 0.5 m with the possibility of change based on the Regulation with special protection (approach pipe) or specific protection (culvert pipe or concrete footing) with the consent of the owner or manager, while applying contact protection,
- gas pipeline – 0.2 m with the possibility of change under the Regulation of the Minister of Economy of 26 April 2013 on the technical conditions to be met by gas networks and their location,
- power cables ≤ 30 kV – to be agreed with the power grid manager, but not less than 0.1 m between the jacket and the cable cover,
- power cables > 30 kV – to be agreed with the power grid manager,
- water supply – to be agreed with the manager of the water supply network, not less than 0.1 m,
- sewerage – to be agreed with the sewerage system manager, not less than 0.1 m.

9.21. Emergency signalling system

In order to immediately identify and locate emergency conditions, minimise operating costs and the cost of any repairs to the heat network, it is necessary to provide for the use of elements equipped with alarm signalling system wires at the design stage.

A prerequisite for the successful operation of the system is therefore the correct design and implementation of the so-called measuring loops.

When designing a heat network equipped with an alarm system, the designer must:

- determine the method of pipeline inspection,
- indicate the location of fixed equipment,
- indicate the locations of the measuring terminals to be installed,
- determine the size of the measuring loops,
- draw a diagram of the alarm system installation with a description of the characteristic points.

If fixed equipment is to be designed, provision should be made for:

- the location of the equipment in accordance with the manufacturer's specifications,
- the power supply to the equipment,
- the location of the alarms.

Another task for the designer is to identify and specify the components of the control system that are mounted directly at the pipeline or placed in its close proximity, including junction and measurement boxes.

It is advisable to install the locator in a place that allows connection to the 230 V AC electrical system.

The measuring loop should be designed so that measurements can be taken from at least both ends of the loop. In the case of extensive loops, it should be possible to disconnect the loop by leading the wires from the pre-insulated element to the measurement post. If a box is placed on a pole, its location should be marked on a map and agreed along with the network location arrangements.

The insulation of the vent stub, drain or valve stem, specially prepared by the manufacturer of the pre-insulated system, can also be used to disconnect the loop.

9.22. Operational routes

The route of the network should be designed to allow operational access to carry out repairs or to remove failures, and, in the case of large-diameter networks, to allow access for heavy equipment involved in the work.

10. Thermal elongation compensation

The choice of method for compensating thermal elongation depends on local conditions and an analysis of the advantages and disadvantages of each method.

Thermal elongations of pipelines can be compensated by natural bends of the route with specially selected geometry, covered with compensating pads depending on the displacement of the free end of the pre-insulated pipeline.

Pipelines can also be laid with preheating – for more details, contact the **RADPOL** Design and Technical Consulting Team.

Commonly used compensation systems are shown in the following figures.

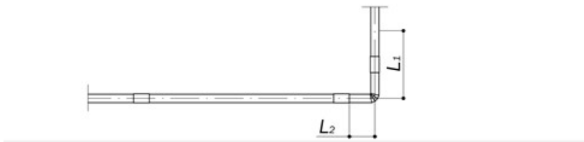

Figure 38: Geometry of an L-shaped compensation system.

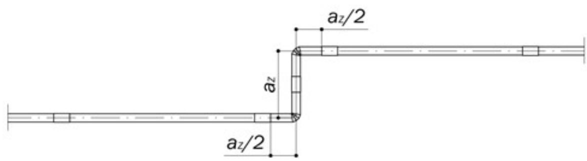

Figure 39: Geometry of a Z-shaped compensation system.
The characteristic sizes for covering with compensating pads are marked.

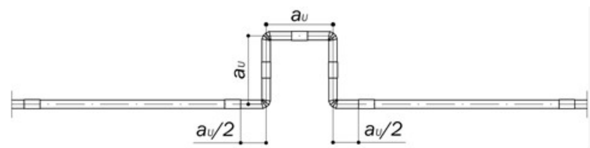

Figure 40: Geometry of a U-shaped compensation system.
The characteristic sizes for covering with compensating pads are marked.

In the selection of compensation, an important element is the calculation of the elongation of the network section in both directions.

When considering a section of the network between two free ends at different depths of the axis of the heat network, the formula for determining the location of the natural fixed point for the scheme shown will be useful.

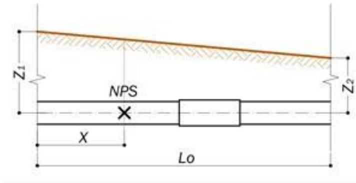

Figure 41: A computational scheme for determining the location of a natural fixed point.

$$X = \frac{2 \cdot Z_1 - \sqrt{2 \cdot (Z_1^2 + Z_2^2)}}{2 \cdot (Z_1 - Z_2)} \cdot L_O \; for \;\; Z_1 \neq Z_2 \qquad (72)$$

Due to the operating temperature range in the catalogue presented, most compensation systems will be limited to the size formed by two interconnected pre-insulated elbows.

For an operating temperature of **125°C/65°C** and elongations of $\boldsymbol{\delta_{MAX}}$ shown in the tables above, the required compensation element heights shown in the table can be used for the basic design.

If the elongation **δ** is different, a detailed recalculation can be made, but Z-shaped and U-shaped compensation elements should be formed using pre-insulated elbows without shortening.

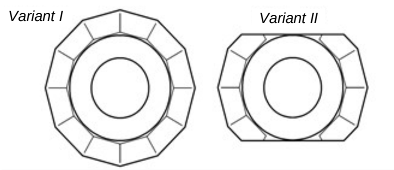

Figure 42: Methods of covering pipelines with compensating pads.

In order to apply the table, the thickness of the compensating pads should be selected according to the formula:

$$D_P = 2{,}4 \cdot \delta \qquad (73)$$

and the pads should be arranged according to Variant II in the figure shown.

Table 19: Selection of natural compensation system heights.

SERIES 1 – STANDARD Insulation	Steel pipes		Jacket	Compensation heights for H=0.6 m and δ_{MAX}		
	dn	d_0 [mm]	Dc [mm]	L_1 m	a_z m	a_U m
DN (2x20)/125	20	26.9	125	1.5	2.0	2.0
DN (2x25)/140	25	33.7	140	1.5	2.0	2.0
DN (2x32)/160	32	42.4	160	2.0	2.0	2.0
DN (2x40)/160	40	48.3	160	2.0	2.0	2.0
DN (2x50)/200	50	60.3	200	2.5	2.0	2.0
DN (2x65)/225	65	76.1	225	3.0	2.0	2.0
DN (2x80)/250	80	88.9	250	3.0	2.5	2.0
DN (2x100)/315	100	114.3	315	3.0	2.5	2.0
DN (2x125)/400	125	139.7	400	3.0	2.5	2.0
DN (2x150)/450	150	168.3	450	3.5	3.0	2.5
DN (2x200)/560	200	219.1	560	3.5	3.5	2.5

11. Auxiliary tables

Below we present auxiliary tables for **TWIN PIPE** assemblies made in **SERIES 2** (Insulation+) and **SERIES 3** (Insulation++) in accordance with **PN-EN 15698-1**.

Table 20: Overview and method of labelling of pre-insulated SERIES 2 and SERIES 3 elements.

Steel pipes						Series 2 INSULATION +			Series 3 INSULATION ++		
	d_0 [mm]	s [mm]	T± [mm]	No. [mm]	A_s [mm²]	Da [mm]	s [mm]	designation [-]	Da [mm]	s [mm]	designation [-]
20	26.9	2.6	0.3	19.0	198.5	140	3.0	DN (2x20)/140	160	3.0	DN (2x20)/160
25	33.7	2.6	0.3	19.0	254.0	160	3.0	DN (2x25)/160	180	3.0	DN (2x25)/180
32	42.4	2.9	0.3	19.0	359.9	180	3.0	DN (2x32)/180	200	3.2	DN (2x32)/200
40	48.3	2.9	0.3	19.0	413.6	180	3.0	DN (2x40)/180	200	3.2	DN (2x40)/200
50	60.3	2.9	0.3	20.0	522.9	225	3.4	DN (2x50)/225	250	3.6	DN (2x50)/250
65	76.1	2.9	0.3	20.0	666.9	250	3.6	DN (2x65)/250	280	3.9	DN (2x65)/280
80	88.9	3.2	0.3	25.0	861.6	280	3.9	DN (2x80)/280	315	4.1	DN (2x80)/315
100	114.3	3.6	0.4	25.0	1252.0	355	4.5	DN (2x100)/355	400	4.8	DN (2x100)/400
125	139.7	3.6	0.4	30.0	1539.3	450	5.2	DN (2x125)/450	500	5.6	DN (2x125)/500
150	168.3	4.0	0.5	40.0	2064.7	500	5.6	DN (2x150)/500	560	6.0	DN (2x150)/560
200	219.1	4.5	0.5	45.0	3033.8	630	6.6	DN (2x200)/630	710	7.2	DN (2x200)/710

Table 21: Frictional force values – SERIES 2 – INSULATION + pipelines.

SERIES 2 INSULATION +	Steel pipes				Jacket	F – frictional force per unit of length [kN/m] for H-cover:						
	dn	d_0 [mm]	s [mm]	A_s [mm²]	Dc [mm]	H=0.8	1.0 m	1.2 m	1.4 m	1.6 m	1.8 m	2.0 m
DN (2x20)/140	20	26.9	2.6	198.5	140	1.96	2.44	2.91	3.38	3.85	4.33	3.85
DN (2x25)/160	25	33.7	2.6	254.0	160	2.26	2.80	3.34	3.88	4.42	4.96	4.42
DN (2x32)/180	32	42.4	2.9	359.9	180	2.56	3.16	3.77	4.38	4.99	5.59	4.99
DN (2x40)/180	40	48.3	2.9	413.6	180	2.56	3.17	3.78	4.38	4.99	5.60	4.99
DN (2x50)/225	50	60.3	2.9	522.9	225	3.24	4.00	4.76	5.51	6.28	7.03	6.28
DN (2x65)/250	65	76.1	2.9	666.9	250	3.63	4.48	5.32	6.16	7.01	7.85	7.01
DN (2x80)/280	80	88.9	3.2	861.6	280	4.11	5.05	6.00	6.94	7.89	8.83	7.89
DN (2x100)/355	100	114.3	3.6	1252.0	355	5.32	6.51	7.71	8.90	10.11	11.31	10.11
DN (2x125)/450	125	139.7	3.6	1539.3	450	6.88	8.40	9.91	11.43	12.96	14.48	12.96
DN (2x150)/500	150	168.3	4.0	2064.7	500	7.78	9.46	11.15	12.83	14.53	16.22	14.53
DN (2x200)/630	200	219.1	4.5	3033.8	630	10.14	12.26	14.39	16.51	18.66	20.78	18.66

Table 22: Values of frictional force – pipelines SERIES 3 – INSULATION ++.

SERIES 2 INSULATION ++	Steel pipes				Jacket	F – frictional force per unit of length [kN/m] for H-cover:						
	dn	d_0 [mm]	s [mm]	A_s [mm²]	Dc [mm]	H=0.8	1.0 m	1.2 m	1.4 m	1.6 m	1.8 m	2.0 m
DN (2x20)/160	20	26.9	2.6	198.5	160	2.25	2.79	3.33	3.87	4.39	4.92	4.39
DN (2x25)/180	25	33.7	2.6	254.0	180	2.55	3.15	3.76	4.37	4.94	5.55	4.94
DN (2x32)/200	32	42.4	2.9	359.9	200	2.85	3.52	4.20	4.87	5.50	6.18	5.50
DN (2x40)/200	40	48.3	2.9	413.6	200	2.86	3.53	4.20	4.88	5.50	6.18	5.50
DN (2x50)/250	50	60.3	2.9	522.9	250	3.61	4.46	5.30	6.14	6.92	7.76	6.92
DN (2x65)/280	65	76.1	2.9	666.9	280	4.09	5.03	5.97	6.92	7.77	8.71	7.77
DN (2x80)/315	80	88.9	3.2	861.6	315	4.64	5.71	6.77	7.83	8.77	9.83	8.77
DN (2x100)/400	100	114.3	3.6	1252.0	400	6.03	7.37	8.72	10.07	11.23	12.58	11.23
DN (2x125)/500	125	139.7	3.6	1539.3	500	7.70	9.39	11.07	12.76	14.18	15.87	14.18
DN (2x150)/560	150	168.3	4.0	2064.7	560	8.78	10.67	12.56	14.44	15.98	17.86	15.98
DN (2x200)/710	200	219.1	4.5	3033.8	710	11.55	13.94	16.33	18.73	20.56	22.95	20.56

Table 23: Calculations for 125°C/65°C network – SERIES 2.

SERIES 2 INSULATION +	Steel pipes				Jacket	Heat network with parameters of 125°C/65°C – installation temperature of 10°C. Backfill density of 18 kN/m^3 Frictional force per unit of length *F* – [kN/m]. Installation length L_{MAX} – [m] and its elongation δL_{MAX} - [mm] for the corresponding cover H:																				
	dn	d_0	s	A_s	Dc	0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m		
		[mm]	[mm]	[mm^2]	[mm]	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}
DN (2x20)/140	20	26.9	2.6	198.5	140	1.96	20.5	16	2.44	16.5	13	2.91	14.0	11	3.38	12.0	9	3.85	10.5	8	4.33	9.5	7	4.80	8.5	6
DN (2x25)/160	25	33.7	2.6	254.0	160	2.26	23.0	18	2.80	18.5	14	3.34	15.5	12	3.88	13.5	10	4.42	12.0	9	4.96	10.5	8	5.49	9.5	7
DN (2x32)/180	32	42.4	2.9	359.9	180	2.56	29.0	22	3.16	23.5	18	3.77	20.0	15	4.38	17.0	13	4.99	15.0	11	5.59	13.5	10	6.20	12.0	9
DN (2x40)/180	40	48.3	2.9	413.6	180	2.56	34.0	26	3.17	27.5	21	3.78	23.0	18	4.38	19.5	15	4.99	17.5	13	5.60	15.5	12	6.21	14.0	11
DN (2x50)/225	50	60.3	2.9	522.9	225	3.24	34.5	26	4.00	28.0	21	4.76	23.5	18	5.51	20.0	15	6.28	17.5	13	7.03	15.5	12	7.79	14.0	11
DN (2x65)/250	65	76.1	2.9	666.9	250	3.63	40.0	30	4.48	32.0	24	5.32	27.0	21	6.16	23.5	18	7.01	20.5	16	7.85	18.5	14	8.69	16.5	13
DN (2x80)/280	80	88.9	3.2	861.6	280	4.11	45.5	35	5.05	37.0	28	6.00	31.0	24	6.94	27.0	21	7.89	23.5	18	8.83	21.0	16	9.78	19.0	15
DN (2x100)/355	100	114.3	3.6	1252.0	355	5.32	52.0	39	6.51	42.5	32	7.71	36.0	27	8.90	31.0	24	10.11	27.5	21	11.31	24.5	19	12.50	22.0	17
DN (2x125)/450	125	139.7	3.6	1539.3	450	6.88	50.5	38	8.40	41.5	31	9.91	35.0	26	11.43	30.5	23	12.96	26.5	20	14.48	24.0	18	15.99	21.5	16
DN (2x150)/500	150	168.3	4.0	2064.7	500	7.78	60.5	46	9.46	50.0	38	11.15	42.0	32	12.83	36.5	28	14.53	32.5	24	16.22	29.0	22	17.90	26.0	20
DN (2x200)/630	200	219.1	4.5	3033.8	630	10.14	70.0	52	12.26	57.5	43	14.39	49.0	37	16.51	43.0	32	18.66	38.0	29	20.78	34.0	26	22.91	31.0	23

Table 24: Calculations for 125°C/65°C network – SERIES 3.

SERIES 2 INSULATION +	Steel pipes				Jacket	Heat network with parameters of 125°C/65°C – installation temperature of 10°C. Backfill density of 18 kN/m^3 Frictional force per unit of length *F* – [kN/m]. Installation length L_{MAX} – [m] and its elongation δL_{MAX} - [mm] for the corresponding cover H:																				
	dn	d_0	s	A_s	Dc	0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m		
		[mm]	[mm]	[mm^2]	[mm]	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}
DN (2x20)/140	20	26.9	2.6	198.5	140	1.96	20.5	16	2.44	16.5	13	2.91	14.0	11	3.38	12.0	9	3.85	10.5	8	4.33	9.5	7	4.80	8.5	6
DN (2x25)/160	25	33.7	2.6	254.0	160	2.26	23.0	18	2.80	18.5	14	3.34	15.5	12	3.88	13.5	10	4.42	12.0	9	4.96	10.5	8	5.49	9.5	7
DN (2x32)/180	32	42.4	2.9	359.9	180	2.56	29.0	22	3.16	23.5	18	3.77	20.0	15	4.38	17.0	13	4.99	15.0	11	5.59	13.5	10	6.20	12.0	9
DN (2x40)/180	40	48.3	2.9	413.6	180	2.56	34.0	26	3.17	27.5	21	3.78	23.0	18	4.38	19.5	15	4.99	17.5	13	5.60	15.5	12	6.21	14.0	11
DN (2x50)/225	50	60.3	2.9	522.9	225	3.24	34.5	26	4.00	28.0	21	4.76	23.5	18	5.51	20.0	15	6.28	17.5	13	7.03	15.5	12	7.79	14.0	11
DN (2x65)/250	65	76.1	2.9	666.9	250	3.63	40.0	30	4.48	32.0	24	5.32	27.0	21	6.16	23.5	18	7.01	20.5	16	7.85	18.5	14	8.69	16.5	13
DN (2x80)/280	80	88.9	3.2	861.6	280	4.11	45.5	35	5.05	37.0	28	6.00	31.0	24	6.94	27.0	21	7.89	23.5	18	8.83	21.0	16	9.78	19.0	15
DN (2x100)/355	100	114.3	3.6	1252.0	355	5.32	52.0	39	6.51	42.5	32	7.71	36.0	27	8.90	31.0	24	10.11	27.5	21	11.31	24.5	19	12.50	22.0	17
DN (2x125)/450	125	139.7	3.6	1539.3	450	6.88	50.5	38	8.40	41.5	31	9.91	35.0	26	11.43	30.5	23	12.96	26.5	20	14.48	24.0	18	15.99	21.5	16
DN (2x150)/500	150	168.3	4.0	2064.7	500	7.78	60.5	46	9.46	50.0	38	11.15	42.0	32	12.83	36.5	28	14.53	32.5	24	16.22	29.0	22	17.90	26.0	20
DN (2x200)/630	200	219.1	4.5	3033.8	630	10.14	70.0	52	12.26	57.5	43	14.39	49.0	37	16.51	43.0	32	18.66	38.0	29	20.78	34.0	26	22.91	31.0	23

Table 25: Calculations for 90°C/55°C network – SERIES 2.

SERIES 3 INSULATION++	Steel pipes				Jacket	Heat network with parameters of 125°C/65°C – installation temperature of 10°C. Backfill density of 18 kN/m³ Frictional force per unit of length *F* – [kN/m]. Installation length L_{MAX} – [m] and its elongation δL_{MAX} - [mm] for the corresponding cover H:																				
	dn	d0	s	As	Dc	0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m		
		[mm]	[mm]	[mm²]	[mm]	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}
DN (2x20)/160	20	26.9	2.6	198.5	160	2.25	18.0	14	2.79	14.5	11	3.33	12.0	9	3.87	10.5	8	4.39	9.0	7	4.92	8.0	6	5.46	7.5	6
DN (2x25)/180	25	33.7	2.6	254.0	180	2.55	20.5	16	3.15	16.5	13	3.76	14.0	11	4.37	12.0	9	4.94	10.5	8	5.55	9.5	7	6.16	8.5	7
DN (2x32)/200	32	42.4	2.9	359.9	200	2.85	26.0	20	3.52	21.0	16	4.20	17.5	14	4.87	15.5	12	5.50	13.5	10	6.18	12.0	9	6.85	11.0	8
DN (2x40)/200	40	48.3	2.9	413.6	200	2.86	30.5	23	3.53	24.5	19	4.20	20.5	16	4.88	17.5	14	5.50	15.6	12	6.18	14.0	11	6.85	12.5	10
DN (2x50)/250	50	60.3	2.9	522.9	250	3.61	31.0	23	4.46	25.0	19	5.30	21.0	16	6.14	18.0	14	6.92	16.0	12	7.76	14.0	11	8.60	13.0	10
DN (2x65)/280	65	76.1	2.9	666.9	280	4.09	35.5	27	5.03	28.5	22	5.97	24.0	18	6.92	21.0	16	7.77	18.5	14	8.71	16.5	13	9.66	15.0	11
DN (2x50)/315	80	88.9	3.2	861.6	315	4.64	40.5	31	5.71	33.0	25	6.77	27.5	21	7.83	24.0	18	8.77	21.5	16	9.83	19.0	14	10.89	17.0	13
DN (2x100)/400	100	114.3	3.6	1252.0	400	6.03	46.0	35	7.37	37.5	28	8.72	31.5	24	10.07	27.5	21	11.23	24.5	19	12.58	22.0	17	13.93	19.5	15
DN (2x125)/500	125	139.7	3.6	1539.3	500	7.70	45.0	34	9.39	37.0	28	11.07	31.5	24	12.76	27.0	21	14.18	24.5	19	15.87	22.0	17	17.55	19.5	15
DN (2x150)/560	150	168.3	4.0	2064.7	560	8.78	53.5	41	10.67	44.0	33	12.56	37.5	28	14.44	32.5	25	15.98	29.5	22	17.86	26.5	20	19.75	24.0	18
DN (2x200)/710	200	219.1	4.5	3033.8	710	11.55	61.5	46	13.94	50.5	38	16.33	43.5	33	18.73	37.5	28	20.56	34.5	26	22.95	30.5	23	25.34	28.0	21

Table 26: Calculations for 90°C/55°C network – SERIES 3.

SERIES 2 INSULATION +	Steel pipes				Jacket	Heat network with parameters of 90°C/55°C – installation temperature of 10°C. Backfill density of 18 kN/m³ Frictional force per unit of length *F* – [kN/m]. Installation length L_{MAX} – [m] and its elongation δL_{MAX} - [mm] for the corresponding cover H:																				
	dn	d0	s	As	Dc	0.8 m			1.0 m			12 m			1.4 m			1.6 m			1.8 m			2.0 m		
		[mm]	[mm]	[mm²]	[mm]	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}	F	L_{MAX}	δL_{MAX}
DN (2x20)/140	20	26.9	2.6	198.5	140	1.96	28.5	10	2.44	22.5	8	2.91	19.0	7	3.38	16.5	6	3.85	14.5	5	4.33	12.5	5	4.80	11.5	4
DN (2x25)/160	25	33.7	2.6	254.0	160	2.26	31.5	11	2.80	25.5	9	3.34	21.5	8	3.88	18.5	7	4.42	16.0	6	4.96	14.5	5	5.49	13.0	5
DN (2x32)/180	32	42.4	2.9	359.9	180	2.56	39.5	14	3.16	32.0	12	3.77	27.0	10	4.38	23.0	8	4.99	20.5	7	5.59	18.0	7	6.20	16.5	6
DN (2x40)/180	40	48.3	2.9	413.6	180	2.56	46.0	17	3.17	37.0	13	3.78	31.0	11	4.38	27.0	10	4.99	23.5	8	5.60	21.0	8	6.21	19.0	7
DN (2x50)/225	50	60.3	2.9	522.9	225	3.24	46.5	17	4.00	37.5	13	4.76	31.5	11	5.51	27.0	10	6.28	24.0	9	7.03	21.5	8	7.79	19.0	7
DN (2x65)/250	65	76.1	2.9	666.9	250	3.63	53.5	19	4.48	43.5	16	5.32	36.5	13	6.16	31.5	11	7.01	27.5	10	7.85	24.5	9	8.69	22.0	8
DN (2x80)/280	80	88.9	3.2	861.6	280	4.11	61.5	22	5.05	50.0	18	6.00	42.0	15	6.94	36.0	13	7.89	32.0	11	8.83	28.5	10	9.78	25.5	9
DN (2x100)/355	100	114.3	3.6	1252.0	355	5.32	69.5	25	6.51	57.0	20	7.71	48.0	17	8.91	41.5	15	10.11	36.5	13	11.31	32.5	12	12.50	29.5	11
DN (2x125)/450	125	139.7	3.6	1539.3	450	6.88	67.0	24	8.40	55.0	19	9.92	46.5	17	11.43	40.5	14	12.96	35.5	13	14.48	32.0	11	16.00	29.0	10
DN (2x150)/500	150	168.3	4.0	2064.7	500	7.78	80.5	28	9.47	66.0	23	11.15	56.0	20	12.84	48.5	17	14.54	43.0	15	16.22	38.5	14	17.91	35.0	12
DN (2x200)/630	200	219.1	4.5	3033.8	630	10.15	92.0	32	12.27	76.0	27	14.39	65.0	23	16.52	56.5	20	18.67	50.0	18	20.79	45.0	16	22.91	40.5	14

Table 27: Heat loss for 125°C/65°C network – SERIES 2 Insulation +.

SERIES 2 INSULATION +	Steel pipes		Jacket	Heat loss under design conditions for 125°C/65°C network					
	dn	d_0 [mm]	Dc [mm]	Cover H = 0.6 m λS = 2.0 W/(mK); ts=0°C			Cover H = 1.6 m λS = 1.6 W/(mK); ts=8°C		
				q_F W/m	q_R W/m	Σq W/m	q_F W/m	q_R W/m	Σq W/m
DIN (2x20)/140	20	26.9	140	13.3	3.3	16.6	12.4	2.4	14.8
DN (2x25)/160	25	33.7	160	14.2	3.5	17.7	13.2	2.5	15.7
DN (2x32)/180	32	42.4	180	15.4	3.9	19.3	14.4	2.8	17.2
DN (2x40)/180	40	48.3	180	17.2	5.3	22.5	15.9	4.0	19.9
DN (2x50)/225	50	60.3	225	17.2	4.9	22.1	15.9	3.6	19.5
DN (2x65)/250	65	76.1	250	19.4	6.6	26.0	17.9	5.1	23.0
DN (2x80)/280	80	88.9	280	20.5	7.9	28.4	18.8	6.3	25.1
DN (2x100)/355	100	114.3	355	20.7	7.4	28.1	19.1	5.8	24.9
DN (2x125)/450	125	139.7	450	19.9	6.7	26.6	18.4	5.2	23.6
DN (2x150)/500	150	168.3	500	22.1	9.4	31.5	20.3	7.5	27.8
DN (2x200)/630	200	219.1	630	23.2	10.1	33.3	21.2	8.1	29.3

Table 28: Heat loss for 125°C/65°C network – SERIES 3 Insulation ++.

SERIES 3 INSULATION++	Steel pipes		Jacket	Heat loss under design conditions for 125°C/65°C network					
	dn	d_0 [mm]	Dc [mm]	Cover H = 0.6 m λS = 2.0 W/(mK); ts=0°C			Cover H = 1.6 m λS = 1.6 W/(mK); ts=8°C		
				q_F W/m	q_R W/m	Σq W/m	q_F W/m	q_R W/m	Σq W/m
DN (2x20)/160	20	26.9	160	12.3	2.3	14.6	11.5	1.6	13.1
DN (2x25)/180	25	33.7	180	13.2	2.5	15.7	12.4	1.7	14.1
DN (2x32)/200	32	42.4	200	14.4	2.8	17.2	13.4	1.9	15.3
DN (2x40)/200	40	48.3	200	15.7	3.9	19.6	14.7	2.8	17.5
DN (2x50)/250	50	60.3	250	15.8	3.5	19.3	14.8	2.4	17.2
DN (2x65)/280	65	76.1	280	17.4	4.5	21.9	16.2	3.3	19.5
DN (2x80)/315	80	88.9	315	18.0	5.4	23.4	16.7	4.1	20.8
DN (2x100)/400	100	114.3	400	18.3	4.9	23.2	17.0	3.7	20.7
DN (2x125)/500	125	139.7	500	17.9	4.7	22.6	16.7	3.5	20.2
DN (2x150)/560	150	168.3	560	19.2	6.4	25.6	17.8	4.9	22.7
DN (2x200)/710	200	219.1	710	19.8	6.6	26.4	18.3	5.1	23.4

Table 29: Heat loss for 90°C/55°C network – SERIES 2 Insulation +.

SERIES 2 INSULATION +	Steel pipes		Jacket	Heat loss under design conditions for 90°C/55°C network					
				Cover H = 0.6 m λS = 2.0 W/(mK); ts=0°C			Cover H = 1.6 m λS = 1.6 W/(mK); ts=8°C		
	dn	d_0 [mm]	Dc [mm]	q_F W/m	q_R W/m	Σq W/m	q_F W/m	q_R W/m	Σq W/m
DN (2x20)/140	20	26.9	140	9.3	3.4	12.7	8.4	2.6	11.0
DN (2x25)/160	25	33.7	160	9.9	3.6	13.5	9.0	2.7	11.7
DN (2x32)/180	32	42.4	180	10.7	4.0	14.7	9.7	3.0	12.7
DN (2x40)/180	40	48.3	180	12.0	5.1	17.1	10.8	3.9	14.7
DN (2x50)/225	50	60.3	225	12.0	4.8	16.8	10.8	3.7	14.5
DN (2x65)/250	65	76.1	250	13.7	6.2	19.9	12.3	4.8	17.1
DN (2x80)/280	80	88.9	280	14.5	7.2	21.7	13.0	5.6	18.6
DN (2x100)/355	100	114.3	355	14.6	6.9	21.5	13.1	5.4	18.5
DN (2x125)/450	125	139.7	450	14.0	6.3	20.3	12.6	4.9	17.5
DN (2x150)/500	150	168.3	500	15.8	8.3	24.1	14.0	6.6	20.6
DN (2x200)/630	200	219.1	630	16.5	8.9	25.4	14.7	7.1	21.8

Table 30: Heat loss for 90°C/55°C network – SERIES 3 Insulation ++.

SERIES 3 INSULATION ++	Steel pipes		Jacket	Heat loss under design conditions for 90°C/55°C network					
				Cover H = 0.6 m λS = 2.0 W/(mK); ts=0°C			Cover H = 1.6 m λS = 1.6 W/(mK); ts=8°C		
	dn	d_0 [mm]	Dc [mm]	q_F W/m	q_R W/m	Σq W/m	q_F W/m	q_R W/m	Σq W/m
DN (2x20)/160	20	26.9	160	8.5	2.7	11.2	7.8	2.0	9.8
DN (2x25)/180	25	33.7	180	9.1	2.9	12.0	8.3	2.1	10.4
DN (2x32)/200	32	42.4	200	9.9	3.2	13.1	9.1	2.3	11.4
DN (2x40)/200	40	48.3	200	10.9	4.0	14.9	9.9	3.0	12.9
DN (2x50)/250	60	60.3	250	10.9	3.8	14.7	10.0	2.8	12.8
DN (2x65)/280	65	76.1	280	12.2	4.6	16.8	11.0	3.5	14.5
DN (2x80)/315	80	88.9	315	12.6	5.2	17.8	11.4	4.0	15.4
DN (2x100)/400	100	114.3	400	12.8	5.0	17.8	11.6	3.8	15.4
DN (2x125)/500	125	139.7	500	12.5	4.8	17.3	11.3	3.6	14.9
DN (2x150)/560	150	168.3	560	13.5	6.0	19.5	12.2	4.7	16.9
DN (2x200)/710	200	219.1	710	13.9	6.2	20.1	12.6	4.9	17.5

Notes

Notes

HEAT-SHRINKABLE TECHNOLOGY

PIPE SOLUTIONS

PRE-INSULATED SYSTEMS

POWER TRANSMISSION INSULATORS

RADPOL S.A. | Prawiedniki Kolonia 57, 20-515 Lublin | +48 81 750 01 70 | radpol@radpol.com.pl | www.radpol.eu

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