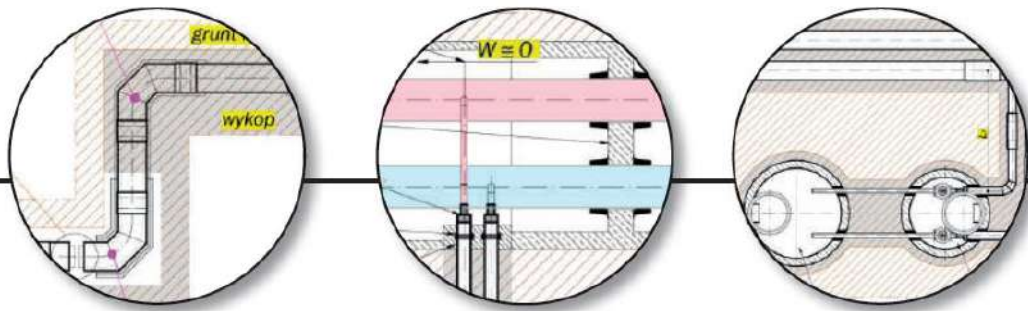


PRE-INSULATED PIPE SYSTEMS
DESIGNER'S GUIDE



1. Introduction

This guide gives general principles for designing pre-insulated heat networks made using RADPOL PIPES 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 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 448** – District heating networks – System of pre-insulated composite pipes for water district heating networks laid directly in the ground – Fittings – assemblies of steel line pipe, polyurethane thermal insulation and polyethylene jacket.
- **PN-EN 488** – District heating networks – System of pre-insulated composite pipes for water district heating networks laid directly in the ground – Fitting assembly for steel line pipes with 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 10216-2** – Seamless steel pipes for pressure applications – Technical conditions of delivery – Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties.
- **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 10217-5** – Welded steel pipes for pressure applications – Technical conditions of delivery – Part 5: Submerged arc welded non-alloy and alloy steel tubes with specific 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”

2. General comments

1. All pre-insulated elements of the **RADPOL PIPES** 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.-1** and **PN-EN 13941.-2** standards.
2. For more complex cases that go beyond these guidelines, please contact the **RADPOL PIPES** 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).

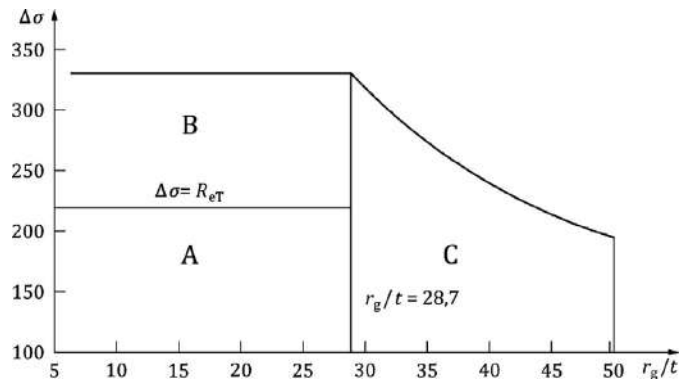


Figure 1: Definition of design classes – for pipes made of steel with yield strength $R_e (23^\circ\text{C})=235 \text{ N/mm}^2$.

4. In accordance with the indications of **PN-EN 13941-1**, the recommendations presented in the guide for the use of line pipes with diameters below **do=355.6×5.6 mm** and axial stress range $\sigma_{\text{MAX}} < R_{eT}/\gamma$ can be used to design heat networks made of pre-insulated elements manufactured in accordance with **PN-EN 253**. These designs qualify as “Class A” designs.
5. Deviations from the rules presented in the “*Guide...*,” according to the provisions of **PN-EN 13941-1**, require full strength calculations.
6. **It is recommended** to use typical sizes of pre-insulated elements presented in **RADPOL PIPES** catalogues. Deviations from the catalogue should be agreed with the relevant departments of our company.
7. **It is not recommended** to shorten pre-insulated fittings and the shortest section of straight pipe, used as a pipeline section, must not be shorter than **1.0 m**.
8. **Under no circumstances** should heat shrinkable couplers be shortened.
9. The guidelines presented in the “*Guide...*” for the use of line pipes with diameters larger than **do=355.6×5.6 mm** are intended only as an aid to the preliminary determination of the geometry of the heat network. As indicated in **EN 13941-1**, the design of these networks requires detailed calculations.
10. 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 $\gamma_s = 19 \text{ kN/m}^3$ and the installation temperature $T_{\text{INST}} = 10^\circ\text{C}$ were also assumed.
11. The drawings included in the study “*RADPOL PIPES – Heat Network Designer’s Guide*” are not intended to be used in designs, and their purpose is to show sample solutions and inspire designers to develop detailed solutions.
12. The study presents the general guidelines of the system concerning:
 - design class specification,
 - calculation of friction force,
 - calculation of friction length,
 - axial stresses,

- hydraulic calculations,
- heat loss calculations,
- thermal elongation compensation,
- the use of compensating pads,
- construction of heat networks using pre-insulated pipes.

Table of contents

1.	Introduction	1
2.	General comments	2
3.	Symbols used	15
4.	Description of the RADPOL PIPES pre-insulated pipe system	24
4.1.	Structure	24
4.2.	Line pipes	25
4.3.	PUR thermal insulation	26
4.4.	Polyethylene jacket.....	28
4.5.	Emergency control and signalling system.....	29
4.5.1.	Resistance system	29
4.5.2.	Impulse system	30
4.6.	Pipe assemblies.....	30
5.	Heat networks of pipe assemblies	31
5.1.	Trenches.....	31
5.2.	Sand bed – pipeline zone	32
5.3.	Trench fill zone	34
5.4.	Compensating pads.....	34
6.	Loads acting on the pipe assembly.....	36
6.1.	Force due to temperature NT.....	36
6.2.	Force due to internal pressure NP	37
6.3.	Force due to friction NF	37
6.4.	Force from the “compensating arm” NR	39
7.	Laying techniques for pre-insulated pipelines	40
8.	Use of stress-reducing techniques.....	42
8.1.	Free end and natural fixed point	42
8.2.	Allowable stresses	42
8.3.	The use of compensating elbows	43
8.3.1.	Permissible installation length LMAX and section elongation	44
8.3.2.	Summary of permissible installation lengths.....	45
8.4.	Application of axial compensators	48
8.4.1.	Pre-insulated bellows compensators.....	49
8.4.2.	Single-use compensators – SUC	52
8.5.	Preheating	56
9.	Hydraulic calculations	58
9.1.	Use of spreadsheets.....	58
9.2.	Graphic method	59
10.	Heat loss calculations	60
11.	Design indications.....	65
11.1.	Conversion of units	65
11.2.	Making a calculation scheme.....	65
11.3.	Occurrence of natural fixed points	66

11.3.1.	Permanent coverage of the pipeline (flat terrain – short sections).....	66
11.3.2.	Evenly changing coverage	66
11.3.3.	Differentiated pipeline coverage	67
11.4.	Trenches.....	68
11.4.1.	Minimum laying depth	69
11.4.2.	Maximum laying depth	70
11.4.3.	Protection plates.....	70
11.4.4.	Relief plates.....	71
11.4.5.	Protective pipes.....	71
11.5.	Earthworks in the vicinity of the pre-insulated heat network	73
11.5.1.	General information	73
11.5.2.	Safe exposure of pipelines	73
11.5.3.	Land reclamation.....	75
(a).	increase in backfill	75
(b).	decrease in backfill	75
11.5.4.	Trenches parallel to the heat network	75
(a).	reinforced trenches.....	75
(b).	unreinforced trenches – made for excavation	76
11.6.	Laying pipelines in a developed area.....	77
11.6.1.	Optimum laying depth	77
11.6.2.	Parallel installation	77
11.6.3.	Crossings	77
11.6.4.	Location of pre-insulated network near trees.....	78
11.6.5.	Operational routes.....	78
11.7.	Change of direction.....	79
11.7.1.	Elbows.....	79
11.7.2.	Bevel	80
11.7.3.	Bent pipes	81
11.8.	Cascades.....	82
11.9.	Reductions of diameters	83
11.10.	Branches	84
11.10.1.	Side branches	84
11.10.2.	Parallel branches.....	85
11.10.3.	Branches from the ducted network.....	85
11.10.4.	Duct niches	86
11.11.	Real fixed points	86
11.12.	Shut-off valves.....	89
11.13.	Venting	90
11.14.	Drainages	91
11.14.1.	Upward.....	92
11.14.2.	Gravity – downward.....	92
11.15.	Connections to elements of the TWIN PIPE system.....	93

11.16. Insulation of connections of pre-insulated elements	94
11.17. Passages through building partitions	95
11.17.1. Sealing rings.....	96
11.17.2. Heat shrinkable end seals – termination sleeves	96
11.17.3. Transition adapters.....	96
11.18. Preheating	96
11.18.1. Heating with a heating medium	99
11.18.2. Steam heating	99
11.18.3. Electric heating.....	99
11.19. Pre-tension	99
11.19.1. Mechanical tension.....	100
11.19.2. Thermal tension.....	101
11.20. Application of bellows compensators.....	102
11.20.1. Pre-insulated bellows compensators.....	102
11.20.2. Bellows compensators – in chambers	103
11.21. Bellows compensators – single-use compensators	104
11.22. Chambers	105
11.23. Connections to ducted networks.....	105
11.24. Connections to overhead networks.....	106
11.25. Examples of solutions for retrofitting ducted networks.....	106
11.25.1. Example 1	106
11.25.2. Example 2	107
11.25.3. Example 3	108
11.25.4. Example 4	109
11.25.5. Example 5	109
11.25.6. Example 6	110
11.25.7. Example 7	111
11.25.8. Example 8	112
11.25.9. Example 9	114
12. Thermal elongation compensation.....	116
12.1. Compensating pads.....	116
12.2. Cooling of pipelines	118
12.3. Compensation of elongations with the “L” type system.....	120
12.3.1. Structure.....	120
12.3.2. Action	120
12.3.3. Contraindications.....	121
12.3.4. Rules for the selection of the “L” type compensation size	122
12.3.5. Use of compensating pads.....	122
12.4. Compensation of elongations with the “Z” type system.....	125
12.4.1. Structure.....	125
12.4.2. Action	125
12.4.3. Rules for the selection of the “Z” type compensation size	127

12.4.4.	Use of compensating pads	127
12.5.	Compensation of elongations with the “U” type system	130
12.5.1.	Structure.....	130
12.5.2.	Action	131
12.5.3.	Rules for the selection of the “U” type compensation size....	132
12.5.4.	Use of compensating pads.....	132
13.	Design of emergency signalling systems	135
13.1.	Resistance system.....	136
13.1.1.	Structure.....	136
13.1.2.	Uniform production principles of pre-insulated elements for the BRANDES system.....	136
13.1.3.	Principle of operation.....	138
(a).	checking the condition of the measuring loop – continuity check	138
(b).	detection of changes in insulation resistance – detection 139	
(c).	indication of the location of the dangerous anomaly – location	139
13.1.4.	MH scale	140
13.1.5.	Creating measuring loops.....	140
13.1.6.	Technical part regarding pipeline equipment.....	141
13.1.7.	Design – instrument part	142
13.1.8.	Connecting the devices	143
13.1.9.	System components.....	144
13.1.10.	Measurement scheme	145
13.1.11.	System connections in the chambers.....	146
13.2.	Impulse system.....	147
13.2.1.	Structure.....	147
13.2.2.	Uniform production principles of pre-insulated elements for the impulse system.....	147
13.2.3.	Principle of operation.....	148
13.2.4.	Creating a measuring loop	149
13.2.5.	Measurement scheme	150
13.2.6.	General principles of impulse system design	151
13.3.	As-built documentation of the system	152
14.	Auxiliary tables.....	155
14.1.	Series 2 – Insulation +	155
14.2.	Series 3 – Insulation ++	161

List of figures

Figure 1:	Definition of design classes	3
Figure 2:	Structure of a pre-insulated composite element	24
Figure 3:	Installation of signalling cables depending on the diameter of the line pipe	29
Figure 4:	Resistance system cables	29
Figure 5:	Cables of the impulse system	30
Figure 6:	Cross-section of the trench with laid pipelines	31
Figure 7:	Limits of grading curves for sand bed according to PN-EN 13941-2.....	33
Figure 8:	Diagram of the loads acting on the pre-insulated pipeline	36
Figure 9:	Diagram for calculating the force due to friction	38
Figure 10:	Maximum stresses in the deceleration zone	40
Figure 11:	Maximum stresses in relation to allowable stresses in high-parameter networks	42
Figure 12:	Required stress distribution in the pipeline	42
Figure 13:	The use of compensating elbows as free ends of the pipeline ..	43
Figure 14:	Stresses in the line pipe at $L1+L2 < 2 L_{MAX}$	44
Figure 15:	Required stress distribution in the pipeline	48
Figure 16:	Use of pre-insulated bellows compensators.....	49
Figure 17:	Heating of the single-use compensator.....	52
Figure 18:	Stress distribution at design temperature.....	52
Figure 19:	Stresses in a heated and backfilled pipeline	56
Figure 20:	Stresses in the pipeline after temperature drop	56
Figure 21:	Stresses in the pipeline after reaching the design temperature ..	57
Figure 22:	Nomogram of flow, diameter selection and pressure loss.....	59
Figure 23:	Model for calculating heat loss in single pipes	60
Figure 24:	Diagram of assumptions for calculating heat loss by the superposition method	60
Figure 25:	Temperature in symmetric (Ts) and antisymmetric (TA) systems..	60
Figure 26:	A section of the calculation scheme of the designed network..	65
Figure 27:	Natural fixed point (NFP) located at the middle of the section ..	66
Figure 28:	A computational scheme for determining the location of a natural fixed point on a uniform slope.	66
Figure 29:	An extreme location of the natural fixed point (NFP).....	67
Figure 30:	Location of a natural fixed point in a terrain with a very differentiated relief and coverage of the heat network	67
Figure 31:	Minimum coverage under the road	69
Figure 32:	Minimum coverage.....	69
Figure 33:	Protection plate under the road.....	71
Figure 34:	Protection plate	71

Figure 35:	Ground-based relief plate	71
Figure 36:	Relief plate on the walls	71
Figure 37:	Pre-insulated pipelines in protective pipes under the road.....	72
Figure 38:	Exposure of a section of the heat network	73
Figure 39:	Distance of the trench wall reinforcement from an active heat network	76
Figure 40:	Parallel trench slope distance	76
Figure 41:	Displacement of the pipeline top and conversion elongations..	79
Figure 42:	A substitute layout using U-shape.....	80
Figure 43:	A substitute layout using Z-shape	80
Figure 44:	Bevelling requirements	81
Figure 45:	Characteristic parameters of a flexibly bent pipe	81
Figure 46:	Location of the reducer depending on the course of the line pipe diameters.....	83
Figure 47:	An abrupt increase in stress on the reducer	83
Figure 48:	Side branch.....	84
Figure 49:	Parallel branch.....	85
Figure 50:	Branching from the ducted network at the location of the fixed point – W~O	85
Figure 51:	Branching from the ducted network using an adapter – W>O...	86
Figure 52:	Real fixed points in the ground.....	86
Figure 53:	Real fixed point loads.....	87
Figure 54:	The size of the real fixed point with reinforcement – figure to table	88
Figure 55:	Diagram of the location of the real fixed point (RFP)	88
Figure 56:	Non-relieved real fixed point	89
Figure 57:	Installation of shut-off fittings in a location that is not subject to displacement	89
Figure 58:	Installation of pre-insulated vents in a common manhole casing ...	91
Figure 59:	Installation of vertical drains in separate casings	92
Figure 60:	Valve manhole	93
Figure 61:	Drainage with a valve manhole and a cooling manhole	93
Figure 62:	Transition fitting from TWIN PIPE to single pipe system – Y type..	94
Figure 63:	The condition of connecting TWIN PIPE pipelines to pipelines according to PN-EN 253	94
Figure 64:	Transition fitting from TWIN PIPE to single pipe system – F type.....	94
Figure 65:	Pipeline penetration through the building wall using sealing rings	95
Figure 66:	Sealing of pipeline penetrations through walls and floors	95
Figure 67:	Passing through a wall using an adapter	96
Figure 68:	Preparation of pipelines for preheating – sand backfill.....	98
Figure 69:	Preparation of pipelines for preheating – apparent fixed point..	98

Figure 70:	Pre-tension – mechanical	100
Figure 71:	Pre-tension – thermal.....	101
Figure 72:	Use of a single pre-insulated bellows compensator	102
Figure 73:	Use of real fixed points between extreme compensators and compensating elbows	103
Figure 74:	Location of the real fixed point between the pre-insulated bellows compensator and the compensating elbow	103
Figure 75:	Example of a compensator chamber	104
Figure 76:	Use of bellows compensators in chambers, traditional networks in duct casings.....	104
Figure 77:	Use of bellows compensators in chambers, in pre-insulated heat networks	104
Figure 78:	Example of the route of a ducted heat network to be retrofitted...	106
Figure 79:	Laying a pre-insulated heat network along the route of the old ducted heat network.....	106
Figure 80:	The simplest heat network route optimisation	107
Figure 81:	Ducted heat network layouts for example no. 2	107
Figure 82:	The heat network for example no. 2 after reconstruction	108
Figure 83:	Ducted heat network layouts for example no. 3	108
Figure 84:	The heat network for example no. 3 after reconstruction	108
Figure 85:	Ducted heat network layouts for example no. 4	109
Figure 86:	The heat network for example no. 4 after reconstruction	109
Figure 87:	Ducted heat network layouts for example no. 5	110
Figure 88:	The heat network for example no. 5 after reconstruction	110
Figure 89:	Ducted heat network layouts for example no. 6	110
Figure 90:	The heat network for example no. 6 after reconstruction without the use of a real fixed point.....	111
Figure 91:	The heat network for example no. 6 after reconstruction using a real fixed point.....	111
Figure 92:	Ducted heat network layouts for example no. 7	111
Figure 93:	The heat network for example no. 7 after reconstruction	112
Figure 94:	Ducted heat network layouts for example no. 8	112
Figure 95:	Protection of the pipeline systems and fittings in chambers....	112
Figure 96:	Protection of the remaining compensations	113
Figure 97:	Use of an additional compensation system.....	113
Figure 98:	A real fixed point between a pre-insulated heat network with bel- lows compensators and natural compensation on a ducted heat network	114
Figure 99:	Use of an additional section of a pre-insulated heat network..	115
Figure 100:	Load of pipelines in the ground	116
Figure 101:	Methods of covering pipelines with compensating pads	117
Figure 102:	Stress distribution in a short pipeline section during heating and cooling	119

Figure 103: “L” type compensation	120
Figure 104: Interaction of the “L” type compensation with the environment at the site of the compensation zone.	121
Figure 105: A change of direction that is not an “L” type compensation.....	122
Figure 106: Use of pads in “L” type compensation.....	123
Figure 107: “Z” type compensation	125
Figure 108: Interaction of “Z” type compensation with the environment at the point of deformation	126
Figure 109: Use of pads in “Z” type compensation with symmetric distribution of elongations	127
Figure 110: Use of pads in “Z” type compensation with asymmetric distribu- tion of elongations.....	128
Figure 111: “U” type compensation.....	130
Figure 112: Interaction of “U” type compensation with the environment at the point of deformation	131
Figure 113: Use of pads in “U” type compensation with symmetric distribution of elongations	132
Figure 114: Use of pads in “U” type compensation with asymmetric distribu- tion of elongations.....	133
Figure 115: Resistance system cables	136
Figure 116: Cables in tees	137
Figure 117: Use of branch tees in different directions	137
Figure 118: Parallel tee wiring in RADPOL PIPES technology	137
Figure 119: Original BRANDES tee	138
Figure 120: Wiring of elbows in RADPOL PIPES technology	138
Figure 121: Measuring loop continuity check	138
Figure 122: Detection.....	139
Figure 123: Location	139
Figure 124: MH scale.....	140
Figure 125: Measuring loop without branches	140
Figure 126: Measuring loop with a branch	141
Figure 127: Overview of the BRANDES resistance system elements.....	144
Figure 128: Measurement diagram for BS-MH3	145
Figure 129: Routing cables from underneath the heat shrinkable end seal – connecting control cables to the two-wire cable.....	145
Figure 130: Installation and connection of the junction box.....	145
Figure 131: Routing out cables for measurements	145
Figure 132: Connection of the BS-MD measuring box for single loop and common loop systems	146
Figure 133: System connections in the chamber	146
Figure 134: System connections in a chamber with a branch	146
Figure 135: System connection in chambers with “left” and “right” branches.....	147

Figure 136: Cables used in the impulse system.....	147
Figure 137: Wiring of the elbow	148
Figure 138: Wiring of the tee.....	148
Figure 139: Image of a short circuit on the reflectometer display	148
Figure 140: Image of a loop break	148
Figure 141: Failure locator – reflectometer	149
Figure 142: Measuring loop without branches	149
Figure 143: Measuring loop with branches and ways of making branches	150
Figure 144: Measurement diagram for LPS-2C	150
Figure 145: Installation of 67LV15 single end box with a control unit.....	151
Figure 146: Installation of 67LV45 double end box with KE-001 cable	151
Figure 147: Terminal box 6 7LV45 with KE- cable	151
Figure 148: Resistance system measurement report.....	152
Figure 149: Impulse system measurement report.....	152

Index of tables

Table 1: Characteristic parameters of P235GH steel ($\gamma=78,5 \text{ kN/m}^3$).....	25
Table 2: Series of steel line pipes	26
Table 3: Characteristic parameters of PUR thermal insulation	27
Table 4: Jacket characteristic quantities	28
Table 5: Characteristic parameters of polyethylene jackets.....	28
Table 6: Product range	30
Table 7: Overview of distances in the trench	32
Table 8: Compensating pad requirements.....	34
Table 9: Frictional force values for different sizes of pipeline cover – SE- RIES 1 – STANDARD Insulation.....	39
Table 10: Laying techniques for pre-insulated pipelines	41
Table 11: Installation lengths for 125°C/65°C network – SERIES 1 – STANDARD insulation	46
Table 12: Installation lengths for 90°C/55°C network – SERIES 1 – STANDARD insulation	47
Table 13: Axial compensators available	48
Table 14: Bellows compensators in 125°C/65°C network – SERIES 1 – STANDARD insulation	51
Table 15: Distance of SUCs from a compensating elbow for 125°C/65°C network – SERIES 1 – STANDARD insulation.....	54
Table 16: Single-use compensators in 125°C/65°C network – SERIES 1 – STANDARD insulation	55
Table 17: Calculated heat loss for 125°C/65°C heat network – SERIES 1 – STANDARD insulation	63
Table 18: Thermal resistances for 125°C/65°C heat network – SERIES 1 – STANDARD insulation	64

Table 19:	Unit conversion	65
Table 20:	Recommended minimum trench dimensions	68
Table 21:	Maximum coverage of pipelines.....	70
Table 22:	Exposure of heat network pipelines	74
Table 24:	Pipes bent on site	81
Table 25:	Flexibly and factory bent pipes.....	82
Table 26:	Typical sizes of real fixed points	87
Table 27:	Permissible displacement of pipelines in the compensation zone	118
Table 28:	Compensation capacity of L-shaped systems.....	124
Table 29:	Compensation capacity of Z-shaped systems.....	129
Table 30:	Compensation capacity of “L-shaped” systems	134
Table 31:	BRANDES resistance system components.....	142
Table 32:	Tools and instruments for system assembly	142
Table 33:	Equipment for manual inspection and location purposes	142
Table 34:	Number of individual elements of the impulse system for the design	152
Table 35:	Frictional force values for different sizes of pipeline cover – SERIES 2 – Insulation +.....	155
Table 36:	Installation lengths for 125°C/65°C network – SERIES 2 – Insulation +	156
Table 37:	Bellows compensators in 125°C/65°C network – SERIES 2 – Insulation +	157
Table 38:	Single-use compensators in 125°C/65°C network – SERIES 2 – Insulation +	158
Table 39:	Distance of SUCs from a compensating elbow for 125°C/65°C network – SERIES 2 – Insulation +	159
Table 40:	Calculated heat loss for 125°C/65°C heat network – SERIES 2 – Insulation +	159
Table 41:	Thermal resistances in 125°C/65°C heat network – SERIES 2 – Insulation +	160
Table 42:	Frictional force values for different sizes of pipeline cover – SE- RIES 3 – Insulation ++	161
Table 43:	Installation lengths for 125°C/65°C network – SERIES 3 – Insulation ++	162
Table 44:	Bellows compensators in 125°C/65°C network – SERIES 3 – Insulation ++	163
Table 45:	Single-use compensators in 125°C/65°C network – SERIES 3 – Insulation ++	164
Table 46:	Distance of SUCs from a compensating elbow for 125°C/65°C network – SERIES 3 – Insulation ++	165

Table 47:	Calculated heat loss for 125°C/65°C heat network – SERIES 3 – Insulation ++	165
Table 48:	Thermal resistances for 125°C/65°C heat network – SERIES 3 – Insulation ++	166

3. Symbols used

The symbols used in figures, tables and formulae are listed below.

Symbol	Name	Unit
A	(fixed points) length of the concrete block	mm, m
A _{IN}	inner surface of the line pipe	mm ²
A _M	axial compensator bellows area	mm ²
A _{MIN}	elongation at break	%
A _S , A _{S1} , A _{S2}	ring surface of a steel pipe	mm ² , m ²
A _{HDPE}	ring surface of the polyethylene jacket	
A*	(network repairs) height of the selected compensation	
B, B'	(fixed points) width of the concrete block	mm, m
B*	(network repairs) height of the selected compensation	m
B*	(trench over network) auxiliary value	–
C, C'	(fixed points) height of the concrete block	mm, m
C	(thermal calculations) distance between pipe axes	m
C _A	elasticity of the axial compensator bellows	N/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 or D _a	outside diameter of the polyethylene jacket series 1 – STANDARD	mm
D _{C+} , D _{C++}	outside diameter of the polyethylene jacket series 2 or 3	mm
D _{Cf}	outside diameter of the polyethylene jacket of the supply	mm

D_{CH}	diameter of the cooling manhole	mm
D_{Cr}	outside diameter of the polyethylene jacket of the return	mm
D_i	inside diameter of the polyethylene jacket	mm
D_P	outside diameter of the compensating pads	mm
D_{SZ}	diameter of the valve manhole	mm
E	linear deformability modulus – Young's modulus	N/mm ² = MPa
E_2 or E_{PUR}	PUR modulus of elasticity	N/mm ² = MPa
E_4 or E_{GRUNT}	modulus of elasticity of the sand bed	N/mm ² = MPa
E_5 or E_{PK}	modulus of elasticity of the compensating pads	N/mm ² = MPa
E_{T2} or E_T	Young's modulus at the assumed temperature	N/mm ² = MPa
F	force due to friction between the HDPE jacket and the sand bed	kN/m
$F_{SR1}, F_{SR2}, F_{SRi}$	sectional average frictional forces	kN/m
F_{calc}	(fixed points) total force transmitted by the fixed point	kN
g	gravitational acceleration	m/s ²
g_P	(in compensations) thickness of a single compensating pad or thickness of a single layer of compensating pads	mm
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 a steel line pipe in 1 m of the pre-insulated element	kN/m
G_w	weight of water inside a line pipe	kN/m
H	pipeline cover	m
H	height of the vertical drain or vent spigot	m
h_a	(thermal calculations) coefficient of the antisymmetric system	–
H_{CZ}	active depth of the cooling manhole	mm

H_{MAX}	maximum coverage of the pre-insulated pipeline	mm or m
h_s	(thermal calculations) coefficient of the symmetric system	–
H_w	depression of the groundwater table level	m
I_x, I_y	moment of inertia of the line pipe	m^4
J	(in compensations) “U” type compensator spacing	m
k	(in hydraulics) tube roughness	mm or m
k_2, k_4, k_5	the rigidity of the material, respectively: PUR, backfill, pads	N/mm^2
K_0	at-rest earth pressure coefficient	–
K_M	(designations) bellows compensator	–
L	length of the slippage zone (friction section)	m
L	(protective pipe) length of the protective pipe	m
l	length of the analysed section (also $L_1, L_2, L_3, L_4, L_5, L_{ODG}$)	m
l_{DOP}	permissible length of branch installation	m
L_1, L_2, L_3	(in compensations) required length of “L” type compensations	m
L_{1B}, L_{2B}	distances to the occurrence of limiting stresses during cooling	m
l_{ALL}	distance of the SUC compensator from a natural fixed point	m
L_{ALL}	SUC compensator spacing	m
L_{OD}	length of the safe excavation section of the pipelines	m
L_g	bend length of the bent pipe	m
L_f, L_r, L_k	length of the compensating arm	m
L-shape	(designations) natural compensation using one elbow	–
L_{KM}	installation length for an assembly with a bellows compensator	m

L_{KS}	distance of the SUC from the compensating elbow	m
L_{NM}	mechanical tension size	mm
L_{MAX}	installation length – from the elbow to the natural fixed point (NPS)	m
L_O	maximum distance between compensating elbows	m
L_{PK}	(in compensations) length of the compensation zone	m
L_{WP}	(in compensations) length of the layer of compensating pads	m
M	(trench) distance between pre-insulated pipelines	mm
m, n	(fixed points) proportions of the height of the real fixed point	mm
N	(trench) distance between the HDPE jacket and the trench wall	mm
N	axial force	N or kN
N	(protective pipe) number of skid sets	pcs
N_1, N_2, \dots, N_i	partial axial forces	N or kN
N_F	component of the axial force caused by friction of the jacket against the ground	N or kN
N_{F1}, N_{F2}	axial forces from ground friction on the analysed sections of the network	N or kN
N_{KM}	component of the axial force caused by the reaction of the axial compensator	N or kN
N_{KM}	(in the figures) number of bellows compensators in one line	pcs
N_{NPS}	equilibrium force at a natural fixed point	N or kN
N_P	component of the axial force due to internal pressure	N or kN
N_{PS}	(designations) natural fixed point	-
N_R	force from the compensating arm and due to lateral ground reaction	N or kN
N_{RPS}	size of the axial force for the selection of the real fixed point	N or kN

N_T	component of the axial force due to temperature difference	N or kN
p	overpressure	MPa or N/mm ²
q	(thermal calculations) heat loss of 1 m of the pre-insulated heat network	W/m
q_A	(thermal calculations) component of the antisymmetric system	W/m
q_F	(thermal calculations) heat loss of the supply pipeline	W/m
q_R	(thermal calculations) heat loss of the return pipeline	W/m
q_S	(thermal calculations) component of the symmetric system	W/m
R	(protective pipe) spacing of skid sets	m
R	(bent pipe) pipe bending radius	m
R	(Brandes) measuring loop resistance	
R_1, R_2	(Brandes) resistance of the cables on both sides of the failure	
R_A	(thermal calculations) thermal resistance of the antisymmetric system	m ² K/W
R_e	(in hydraulics) Reynolds number	–
R_e	(in mechanics) yield strength	N/mm ²
R_{eT}	yield strength at the assumed temperature	N/mm ²
R_{EL}	minimum radius of flexible pipe bending on site	m
R_{MIN}	minimum yield strength	N/mm ²
R_F	(Brandes) insulation resistance at the point of failure	
R_{FA}	minimum radius of factory pipe bending	m
R_{ME}	minimum radius of mechanical pipe bending on site	m
R_{MIN}	minimum radius of pipe bending for calculation purposes	m
R_i	(in hydraulics) linear flow resistance	Pa/m
R_o	(thermal calculations) coefficient of heat exchange between ground and air	m ² K/W

R_{PUR}	(Brandes) dry insulation resistance	
R_S	(thermal calculations) thermal resistance of the symmetric system	m^2K/W
RPS	(designations) real fixed point	m
SUC	(designations) Single Use Compensator	–
t or t_0	wall thickness of the steel line pipe	mm
t_c	wall thickness of the polyethylene jacket series 1 – STANDARD	mm
t_{C+}, t_{C++}	wall thickness of the polyethylene jacket series 2 and 3	mm
T	design temperature	$^{\circ}C$
T_2	SUC compensator closure temperature	$^{\circ}C$
T_A	temperature of the medium for the antisymmetric system	$^{\circ}C$
$T_F T_f$ or t_f	temperature of the medium in the supply pipeline	$^{\circ}C$
T_1 or T_{INST}	installation temperature	$^{\circ}C$
T_{PH}	preheat temperature	$^{\circ}C$
t_{PUR}	PUR thermal insulation thickness	mm
t_{PK}	thickness of the compensating pads used	mm
$T_R T_r$ or t_r	temperature of the medium in the return pipeline	$^{\circ}C$
t_s	temperature of undisturbed ground at the pipeline level	$^{\circ}C$
T_S	temperature of the medium for the symmetric system	$^{\circ}C$
T_{SR}	average medium temperature	$^{\circ}C$
T_{\pm}	steel pipe wall thickness tolerance	mm
u	elongation of the installation section with SUC compensators	mm
U	(Brandes) voltage supplying the measuring system	V
U_1	(Brandes) voltmeter readings	V
U-shape	(designations) natural compensation using four elbows	–

U	(in compensations) required height of "U" type compensation	m
w	(in hydraulics) heating medium flow velocity	m/s
W or W _{MAX}	displacement of the point of incorporation into the ducted network pipeline	mm
W ₁ , W ₂	(route geometry) conversion elongation	mm
W _A	water absorption by PUR	%
W _{min}	minimum height of the protection plate above the pipeline gauge	m, mm
X	(Brandes) computational location of the natural fixed point	m
X%	(Brandes) location of failure	%
X ₁ %...X ₈ %	(Brandes) readings of loop lengths at characteristic points	%
Z, Z ₁ , Z ₂	pipe assembly axis depression	m
Z	(in hydraulics) local resistance	Pa/m
Z	(in compensations) required height of "Z" type compensation	m
Z-shape	(designations) natural compensation using two elbows	-
Z _C	(thermal calculations) substitute pipe assembly axis depression	m

Greek symbols

Symbol	Name	Unit
α	coefficient of linear expansion	1/K
α or α°	(route geometry) angle of pipeline axis deviation	°
α_{EL}	flexible bending angle of the pre-insulated pipe	°
α_{FA}	factory bending angle of the pre-insulated pipe	°
α_{HDPE}	coefficient of linear expansion of HDPE polyethylene	1/K

α_{ME}	mechanical bending angle of the pre-insulated pipe	°
$\alpha_T, \alpha_{T2}, \alpha_{PH}$	coefficient of linear expansion at the assumed temperature	1/K
β	(thermal calculation) auxiliary variable	-
β°	(route geometry) angle of pipeline axis deviation	°
γ_m	safety coefficient	-
γ_μ	(fixed points) fixed point conversion coefficient	-
γ_s	specific gravity of the backfill and sand bed	kN/m ³
γ or γ_{ST}	specific gravity of steel	kN/m ³
γ_{SW}	specific gravity of sand skeleton	kN/m ³
γ'_{SW}	specific gravity of wet sand	kN/m ³
γ_w	specific gravity of water	kN/m ³
δ	friction angle between the ground and the pipeline	°
$\bar{\delta}, \bar{\delta}_1, \bar{\delta}_2$	elongation of the pipeline section	mm, m
$\bar{\delta}_{KM}$	displacement of the free end at the site of the axial compensator	mm
$\bar{\delta}_W, \bar{\delta}_{W1}, \bar{\delta}_{W2}$	(in compensations) incidental displacement of the elbow	mm
$\bar{\delta}_{MAX}$	elongation at the elbow location for the LMAX installation length	mm
ΔL	compensation capacity of the bellows compensator	mm
$\Delta L_1, \Delta L_2, \Delta L_3$	(in compensations) elongation of the section in "L" type compensation	mm
$\Delta L_{1B}, \Delta L_{2B}$	"contraction" of sections during cooling down	mm
Δp	(in hydraulics) the sum of the pressure loss	Pa
$\Delta \sigma$	increase or decrease in stress	N/mm ²
ΔT	temperature difference or rise	K
ΔT_T	temperature rise for the pipe assembly	K
$\Delta U_1, \Delta U_2, \Delta U_3$	(in compensations) elongation of the section in "U" type compensation	mm
Δu	SUC compensator setting	mm

$\Delta Z_1 \Delta Z_2 \Delta Z_3$	(in compensations) elongation of the section in "Z" type compensation	mm
ε	(in hydraulics) relative roughness of the tube	–
ε	(protective pipe) eccentric shift of pipe axis	mm
ε_{gr}	(in hydraulics) relative boundary roughness of a pipe	–
ζ	(in hydraulics) local resistance coefficient	–
λ	(in hydraulics) linear resistance coefficient	–
λ	thermal conductivity coefficient	W/mK
λ_{50}	thermal conductivity coefficient of 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	W/mK
λ_s	thermal conductivity coefficient of the ground	W/mK
μ	friction coefficient	–
ν	Poisson's ratio	for steel = 0.3
ν	(in hydraulics) dynamic viscosity	m ² /s
π	mathematical constant	3.14...
ρ	(in hydraulics) density of the medium at the assumed temperature	kg/m ³
ρ_{SR}	minimum density of PUR foam at pipe ends – average density	kg/m ³
ρ_{HDPE}	minimum density of HDPE polyethylene	kg/m ³
σ	stresses	N/mm ²
σ_1, σ_2	axial stresses in the cross-sections analysed	N/mm ²
σ_1	axial stresses allowed during SUC closure	N/mm ²
σ_2	residual axial stresses after SUC closure	N/mm ²
$\sigma_{10\%}$	compressive strength in the radial direction	N/mm ²
σ_a	axial stresses	N/mm ²
σ_{DOP} or σ_{ALL}	permissible axial stresses	N/mm ²
σ_F	axial stress in the supply pipe	N/mm ²
σ_{max}	maximum 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_u	effective ground stresses at the pipeline axis level	N/mm ²
σ_x	component of the axial stress due to internal pressure	N/mm ²
T_{ax}	axial shear strength of PUR foam	N/mm ²
T_{TAN}	tangential shear strength of PUR foam	N/mm ²
φ or φ'	angle of internal friction of the ground	°
ψ	adjusted value of closed cells	%

4. Description of the RADPOL PIPES pre-insulated pipe system

Modern **RADPOL PIPES** pre-insulated pipe systems, which meet increasingly stringent quality requirements, are an effective option for the construction of heat networks from elements prepared in the factory conditions suitable for direct laying in the ground.

4.1. Structure

The pre-insulated element, the cross-section of which is shown in the figure, consists of:

- a **steel line pipe** (1) laid inside the
- **polyethylene jacket** (3), with the space between the line pipe and the jacket filled with thermal insulation material made of –
- **rigid polyurethane foam** (2), in which 2 or 4 cables from one of two commonly used **emergency control and signalling systems** (4) and (5) are placed.

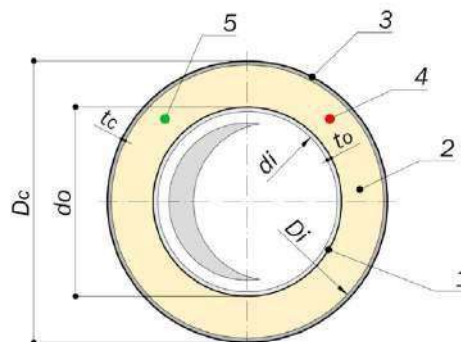


Figure 2: Structure of a pre-insulated composite element. (1) line pipe, (2) PUR thermal insulation, (3) polyethylene jacket, (4) control cable, (5) return cable

4.2. Line pipes

Steel pipes made of **P 235 GH** steel are used as line pipes.

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

- yield strength of steel

$$R_{eT} = 227 - 0,28 \cdot (T - 50) \quad T \leq 140^{\circ}C \quad \frac{N}{mm^2} \quad (1)$$

- Young's modulus

$$E_T = \left(21,4 - \frac{T}{175} \right) \cdot 10^4 \quad \frac{N}{mm^2} \quad (2)$$

- coefficient of linear expansion

$$\alpha_T = \left(11,4 + \frac{T}{129} \right) \cdot 10^{-6} \quad \frac{1}{K} \quad (3)$$

The symbols used in the formulae are in accordance with Chapter 3. **Symbols used.** The steel parameters depending on the temperature are shown in Table 1.

Table 1: Characteristic parameters of P235GH steel ($y=78,5 \text{ kN/m}^3$)

Parameter										
	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C	140°C
α_T mm/(mK)	1.18	1.19	1.19	1.20	1.21	1.22	1.23	1.23	1.24	1.25
R_{eT} N/mm ²	227.0	224.0	221.0	219.0	216.0	213.0	210.0	207.0	205.0	202.0

Pipes are made in accordance with **PN-EN 10217-2** or **PN-EN 10217-5**, and their series used by **RADPOL PIPES** is presented in Table 2.

Table 2: Series of steel line pipes

dn	d _o [mm]	t [mm]	T± [mm]	As [mm ²]	GS [N/m]	method of production [-]	as per PN-EN [-]
25	33.7	2.6	0.3	254.0	19.6	HFW	10217-2
40	48.3	2.9	0.3	413.8	31.9	HFW	10217-2
65	76.1	2.9	0.4	666.9	51.4	HFW	10217-2
100	114.3	3.6	0.6	1252.0	96.4	HFW	10217-2
150	168.3	4.0	0.8	2064.7	159.0	HFW	10217-2
250	273.0	5.0	1.0	4209.7	324.2	HFW	10217-2
350	355.6	5.6	1.6	6157.5	474.2	HFW	10217-2
450	457.0	6.3	1.6	8920.3	686.9	SAWL/SAWH	10217-5
600	610.0	7.1	1.6	13447.9	1035.6	SAWH / SAWL	10217-5
800	813.0	8.8	1.6	22232.9	1712.1	SAWH / SAWL	10217-5
1000	1016.0	11.0	1.6	34730.3	2674.5	SAWH / SAWL	10217-5

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

4.3. PUR thermal insulation

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**.

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

Table 3: Characteristic parameters of PUR thermal insulation

Itemisation	Symbol	Unit of measure	Requirements acc. to PN-EN 253
Minimum density at pipe ends	ρ_{SR}	kg/m ³	≥ 55
Axial shear strength at room temperature (23 ±2)°C	T_{ax}	N/mm ²	0.12
Tangential shear strength	T_{TAN}	N/mm ²	0.2
Corrected closed cell content in PUR	ψ	%	≥ 88
Modulus of elasticity at room temperature (23 ±2)°C	E_{PUR}	N/mm ²	10.0
Safety coefficient with spacing of adjacent elbows up to 20 m	γ_m	-	2.0

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: Jacket characteristic quantities

D _n	D _c [mm]	t _c [mm]	D _t [mm]	A _{HDPE} [mm ²]	G _{HDPE} [N/m]
110	110.0	3.0	104.0	1008.5	9.5
140	140.0	3.0	134.0	1291.2	12.2
180	180.0	3.0	174.0	1668.2	15.7
225	225.0	3.4	218.2	2367.0	22.3
280	280.0	3.9	272.2	3382.8	31.9
355	355.0	4.5	346.0	4955.1	46.8
450	450.0	5.2	439.6	7266.4	68.6
560	560.0	6.0	548.0	10442.7	98.6
710	710.0	7.2	695.6	15897.0	150.1
900	900.0	8.7	882.6	24360.9	230.0
1100	1100.0	10.2	1079.6	34921.8	329.7
1400	1400.0	12.5	1375.0	54487.0	514.4

Table 5: Characteristic parameters of polyethylene jackets

Itemisation	Symbol	Unit of measure	Size
Minimum density	ρ_{HDPE}	kg/m ³	≥ 944
Coefficient of linear expansion	α_{HDPE}	1/K	0.00018
Impact resistance	-	°C	> -50

The characteristic sizes of the jackets produced are shown beside the table.

4.5. Emergency control and signalling system

Pre-insulated elements are fitted with cables of the emergency control and signalling system meeting the requirements of **PN-EN 14419**, with one pair of signalling cables installed in elements with a nominal diameter of the line pipe **dn ≤ 400 mm**, and at least two pairs of signalling cables installed in elements with a line pipe **dn ≥ 450 mm**.

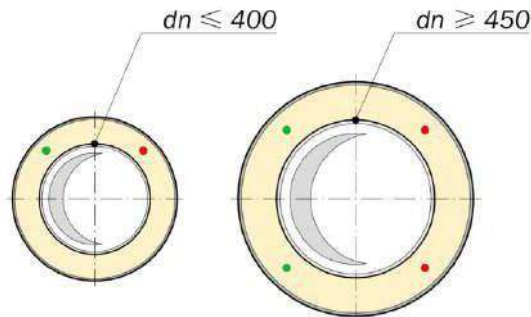


Figure 3: Installation of signalling cables depending on the diameter of the line pipe

Alternatively, depending on the preference of the customer ordering **RADPOL PIPES** products, one of two types of systems can be installed, that is, a resistance system or an impulse system.

4.5.1. Resistance system

The resistance alarm system works on the principle of measuring the resistance of thermal insulation. The equipment of the pre-insulated elements consists of two cables:

- sensor cable – **designation BS-FA – NiCr 8020** – nickel-chromium with the following composition: **80% - Ni, 20% – Cr**. The diameter of the cable is **0.5 mm** and the constant resistance is **5.7 Ω/m**. The cable is made with red Teflon insulation with perforations every 15 mm
- return cable – **designation BS-RA – Cu** – copper with a diameter of **0.8 mm** and a constant resistance of **0.036 Ω/m**. The cable is made with green Teflon insulation – without perforations.

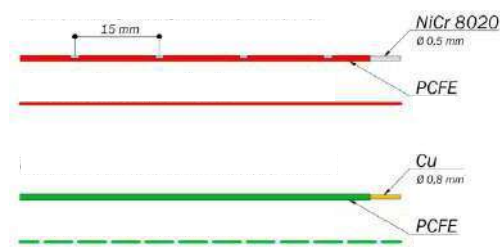


Figure 4: Resistance system cables

4.5.2. Impulse system

The operation of the impulse system is based on the measurement of both resistance and impedance. The equipment of the pre-insulated elements consists of two cables:

- **Cu** sensor cable – tinned copper – with a diameter of Φ 1.39 mm and a cross-section of 1.5 mm².
- **Cu** return cable – pure copper – with a diameter of Φ 1.39 mm and a cross-section of 1.5 mm².

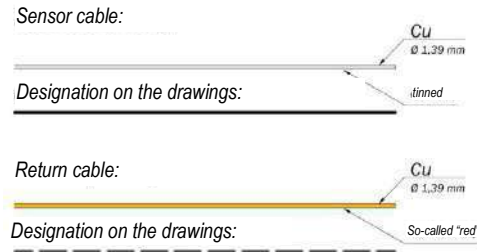


Figure 5: Cables of the impulse system

4.6. Pipe assemblies

Pipe assemblies manufactured using **RADPOL PIPES** technology meet the requirements and conditions of the **PN-EN 253** group of standards.

They are produced in three series differing in insulation thickness. The following table shows the different series of pipe assemblies.

Table 6: Product range

line pipes											
dn	d ₀ [mm]	t [mm]	D _c [mm]	t _c [mm]	Weight of 1 m With water [N/m]	D _{c+} [mm]	t _{c+} [mm]	Weight 1m With water [N/m]	D _{c++} [mm]	t _{c++} [mm]	Weight of 1 m With water [N/m]
25	33.7	2.6	90	3.0	35.5	110	3.0	29.5	125	3.0	41.6
40	48.3	2.9	110	3.0	57.9	125	3.0	49.9	140	3.0	63.5
65	76.1	2.9	140	3.0	104.2	160	3.0	94.7	180	3.0	113.0
100	114.3	3.6	200	3.2	208.1	225	3.4	194.0	250	3.6	224.7
150	168.3	4.0	250	3.6	383.7	280	3.9	364.3	315	4.1	409.9
250	273.0	5.0	400	4.8	912.8	450	5.2	874.9	500	5.6	974.8
350	355.6	5.6	500	5.6	1460.6	560	6.0	1406.0	630	6.6	1559.7
450	457.0	6.3	630	6.6	2308.2	710	7.2	2232.3	800	7.9	2470.0
600	610.0	7.1	800	7.9	3888.9	900	8.7	3776.3	1000	9.4	4125.1
800	813.0	8.8	1000	9.4	6688.2	1100	10.2	6503.3	1200	11.0	6977.9
1000	1016.0	11.0	1200	11.0	10354.1	1400	12.5	10186.8	1400	12.5	10691.3

5. Heat networks of pipe assemblies

The way in which the elements of the pipe assemblies that make up the heat network are laid in the trench is very important. While the production of pre-insulated elements is regulated by the standard:

- **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 and related standards **PN-EN 448**, **PN-EN 488**, **PN-EN 489** and **PN-EN 14419**, their use is standardised by the provisions of the following standards:
- **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.

To ensure that pipelines operate as designed, conditions during construction and operation should be as close as possible to those assumed at the design stage. The requirements are specified in the **PN-EN 13941-2** standard.

5.1. Trenches

Trenches for the pipeline shall be carried out in accordance with the requirements resulting from the route and its depth requirements.

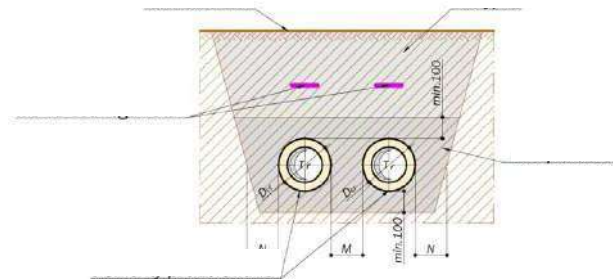


Figure 6: Cross-section of the trench with laid pipelines

The minimum trench dimensions (minimum width at the level of the horizontal axis of the pipelines) 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.

Table 7: Overview of distances in the trench

Jacket diameter Dc [mm]	Distance between pipe jackets M [mm]	Distance between the jacket and the trench wall N [mm]
225 < Dc ≤ 560	250	250

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.

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

By convention, pipelines should be laid in the trench so that the supply pipeline lies “to the right” when looking at the direction of flow of the medium in the supply pipeline.

5.2. Sand bed – pipeline zone

Before backfilling the pipelines, a final inspection of the installed pipe system should be carried out. Such inspection involves a visual check of the pipe assembly and control of the recording of as-built data such as pipe and element dimensions and their survey inventory.

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.

The backfill material should have adequate bearing capacity and the required mechanical and hydraulic properties to meet the design criteria. The backfill material should have such properties that it can be compacted with appropriate tools and force.

This space **should** be filled with non-cohesive sand of medium to coarse granulation with the parameters listed below.

- Granularity – **0÷4 mm**.
- Grains with round edges.
- Grading curve according to **PN-EN 13941-2**.

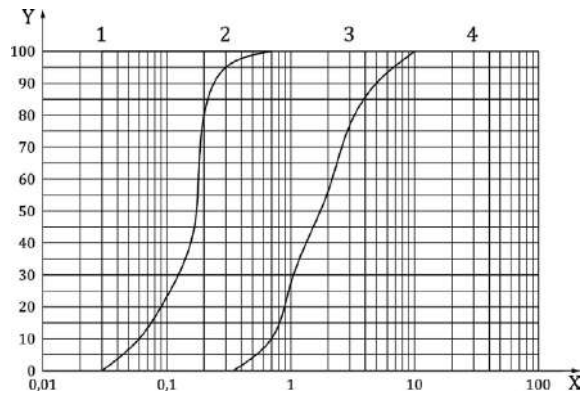


Figure 7: Limits of grading curves for sand bed according to **PN-EN 13941-2** (1) silt, (2) sand, (3) gravel, (4) stones

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

Avoid large-grained sand with sharp edges that could damage the pipeline or joint.

The composition of the material should make it possible to obtain, after careful compaction, a coefficient of friction in accordance with the design of the development.

The compaction index of the compacted backfill material according to Proctor must average between **97%** and **98%**. Values below **94%** according to Proctor are unacceptable.

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.

The further calculations assumed medium compacted sand with a weight of $\gamma_s = 19 \text{ kN/m}^3$ with an angle of internal friction of $\varphi = 32.5^\circ$.

5.3. Trench fill zone

The trench fill zone, that is, the space between the pipeline zone and the upper structure (e.g. road), should be made with such material and in such a manner (in layers) that the requirements of the structures above the pipeline are met.

Do not use unsuitable materials such as stones or rock fragments.

The upper construction zone (e.g. road foundation), that is, the space between the fill zone and the pavement, should be filled in accordance with the recommendations of the institutions responsible for the pavement.

To reduce the risk of damage to the pipeline by third parties, the installed pipeline should be marked with warning tape. The warning tape should be placed approximately **0.2 m to 0.5 m** above the heat pipe.

5.4. Compensating pads

In order to protect the pre-insulated pipe assembly, where there is lateral movement of the pipelines, it is necessary to design their covering with flexible materials that make it easier for 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.

Table 8: Compensating pad requirements

Normative designation of types of compensating pads according to PN-EN 13941-1			
	40% [kPa]	50% [kPa]	75% [kPa]
Type 2: MEDIUM HARD	60 ±15%	90 ±15%	275 ±15%

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.

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 drain spigots.

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.

6. Loads acting on the pipe assembly

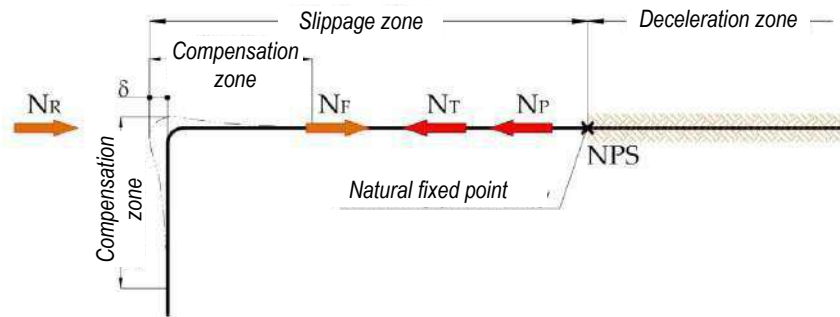


Figure 8: Diagram of the loads acting on the pre-insulated pipeline NT – force due to temperature, NP – force due to pressure, NF – force due to friction, NR – force from the compensating arm

The figure above shows the loads that directly affect the working pre-insulated pipeline laid in a trench.

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).

The figure also shows:

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

6.1. Force due to temperature NT

In pre-insulated pipelines, one of the components of the force due to temperature is the force caused by stresses induced by temperature rise, calculated as:

$$\Delta T_T = T - T_{inst} \quad (4)$$

Axial stresses then take the value:

$$\sigma = E \cdot \alpha \cdot \Delta T_T \quad (5)$$

while the axial force:

$$N_T = A_s \cdot (E \cdot \alpha \cdot \Delta T_T) \quad (6)$$

6.2. Force due to internal pressure NP

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:

$$\sigma_p = \frac{p \cdot d_o}{2 t} \quad (7)$$

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:

$$\sigma_x = \frac{p \cdot d_o}{4 t} \quad (8)$$

As you can see,

$$\sigma_x = 0,5 \cdot \sigma_p \quad (9)$$

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

$$\sigma_x = -\nu \cdot \sigma_p \quad (10)$$

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

$$\sigma_x = (0,5 - \nu) \cdot \sigma_p \quad (11)$$

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

$$N_p = A_s \cdot (0,5 - \nu) \cdot \sigma_p \quad (12)$$

6.3. Force due to friction NF

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 ground resistance, the magnitude of which will depend on:

- coefficient of friction between the polyethylene jacket and the backfill

$$\mu = \operatorname{tg} \delta \quad (13)$$

where the angle of friction between the ground and the pipeline

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

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

$$\sigma_v = \gamma_s \cdot Z \quad (H_w \geq Z) \quad (15)$$

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

$$\sigma_v = \gamma_s \cdot H_w + \gamma_{sw} \cdot (Z - H_w) \quad (H_w < Z) \quad (16)$$

- if the groundwater level is above the axis of the pipe assembly, where:

$$\gamma_{sw} = \gamma'_{sw} - \gamma_w \quad (17)$$

and

$$Z = H + \frac{D_c}{2} \quad (18)$$

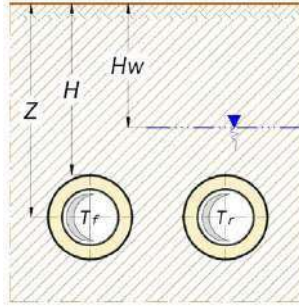


Figure 9: Diagram for calculating the force due to friction

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. We calculate this weight from the formula:

$$G = G_{ST} + G_W + G_{PUR} + G_{HDPE} \quad (19)$$

whose individual components can be calculated using the formulae below. And so, the weight of steel,

$$G_{ST} = \pi \cdot (d_o - t) \cdot t \cdot \gamma_{ST} \quad (20)$$

the weight of thermal insulation,

$$G_{PUR} = \left\{ \frac{\pi \cdot D_i}{4} - \frac{\pi \cdot d_o}{4} \right\} \cdot \gamma_{PUR} \quad (21)$$

the weight of the polyethylene jacket,

$$G_{HDPE} = \pi \cdot (D_C - t_C) \cdot t_C \cdot \gamma_{HDPE} \quad (22)$$

and the weight of water:

$$G_W = \frac{\pi \cdot (d_o - 2 \cdot t)}{4} \cdot \gamma_W \quad (23)$$

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:

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

for laying above groundwater and

$$F = \mu \cdot \left(\frac{(1+K_o)}{2} \cdot (\gamma_s \cdot H_w + \gamma_{sw} \cdot (Z - H_w)) \cdot \pi \cdot D_C + G - \gamma_s \cdot \pi \cdot \left(\frac{D_C}{2} \right)^2 \right) \quad \text{for } (H_w < Z) \quad (25)$$

when laying pipelines below the groundwater table.

Ultimately, the force due to friction acting on the section under consideration 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 designations used in the formulae are in accordance with Chapter 3. **Symbols used.**

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.**

6.4. Force from the “compensating arm” NR

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:

$$N_R \approx 0,1 \cdot F \cdot l \quad (27)$$

Table 9: Frictional force values for different sizes of pipeline cover – SERIES 1 – STANDARD Insulation

SERIES 1 STANDARD insulation	Steel pipes				Jacket Dc [mm]	F – frictional force per unit of length [kN/m] for cover H:						
	dn	d ₀ [mm]	t [mm]	A ₃ [mm]		H=0.8 m	1.0 m	1.2 m	1.4 m	1.6 m	1.8 m	2.0 m
DN 20/90												
DN 25/90	25	33.7	2.6	254.0	90	1.29	1.60	1.91	2.22	2.53	2.85	3.16
DN 40/110	40	48.3	2.9	413.6	110	1.58	1.96	2.35	2.73	3.11	3.49	3.87
DN 65/140	65	76.1	2.9	666.9	140	2.04	2.52	3.01	3.49	3.98	4.47	4.95
DN 100/200	100	114.3	3.6	1252.0	200	2.97	3.66	4.35	5.05	5.74	6.44	7.13
DN 150/250	150	168.3	4.0	2064.7	250	3.79	4.66	5.53	6.39	7.26	8.13	9.00
DN 250/400	250	273.0	5.0	4209.7	400	6.35	7.74	9.13	10.51	11.90	13.29	14.68
DN 350/500	350	355.6	5.6	6157.5	500	8.20	9.94	11.67	13.41	15.14	16.87	18.61
DN 400/560												
DN 450/630	450	457.0	6.3	8920.3	630	10.75	12.93	15.12	17.30	19.49	21.67	23.86
DN 600/800	600	610.0	7.1	13447.9	800	14.40	17.17	19.95	22.72	25.50	28.27	31.05
DN 800/1000	800	813.0	8.8	22232.9	1000	19.27	22.74	26.21	29.68	33.15	36.62	40.09
DN 900/1100	900	914.0	10.0	28400.0	1100	21.93	25.75	29.56	33.38	37.19	41.01	44.82
DN 1000/1200	1000	1016.0	11.0	34730.3	1200	24.71	28.87	33.04	37.20	41.36	45.52	49.69

7. Laying techniques for pre-insulated pipelines

In the pipelines, as the temperature rises to the design temperature T , there is an increase in the axial stresses, which reach a maximum value at a level that can be calculated from the formula:

$$\sigma_{max} = E \cdot \alpha \cdot (T - T_{inst}) - \nu \cdot \sigma_p \quad (28)$$

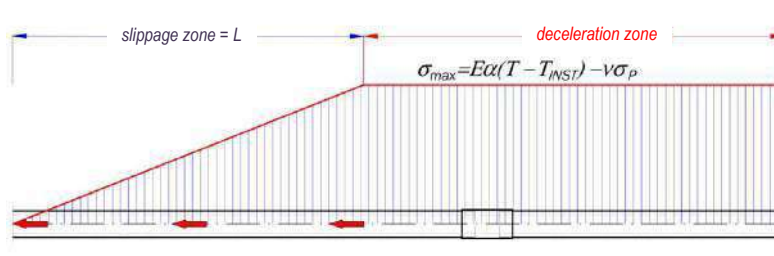


Figure 10: Maximum stresses in the deceleration zone

However, as you can see, they will reach their highest value when there is a sharp drop in pipeline pressure.

For such a pipeline scheme, the length of the slippage zone (friction section) can be calculated from the formula:

$$L = \frac{A_s}{F} \cdot \left(E \cdot \alpha \cdot \Delta T + \left(\frac{1}{2} - \nu \right) \cdot \sigma_p - \frac{N_R}{A} \right) \quad (29)$$

And the elongation at the end of the slippage zone – the end of the pipe assembly (section elongation) from the formula:

$$\delta = \frac{F \cdot L^2}{2 \cdot E \cdot A_s} \quad (30)$$

Depending on the temperature of the medium in the 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.

Table 10: Laying techniques for pre-insulated pipelines

Technique used	Advantages	Disadvantages
Pre-insulated bellows compensators	<ul style="list-style-type: none"> > axial stresses at most equal to the permissible ones, > easy installation, > possibility of direct backfilling of trenches, > easy to operate. 	<ul style="list-style-type: none"> > significant difficulties in making new branches due to compensators and their absence on the maps, > sensitive and constantly moving element of the line pipe, > for long sections, real fixed points are required, > limited range of compensation capacity
Preheating	<ul style="list-style-type: none"> > low axial stresses, reduced operating elongations, low height of the compensating arms when heated electrically, low vulnerability when conducting parallel work, > the possibility of using different means of heating (liquid, steam, electricity), > any location of the branches. 	<ul style="list-style-type: none"> > the trench between the two free ends must remain uncovered, > difficulties in the removal of a failure related to the cutting of the network.

PN-EN 13941 allows the design of heat networks in the full range of axial stresses for a maximum temperature of the heating medium of **140°C**. However, taking into account the indications given in the study by **PZITS** and **Izba Gospodarcza Ciepłownictwo Polskie (Polish Economic Chamber of Heating)** entitled “Technical conditions for the execution, acceptance and operation of pre-insulated pipelines in **HDPE** jacket laid directly in the ground,” it is not recommended to design and construct pre-insulated pipelines with axial stress values exceeding **190 MPa** in urban areas.

Hence, it is advisable to use laying techniques that keep axial stresses below the permissible values.

$$\sigma_{max} > \sigma_{DOP} \quad (31)$$

There are pipeline laying techniques available that allow you to meet this condition.

8. Use of stress-reducing techniques

8.1. Free end and natural fixed point

For the purpose of further explanation, two frequently used terms for areas of a pre-insulated heat network are introduced here:

- **free end** –the place where axial displacement or lateral deformation of the pipeline is possible,
- **natural fixed point** –the place where the axial force acting on the pipe assembly from the environment is equalised with the axial force induced inside the pipeline (the deceleration zone) or the place where the axial forces acting from opposite directions are equalised (between two free ends)

8.2. Allowable 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:

$$\sigma_{DOP} = \frac{R_{\epsilon T}}{\gamma_m} \quad (32)$$

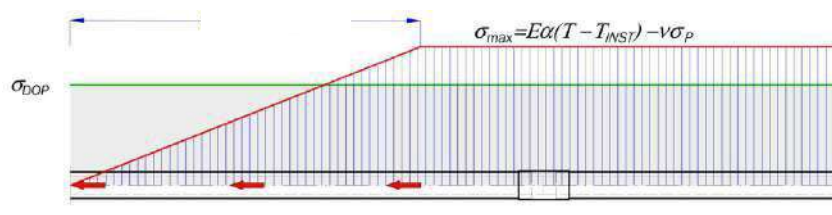


Figure 11: Maximum stresses in relation to allowable stresses in high-parameter networks

For the adopted temperature range, the allowable stresses are:

- for a **125°C/65°C** network, based on calculations, $\sigma_{DOP} = 187 \text{ N/mm}^2$ was assumed (for $\gamma_m=1.1$),
- for **90°C/55°C** consumer installations – $\sigma_{DOP} = 196 \text{ N/mm}^2$.

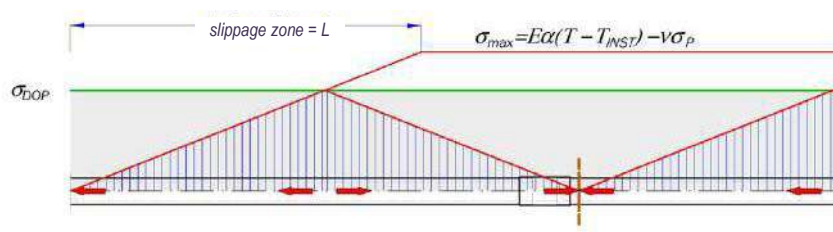


Figure 12: Required stress distribution in the pipeline

Therefore, it is necessary to design the section of the heat network so that the stress pattern in the line pipe is similar to that shown in the figure above.

In **RADPOL PIPES** technology, the following can be used for this purpose:

- **compensating elbows** – that is, the design of the heat network by selecting the appropriate geometry of the heat network route,
- **pre-insulated bellows compensators** – that is, the design of the heat network with the use of axial compensators, i.e. elements that work continuously to absorb any movements of pipelines,
- **Single-Use Compensators (SUC)** – that is, the design of the heat network with the use of single-use axial compensators, which absorb only part of the elongations, and then are permanently blocked after preheating,
- **preheating** – that is, the design of the heat network with the use of preheating of pipelines and the introduction of pre-stresses even before backfilling so that during operation the temperature rises and falls do not cause the permissible stresses to be exceeded, in addition, you can use a mixed technique, that is, the **use of axial compensators in the chambers** and pre-insulated pipelines between the chambers.

8.3. The use of compensating elbows

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

$$L_o = 2 \cdot L_{max} \quad (33)$$

where L_{max} is the so-called “**permissible installation length**,” that is, the length of the pipeline section from the free end to the point where the permissible stresses are reached in the line pipe.

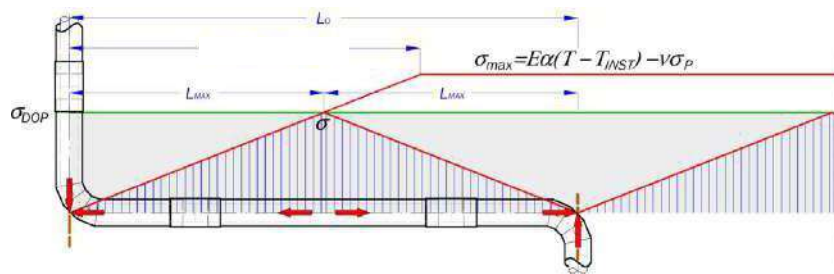


Figure 13: The use of compensating elbows as free ends of the pipeline

If the distance between the free ends is smaller, the stresses will be correspondingly lower – as shown in the next figure.

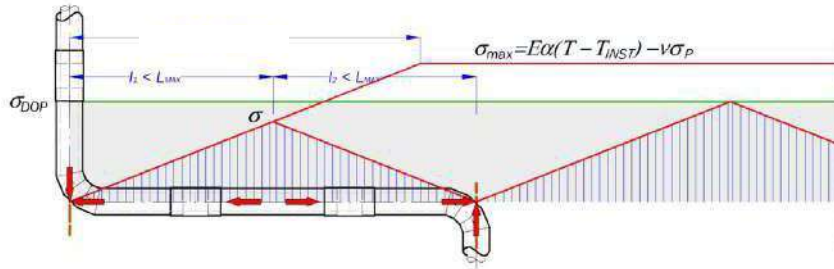


Figure 14: Stresses in the line pipe at $L_1+L_2 < 2 L_{MAX}$

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

If the temperature rise in the supply pipeline exceeds about **75°C** in relation to the installation temperature, the installation length must be limited to the value calculated from the formula:

$$L_{MAX} = \frac{(\sigma_{DOP} \cdot A_S + 0,5 \cdot \sigma_P \cdot A_S - N_R)}{F} \quad (34)$$

Taking into account that, for the preliminary calculations, the value of the force **NR** due to the reaction of the transverse arm was assumed to be **10%** of the force caused by friction on the considered section from the length **l**

$$N_R \approx 0,1 F l \quad (35)$$

that is, the index of the magnitude of the contribution of the arm reaction force is:

$$W_{NR} = \frac{N_R}{F \cdot l} = 0,1 \quad (36)$$

the formula for calculating L_{MAX} can take the form of

$$L_{MAX} = (1,0 - W_{NR}) \cdot \frac{(\sigma_{DOP} \cdot A_S + 0,5 \cdot \sigma_P \cdot A_S)}{F} \quad (37)$$

However, as the pressure-related part of the formula results in favourable load changes, and as the heat network should be safe under all conditions, even if there is an outage combined with a pressure drop, it is advisable to omit this part of the formula for further calculations, so that the calculation of L_{MAX} should be based on:

$$L_{MAX} = (1,0 - W_{NR}) \cdot \frac{\sigma_{DOP} \cdot A_S}{F} \quad (38)$$

During operation of the network under operating pressure, the axial stress at a point located at a distance **l** from the free end will be, in absolute value, equal to:

$$\sigma_x = \frac{l \cdot F}{(1,0 - W_{NR}) \cdot A_S} - 0,5 \cdot \sigma_P \quad (39)$$

and will reach a maximum at the L_{MAX} distance when the network pressure drops.

When correcting the effect of the lateral force N_R , the coefficient W_{NR} in the formulae should be corrected accordingly and calculations should be made on the absolute values of the existing stresses.

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

$$\delta = \frac{l}{E} \left(E \cdot \alpha \cdot \Delta T_T - \frac{F \cdot l}{2 \cdot A_s} + (0,5 - \nu) \cdot \sigma_p - \frac{N_R}{A_s} \right) \quad (40)$$

where l is the distance from the free end to the section under consideration. In this case:

$$l = L_{max} \quad (41)$$

the formula for the elongation of the section can be written in simpler form as:

$$\delta = \frac{l}{E} \left(E \cdot \alpha \cdot \Delta T_T - \frac{F \cdot l}{2 \cdot A_s} + (0,5 - \nu) \cdot \sigma_p - \frac{W_{NR} F l}{A_s} \right) \quad (42)$$

If the network is no longer working under pressure, both parts of the formula related to the working pressure in the calculation result in zero values and the maximum elongation of the section should be calculated from the formula:

$$\delta = l \cdot \alpha \cdot \Delta T - \frac{(1 + W_{NR}) \cdot F \cdot l^2}{2 \cdot E \cdot A_s} \quad (43)$$

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

8.3.2. 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 and for **90°C/55°C** consumer installations and for the basic **SERIES 1 – standard insulation**.

As can be seen from the attached tables, the maximum installation lengths for low-parameter networks are only about **5%** greater than for high-parameter networks, so no further tables have been presented for these networks.

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

Table 11: Installation lengths for 125°C/65°C network – SERIES 1 – STANDARD insulation

SERIES 1 STANDARD insulation	Steel pipes				Jacket Dc [mm ²]																								
	dn	d ₀ [mm]	t [mm]	A _S [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
					F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	F	L _{MAX}	[mm]	
DN 25/90	25	33.7	2.6	254.0	90	1.29	33.2	32	1.60	26.8	26	1.91	22.4	22	2.22	19.3	19	2.53	16.9	16	2.85	15.0	15	3.16	13.5	13			
DN 40/110	40	48.3	2.9	4136	110	1.58	44.1	43	1.96	35.6	35	2.35	29.7	29	2.73	25.5	25	3.11	22.4	22	3.49	20.0	19	3.87	18.0	18			
DN 65/140	65	76.1	2.9	666.9	140	2.04	55.1	54	2.52	44.6	43	3.01	37.3	36	3.49	32.2	31	3.98	28.2	27	4.47	25.1	24	4.95	22.7	22			
DN 100/200	100	114.3	3.6	1252.0	200	2.97	71.0	69	3.66	57.7	56	4.35	48.5	47	5.05	41.8	41	5.74	36.8	36	6.44	32.8	32	7.13	29.6	29			
DN 150/250	150	168.3	4.0	2064.7	1,250	3.79	91.8	89	4.66	74.7	73	5.53	62.9	61	6.39	54.5	53	7.26	47.9	47	8.13	42.8	42	9.00	38.7	38			
DN 250/400	250	273.0	5.0	4209.7	400	6.35	111.7	109	7.74	91.7	89	9.13	77.7	76	10.51	67.5	66	11.90	59.6	58	13.29	53.4	52	14.68	48.3	47			
DN 350/500	350	355.6	5.6	6157.5	500	8.20	126.6	123	9.94	104.4	102	11.67	88.9	87	13.41	77.4	75	15.14	68.5	67	16.87	61.5	60	18.61	55.8	54			
DN 450/630	450	457.0	6.3	8920.3	630	10.75	139.9	136	12.93	116.3	113	15.12	99.4	97	17.30	86.9	85	19.49	77.1	75	21.67	69.4	68	23.86	63.0	61			
DN 600/800	600	610.0	7.1	13447.9	800	14.40	157.4	153	17.17	132.0	129	19.95	113.6	111	22.72	99.8	97	25.50	88.9	87	28.27	80.2	78	31.05	73.0	71			
DN 800/1000	800	813.0	8.8	22232.9	1000	19.27	194.5	189	22.74	164.8	161	26.21	143.0	139	29.68	126.3	123	33.15	113.0	110	36.62	102.3	100	40.09	93.5	91			
DN 1000/1200	1000	1016.0	11.0	34730.3	1200	24.71	236.9	231	28.87	202.8	198	33.04	177.2	173	37.20	157.4	153	41.36	141.5	138	45.52	128.6	125	49.69	117.8	115			

Table 12: Installation lengths for 90°C/55°C network – SERIES 1 – STANDARD insulation

SERIES 1 STANDARD insulation	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}			
DN 25/90	25	33.7	2.6	254.0	90	1.29	34.8	17	1.60	28.0	14	1.91	23.5	12	2.22	20.2	10	2.53	17.7	9	2.85	15.7	8	3.16	14.2	7			
DN 40/110	40	48.3	2.9	413.6	110	1.58	46.2	23	1.96	37.3	19	2.35	31.1	16	2.73	26.8	13	3.11	23.5	12	3.49	20.9	11	3.87	18.9	9			
DN 65/140	65	76.1	2.9	666.9	140	2.04	57.7	29	2.52	46.7	24	3.01	39.1	20	3.49	33.7	17	3.98	29.6	15	4.47	26.3	13	4.95	23.8	12			
DN 100/200	100	114.3	3.6	1252.0	200	2.97	74.4	37	3.66	60.4	30	4.36	50.7	26	5.05	43.8	22	5.74	38.5	19	6.44	34.3	17	7.13	31.0	16			
DN 150/250	150	168.3	4.0	2064.7	250	3.79	96.2	48	4.66	78.2	39	5.53	65.9	33	6.40	57.0	29	7.26	50.2	25	8.13	44.8	23	9.00	40.5	20			
DN 250/400	250	273.0	5.0	4209.7	400	6.36	116.9	59	7.74	96.0	48	9.13	81.4	41	10.52	70.7	36	11.91	62.4	31	13.29	55.9	28	14.68	50.6	25			

8.4. Application of axial compensators

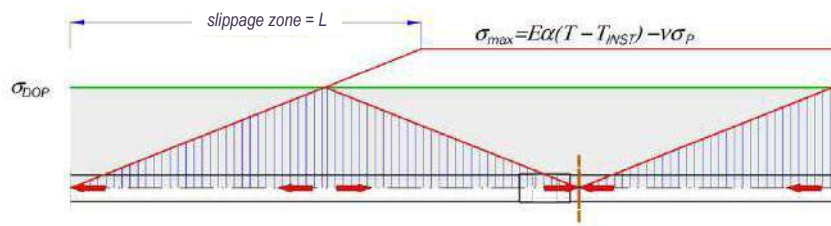


Figure 15: Required stress distribution in the pipeline

Another solution is to use axial compensators where the free end should fall. **RADPOL PIPES** technology has a set of compensators, as shown in the table below.

Table 13: Axial compensators available

Steel spigots														Pre-insulated Compensators -Series A			Pre-insulated Compensators - Series 0			Single-Use Compensators (SUC)		
DN	d ₀ [mm]	t [mm]	A _S [mm ²]	A _{IN} [mm ²]	ΔL [mm]	C _A [N/mm]	A _M [mm ²]	ΔL [mm]	C _A [N/mm]	A _M [mm ²]	ΔL [mm]	C _A [N/mm]	A _M [mm ²]									
25	-	-	-	-	-	-	-	-	-	-	-	-	-									
40	48.3	2.9	413.6	1419	100	15	4100	-	-	-	50	1600	2910									
65	76.1	2.9	666.9	3882	100	51	7600	-	-	-	70	2000	6160									
100	114.3	3.6	1252.0	9009	125	27	17300	155	25	17300	80	2800	12890									
150	168.3	4.0	2064.7	20182	125	63	33200	165	53	33200	100	4800	25510									
250	273.0	5.0	4209.7	54325	125	81	81000	170	42	81000	120	8900	67020									
350	355.6	5.6	6157.5	93157	125	101	130500	190	62	130500	140	12000	110450									
450	457.0	6.3	8920.3	155109	125	144	213500	200	94	213500	150	16100	178410									
600	610.0	7.1	13447.9	278799	125	175	358400	200	104	358400	150	21800	310740									
800	-	-	-	-	-	-	-	-	-	-	-	-	-									
1000	-	-	-	-	-	-	-	-	-	-	-	-	-									

8.4.1. Pre-insulated bellows compensators

A characteristic feature of **pre-insulated bellows compensators** is their continuous axial operation, which is a reaction to all deformations (elongations and contractions) of the line pipe.

When using pre-insulated bellows compensators, the pipeline is not affected by the reaction from the transverse arm N_R , but there is a reaction associated with:

- increased cross-sectional area of the bellows A_M in relation to the cross-sectional area of the steel pipe
- elasticity of the bellows C_A

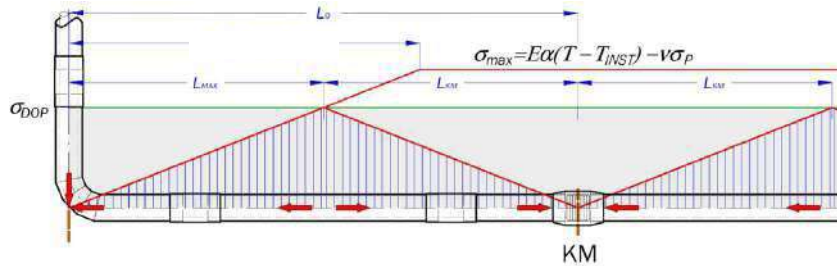


Figure 16: Use of pre-insulated bellows compensators

The magnitude of this reaction can be described by the formula:

$$N_{KM} = p \cdot A_M + C_A \cdot \Delta L \quad (44)$$

Accordingly, the installation length of a section of the heat network with **pre-insulated bellows compensators** will be:

$$L_{KM} = \frac{A_S}{F} \cdot \left(\sigma_{DOP} - \nu \cdot \sigma_P - \frac{N_{KM}}{A_S} \right) \quad (45)$$

and after expansion

$$L_{KM} = \frac{A_S}{F} \cdot \left(\sigma_{DOP} - \nu \cdot \sigma_P - \frac{(p \cdot A_M + C_A \cdot \Delta L)}{A_S} \right) \quad (46)$$

Since the force associated with the elasticity of the bellows is negligible compared to the other components, the installation length can be calculated from the formula:

$$L_{KM} = \frac{A_S}{F} \cdot \left(\sigma_{DOP} - \nu \cdot \sigma_P - \frac{p \cdot A_M}{A_S} \right) \quad (47)$$

and the elongation of the section between the natural fixed point and the compensator will be:

$$\delta_{KM} = \frac{l}{E} \cdot \left(E \cdot \alpha \cdot \Delta T - \frac{F \cdot l}{2 \cdot A_S} - \nu \cdot \sigma_P - \frac{p \cdot A_M}{A_S} \right) \quad (48)$$

If the network is no longer working under pressure, both parts of the formula related to the working pressure in the calculation result in zero values and the maximum elongation of the section should be calculated from the formula:

$$\delta_{KM} = l \cdot \alpha \cdot \Delta T - \frac{F \cdot l^2}{2 \cdot E \cdot A_s} \quad (49)$$

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

When using **pre-insulated bellows compensators**, the axially of their operation is very important, so bevelling is not allowed on the first joints of the compensator. A narrow bevel is allowed only **12.0 m** from the weld of the factory-made element – the **pre-insulated bellows compensator**.

Due to the required axially of operation, bellows compensators are well suited to long straight sections of transmission networks.

The use of an elbow in close proximity to a compensator should be considered a design error.

The table on the following page shows the permissible installation lengths and elongations of the section adjacent to the compensator for **125°C/65°C** network and the basic **SERIES 1 – standard insulation**.

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

Table 14: Bellows compensators in 125°C/65°C network – SERIES 1 – STANDARD insulation

SERIES 1 Insulation STANDARD	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}			
DN 25/90	25	33.7	2.6	254.0	90	1.29	-	-	1.60	-	-	1.91	-	-	2.22	-	-	2.53	-	-	2.85	-	-	3.16	-	-			
DN 40/110	40	48.3	2.9	413.6	110	1.58	44	45	1.96	35	36	2.35	30	30	2.73	25	26	3.11	22	22	3.49	20	20	3.87	18	18			
DN 65/140	65	76.1	2.9	666.9	140	2.04	53	55	2.52	43	44	3.01	36	37	3.49	31	32	3.98	27	28	4.47	24	25	4.95	22	23			
DN 100/200	100	114.3	3.6	1252.0	200	2.97	67	70	3.66	54	56	4.35	45	47	5.05	39	41	5.74	34	36	6.44	31	32	7.13	28	29			
DN 150/250	150	168.3	4.0	2064.7	250	3.79	83	87	4.66	67	71	5.53	57	60	6.39	49	52	7.26	43	45	8.13	39	41	9.00	35	37			
DN 250/400	250	273.0	5.0	4209.7	400	6.35	95	102	7.74	78	84	9.13	66	71	10.51	58	62	11.90	51	55	13.29	46	49	14.68	41	44			
DN 350/500	350	355.6	5.6	6157.5	500	8.20	104	113	9.94	86	93	11.67	73	79	13.41	64	69	15.14	56	61	16.87	51	55	18.61	46	50			
DN 450/630	450	457.0	6.3	8920.3	630	10.75	110	121	12.93	91	100	15.12	78	86	17.30	68	75	19.49	60	66	21.67	54	60	23.86	49	54			
DN 600/800	600	610.0	7.1	13447.9	800	14.40	116	130	17.17	98	110	19.95	84	94	22.72	74	83	25.50	66	74	28.27	59	66	31.05	54	61			
DN 800/1000	800	813.0	8.8	22232.9	1000	19.27	-	-	22.74	-	-	26.21	-	-	29.68	-	-	33.15	-	-	36.62	-	-	40.09	-	-			
DN 1000/1200	1000	1016.0	11.0	34730.3	1200	24.71	-	-	28.87	-	-	33.04	-	-	37.20	-	-	41.36	-	-	45.52	-	-	49.69	-	-			

8.4.2. Single-use compensators – SUC

Unlike pre-insulated bellows compensators that absorb the elongations of the line pipe throughout its service life, single-use compensators absorb only a portion of the initial elongation of the pipeline, and then, when the designed compression is reached, are welded in place and from then on act as a rigid section of the line pipe.

Three elements are important when using **SUCs**:

- determination of the temperature of the designed compression of the compensator,
- spacing of SUCs
- and the position of the compensator.

The **PN-EN 13941-1** standard provides for how to select **SUCs**. For the predicted stress increase in the line pipeline determined from the formula:

$$\Delta \sigma = E \cdot \alpha_T \cdot (T - T_1) \quad (50)$$

the permissible stresses that can occur in the pipeline at the time of the compensator's closure should be:

$$\sigma_1 = 2 \cdot \sigma_{ALL} - \Delta \sigma \quad (51)$$

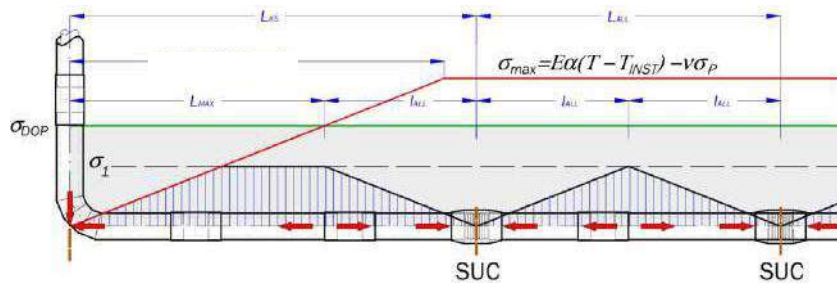


Figure 17: Heating of the single-use compensator

the value of the remaining (residual) stresses that the compensator will transfer already as a rigid element will be:

$$\sigma_2 = \Delta \sigma - \sigma_{ALL} \quad (52)$$

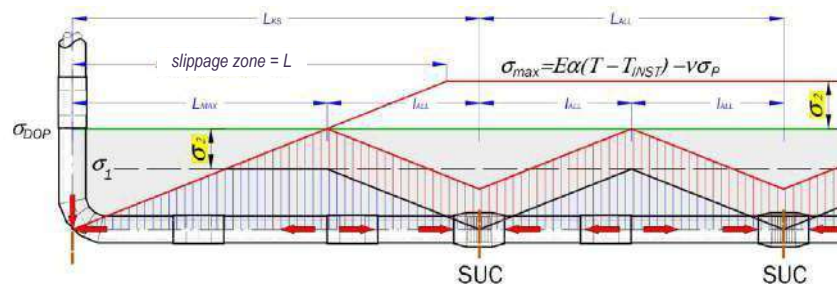


Figure 18: Stress distribution at design temperature

We can calculate the distance of the single-use compensator from a natural fixed point (the length of the installation section) from the formula:

$$l_{ALL} = \frac{\sigma_1 \cdot A_S}{F} \quad (53)$$

while the spacing of the single-use compensators will be

$$L_{ALL} = 2 \cdot l_{ALL} \quad (54)$$

and starting from the value of residual stresses

$$\sigma_2 = \alpha_T \cdot (T - T_1) \cdot E - \sigma_{ALL} \quad (55)$$

we can determine the temperature of the single-use compensator closure, which is:

$$T_2 = T_1 + \frac{\sigma_{ALL}}{\alpha_T \cdot E} \quad (56)$$

Knowing the temperature of the compensator closure, we can calculate the elongation of the installation section:

$$u = \alpha_{T_2} \cdot (T_2 - T_1) \cdot l_{ALL} - \frac{F \cdot l_{ALL}^2}{2 \cdot E_{T_2} \cdot A_S} \quad (57)$$

and the compensator setting:

$$\Delta u = 2 \cdot u \quad (58)$$

If there are different external conditions on both sides of the compensator, the calculations should be adjusted accordingly.

The table on the following page shows the spacing of the **SUCs** and their settings for **125°C/65°C** network and the basic **SERIES 1 – standard insulation**. The table below shows the distance between the single-use compensator and the compensating elbow.

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

Table 15: Distance of SUCs from a compensating elbow for 125°C/65°C network – SERIES 1 – STANDARD insulation

SERIES 1 STANDARD insulation							
	H=0.8 m L _{KS}	1.0 m L _{KS}	1.2 m L _{KS}	14 m L _{KS}	1.6 m L _{KS}	1.8 m L _{KS}	2.0 m L _{KS}
DN 25/90	-	-	-	-	-	-	-
DN 40/110	65.1	52.6	43.9	37.7	33.1	29.5	26.6
DN 65/140	81.4	65.9	55.1	47.6	41.7	37.1	33.5
DN 100/200	104.9	85.2	71.6	61.7	54.3	48.4	43.7
DN 150/250	135.6	110.3	92.9	80.5	70.8	63.2	57.1
DN 250/400	165.0	135.4	114.8	99.7	88.0	78.9	71.4
DN 350/500	186.9	154.2	131.3	114.3	101.2	90.8	82.4
DN 450/630	206.6	171.7	146.8	128.3	113.9	102.5	93.0
DN 600/800	232.4	194.9	167.8	147.4	131.3	118.4	107.8
DN 800/1000	-	-	-	-	-	-	-
DN 1000/1200	-	-	-	-	-	-	-

Table 16: Single-use compensators in 125°C/65°C network – SERIES 1 – STANDARD insulation

SERIES 1 STANDARD insulation	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
					F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u				
DN 25/90	25	33.7	2.6	254.0	90	1.29	-	-	1.60	-	-	1.91	-	-	2.2?	-	-	2.53	-	-	2.85	-	-	3.16	-	-			
DN 40/110	40	48.3	2.9	413.6	110	1.58	42.0	29	196	33.9	23	2.35	28.3	20	2.73	24.3	17	3.11	21.4	15	3.49	19.0	13	3.87	17.2	12			
DN 65/140	65	76.1	2.9	666.9	140	2.04	52.5	36	2.52	42.5	29	3.01	35.6	25	3.49	30.7	21	3.98	26.9	19	4.47	24.0	17	4.95	21.6	15			
DN 100/200	100	114.3	3.6	1252.0	200	2.97	67.7	47	3.66	54.9	38	4.35	46.2	32	5.05	39.8	27	5.74	35.0	24	6.44	31.2	22	7.13	28.2	19			
DN 150/250	150	168.3	4.0	2064.7	250	3.79	87.5	60	4.66	71.2	49	5.53	60.0	41	6.39	51.9	36	7.26	45.7	32	8.13	40.8	28	9.00	36.8	25			
DN 250/400	250	273.0	5.0	4209.7	400	6.35	106.5	73	7.74	87.4	60	9.13	74.1	51	10.51	64.3	44	11.90	56.8	39	13.29	50.9	35	14.68	46.1	32			
DN 350/500	350	355.6	5.6	6157.5	500	8.20	120.6	83	9.94	99.5	69	1167	84.7	58	1341	73.8	51	15.14	65.3	45	16.87	58.6	40	18.61	53.1	37			
DN 450/630	450	457.0	6.3	8920.3	630	10.75	133.3	92	12.93	110.8	76	15.12	94.8	65	17.30	82.8	57	19.49	73.5	51	21.67	66.1	46	23.86	60.0	41			
DN 600/800	600	610.0	7.1	13447.9	800	14.40	150.0	103	17.17	125.8	87	19.95	108.3	75	22.72	95.1	66	25.50	84.7	58	28.27	76.4	53	31.05	69.6	48			
DN 800/1000	800	813.0	8.8	22232.9	1000	19.27	-	-	22.74	-	-	26.21	-	-	29.68	-	-	33.15	-	-	36.62	-	-	40.09	-	-			
DN 1000/1200	1000	1016.0	11.0	34730.3	1200	24.71	-	-	28.87	-	-	33.04	-	-	37.20	-	-	41.36	-	-	45.52	-	-	49.69	-	-			

8.5. Preheating

The preheating technique involves heating the heat network pipelines before back-filling, that is, inducing deformation in the line pipes without applying high levels of stress to them.

For the selected design temperature range T and installation temperature T_{INST} , we select the corresponding preheat temperature of T_{PH} calculated from the formula:

$$T_{PH} = \frac{T + T_{INST}}{2} \quad (59)$$

A pipeline laid in a trench and heated to a given temperature is subjected to trace stresses.

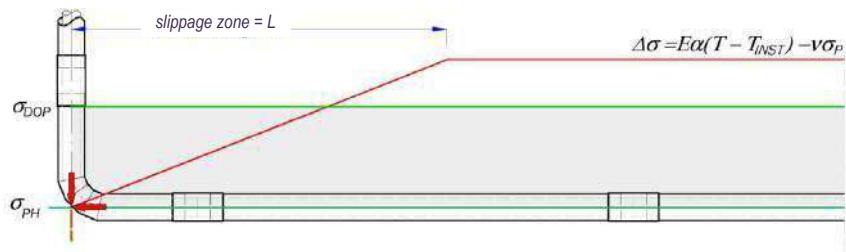


Figure 19: Stresses in a heated and backfilled pipeline

If the heated pipeline is backfilled with all the regimes of the adopted technology, such a pipeline will tend to “shrink” after the temperature is lowered. This is counteracted by the backfilling through the jacket and thermal insulation (composite system), which will induce axial – tensile – stresses in the pipeline wall, which for the active network will reach a value of:

$$\sigma_{min} = E \cdot \alpha_{PH} \cdot (T_{PH} - T_{INST}) - v \cdot \sigma_P \quad (60)$$

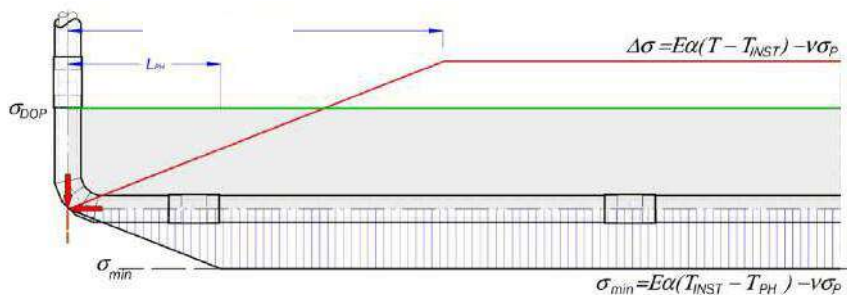


Figure 20: Stresses in the pipeline after temperature drop

When starting the pipeline heating (network operation) until the temperature at which the pipeline was backfilled is reached, i.e. the preheat temperature, the value of the tensile stresses in the wall of the steel pipe will decrease, again reaching a value close to zero at the preheat temperature.

When the temperature of the medium continues to rise, compressive stresses will occur in the pipe wall, the value of which at the design temperature and working under pressure of the network will be:

$$\sigma_{max} = E \cdot \alpha_T \cdot (T - T_{PH}) - \nu \cdot \sigma_P \quad (61)$$

For a heat network with parameters **125°C/65°C**, the preheat temperature will be approximately:

$$T_{PH} = \frac{T - T_{INST}}{2} = \frac{125 - 10}{2} = 57,5^\circ C \quad (62)$$

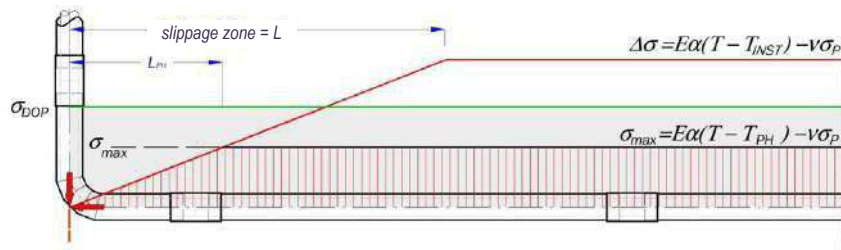


Figure 21: Stresses in the pipeline after reaching the design temperature

For most of the district heating networks in Poland, operating at a maximum supply temperature of **130°C**, with properly designed heating, the stresses during the peak period will be **155 N/mm²**.

9. Hydraulic calculations

9.1. 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**:

$$Re = \frac{w \cdot d_i}{\nu} \quad (63)$$

linear resistance coefficient λ for the range **Re** ≤ 2300

$$\lambda = \frac{64}{Re} \quad (64)$$

and for the range **2300** $< Re \leq 4000$, in the critical zone, we can determine the resistance coefficient with sufficient accuracy from the **Walden** formula:

$$\lambda = \frac{1}{\left(-2 \cdot \log \left(\frac{6,10}{Re^{0,916}} + \frac{0,268 \cdot k}{d_i} \right)\right)^2} \quad (65)$$

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:

$$\epsilon = \frac{k}{d_i} > \epsilon_{gr} = \frac{23}{Re} \quad (66)$$

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

$$\lambda = \left(2 \cdot \log \frac{\sqrt{\lambda} \cdot Re}{2,51}\right)^{-2} \quad (67)$$

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

$$\lambda = \frac{1}{\left(-2 \cdot \log \left(\frac{2,51}{Re \cdot \sqrt{\lambda}} + \frac{\epsilon}{3,71} \right)\right)^2} \quad (68)$$

In both cases, due to the complex forms 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:

$$Ri = \frac{\lambda \cdot w^2 \cdot \rho}{2 \cdot d_i} \quad (69)$$

while local resistances based on the relationship:

$$Z = \sum \xi \cdot \frac{\rho \cdot w^2}{2} \quad (70)$$

the total pressure loss can be calculated from the relationship:

$$\Delta p = 2 \cdot l \cdot R_i + Z \quad (71)$$

9.2. 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.

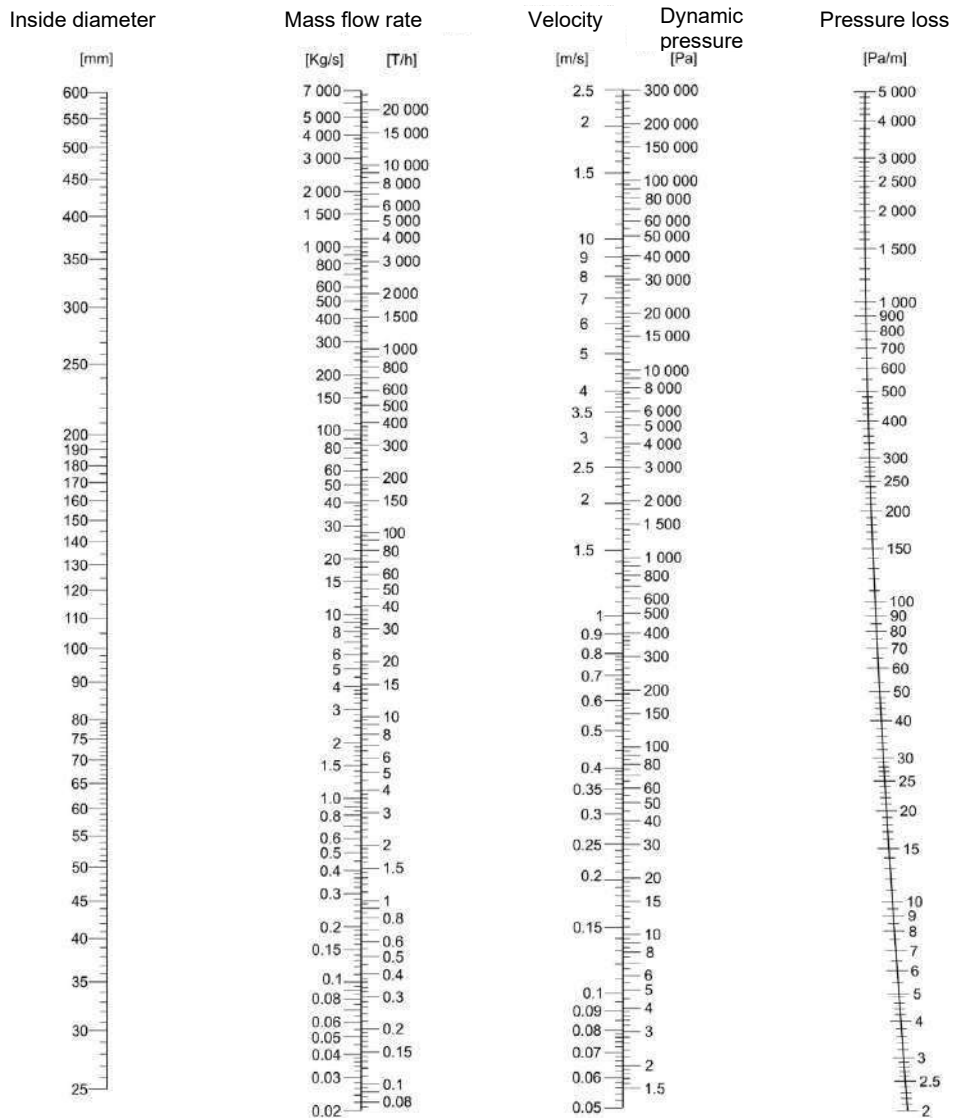


Figure 22: Nomogram of flow, diameter selection and pressure loss

10. Heat loss calculations

The computational model is shown in the figure below:

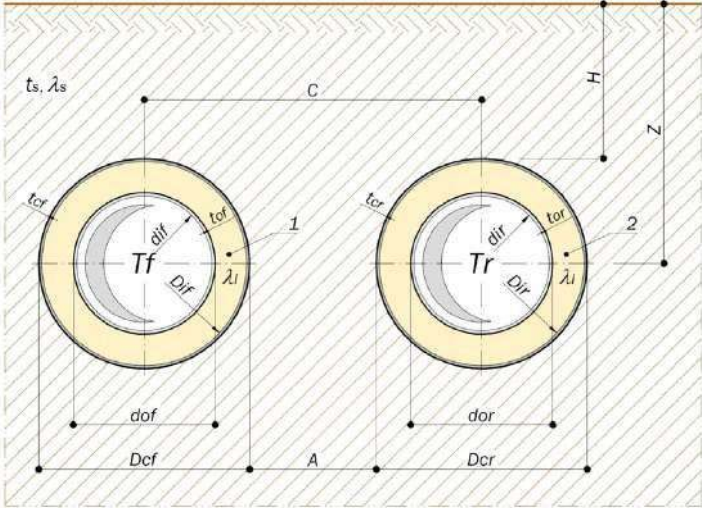


Figure 23: Model for calculating heat loss in single pipes

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

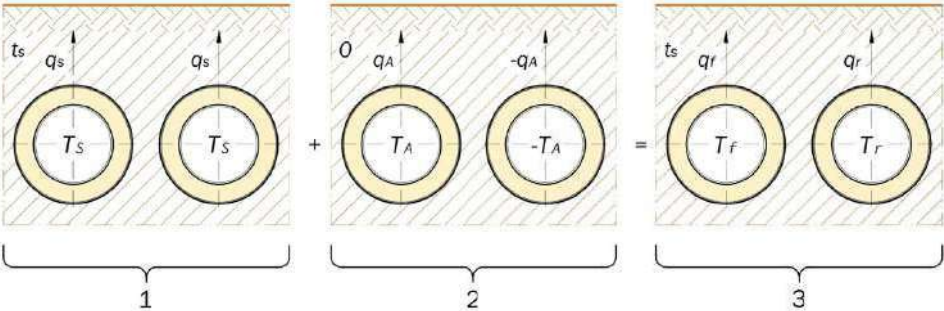


Figure 24: Diagram of assumptions for calculating heat loss by the superposition method

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. For each system, we calculate the required temperature:

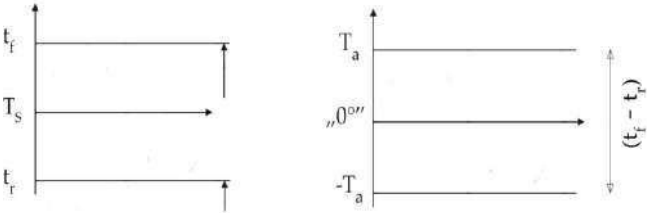


Figure 25: Temperature in symmetric (T_s) and antisymmetric (T_A) systems

For the symmetric system, the temperature is:

$$T_s = \frac{T_F + T_R}{2} \quad (72)$$

and for the antisymmetric system it is:

$$T_A = \frac{T_F - T_R}{2} \quad (73)$$

By introducing an auxiliary variable:

$$\beta = \frac{\lambda_s}{\lambda_i} \ln\left(\frac{D_i}{d_o}\right) \quad (74)$$

we now move on to the calculation of heat loss coefficients for a symmetric system:

$$h_s^{-1} = \ln\left(\frac{4 \cdot Z_c}{D_i}\right) + \beta + \ln\left(\sqrt{1 + \left(\frac{2 \cdot Z_c}{C}\right)^2}\right) \quad (75)$$

and an antisymmetric system:

$$h_A^{-1} = \ln\left(\frac{4 \cdot Z_c}{D_i}\right) + \beta - \ln\left(\sqrt{1 + \left(\frac{2 \cdot Z_c}{C}\right)^2}\right) \quad (76)$$

The thermal resistance for each system can be calculated from the formulae:

$$R_s = \frac{1}{2 \cdot \pi \cdot \lambda_s} \left(\ln\left(\frac{4 \cdot Z_c}{D_i}\right) + \beta + \ln\left(\sqrt{1 + \left(\frac{2 \cdot Z_c}{C}\right)^2}\right) \right) \quad (77)$$

for a symmetric system and

$$R_A = \frac{1}{2 \cdot \pi \cdot \lambda_s} \left(\ln\left(\frac{4 \cdot Z_c}{D_i}\right) + \beta - \ln\left(\sqrt{1 + \left(\frac{2 \cdot Z_c}{C}\right)^2}\right) \right) \quad (78)$$

for an antisymmetric system, where:

$$Z_c = Z + R_o \cdot \lambda_s \quad [m] \quad (79)$$

$$R_o = 0,0685 \frac{m^2 \cdot K}{W} \quad (80)$$

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

$$\begin{aligned}\lambda_s &= 1,0 \frac{W}{m \cdot K} \\ \lambda_s &= 1,6 \frac{W}{m \cdot K} \\ \lambda_s &= 2,0 \frac{W}{m \cdot K}\end{aligned}\quad (81)$$

We calculate the heat loss in the supply pipeline from the formula:

$$q_F = q_S + q_A \quad \frac{W}{m} \quad (82)$$

and the heat loss in the return pipeline from the formula:

$$q_R = q_S - q_A \quad \frac{W}{m} \quad (83)$$

We determine the individual components needed for these calculations from the formulae – for a symmetric system:

$$q_S = (T_S - t_S) \cdot 2 \cdot \pi \cdot \lambda_s \cdot h_s \quad \frac{W}{m} \quad (84)$$

i.e.:

$$q_S = \frac{(T_S - t_S)}{R_S} \quad \frac{W}{m} \quad (85)$$

and for an antisymmetric system

$$q_A = T_A \cdot 2 \cdot \pi \cdot \lambda_s \cdot h_A \quad \frac{W}{m} \quad (86)$$

i.e.:

$$q_A = \frac{T_A}{R_A} \quad \frac{W}{m} \quad (87)$$

and the total heat loss through both pipelines of the heat network is:

$$\Sigma q = q_F + q_R = 2 \cdot q_S \quad \frac{W}{m} \quad (88)$$

The heat loss for the pipelines is shown below. Due to their location in the frost zone, for the calculation of pipelines with a cover of **H=0.6 m**, the thermal conductivity coefficient of the backfill was assumed to be the same as for damp sand, i.e. **$\lambda_s=2.0 \text{ W/mK}$** , and the temperature of the undisturbed ground at the level of the

pipeline axis was assumed to be $t_s=0^{\circ}\text{C}$. For pipelines laid deeper, $\lambda_s=16\text{ W/mK}$ and $t_s=8^{\circ}\text{C}$ were assumed, respectively.

Table 17: Calculated heat loss for 125°C/65°C heat network – SERIES 1 – STANDARD insulation

SERIES 1 STANDARD insulation	Steel pipes		Jacket							
	dn	d ₀ [mm]	Dc [mm]	Di [mm]	H=0.6 m			H=2.0 m		
					for $\lambda_s=2.0\text{ W/(mK)}$; $\lambda_i=0.029\text{ W/(mK)}$ and $t_s=0.0^{\circ}\text{C}$					
					q _F	q _R	Σq	q _F	q _R	Σq
DN 25/90	25	33.7	90	84.0	23.26	11.61	34.87	22.28	10.71	32.99
DN 40/110	40	48.3	110	104.0	27.47	13.63	41.10	26.14	12.41	38.55
DN 65/140	65	76.1	140	134.0	36.51	17.88	54.39	34.29	15.83	50.12
DN 100/200	100	114.3	200	193.6	39.33	19.27	58.60	36.89	17.02	53.91
DN 150/250	150	168.3	250	242.8	55.06	26.77	81.83	50.64	22.76	73.40
DN 250/400	250	273.0	400	390.4	57.21	28.01	85.22	52.80	23.99	76.79
DN 350/500	350	355.6	500	488.8	64.08	31.29	95.37	58.87	26.54	85.41
DN 450/630	450	457.0	630	616.8	68.22	33.47	101.69	62.67	28.44	91.11
DN 600/800	600	610.0	800	784.2	80.70	39.37	120.07	73.49	32.92	106.41
DN 800/1000	800	813.0	1000	981.2	105.14	50.60	155.74	94.13	40.82	134.95
DN 1000/1200	1000	1016.0	1200	1178.0	130.50	61.94	192.44	114.92	48.33	163.25

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

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

Table 18: Thermal resistances for **125°C/65°C** heat network – **SERIES 1 – STANDARD** insulation

SERIES 1 STANDARD insulation														
	H=0.8 m		1.0 m		1.2 m		1.4 m		1.6 m		1.8 m		2.0 m	
	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A
DN 75/90	5.5991	5.1850	5.6367	5.1852	5.6683	5.1854	5.6956	5.1855	5.7197	5.1855	5.7411	5.1856	5.7604	5.1856
DN 40/110	4.7684	4.3679	4.8056	4.3681	4.8369	4.3683	4.8640	4.3684	4.8879	4.3685	4.9092	4.3685	4.9284	4.3686
DN 65/140	3.6324	3.2502	3.6690	3.2505	3.7000	3.2507	3.7268	3.2508	3.7504	3.2509	3.7715	3.2510	3.7906	3.2510
DN 100/200	3.3696	3.0180	3.4051	3.0185	3.4353	3.0187	3.4815	3.0189	3.4847	3.0190	3.5055	3.0191	3.5243	3.0192
DN 150/250	2.4375	2.1493	2.4718	2.1501	2.5012	2.1506	2.5268	2.1510	2.5496	2.1512	2.5700	2.1514	2.5885	2.1515
DN 250/400	2.3316	2.0791	2.3635	2.0803	2.3910	2.0810	2.4153	2.0815	2.4369	2.0818	2.4565	2.0821	2.4743	2.0823
DN 350/500	2.0868	1.8523	2.1172	1.8536	2.1436	1.8545	2.1670	1.8551	2.1880	1.8555	2.2070	1.8558	2.2244	1.8560
DN 450/630	1.9544	1.7484	1.9828	1.7500	2.0079	1.7511	2.0302	1.7519	2.0503	1.7525	2.0686	1.7529	2.0854	1.7533
DN 600/800	1.6620	1.4732	1.6884	1.4751	1.7118	1.4764	1.7329	1.4773	1.7520	1.4780	1.7695	1.4785	1.7856	1.4790
DN 800/1000	1.2920	1.1189	1.3164	1.1209	1.3382	1.1224	1.3580	1.1235	1.3760	1.1243	1.3926	1.1250	1.4080	1.1255
DN 1000/1200	1.0548	0.8937	1.0773	0.8959	1.0977	0.8975	1.1163	0.8988	1.1334	0.8997	1.1492	0.9004	1.1639	0.9010

11. Design indications

11.1. Conversion of units

For the purpose of performing various calculations, the following table shows the conversion rates between the units of different measurement systems.

Table 19: Unit conversion

1.0 J/s (W)	$0.2388 \cdot 10^{-3}$ kcal/s	0.8598 kcal/h
1.0 kcal/h	1.163 W	$0.2778 \cdot 10^{-3}$ kcal/s

1.0 J	$0.2778 \cdot 10^{-6}$ kWh	$0.2388 \cdot 10^{-3}$ kcal
1.0 kcal	$1.163 \cdot 10^{-3}$ kWh	4186.8 J

1.0 N/m ² (Pa)	0.00001 bar	0.981 mm H ₂ O
1.0 mm H ₂ O	$9.81 \cdot 10^{-5}$ bar	9.81 Pa

11.2. Making a calculation scheme

In the initial design phase, it is very important to create a calculation scheme of the designed network.

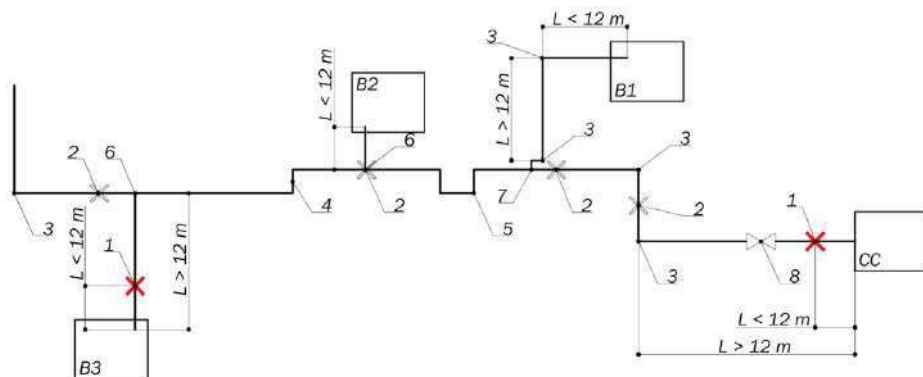


Figure 26: A section of the calculation scheme of the designed network. (1) real fixed point, (2) natural fixed point, (3) L-shape compensation, (4) Z-shape compensation, (5) U-shape compensation, (6) side branch, (7) parallel branch, (B1,B2,B3) supplied buildings, (CC) source

This scheme allows you to divide the network into fragments that form compensation systems. They are located between two adjacent fixed points, whether they are real fixed points (**RPS**) or natural fixed points (**NPS**).

11.3. Occurrence of natural fixed points

While the location of real fixed points is imposed by the designer, the location of natural fixed points should be determined according to the terrain, the course of the network and its cover.

11.3.1. Permanent coverage of the pipeline (flat terrain – short sections)

When the heat network is laid with a minimum slope, in flat terrain, the natural fixed point can be assumed to be at the midpoint between two free ends (elbows or axial compensators).

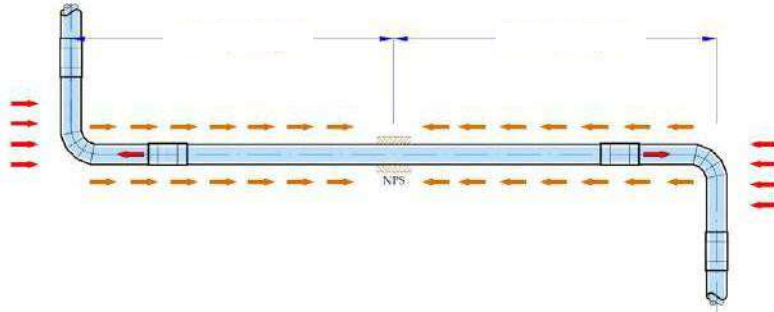


Figure 27: Natural fixed point (NPS) located at the middle of the section

11.3.2. Evenly changing coverage

One of the most common mistakes made at the initial design stage is to assume that all natural fixed points are located in the middle of a network section.

However, when considering a section of the network between two free ends at varying depths of the heat network axis, more complex methods must be used. For this purpose, the formula for determining the location of a natural fixed point for the scheme shown will be useful.

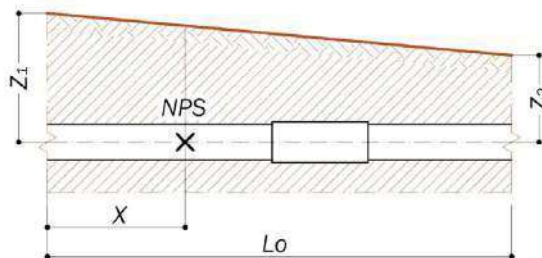


Figure 28: A computational scheme for determining the location of a natural fixed point on a uniform slope.

$$X = \frac{2 \cdot Z_1 - \sqrt{2 \cdot (Z_1^2 + Z_2^2)}}{2 \cdot (Z_1 - Z_2)} \cdot L_0 \quad \text{dla } Z_1 \neq Z_2 \quad (89)$$

11.3.3. Differentiated pipeline coverage

In the case of searching for a natural fixed point for a heat network laid in a terrain with a very differentiated relief and coverage, the location of the natural fixed point should be carried out using the method of successive approximations.

Very often it turns out that the natural fixed point is in an extreme location in relation to the network layout.

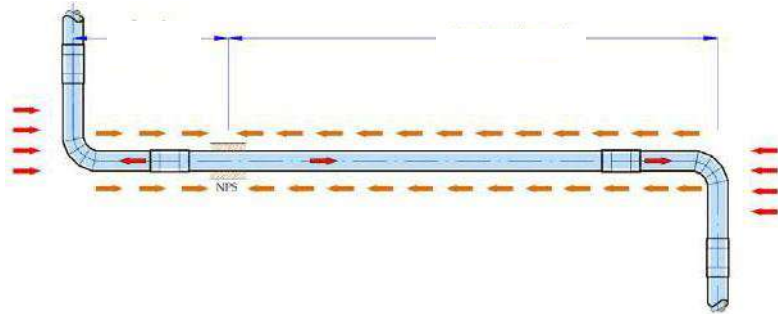


Figure 29: An extreme location of the natural fixed point (NPS)

For example, for the scheme shown in the figure:

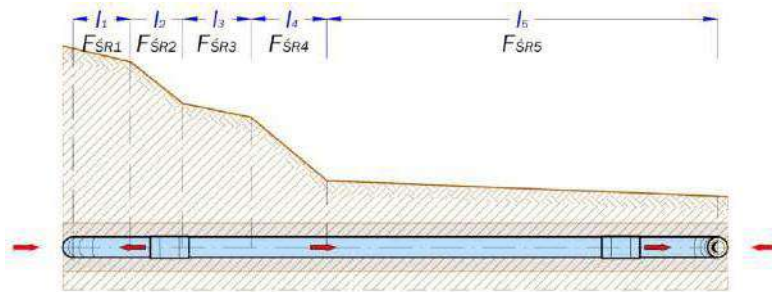


Figure 30: Location of a natural fixed point in a terrain with a very differentiated relief and coverage of the heat network

From the previous information, it is clear that the natural fixed point will be located at the point of equalisation of axial forces acting with opposite returns.

To determine the location of the fixed point, it may be helpful to divide the section of the network between the two free ends into parts that can be described by a uniform slope of the terrain in relation to the alignment of the heat network (e.g. 1, 2, 3, 4 and 5).

The approximate value of this force will be:

$$N_{NPS} = \frac{F_{SR1} \cdot l_1 + F_{SR2} \cdot l_2 + F_{SR3} \cdot l_3 + F_{SR4} \cdot l_4 + F_{SR5} \cdot l_5}{2} \quad (90)$$

Then, using the method of successive steps, perform calculations while comparing the calculated force **N** with the value of force **N_{NPS}** to find the section within which the forces are aligned:

Step 1 – calculate and compare the force **N**:

$$N_1 = F_{SR1} \cdot l_1 > N_{NPS} ? \quad (91)$$

if not then step two:

$$N_2 = F_{SR1} \cdot l_1 + F_{SR2} \cdot l_2 + \dots > N_{NPS} ? \quad (92)$$

if not then step three and so on until:

$$N_i = F_{SR1} \cdot l_1 + \dots + F_{SRi} \cdot l_i > N_{NPS} \quad (93)$$

In a situation where $N_i > N_{NPS}$ and the last added part of the formula refers to the sought section within which the sought point is located. The location of this point can be determined:

$$L_1 = l_1 + \dots + l_{(i-1)} + \frac{N_{NPS} - N_{(i-1)}}{\left(\frac{N_i - N_{(i-1)}}{l_i} \right)} \quad (94)$$

11.4. 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.

Table 20: Recommended minimum trench dimensions

SERIES 1 STANDARD insulation						
	M [mm]	N [mm]	Sand bed width [m]	M [mm]	N [mm]	Sand bed width [m]
DN 25/90	150	150	0.63	150	500	1.33
DN 40/110	150	150	0.67	150	500	1.37
DN 65/140	150	150	0.73	150	500	1.43
DN 100/200	150	150	0.85	150	500	1.55
DN 150/250	250	250	1.25	250	500	1.75
DN 250/400	250	250	1.55	250	500	2.05
DN 350/500	250	250	1.75	250	500	2.25
DN 450/630	300	300	2.16	300	500	2.56
DN 600/800	300	300	2.50	300	500	2.90
DN 800/1000	400	500	3.40	400	500	3.40
DN 1000/1200	400	500	3.80	400	500	3.80

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.

In networks run with a steep slope or located on hills, 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.

11.4.1. Minimum laying depth

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**.

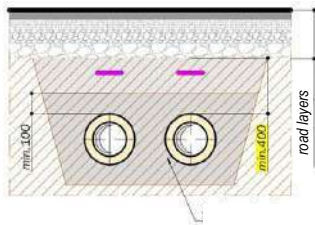


Figure 31: Minimum coverage under the road

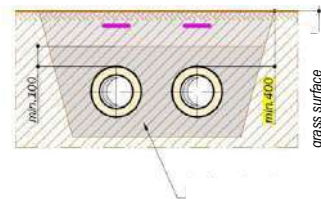


Figure 32: Minimum coverage

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

When crossing paved surfaces (roads, manoeuvring yards, car parks, etc.) 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 protects the pipelines from the impact of coarse fractions of the substructure, which could damage the polyethylene jacket.

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, protection plates, etc.)

11.4.2. Maximum laying depth

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

Table 21: Maximum coverage of pipelines

Maximum coverage of pre-insulated pipelines manufactured in FINPOL											
line pipes			Pre-insulated elements SERIES 1 – Standard insulation			Pre-insulated elements SERIES 2 – Insulation +			Pre-insulated elements SERIES 3 – Insulation ++		
dn	d ₀ [mm]	t [mm]	D _c [mm]	Distance between elbows in [m]		D _{c+} [mm]	Distance between elbows in [m]		D _{c++} [mm]	Distance between elbows in [m]	
				L ≤ 20 Y _m = 2	20 < L Y _m = 3		L ≤ 20 Y _m = 2	20 < L Y _m = 3		L ≤ 20 Y _m = 2	20 < L Y _m = 3
	26.9	2.6	90	2.1	1.4	110	1.7	1.2	125	1.5	1.0
25	33.7	2.6	90	2.7	1.8	110	2.2	1.5	125	1.9	1.3
32	42.4	2.6	110	2.8	1.8	125	2.4	1.6	140	2.2	1.4
40	48.3	2.9	110	3.2	2.1	125	2.8	1.8	140	2.5	1.6
50	60.3	2.9	125	3.5	2.3	140	3.1	2.0	160	2.7	1.8
65	76.1	2.9	140	3.9	2.6	160	3.4	2.3	180	3.0	2.0
80	88.9	3.2	160	4.0	2.6	180	3.5	2.3	200	3.2	2.1
100	114.3	3.6	200	4.1	2.7	225	3.6	2.4	250	3.3	2.1
125	139.7	3.6	225	4.4	2.9	250	4.0	2.6	280	3.5	2.3
150	168.3	4.0	250	4.8	3.2	280	4.3	2.8	315	3.8	2.5
200	219.1	4.5	315	4.9	3.3	355	4.4	2.9	400	3.9	2.5
250	273.0	5.0	400	4.8	3.2	450	4.3	2.8	500	3.8	2.5
300	323.9	5.6	450	5.1	3.3	500	4.6	3.0	560	4.0	2.7
350	355.6	5.6	500	5.0	3.3	560	4.5	2.9	630	3.9	2.6
400	406.4	6.3	560	5.1	3.3	630	4.5	2.9	710	4.0	2.6
450	457.0	6.3	630	5.1	3.3	710	4.5	2.9	800	3.9	2.6
500	508.0	6.3	710	5.0	3.3	800	4.4	2.9	900	3.9	2.5
600	610.0	7.1	800	5.3	3.4	900	4.7	3.0	1000	4.2	2.7
700	711.0	8.0	900	5.4	3.5	1000	4.9	3.2	1100	4.4	2.8
800	813.0	8.8	1000	5.6	3.6	1100	5.0	3.3	1200	4.6	2.9
900	914.0	10.0	1100	5.7	3.7	1200	5.2	3.3	1400	4.4	2.8
1000	1016.0	11.0	1200	5.7	3.7	1400	4.9	3.1	1400	4.9	3.1

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**.

11.4.3. Protection plates

If it is necessary to lay the heat network shallow, with a cover of less than **0.4 m**, **protection plates** should be used to protect the sand bed. These plates also protect the pre-insulated pipelines from the impact of coarse fractions of the paved substructure or from the impact of vehicles travelling over unpaved terrain.

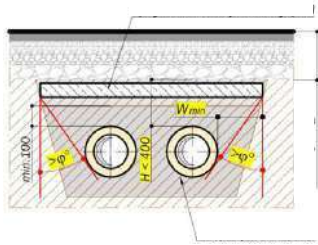


Figure 33: Protection plate under the road

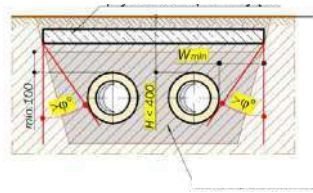


Figure 34: Protection plate

The protection plate should be laid above the sand bed of the pipelines, and its lateral dimension should depend on the angle of internal friction of the ground.

If such protection is not possible, other solutions should be used to increase the depth of the heat network.

11.4.4. Relief plates

If it is necessary to lay the heat network deep with a cover exceeding the maximum allowable cover, **relief plates** should be used.

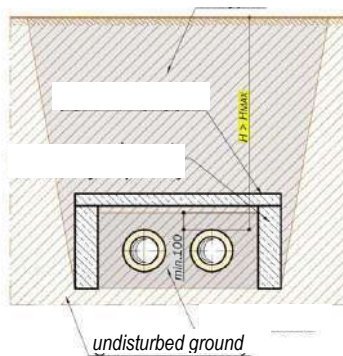


Figure 35: Ground-based relief plate

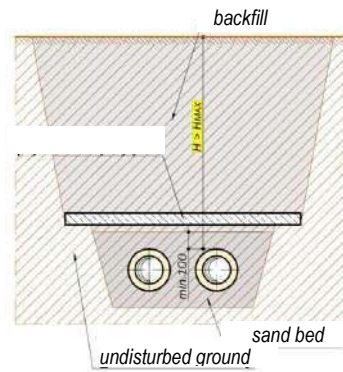


Figure 36: Relief plate on the walls

Relief plates differ from protection plates primarily in that they must be supported on undisturbed ground and, if the ground is not load-bearing, they must be supported by additional structural elements.

In addition, the relief plate and its support must be designed to carry any loads that can be found above the pipeline. This is needed in the event that the sand bed washes out and a void is created under the plates.

11.4.5. Protective pipes

When pre-insulated pipelines cross paved surfaces, often, especially for roads, the manager requires that the work be carried out without disturbing the pavement or that the heat network pipelines be laid in protective pipes.

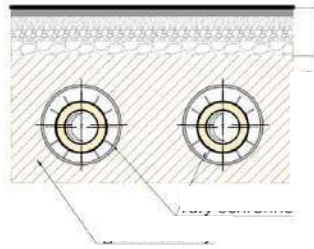
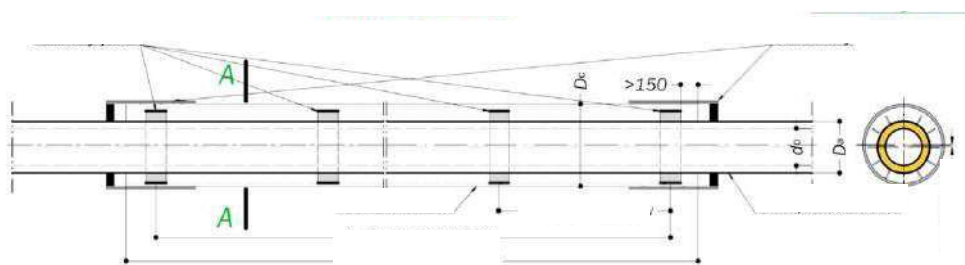


Figure 37: Pre-insulated pipelines in protective pipes under the road

Such a solution requires the use of a suitably selected protective pipe, which usually is also a drill pipe, with a diameter greater than the maximum diameter of the pre-insulated pipeline assembly to be inserted and the spacer skids used. Care should be taken to ensure that the inside diameter of the protective pipe is small enough to prevent lateral movement of the pipelines inside.

It is recommended that the difference between the inside diameter of the protective pipe and the outside diameter of the jacket of the pre-insulated pipe should be about 100 mm and be adapted to the length of the protective pipe.



Pre-insulated pipelines laid inside protective pipes

- should not be subject to lateral thermal deformation,
- should be free from high axial stresses and
- it should be possible to replace them.

Passages through protective pipes, whether in open trenches or by drilling, are only permitted at the express request of road managers or railroad services, or where conditions are such that trench excavation is not possible.

Where land development above or below ground makes it impossible to replace a pre-insulated pipeline installed in this way during its service life, protective pipes should not be used.

Selected skids, installed at an appropriate spacing adapted to the weight to be carried, should allow the axial movement of the pre-insulated pipes as well as their unrestrained installation on site.

It is advisable that the skids are equipped with wheels or castors.

The ends of the protective pipes should be equipped with flexible sleeves or reducing connectors to prevent sand and backfill from entering the space between the protective and casing pipes.

The straps on the flexible sleeves or connectors should be made of stainless steel.

11.5. Earthworks in the vicinity of the pre-insulated heat network

11.5.1. General information

Heat networks made of pre-insulated pipes and elements are designed to operate in a specific and rigorously prepared environment. Any change in the pipe environment alters the intended strength system, resulting in a risk of failure due to:

- buckling of straight pipe sections,
- overloading of the cross-sections of the line pipe,
- overloading of branch points,
- destruction of the thermal insulation,
- a change in the operating conditions of the compensating elements,

and a number of other effects, which also cause financial losses due to the interruption in heat supply or the destructive effect of the medium on elements located near the damaged pipeline.

The heat network operator, when participating in the agreement on the location of adjacent underground or above-ground utilities, should determine the details of the possibility of carrying out work in the immediate vicinity of the network on a case-by-case basis, as these conditions can only be determined on the basis of its designs and inventories.

11.5.2. Safe exposure of pipelines

The most significant limitation is the definition of the safe length over which active heat network pipelines can be excavated. The need for such work arises during the normal operation of the heat network, for example when performing hot branching or repairing a minor failure, but also when carrying out earthworks to lay or refurbish underground utilities adjacent to the heat network.

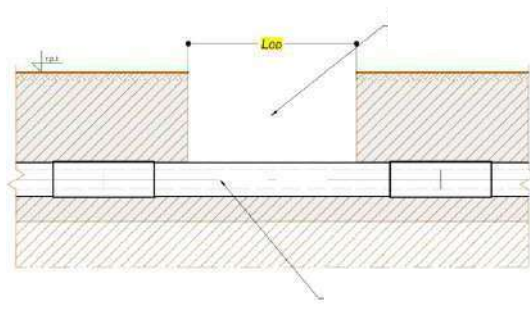


Figure 38: Exposure of a section of the heat network

This length depends on the axial forces present in the pipelines of the heat network. It can be determined using the formula:

$$L_{OD} = \sqrt{\frac{\pi^2 \cdot E \cdot I}{\gamma_a \cdot \gamma_M \cdot N}} \quad (95)$$

where:

γ_a – safety coefficient equal to 1.35 (according to PN-EN 13941-1)

γ_M – safety coefficient equal to 1.10 (according to PN-EN 13941-1)

This formula can also be applied to the stresses occurring in the cross-section of the line pipe of an active heat network.

$$L_{OD} = \frac{B}{\sqrt{\sigma_x}} \quad (96)$$

The following table shows the safe distances **LOD** for the maximum allowable axial stresses occurring in the pre-insulated network and the auxiliary value **B** used to calculate this length for other stress levels.

Table 22: Exposure of heat network pipelines

Steel pipes					Auxiliary value for the formula	Maximum length of safe exposure of pipelines
DN	d ₀ [mm]	t [mm]	A _s [mm ²]	I _y [mm ⁴]	B [-]	L _{OD} [mm ²]
25	33.7	2.6	254.0	30,927	12.9	0.9
40	48.3	2.9	413.6	107,002	18.9	14
65	76.1	2.9	666.9	447,376	30.4	2.2
100	114.3	3.6	1252.0	1,919,837	45.9	3.4
150	168.3	4.0	2064.7	6,970,917	68.1	5.0
250	273.0	5.0	4209.7	37,808,149	111.1	8.1
350	355.6	5.6	6157.5	94,311,187	145.1	10.6
450	457.0	6.3	8920.3	226,541,597	186.9	13.7
600	610.0	7.1	13447.9	611,102,853	249.9	18.3
800	813.0	8.8	22232.9	1,797,573,939	333.4	24.4
1000	1016.0	11.0	34730.3	4,385,335,060	416.6	30.4

11.5.3. Land reclamation

It is common for property owners or managers to carry out land reclamation, the measurable effect of which on the operation of the network is an increase or decrease in backfill.

(a). increase in backfill

Reclamation resulting in an increase in backfill above the heat network can lead to:

- exceeding the permissible axial stresses in the walls of the line pipes,
- exceeding the permissible shear stresses in the polyurethane insulation, which will cause the **PUR** foam to separate from the **HDPE** jacket or steel pipe. Such a situation leads to destruction of the composite system and uncontrolled operation of the pipelines.

(b). decrease in backfill

Reclamation resulting in a decrease in the backfill above the heat network can in turn lead to:

- reduced frictional force,
- the risk of pipeline buckling,
- increasing pipeline elongation,
- overloading of branch sites,
- increasing the loads on the compensating elements,
- improper interaction of the pipelines with the environment through excessive compression of the compensating pads at their place of application.

11.5.4. Trenches parallel to the heat network

If the rules for the length of safe exposure of pipelines are followed, no additional restrictions are required for parallel trenches.

However, if the length of the adjacent trench is greater than the length of L_{00} , the following rules should be followed, with additional consideration given to whether, in the event of a change in direction of the heat network, the trench is on the outside or inside of the change in direction (bevel, bent pipes, elbows).

(a). reinforced trenches

The reinforcement of the trench on the side of the heat network must be complete. When installing the casing, the safe pipeline exposure distance must not be exceeded, which means that for longer sections, the pipelines must be made in sections.

It is necessary to maintain a minimum distance between the heat network pipeline and the trench support. This distance, G_u , should not be less than **0.3 m**.

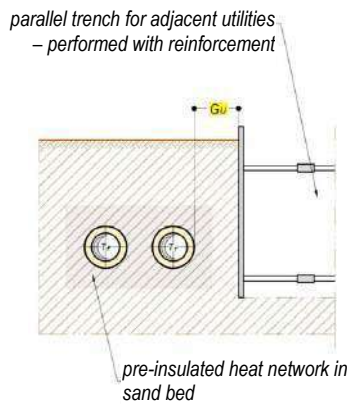


Figure 39: Distance of the trench wall reinforcement from an active heat network

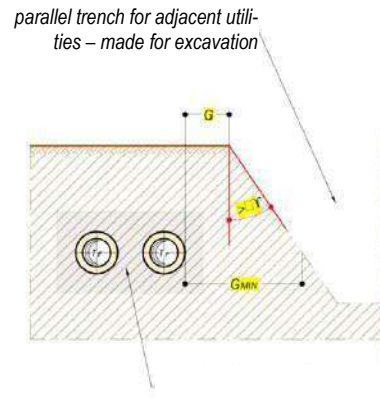


Figure 40: Parallel trench slope distance

(b). unreinforced trenches – made for excavation

For unreinforced trenches, the minimum distance **G** of the edge of the trench from the gauge of the heat network should be at least:

- **0.7 m** for pre-insulated pipelines with diameters \leq **DN 150/250**
- **1.0 m** for pre-insulated pipelines with diameters \leq **DN 300/450**

When the trench is made on the side of the return pipeline, the distance **G** can be reduced by half.

The distance of the network gauge from the slope of the trench at the pipe axis level must meet the conditions of **G_{MIN}**.

For larger diameters (\geq DN 350/500) a verification calculation must be carried out in each case.

(a). storage of soil from the trench

The storage of soil from the trench, in the area under which the pre-insulated heat network has been laid, usually results in the permissible shear stresses in the polyurethane insulation being exceeded, causing the **PUR** foam to separate from the **HDPE** jacket or steel pipe, destroying the composite system and leading to uncontrolled operation of the pipelines.

11.6. Laying pipelines in a developed area

11.6.1. Optimum laying depth

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 and a significant part of the gas pipelines.

11.6.2. Parallel installation

The heat network should be designed so 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.

11.6.3. 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.

11.6.4. Location of pre-insulated network near trees

When laying heat networks with the maximum permissible stresses, it is necessary to limit their routing along rows of trees, which sway in the wind and can change the ground conditions in the immediate vicinity of the pipelines.

11.6.5. 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.

11.7. Change of direction

11.7.1. 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 $75^\circ \div 90^\circ$.

If there are bends with an angle of deviation of the network route from $5^\circ \div 75^\circ$, they should be treated as non-compensating.

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 $5^\circ \div 75^\circ$, 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.

Table 23: Elongations allowed

Angle of deviation of the network axis	$(W_1+W_2)_{DOP}$ mm
10°	16.0
20°	18.0
30°	26.0
40°	39.0
50°	57.0
60°	80.0
70°	104.0

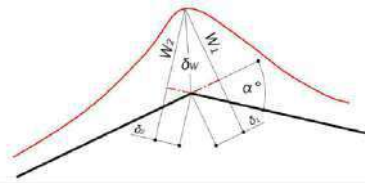


Figure 41: Displacement of the pipeline top and conversion elongations

The values of W_1 and W_2 can be calculated from the formulae:

$$W_1 = \frac{\delta_1}{\operatorname{tg} \alpha} + \frac{\delta_2}{\sin \alpha} \quad (97)$$

$$W_2 = \frac{\delta_2}{\operatorname{tg} \alpha} + \frac{\delta_1}{\sin \alpha} \quad (98)$$

$$\delta_w = \sqrt{W_1^2 + W_2^2} \quad (99)$$

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 $5^\circ \div 75^\circ$, and if this is not possible, then the quotient of the lengths of the sections should not be greater than 3.

The most advantageous solution is to use a substitute layout. Example solutions are shown in the figures below.

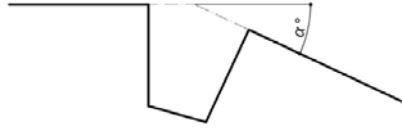


Figure 42: A substitute layout using U-shape

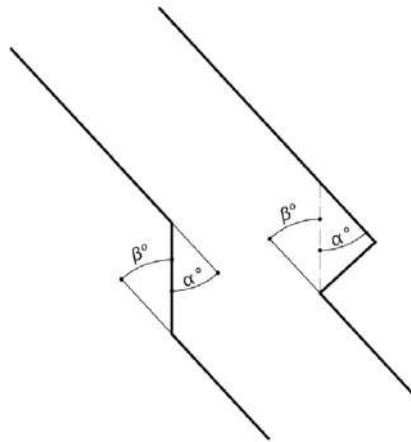


Figure 43: A substitute layout using Z-shape

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.

11.7.2. 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 should not be less than 20 outside diameters of the line steel pipe.

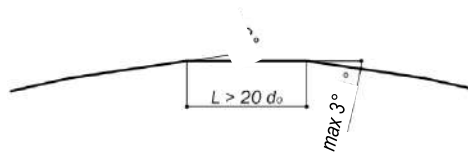


Figure 44: Beveling requirements

11.7.3. Bent pipes

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

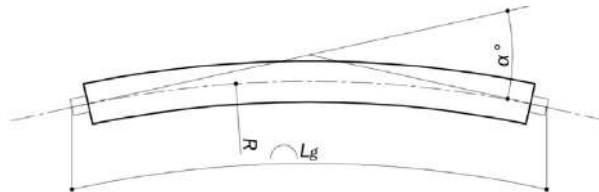


Figure 45: Characteristic parameters of a flexibly bent pipe

In the case of small diameter line pipes, on-site bending can be performed as flexible bending without the use of auxiliary tools and mechanical bending performed with simple bending machines for pre-insulated pipes.

Table 24: Pipes bent on site

SERIES 1 STANDARD insulation							
	Steel pipes			Flexible bending		Mechanical bending	
	dn	d _o [mm]	t [mm]	Minimum R _{EL} [m]	Maximum α _{EL} [°]	Minimum R _{FA} [m]	Maximum α _{FA} [°]
DN 25/90	25	33.7	2.6	23.0	29.0°	-	-
DN 40/110	40	48.3	2.9	32.0	21.0°	11.0	62.0°
DN 65/140	65	76.1	2.9	51.0	13.0°	17.0	40.0°

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

$$R_{EL} = \frac{E \cdot d_o}{1,3 \cdot R_e} \quad (100)$$

and for mechanical bending

$$R_{ME} = \frac{E \cdot d_o}{4,0 \cdot R_e} \quad (101)$$

The maximum bending angle was calculated based on:

$$\alpha = \frac{180 \cdot L}{\pi \cdot R_{MIN}} \quad (102)$$

When designing the application of bent pipes, it is necessary first to determine the required angle of change in the direction of the route – α , and on this basis to determine the required bending radius R

$$R = \frac{180 \cdot L}{\pi \cdot \alpha} \geq R_{MIN} \quad (103)$$

selecting the appropriate length of the bent section L so that the minimum bending radius is not exceeded for a given diameter and the chosen bending method.

In addition, factory-bent pipes are produced, the technical parameters of which are shown in the following table. The minimum factory bending radii shown in the table were calculated using the following formula:

$$R_{FA} = \frac{4 \cdot A_s \cdot \sigma_{DOP}}{\pi \cdot d_a \cdot \sigma_{PUR}} \quad (104)$$

The difference in bending between flexibly bent pipes and factory-bent pipes is that flexibly bent pipes deform in the trench along their entire length (from weld to weld), whereas factory-bent pipes have straight sections of approx. **1.0 m** on both sides for installation reasons. This means that a factory-bent pipe with a length of **l=12.0 m** has a bend length of about **10.0 m**.

Table 25: Flexibly and factory bent pipes

SERIES 1 STANDARD insulation	Steel pipes						
	Steel pipes			Flexible bending		Factory bending	
	dn	d ₀ [mm]	t [mm]	Minimum R _{EL} [m]	Maximum α_{EL} [°]	Minimum R _{FA} [m]	Maximum α_{FA} [°]
DN 25/90	25	33.7	2.6	23.0	29.0°	12.0	47.0°
DN 40/110	40	48.3	2.9	32.0	21.0°	14.0	40.0°
DN 65/140	65	76.1	2.9	51.0	13.0°	14.0	40.0°
DN 100/200	100	114.3	3.6	77.0	8.0°	17.0	33.0°
DN 150/250	150	168.3	4.0	113.0	6.0°	20.0	28.0°
DN 250/400	250	273.0	5.0	183.0	3.0°	25.0	22.0°

11.8. 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 from 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.

11.9. Reductions 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.

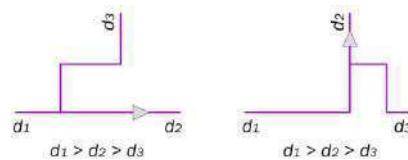


Figure 46: Location of the reducer depending on the course of the line pipe diameters

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.

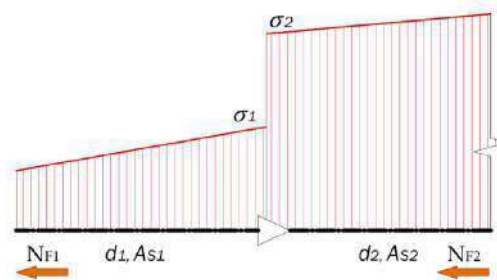


Figure 47: An abrupt increase in stress on the reducer

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 $\leq 150 \text{ MPa}$ 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 $\leq 150 \text{ MPa}$ 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.

If larger reductions are required at one site, they should be secured using real fixed points.

For small-diameter pipelines with an outside diameter of the polyethylene jacket **Dc<315 mm**, it is permissible to design steel reductions in the connection between pipes and pre-insulated elements with different line pipe diameters. If the diameter of the casing is changed at the same time, heat-shrinkable reducers must be used to insulate the connection of such pre-insulated elements.

The rules for the use of reductions in couplers are consistent with those for pre-insulated reducers.

The use of other than symmetric reducers is not recommended.

11.10. Branches

As branches are system elements subject to high loads, an in-depth analysis must be carried out to determine which branch model should be selected.

11.10.1. Side branches

The **T-45°** side branch is the simplest and most natural way to create an outlet.

The distance from the location of the branch to the location of the free end should be no less than **2.0 m** and no more than **6.0 m** depending on the ratio of the diameter of the passage to the diameter of the branch. The use of longer lengths should be checked by calculation.

Due to the lack of compensation on the **45°** elbow element, regardless of the operating temperature, in the case of longer distances, a fixed point must be made after a maximum of **6 m**. The use of a fixed point should be checked by calculation.

- The side branch of the network should be made in such a way as to reduce its impact on the point of entry into the main pipeline, and the selected lengths of the sections should meet the compensation requirements for the displacement of the main and branch pipelines.

It is not allowed to use side branches with straight section lengths exceeding **12 m** from the point of entry into the main pipeline to the first bend.

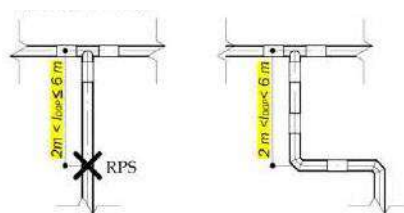


Figure 48: Side branch

11.10.2.Parallel branches

Most “upward” branches can be made by replacing the side branch tee with a parallel tee, especially where longer branch lengths are required. With such a branch, an L-shaped compensation which protects the tee is automatically formed.

The parallel section should be selected as the compensating element, except that **the L-shape** should not be shorter than **2.0 m** and at the same time not longer than **6 m**. Such compensating arms, especially for smaller diameters, make it possible to run sections of considerable length perpendicular to the main pipe. The length of the parallel section should be equal to the length of the compensating arm L_k increased by **1.0 m**.

The length of the parallel section depends on the length of the section perpendicular to the main pipeline, but in most cases and for short branches, the parallel section does not need to be longer than **1.50 m** (tee+elbow). It is required to install compensating mats over the branch pipeline on the vertical section and the horizontal section that is its elongation (in accordance with the principles of maintaining compensation). Do not design parallel tees with “downward” branches.

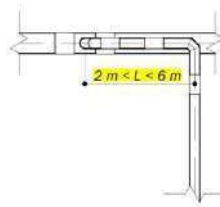


Figure 49: Parallel branch

11.10.3.Branches from the ducted network

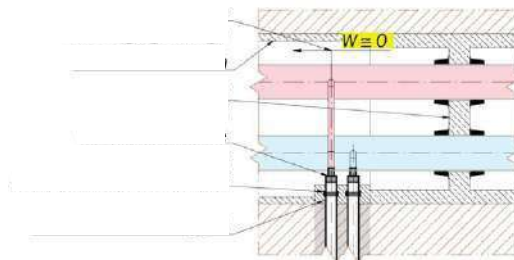


Figure 50: Branching from the ducted network at the location of the fixed point – $W \sim 0$

The method of branching a pre-insulated network from a network made with duct technology depends on the distance of the place of entry from the fixed point of the ducted network.

A branch by direct welding can be made both in a chamber and inside a duct. In this case, the wall thickness of the branch pipeline must not be less than **80%** of the wall thickness of the main pipe.

In the case of an entry in close proximity to a fixed point, where the elongation of the ducted network pipeline is close to zero, the branch should be designed according to the principles of the side branch.

Moving away from the fixed point, with increasing elongation, it is advisable to use transition adapters and parallel branches.

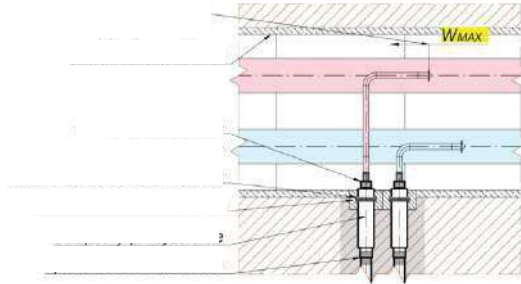


Figure 51: Branching from the ducted network using an adapter – $W > 0$

Passages through the walls of a duct or chamber should be made in accordance with the general rules for the passage of pre-insulated pipelines through building partitions.

11.10.4. Duct niches

When designing a branch of pre-insulated pipelines from the ducted network in a place with significant axial displacement of the main pipelines, which prevents the use of adapters, it is necessary to design branches in duct niches or, if verification calculations allow it, to break the duct and insert a pre-insulated tee.

11.11. Real fixed points

In the design of pre-insulated pipelines, due to their size and the difficulty of locating them in developed terrain, the use of real fixed points (**RPS**) should be avoided and, if it is necessary to use them, it is advisable to develop the design be developed individually with adaptation to the existing situation in the field.

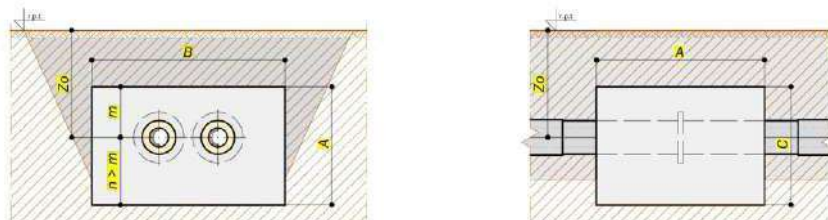


Figure 52: Real fixed points in the ground

Sometimes, however, there is a need for real fixed points, which in ductless technology usually take the form of reinforced concrete blocks of considerable size. They are used to protect:

- bellows compensators against changes caused by the phenomenon of “flow,”
- a significant reduction in the line pipe used;
- the site of a branch made without a flexible connection;
- ducted network pipelines from the effects of ductless network pipelines, which change the distribution of forces in existing systems;
- elbow systems with insufficient compensation capacity in relation to the needs of the pipelines being laid;
- in addition, to eliminate compensating elbows and immobilise pipelines at bends.

The designed real fixed point should ensure that the pipelines are immobilised at the designed location so that the forces from the pipelines acting on it from one side are not transferred to the pipelines on the other side.

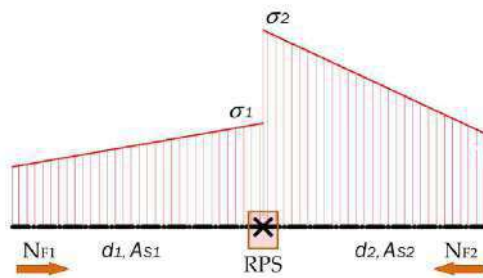


Figure 53: Real fixed point loads

For small networks, the table below shows the dimensions of concrete fixed point blocks for pipelines with diameters $dn \leq 300$ mm.

Table 26: Typical sizes of real fixed points

SERIES 1 STANDARD insulation	Steel pipes			Strength	Fixed point dimensions			Reinforcement
	dn	d ₀ [mm]	t [mm]	F _{calc} [kN]	A [m]	B [m]	C [m]	φ [mm]
DN 25/90	25	33.7	2.6	120.0	0.5	0.7	0.5	8.0
DN 40/110	40	48.3	2.9	140.0	0.5	0.8	0.6	8.0
DN 65/140	65	76.1	2.9	260.0	0.9	1.0	0.7	12.0
DN 100/200	100	114.3	3.6	470.0	1.1	1.5	0.9	12.0
DN 150/250	150	168.3	4.0	790.0	1.2	1.9	1.2	20.0
DN 250/400	250	273.0	5.0	1600.0	1.2	4.1	1.4	20.0

All concrete blocks were calculated taking into account the following parameters:

- internal pressure in the supply and return pipelines – **1.6 MPa**
- pipeline cover – **0.8 m**
- ground compressive stresses – **150 kN/m²**
- coefficient of friction between the ground and concrete – **0.8**
- relative displacement of the concrete block – **2%**
- surface force on concrete block – **25 MN/m²**

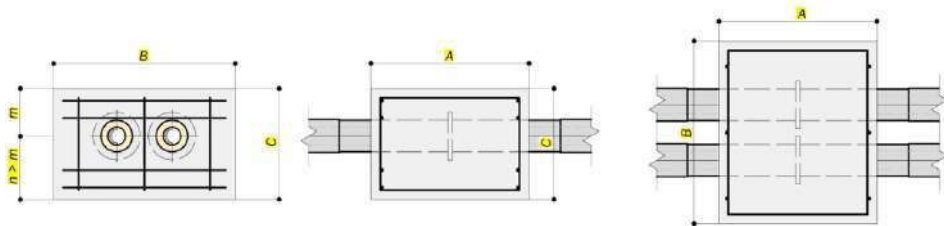


Figure 54: The size of the real fixed point with reinforcement – figure to table

The minimum thickness of the layer of concrete covering the reinforcement from the external surface is **50 mm**.

The concrete must be properly set before the concrete block is subjected to forces.

When the design provides for a different cover and different pipeline lengths than the maximum lengths due to allowable stresses, it is recommended to recalculate the concrete block dimensions.

The dimensions of the concrete block for a length other than the design length of the pipeline can be determined as follows:

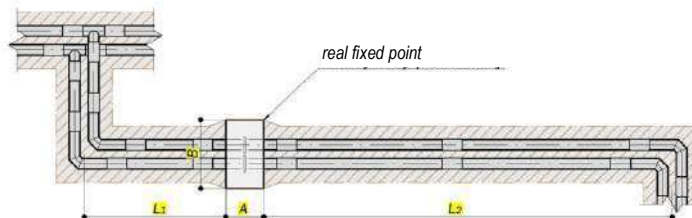


Figure 55: Diagram of the location of the real fixed point (RPS)

for

$$L_1 < L_2 \quad (105)$$

the reduction coefficient is:

$$\gamma_\mu = \frac{L_2 - L_1}{L_{MAX}} \quad (106)$$

With this coefficient we can change the height (=C) or width (=B):

$$B' = \gamma_\mu \cdot B \quad (107)$$

$$C' = \gamma_\mu \cdot C \quad (108)$$

It should also be noted that if you design a shut-off fitting in the vicinity of the fixed point, it can affect the distribution of forces acting on the fixed point when the section of pipeline is shut down (particularly in the case of a high pressure supply pipeline).

This is particularly the case for larger diameter pipelines where the fixed point protects the compensation and there are short sections of L_1 and L_2 adjacent to it – see figure below.

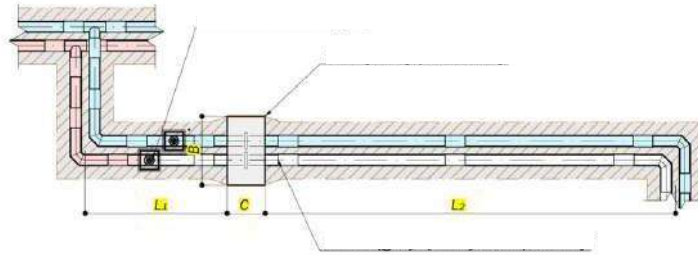


Figure 56: Non-relieved real fixed point

11.12. Shut-off valves

Barrier (shut-off) fittings installed in heat networks should be designed in locations justified by operational considerations, but always outside the compensation zones.

The stems of pre-insulated fittings should be placed in specially made housings with stems in casing pipes equipped with protective caps and compensating pads taking into account the possibility of pipeline movement.

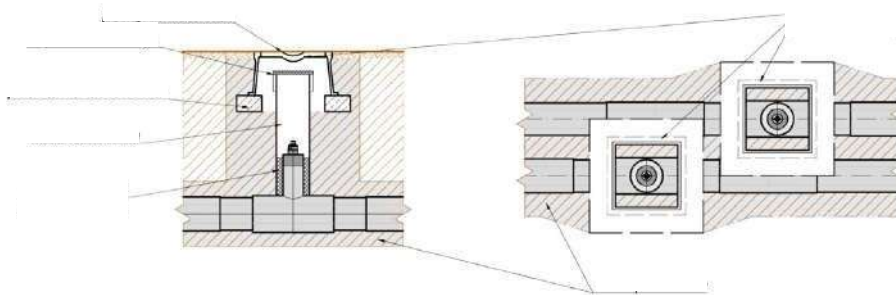


Figure 57: Installation of shut-off fittings in a location that is not subject to displacement

Pre-insulated ball valves can be installed anywhere in a pipeline designed with stress limitation.

Fittings should be located away from roads with heavy traffic.

If such a location is unavoidable, stud housings should be mounted on suitably sized reinforced concrete relief plates.

Where fittings are installed on branches from the main pipeline, at the point of a flexible branch, the shut-off element should be located as close as possible to a natural fixed point.

The design documentation for pre-insulated fittings should include:

- design solutions for manholes allowing access to the fittings for operation (opening/closing),
- information on the method of operation: with a wrench, fixed or portable gearbox, type and degree of gear ratio,

- the location of the fittings in relation to the compensation zones.

For operational reasons, it is recommended that the shut-off fittings outside the perimeter of the pre-insulated pipeline (in the “top” vent/drainage panel) and the stem of the pre-insulated shut-off fittings installed in the manhole be protected by a protective cap.

The cap should not be fixed, but should be loosely fitted to the valve stem protection pipe or to the vent/drainage shut-off valve protection pipe. It should be made of plastic and suitably ballasted to ensure full protection of the fittings in the event of flooding of the manhole by external water – rainwater or groundwater, with a lifting handle attached. The **HDPE** element of the end coupler can be used as a protective cap.

The manhole casing should be filled with a layer of sand (to a height of about 20 to 30 cm from the bottom of the casing) and topped up with gravel to the level of the protective hood. The hatches designed for the casings should be adapted to the type of pavement at the valve location.

To make it easier to locate fittings installed in this way in the field, a suitable measuring plate should be placed on the nearest fixed object (building, fence, etc.) or on a post.

Valves with a diameter of up to **DN 125 mm**, as pre-insulated, should be designed to be opened with a “T” wrench, while valves with a larger diameter should be designed with worm gears or as adapted to portable – planetary gears.

In the case of fittings with smaller nominal diameters, the stems can be encased in a common housing with vent or drain spigots.

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

Due to the tensile stresses that occur in pre-insulated pipelines during cooling, fittings with welding ends should be used in chambers.

11.13. Venting

The purpose of venting is to allow the removal of air from the heat network pipes during water pressure testing and network operation, and to aerate the pipes during drainage.

The geometrical layout of the network (profiles) should be designed to maximise the possibility of venting in the rooms of the district heating substations or in chambers with shut-off fittings.

Where this is not possible, tees with ball valves for venting can be installed anywhere in the pipeline. They should be designed in lightweight casings, for example, **Ø 425 mm** made of corrugated pipes of sewer systems, with hatches adapted to the existing pavement at the place of installation of the casing.

For small diameters, the supply and return pipeline vents can be placed in a common manhole casing.

To enable ground level handling operations, the vertical distance from the top of the hatch to the levers of the vent valves must not exceed:

- 400 mm – if they are installed in a common manhole or manhole casing;
- 300 mm – if they are installed in separate manholes or manhole casings.

The vents are fitted with service valves. The valve bodies are made of stainless steel and have female threads secured by plugs. A hole is made in the thread of the plug to allow easy and safe venting of the network.

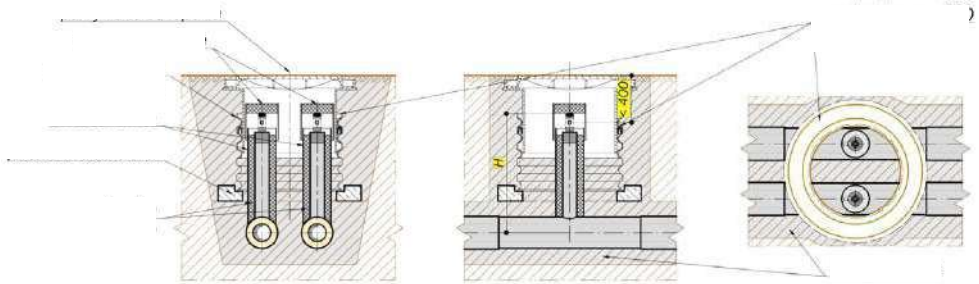


Figure 58: Installation of pre-insulated vents in a common manhole casing

It is necessary to take into account the possibility of movement of the vent spigot inside the manhole casing due to the displacement of the main pipeline, and it is essential to protect the vent spigot with:

- polyethylene compensating pads of a thickness adapted to the displacement (**at least 40 mm** – all around, over the entire height of the spigot's polyethylene jacket);
- a cap (hood) to protect the vent valve.

In exceptional cases, the pre-insulated “vent tee” element can be replaced with a specially made vent spigot at the stage of the task implementation.

It is advisable to use service valves with higher chromium, molybdenum and titanium content in the design.

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

11.14. Drainages

The pipelines of the district heating network should be laid with a slope that allows drainage.

The design should include a solution for the discharge of mains water in accordance with the applicable regulations.

Operational experience shows that it is not necessary to install drainage at every lowest point of the pipeline. For pre-insulated pipelines with small diameters (**up to DN 125**), drainage should only be used if the expected amount of water to be removed (the capacity of the pipeline to be drained) is greater than **2 m³**.

The water can be removed either by gravity, by discharging the mains water into manholes (so-called “to manhole” drainage) – or by “blowing out” the mains water with compressed air.

11.14.1.Upward

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.

Drainage of pipelines with larger diameters should be designed individually.

As in the case of vents, they should be designed in lightweight casings, for example, **Ø 425 mm** made of corrugated pipes of sewer systems, with hatches adapted to the existing pavement at the place of installation of the casing.

For small diameters, the supply and return pipeline drainage can be placed in a common manhole casing.

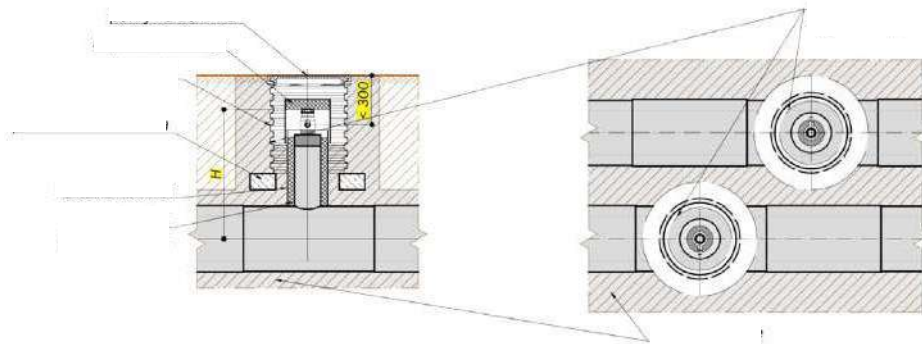


Figure 59: Installation of vertical drains in separate casings

It is not allowed to use street boxes to house valves. When designing “upward” drains, you should:

- make sure that the network user is prepared to drain the network in this particular way,
- provide an element that prevents water from flowing vertically upward on the threaded end of the valve,
- use service valves with increased chromium, molybdenum and titanium content in the design.

11.14.2.Gravity – downward

Traditionally used “downward” gravity drainage should be made in one of two versions:

- to a valve manhole – where hoses can be connected to drain water – this drainage should be assisted by connecting the compressor to the vent spigots,
- to a set of drainage manholes – a valve manhole and a cooling manhole. The heating medium drained from the pipeline should be led out from the valve manhole through steel pipes to the pipeline to the second manhole – the cooling manhole.

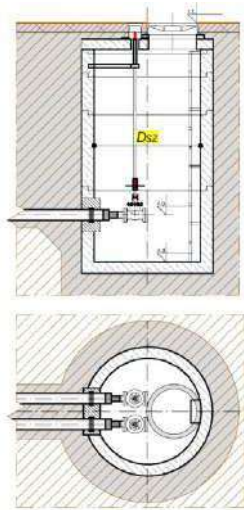


Figure 60: Valve manhole

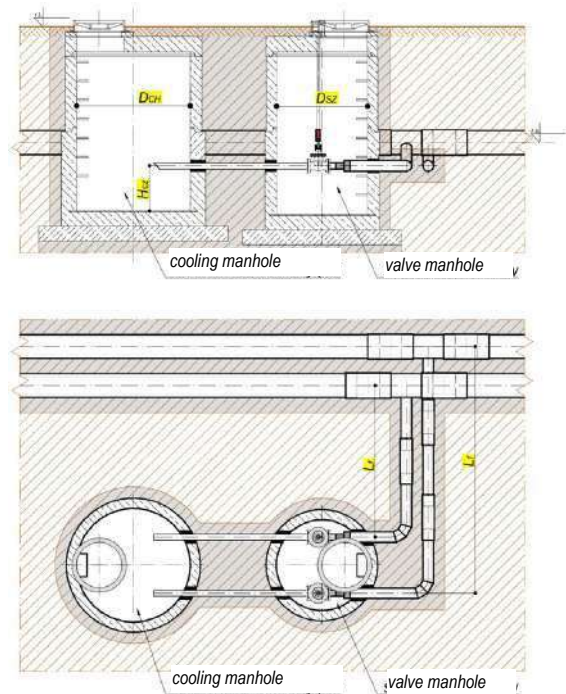


Figure 61: Drainage with a valve manhole and a cooling manhole

The depth of the cooling manhole should be selected so that the vertical distance from the bottom of the outer surface of the pipeline casing to the bottom of the manhole is not less than 500 mm.

The cooling manhole must be constructed as a “sealed” manhole.

It is necessary to choose the correct active volume of the cooling manhole, the diameter of which must be selected according to the possibilities of the terrain and soil.

The minimum active volume of the cooling manhole should be **1.5 m³**.

The connection of the “to manhole” drainage should be of sufficient length to compensate for the displacement of the drained pipe at the point of the inclusion of the drainage.

11.15. Connections to elements of the TWIN PIPE system

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.

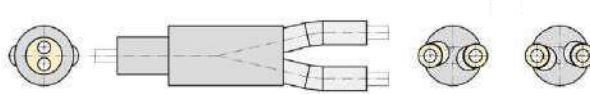


Figure 62: Transition fitting from TWIN PIPE to single pipe system – Y type

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.

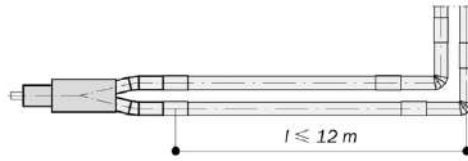


Figure 63: The condition of connecting TWIN PIPE pipelines to pipelines according to PN-EN 253

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

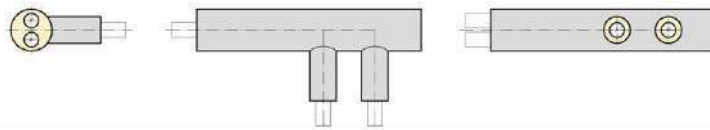


Figure 64: Transition fitting from TWIN PIPE to single pipe system – F type

11.16. Insulation of connections of pre-insulated elements

The selection of the appropriate type of insulation joint should take into account its resistance to installation conditions, soil conditions, ground water level, magnitude of forces acting on the jacket, outside diameter of the jacket, and the experience of the contractor and investor.

Installation of connectors should not be carried out during wet weather and rain. In special cases, it is permissible to carry out the installation of connectors with the use of protection in the form of installation tents and mandatory drying of the joint areas.

The following elements can be used:

- slip-on couplings – radiation-crosslinked heat shrinkable,
- reduction couplings – radiation-crosslinked heat shrinkable,
- elbow couplings – radiation-crosslinked heat shrinkable,
- open couplers – electrically welded.

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.

All joints should be checked for leaks after installation of the jacket and before insulation with liquid PUR foam.

The length of the coupler should depend on the length of the bare ends of the pre-insulated elements. Bare pipe ends must not be painted after cleaning and before insulation with liquid PUR foam.

Under no circumstances should heat shrinkable couplers be shortened.

11.17. Passages through building partitions

A passage through building partitions (buildings, chambers or manholes), 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).

Depending on the geometry of the network and the expected directions of pipeline movements,

- in places where axial and lateral displacements will not occur, use single rubber rings with a diameter adapted to the outside diameter of the jacket pipe,
- in places of anticipated axial displacements use double sealing,
- in the case of lateral displacement use transition adapters.

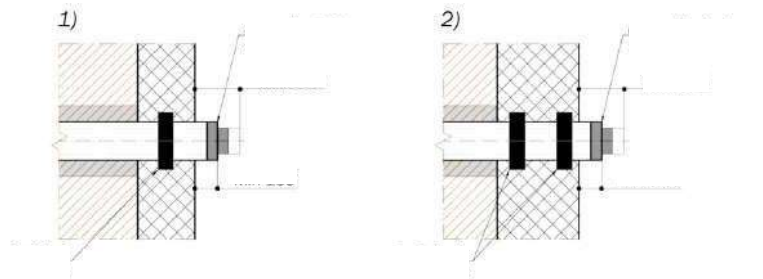


Figure 65: Pipeline penetration through the building wall using sealing rings

Entry through a building wall can also be made using an elbow.

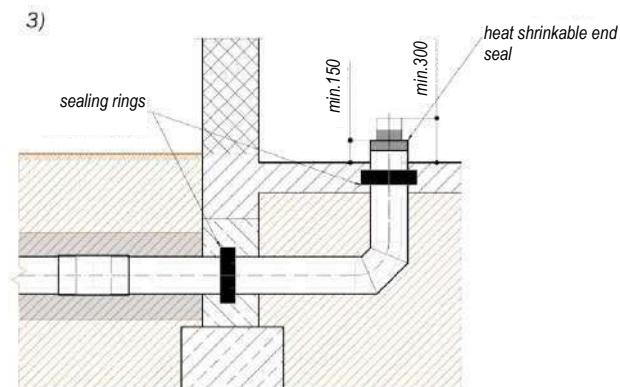


Figure 66: Sealing of pipeline penetrations through walls and floors

Additional sealing is not required for chamber wall penetrations.

If groundwater is present, sealing should be adapted to the conditions.

At the ends of pre-insulated pipes in buildings, it is necessary to provide for the installation of heat shrinkable ends.

The polyethylene jacket of pre-insulated elements should be inserted **at least 15 cm** inwards, beyond the outline of the wall or partition of the building.

11.17.1. Sealing rings

The sealing ring as the primary seal of the passage through building partitions should be made of materials with increased resistance to the external conditions associated with its installation site and should retain flexibility for the minimum required service life of the pre-insulated heat network.

Additional external seals at building wall penetrations should be **WGC type** seals.

11.17.2. Heat shrinkable end seals – termination sleeves

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.

11.17.3. Transition adapters

When passing through a building partition or the wall of a concrete duct casing at a point where the pre-insulated pipeline will be subject to lateral movement, sealing adapters are permitted.

The sealing between the adapter and the building partition should be similar to the sealing of the pre-insulated pipe in the wall.

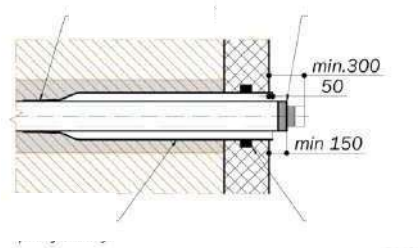


Figure 67: Passing through a wall using an adapter

11.18. Preheating

Preheating is a technique aimed at inducing partial thermal deformation in the walls of the line pipes of unburied pre-insulated pipelines, so that when they are buried and the heat network is put into operation, the residual deformation does not cause the allowable stresses to be exceeded.

If the heated pipeline is backfilled while maintaining all the regimes of the applied technology, then such a pipeline will tend to “shrink” after the temperature is lowered,

because the backfill, through the jacket and thermal insulation (the composite system), will counteract this, which will induce axial tensile stresses in the pipeline wall.

When starting the pipeline heating (network operation) until the temperature at which the pipeline was backfilled is reached, i.e. the preheat temperature, the value of axial stresses in the wall of the steel pipe will decrease. In adverse weather conditions, when the temperature of the medium continues to rise, compressive stresses will appear in the pipe wall. When designing the preheating, the following must be taken into account:

- the maximum operating temperature of **153°C**
- the preheat temperature of the supply and return pipes is a minimum of **50°C** and a maximum of **83°C**,
- the preheat temperature should be half the difference between the operating temperature and the backfill temperature,
- maximum design pressure of pipelines – **PN 25**.

It is essential that the sand bed construction and trench backfilling are carried out at a constant and identical preheat temperature for the supply and return pipelines.

Diameter reductions of multiple dimensions are unacceptable in the deceleration zone, while a reduction of one dimension is possible due to the relatively rapid equalisation of the peak stress increase.

To ensure a smooth preheating process, the design should provide for the assumptions of a precise plan of action – a concept and a detailed work schedule. The following must be designated and established:

- the method of performing preheating,
- the division of the network into individual sections and the determination of their length,
- the directions of the slopes of the pipeline sections – **at least 3‰**,
- the possibility of connecting water and electricity for each section,
- the location of the power generating unit or the location of its connection for each section,
- the location of sand piles, measuring devices and auxiliary materials at each section,
- the order and time of preheating of individual sections,
- information on whether or not the branch routes are to be backfilled,
- information on which wall penetrations cannot be permanently fixed or concreted.

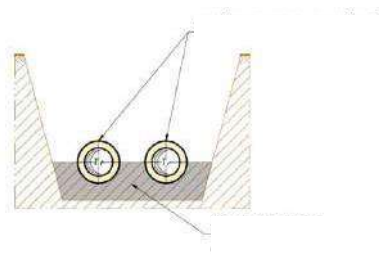


Figure 68: Preparation of pipelines for preheating – sand backfill

After installing the pipelines and before preheating, partially backfill the pipelines (up to half the height of the jacket, as shown in the drawing) and create an apparent fixed point by completely backfilling part of the pipelines.

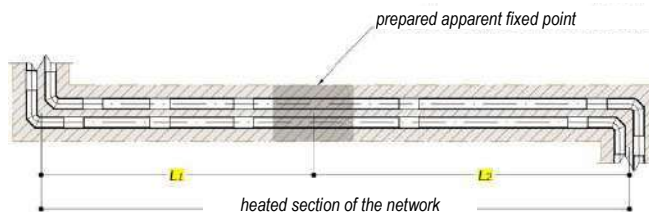


Figure 69: Preparation of pipelines for preheating – apparent fixed point

The advantages of preheating include:

- the ability to maintain a lower level of compressive stress than other techniques,
- immobilisation of a significant section of the pipeline,
- reduction in the number of welded joints,
- the possibility of making branches “anywhere”,
- high stability of the pipeline,
- theoretically available for any diameter,
- extending the service life of pipelines,
- available in most networks,
- reduced thickness of the compensating pads,
- reduced operating elongations (in the case of electric heating),
- the possibility of carrying out earthworks close to the network during the non-heating season without the risk of buckling of the pipelines,
- the possibility of partial execution with the division of pipelines into sections (in the case of electric heating).

A major disadvantage of preheating is the need to keep the trench uncovered until the work associated with heating the section of pipeline has been completed and the pipeline backfilled, while inconveniences during the operating period include the inability to cut the pipelines freely without the use of protective techniques.

11.18.1. Heating with a heating medium

This method is useful whenever the heated section is connected directly to the existing network and it is not necessary to drain the pipelines before the final commissioning of the route.

An additional condition to be met is that the temperature of the medium can be adjusted to the temperature needed for pre-stressing, both for the supply and return pipelines.

11.18.2. Steam heating

In terms of useful heat transfer, steam gives off 15 times more heat than water. Therefore, a great advantage of this method of preheating is the low water consumption and significantly shorter heating time of the pipeline compared to the first method – heating with a heating medium.

Under normal conditions at atmospheric pressure, **100°C** steam is produced at **100°C**. However, a temperature of **60°C** to **75°C** is required for pre-stressing. When the air pressure is reduced to **0.4 bar** using a vacuum pump, water boils already at **75°C** and steam of the same temperature is produced. It transports **756 W/kg** of heat.

11.18.3. Electric heating

With this method, it is possible to apply pre-stressing in sections of any length in a manner adapted to the progress of the installation work. You can avoid many additional elements, such as a bypass connecting

the supply pipeline to the return pipeline due to an electrical short-circuit.

The application of stresses by means of electric current can only be used for pipelines of the same diameter. It is not possible to pre-stress pipes of different diameters, as smaller diameters can significantly increase their temperature above the design range.

The disadvantages of this method are the need for a **380 V** power supply and specialised equipment. The main advantages are:

- uniform heating temperature throughout the heated section,
- it is suitable for the entire series of pipes,
- possibility of staged execution,
- no consumption of mains water,
- no corrosion,
- heating time adjustment,
- “maintenance-free” devices,
- application at negative outside temperatures,
- reduced operating elongations.

11.19. Pre-tension

If it is not possible to perform preheating, in a situation where there is a need to reduce the heights of the compensating elements or partially reduce the thickness of the compensating pads, we can use one of the two pre-tension techniques:

- mechanical tension – when tensions are applied to a cold pipeline
- in the elbows of the compensating elements,
- thermal tension – when we can put the buried pipeline into service while allowing a selected unburied compensation to deform freely.

11.19.1. Mechanical tension

Known and very widely used in the technology of construction of heat networks in duct housing and overhead networks. It allowed the mechanical application of stresses to the elements of natural compensation. In this way, compensations can have reduced heights, selected as for smaller thermal elongations.

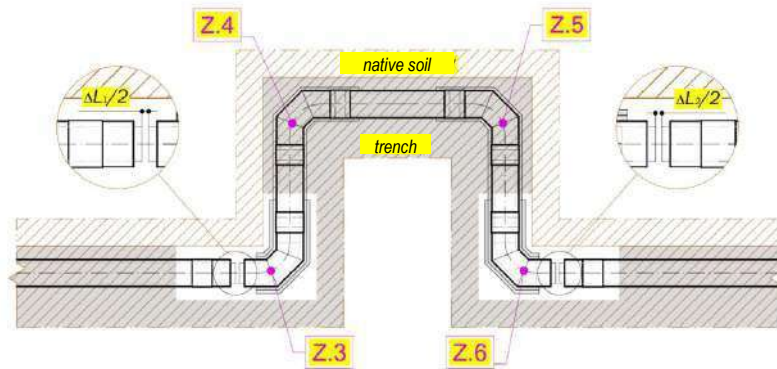


Figure 70: Pre-tension – mechanical

In this technique, when pre-insulated pipes are laid, between the compensating elbows and adjacent straight sections of pipelines, gaps are left between the ends of the line pipes of these elements on one or both sides of the compensator. The gaps should be provided for at the design stage and the design should specify the size of the gaps (not more than half of the thermal elongations of the straight sections).

$$L_{NM} < \frac{\Delta L_1 + \Delta L_2}{2} \quad (109)$$

After assembling, installing couplers, making the sand bed and backfilling the entire pipeline, except for the areas adjacent to the gaps and arms of the compensator, proceed with tensioning. The task is to stretch the compensator so that the correct weld can be made in the space previously left. For tensioning, it is best to use so-called turnbuckles welded to the pipeline or hydraulic jacks, depending on the size of the pipelines. When using jacks, protect the jacket of the pre-insulated elbow.

Then proceed to install the couplings and backfill the pipelines in the tension areas.

Tensile stresses are applied to a compensator made in this way at a safe level. After heating and reaching the temperature T_{SR} calculated from the following formula:

$$T_{SR} \approx \frac{T - T_{INST}}{2} \quad (110)$$

the compensating element operates with stresses close to zero and, after reaching the operating temperature T , it operates in a safe range, despite absorbing the total thermal elongation of the straight sections adjacent to the compensator.

The as-built design should describe in detail where this technique has been applied and the magnitude of the mechanical tension used.

11.19.2. Thermal tension

Thermal tension is useful when thermal elongations require the use of expansion pads in quantities that pose a risk to the polyethylene jacket by exceeding its surface temperature.

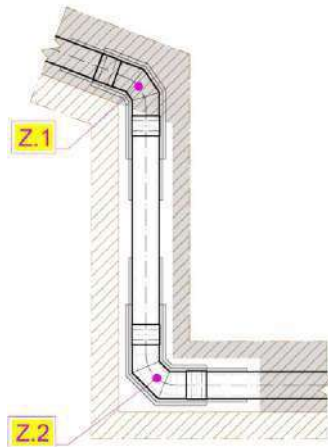


Figure 71: Pre-tension – thermal

This technique consists of leaving, during comprehensive pipeline construction, an uncovered compensating arm for which a reduction in the thickness of the compensating pads is designed.

The trench is left uncovered until the average temperature of the heating medium is reached.

After the sand bed has been made and backfilled, the compensating pads placed on the compensating element are in a “dormant” state – that is, they have not absorbed the displacements of the pipelines, whereas the compensating element is already partially loaded. Once the operating temperature is reached, the compensating element is loaded to the maximum design value, while the pads only absorb part of the elongation. A similar situation arises when the pipeline cools down.

It is advisable to limit the use of this technique to sections with a length of L_0 close to L_{MAX} , and not to reduce the number of pads by more than one layer and the construction design and the as-built design should describe the use of this technique.

11.20. Application of bellows compensators

Pre-insulated heat networks work best and last longest when they move as little as possible and when they have as few moving parts as possible, either by limiting the number of compensations or, additionally, by limiting thermal elongation due to heating.

However, when field conditions force the laying of the heat network in a straight line, the length of such a section exceeds the permissible installation lengths, and we also do not have the possibility of preheating, it is possible to use a bellows compensator or several bellows compensators on the section between two compensating elbows. They can be used in different variations.

11.20.1. Pre-insulated bellows compensators

Pre-insulated bellows compensators are the only pre-insulated elements with moving parts under the jacket and insulation offered in the pre-insulated pipe systems. The convenience of their use often outweighs their disadvantages, which include the interruption of the continuity of the composite system and the **PUR** insulation.

On a long straight section of several hundred metres in length, there can be considerable variations in conditions during network operation. This can be caused mainly by:

- local occurrence of groundwater,
- periodic occurrence of local surface water,
- variable geotechnical conditions,
- the laying of pre-insulated pipelines in existing ducts after heat networks,
- the use of protective pipes,
- the quality of the sand bed and backfill execution,
- or the occurrence of all the above causes at the same time.

This can cause variability in the operation of compensating elements and unpredictable load shifts. The situation does not pose a threat to compensation elements using elbows due to frequent changes in the direction of pipelines at compensation points, but it may pose a threat when using axial (pre-insulated bellows) compensators.

When a single bellows compensator is used, the network section between elbows is short enough that significant variation in conditions should not occur. Therefore, for diameters up to **DN 300/450**, a single pre-insulated compensator can be inserted between two compensating elbows. For larger diameters, verification calculations should be carried out.

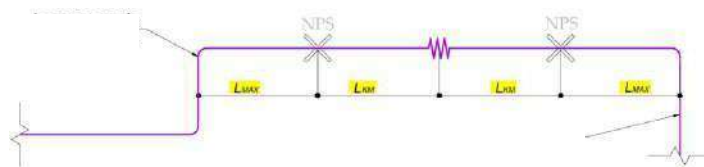


Figure 72: Use of a single pre-insulated bellows compensator

In the case of long sections where it may be necessary to use several pre-insulated bellows compensators, the considerable variability of conditions in large spaces may cause periodic changes in the loads on the compensators and their movements. That is why, after studying the existing geotechnical conditions, the use of fixed points between the extreme axial compensators and compensating elbows should be considered. In unfavourable conditions for large diameters, calculations should be carried out to verify the possible need for real fixed points between individual compensators in the string.

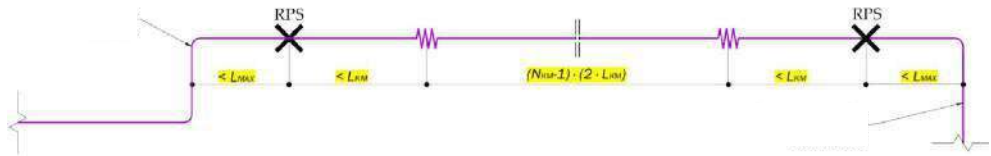


Figure 73: Use of real fixed points between extreme compensators and compensating elbows

When the analysis of the existing conditions shows that the occurrence of significant variation in conditions is possible and it is decided to use real fixed points, these points should be installed in the place where the forces on the side of the compensating elbow and the forces on the side of the bellows compensator are balanced. The diagram is shown in the following figure.

The real fixed point located in such a place will have the smallest dimensions.

The force for which the fixed point is selected should depend on the possible location of the shut-off fittings and the actual working pressure. For a fixed point located as shown in the figure, the recommended force should be at least equal to:

$$N_{RPS} \geq L_{MAX} \cdot F \quad (111)$$

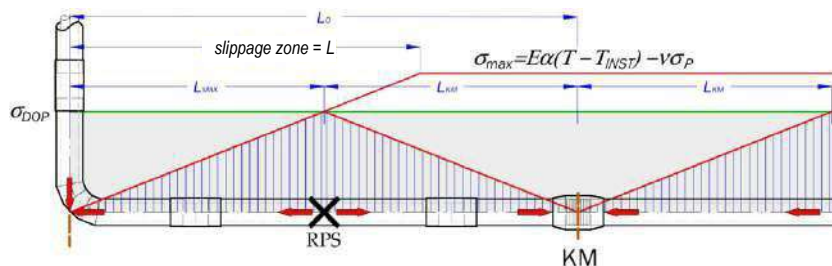


Figure 74: Location of the real fixed point between the pre-insulated bellows compensator and the compensating elbow

Pre-insulated bellows compensators should be used in agreement with the operator of the heat network.

11.20.2. Bellows compensators – in chambers

Placing bellows compensators in a chamber allows the use of compensators with higher compensation capacities and the location of a pair of such compensators within a single fixed point – an example is shown in the figure.

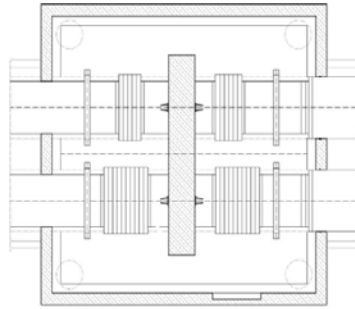


Figure 75: Example of a compensator chamber

Such systems have often been used in heat networks made in concrete enclosures where sections of transmission networks were of considerable length. Typically, fixed points were mounted directly in the duct, a valve chamber or a network branch chamber between two chambers with bellows compensators.

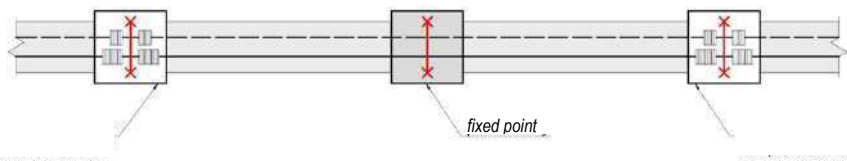


Figure 76: Use of bellows compensators in chambers, traditional networks in duct casings

Such systems can be used in pre-insulated heat networks. They can also be easily adapted to work with pre-insulated heat networks.

An analogous system can be created on the basis of a pre-insulated network:

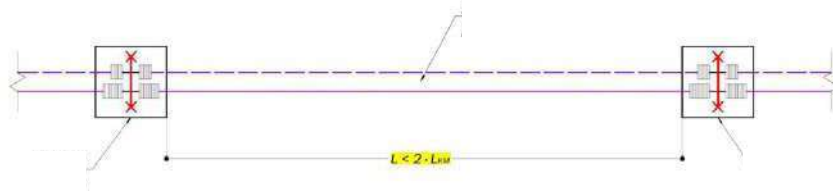


Figure 77: Use of bellows compensators in chambers, in pre-insulated heat networks

11.21. Bellows compensators – single-use compensators

Another technique that facilitates the laying of long straight sections is the use of Single-Use Compensators (**SUC**) to reduce stresses in pipelines. The difference between preheating and **SUCs** is that preheating is carried out in an uncovered trench, while the application of **SUCs** allows immediate backfilling of the pipelines outside the compensator locations.

The compensator locations remain uncovered until the heating system reaches the compensator closing temperature. The compensators are then welded, insulated and backfilled.

The design of each compensator should specify the settings and closing parameters.

Compensator selection rules and installation tables are presented in Chapter **8.4.2. Single-Use Compensators – SUC**.

11.22. Chambers

The operator or owner of the network chooses the chamber solution and the designer's task is to ensure functionality, maintenance of proper spacing (old and new standards help) and protection of pipelines inside the chamber from external forces.

The design of new chambers and manholes along the route of pre-insulated pipelines for the location of shut-off fittings (as well as drain and vent fittings) and control and measurement instruments should be limited to the locations clearly indicated by the operator – at network substations.

New chambers should be located where there is little axial displacement of the main pipelines.

Among other things, due to the ability to effectively seal the passage of pipelines through flat walls, it is recommended to use chambers with a rectangular cross-section.

In the case of conversion of ducted networks to pre-insulated networks, the advisability of leaving the existing chambers should be considered, especially if there is a need to adapt their dimensions and design to current legislation, including health and safety regulations.

The current requirements are:

- minimum clear chamber height of at least **1.8 m**,
- distances between elements and equipment in the chamber in accordance with BN-77/8973-11,
- free space in the clearance of each manhole,
- at least two manholes with a minimum diameter of **600 mm**,
- stainless steel ladders.

11.23. Connections to ducted networks

In the case of connecting a pre-insulated heat network to a ducted heat network, solutions typical of pre-insulated systems should be used.

When connecting a new section of a pre-insulated heat network to an existing network made using duct technology, the designer should check and determine the interaction of these network sections at the point of contact.

The connection should ensure the tightness of the passage of pre-insulated pipes through the wall of the duct or chamber, as well as the protection of the duct pipelines from the transmission of forces from the pre-insulated pipelines.

The solution for the construction of the casing of the pre-insulated branch from the network made in a duct casing should be attached to the design.

It is not permissible to make branches at the bends of the ducted network at compensation points or in the existing chambers made at the bends of the ducted network.

It is recommended to connect the networks at the point of minimum movement.

11.24. Connections to overhead networks

As with the connections to pipelines laid in duct casings, the interconnected pre-insulated and overhead networks must be protected from mutual interference.

The most effective protection is the use of natural compensation systems.

In addition, the pre-insulated pipeline in the **HDPE** jacket coming out of the ground should be protected.

The insulation of the connection between these networks should be made just above the surface of the ground using a heat shrinkable coupling. In the case of large diameters, the coupling can be made of stainless steel or aluminium sheet.

It is necessary to cover the vertical part of the pre-insulated network pipelines extending above ground level with compensating mats in accordance with the rules, with a minimum cover thickness of **40 mm**.

11.25. Examples of solutions for retrofitting ducted networks

Currently, most work is related to the replacement of old heat networks in duct casings with heat networks made in pre-insulated pipe technology for laying directly into the ground.

In such projects, it is very important to properly decide on the scope of retrofit work.

11.25.1.Example 1

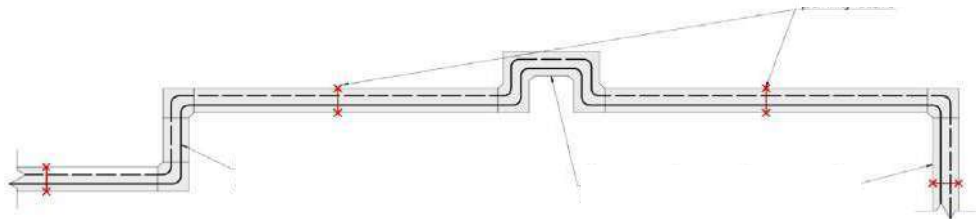


Figure 78: Example of the route of a ducted heat network to be retrofitted

The simplest and most commonly used solution is to lay pre-insulated pipelines exactly along the route of the old network, often in the existing duct.

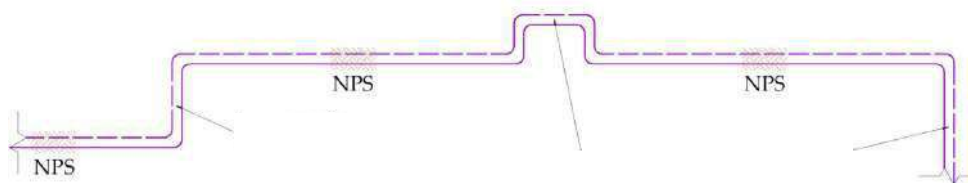


Figure 79: Laying a pre-insulated heat network along the route of the old ducted heat network

Although such a solution can be considered advantageous from the point of view of location arrangements, installation in the old duct is one of the most common mistakes. Small changes often make it possible to optimise the geometry of the network and improve its operating conditions.



Figure 80: The simplest heat network route optimisation

It is unfavourable for the operation of the pre-insulated network to lay the pipelines directly in the ground, using the space of the old concrete duct. The risks of this solution are:

- too small dimensions of duct no. 1 – especially in the case of large diameters, there is not enough space to maintain the required distances between the pipelines, as well as between the pipelines and the duct walls,
- too small dimensions of duct no. 2 – inability to compact the sand bed,
- too small dimensions of duct no. 3 – not enough space for the appropriate number of compensating pads,
- drainage function of the concrete duct – uncovered and backfilled with soil, the duct often turns into a land drainage duct, making the pipes work in unfavourable ground conditions,
- installation error no. 1 – leaving in the duct concrete and steel elements previously used to carry the loads of the ducted network pipelines,
- installation error no. 2 – passing pre-insulated pipelines through a covered section of the duct without any protection,

11.25.2. Example 2

A ducted network can be easily retrofitted between two natural compensations.

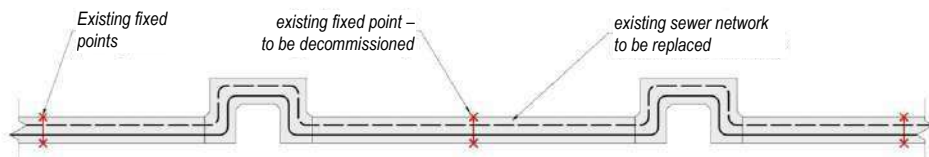


Figure 81: Ducted heat network layouts for example no. 2

In such a case, the design rules for ducted heat networks allow for the replacement of the pipeline section between two natural compensations (in this case, U-shaped compensators) and the elimination of the fixed point.

The verification of the compensation capacity of the natural compensation adjacent to the heat network should be carried out in accordance with **PN-EN 13480**. Due to the

different range of permissible stresses, it is not permissible to use charts or tables for the selection of compensation for pre-insulated heating networks.

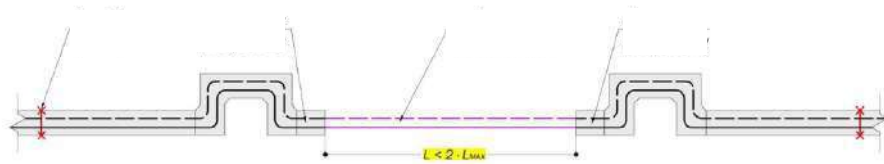


Figure 82: The heat network for example no. 2 after reconstruction

It should be noted that in the case of compensations, especially **Z-shaped and U-shaped**, pre-tensions of 50% ΔL have been applied to reduce their heights.

A straight section of the ducted network (transition area) should be left in front of the compensations to allow free deformation of the compensations and effective sealing of the passage of pre-insulated pipeline through the wall enclosing the duct.

11.25.3. Example 3

The situation is similar for a series of three compensators.

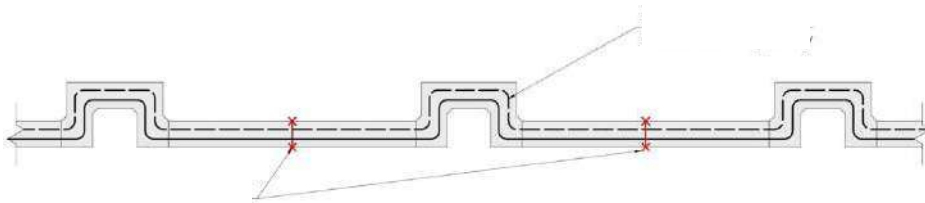


Figure 83: Ducted heat network layouts for example no. 3

Similarly to example 1, the network route can be optimised by eliminating one of the compensators (see figure).

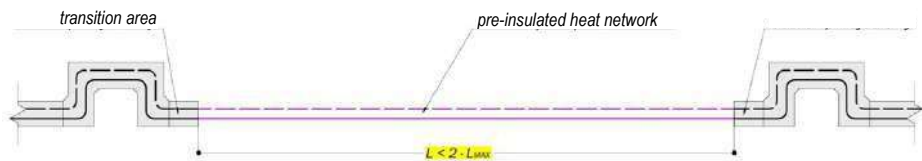


Figure 84: The heat network for example no. 3 after reconstruction

In such a situation, significant elongations of the pre-insulated network section and special requirements for the applied sealing of the wall passage are to be expected. Due to the presence of high axial forces, the way in which the walls enclosing the duct are constructed is also important.

As in the previous example, the compensation capacity of adjacent natural compensations should be checked, and transition areas should be maintained.

11.25.4. Example 4

When eliminating a fixed point between two natural compensations, as shown in the figure, attention must be paid to the new thermal elongation distribution that will appear after the reconstruction.

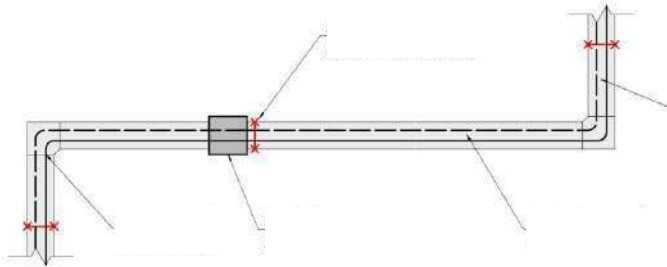


Figure 85: Ducted heat network layouts for example no. 4

As presented earlier, it is required that the new pre-insulated heat network does not change the load of the remaining compensation made in the duct technology, and in addition to the elongations of the pipelines laid in the duct, there are new elongations from the free end of the pre-insulated pipelines.

In addition, there will be displacements of elements mounted on the ducted network in the chamber that did not previously occur due to the adjacent fixed point.

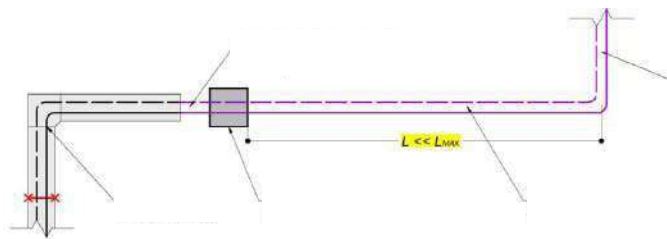


Figure 86: The heat network for example no. 4 after reconstruction

In this case, it is necessary to reconstruct the heat network outside the chamber to reduce the sum of the elongations acting on the compensation and to limit the displacements in the chamber. It is also advisable to apply mechanical pre-tensioning to the self-compensating arm adjacent to the pre-insulated pipelines.

11.25.5. Example 5

In systems with existing bellows compensator chambers, the intermediate fixed point can be eliminated by rebuilding a section of the network between the chambers without having to rebuild the ducted network outside the chambers.

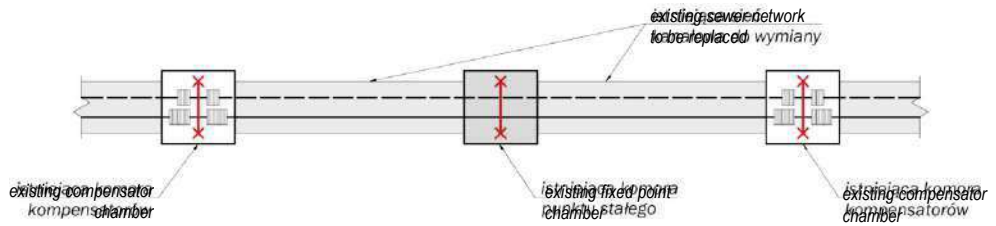


Figure 87: Ducted heat network layouts for example no. 5

It is important that the retrofit is carried out along the entire section between the two chambers.

At the design stage, it is necessary to additionally check the compensation capacity of bellows compensators and determine their pre-setting required before the installation of pre-insulated pipelines.

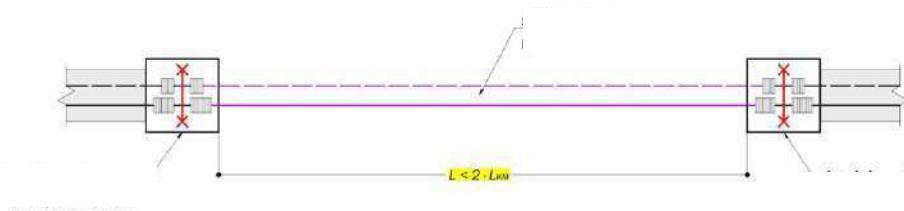


Figure 88: The heat network for example no. 5 after reconstruction

11.25.6. Example 6

The extreme compensator chambers are also adjacent to natural compensations.

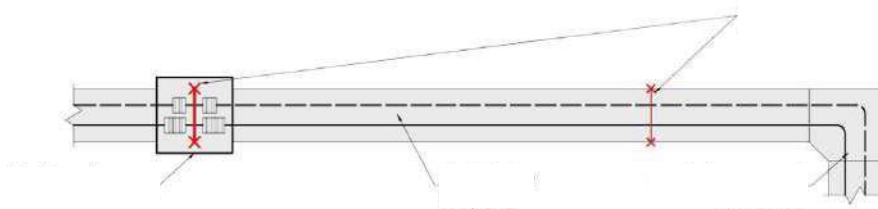


Figure 89: Ducted heat network layouts for example no. 6

These systems are separated by fixed points.

The need for a real fixed point should be taken into account when reconstructing this section of the ducted heating network. If the length of the section from the chamber to the compensating elbow meets the condition:

$$L \leq L_{MAX} + L_{KM} \quad (112)$$

and the bellows compensator will have sufficient compensation capacity after pre-setting, there is no need to use a real fixed point for such an arrangement.

If the bellows compensator does not have sufficient compensation capacity, a real fixed point should be used.

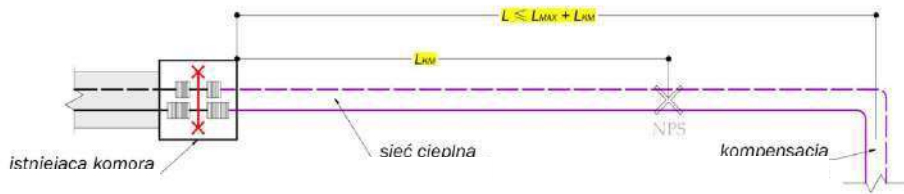


Figure 90: The heat network for example no. 6 after reconstruction without the use of a real fixed point

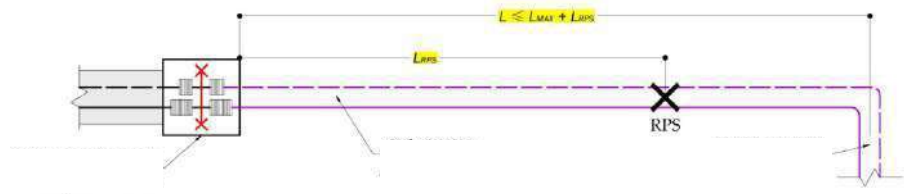


Figure 91: The heat network for example no. 6 after reconstruction using a real fixed point

The distance of **LRPS** should depend on the compensation capacity of the bellows compensator and the frictional forces present.

11.25.7. Example 7

If a network section is to be reconstructed between two existing chambers where there is natural compensation (in this case U-shaped), solutions must be used to protect the network systems in the chambers.

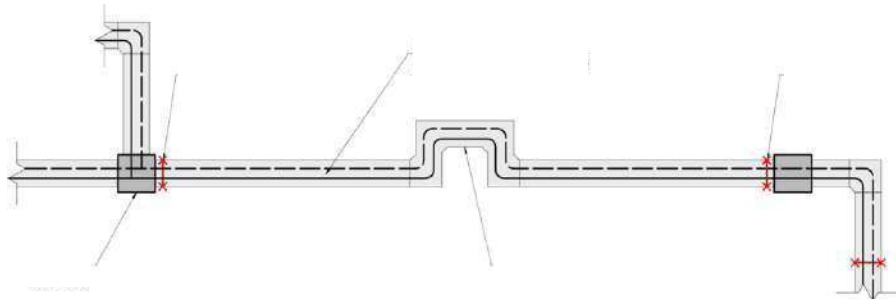


Figure 92: Ducted heat network layouts for example no. 7

This can be achieved by performing protection systems in front of the chambers, up to 12 m from the chamber (see figure on the next page).

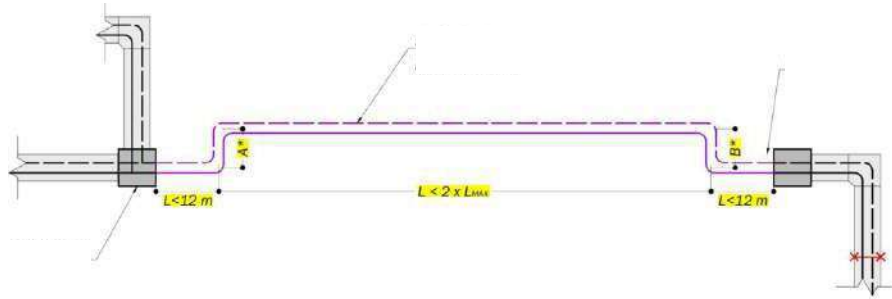


Figure 93: The heat network for example no. 7 after reconstruction

11.25.8. Example 8

In the case of a comprehensive retrofit of a ducted heat network, which must be carried out in stages, certain rules must be observed in order to protect the remaining parts of the ducted heat network that are not rebuilt and to ensure the correct operation of the pre-insulated heat network.

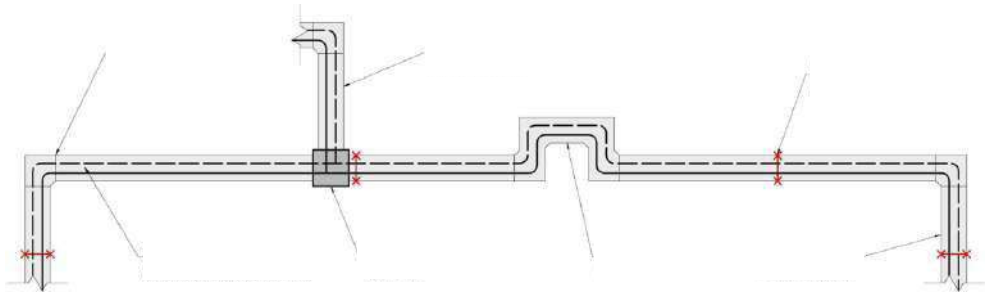


Figure 94: Ducted heat network layouts for example no. 8

- It is important to remember to protect pipelines and their systems in chambers.

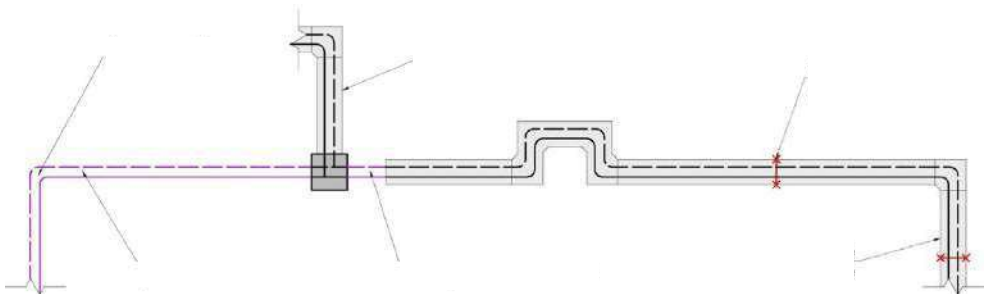


Figure 95: Protection of the pipeline systems and fittings in chambers

- Remember to protect the remaining compensation systems.

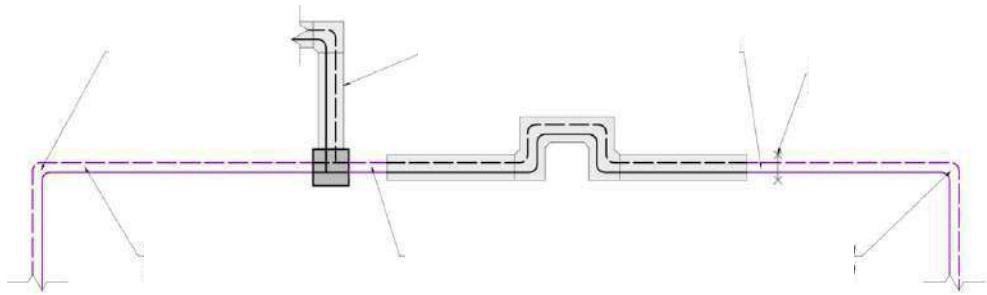


Figure 96: Protection of the remaining compensations

If the distance between the extreme natural compensations meets the condition

$$L \geq 2 \cdot L_{MAX} \quad (113)$$

design an intermediate compensation system, preferably in a location that will help to provide a natural fixed point in the area of the remaining chamber.

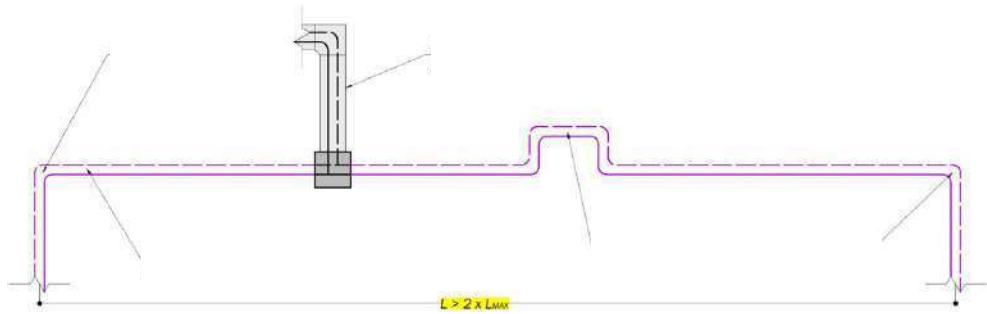


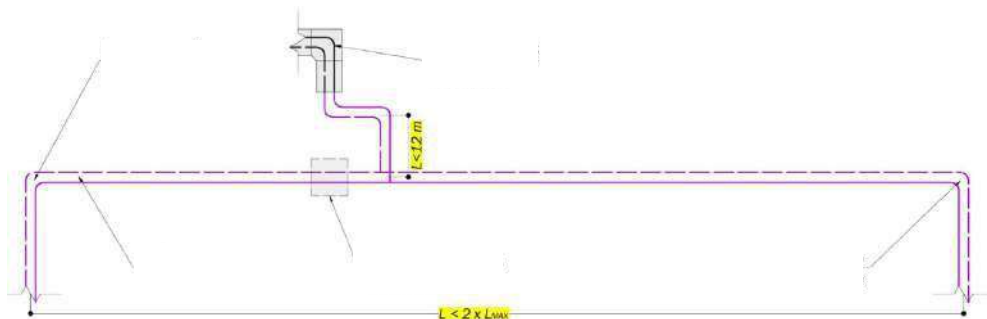
Figure 97: Use of an additional compensation system

If the distance between the extreme natural compensations meets the condition

$$L < 2 \cdot L_{MAX} \quad (114)$$

there is no need for additional compensation.

- The branch can be made by “hot cutting,” and the point of entry can be secured by making a compensation at a distance of up to 12 m from the main pipe on the pre-insulated network which is the branch.



- Once the branch has been completed, the chamber can be decommissioned.

When implementing the conversion of a ducted heat network to a pre-insulated heat network with the required staging of the work, do not design techniques involving the introduction of pre-stresses.

11.25.9. Example 9

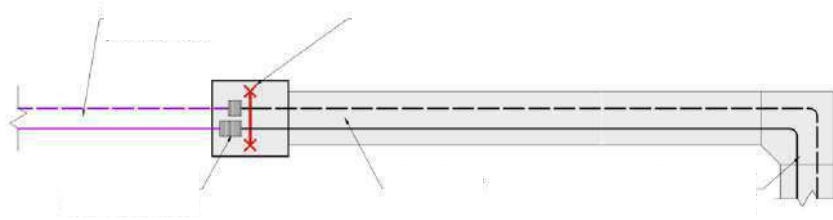


Figure 98: A real fixed point between a pre-insulated heat network with bellows compensators and natural compensation on a ducted heat network

This example illustrates the situation where the pre-insulated pipeline must be laid in a straight line, while it is not possible to rebuild the entire system with natural compensation applied to the ducted heat network.

The compensators used protect the fixed point from friction-induced forces, but create the need for serious reinforcement of this point.

It should be borne in mind that in this arrangement, on the one hand, the pressure inside the pipeline acting on the elbow used in natural compensation tries to pull the pipeline from this point, and on the other hand, the same pressure induces in the axial compensator a force that pushes the fixed point. These forces act with the same return, cumulating at the fixed point. This phenomenon for one pipeline is represented by the formula:

$$N_p = (A_{IN} + A_M) \cdot P + \Delta L \cdot C_A \quad (115)$$

If the axial compensator is offset from the fixed point, additional loads are caused by the friction forces of the pre-insulated pipelines installed between the compensator and the fixed point.

This is illustrated by the formula

$$N_a = (A_{IN} + A_M) \cdot P + 2 \cdot l \cdot F + \Delta L_F \cdot C_A + \Delta L_R \cdot C_A \quad (116)$$

where l is the distance of the compensator bellows from the fixed point. Calculations show that this arrangement is unfavourable as it causes an additional increase in the force acting on the fixed point.

To mitigate the effects of axial compensators on the side of the pre-insulated heat network, an attempt can be made, if possible, to replace a section of the ducted network with a network of pre-insulated pipes.

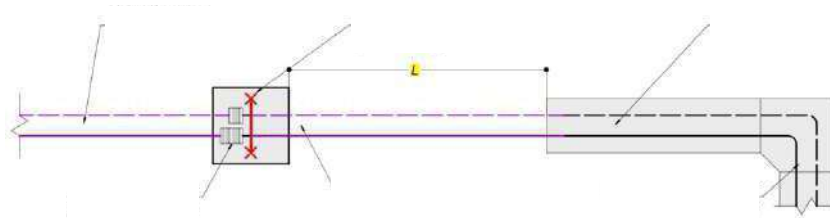


Figure 99: Use of an additional section of a pre-insulated heat network

When selecting the length of the additional section **L**, it is necessary to take into account the situation where there is a sharp drop in pressure in the pipelines (for example, in the event of failure) and only frictional forces act on the fixed point.

12. Thermal elongation compensation

The choice of method of compensating for pipeline elongations depends on local conditions, approved techniques and an analysis of the advantages and disadvantages of the techniques that can be used under the given conditions.

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 PIPES** Design and Technical Consulting Team.

Commonly used compensation systems are shown in the following figures.

12.1. Compensating pads

An important element for the protection of pre-insulated elements moving laterally in the ground are compensating pads. At the point of change of direction of the pre-insulated pipeline, the effects of pipeline deformation can be represented by four springs:

- steel pipe (k_1),
- rigid polyurethane foam (PUR) insulation (k_2),
- HDPE jacket (k_3),
- and backfill (k_4).

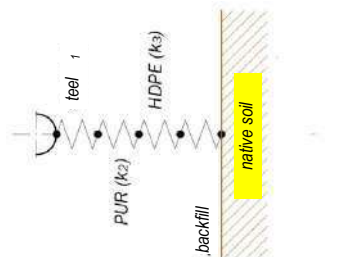


Figure 100: Load of pipelines in the ground

The deforming steel pipe “presses” on the remaining “springs,” which react to the pressure due to their rigidity, of which the **HDPE** jacket, due to the material used, is very susceptible to deformation.

In this comparison, the **PUR** foam is the weakest element, so an additional material is required, an additional spring, which will be more susceptible to deformation (k_5).

In order to determine the required thickness of the compensating pads, approximate calculations can be made for the preliminary design to check that the compressive stresses in the **PUR** foam determined from the formula below will meet the strength requirements.

$$\sigma_{PUR} = \frac{k \cdot \delta_w}{2 \cdot d_{ct}} < 0,15 \frac{N}{mm^2} \quad (117)$$

where

$$\frac{1}{k} = \frac{1}{k_2} + \frac{1}{k_5} + \frac{1}{k_4} \quad (118)$$

Rigidity of the PUR foam:

$$k_2 = \frac{E_{PUR}}{t_{PUR}} \cdot d_o \quad (119)$$

and the thickness of the PUR insulation is calculated from the formula:

$$t_{PUR} = \frac{D_C - d_o - 2 \cdot t_{HDPE}}{2} \quad (120)$$

Rigidity of compensating pads:

$$k_5 = \frac{E_{PK}}{t_{PK}} \cdot D_C \quad (121)$$

and backfill:

$$k_4 = E_{GRUNT} \quad (122)$$

where:

$$\begin{aligned} E_2 \approx E_{PUR} &= 10 \frac{N}{mm_2} \\ E_4 \approx E_{GRUNT} &= 20 \frac{N}{mm_2} && \leq dn 80 \\ E_4 \approx E_{GRUNT} &= 35 \frac{N}{mm_2} && \leq dn 250 \\ E_4 \approx E_{GRUNT} &= 50 \frac{N}{mm_2} && \leq dn 600 \\ E_5 \approx E_{PK} &= 0,1 \frac{N}{mm_2} \end{aligned} \quad (123)$$

There are two ways to install pads next to pipes.

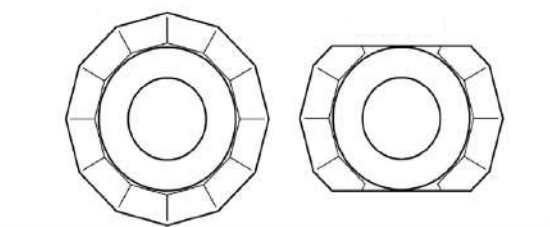


Figure 101: Methods of covering pipelines with compensating pads

For pipelines with small diameters, it is recommended that compensating pads be laid on both sides of the pipeline in equal numbers.

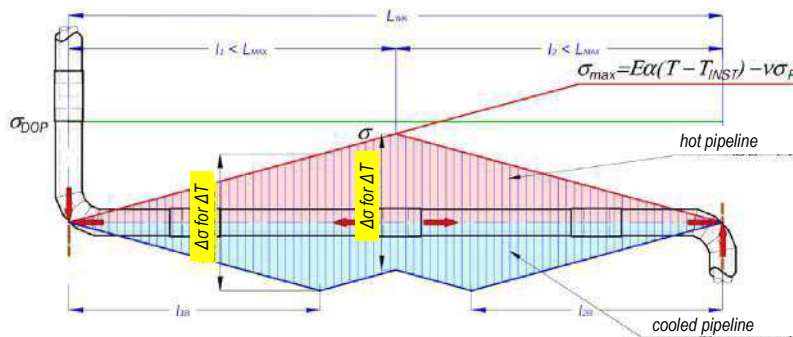
However, for larger diameters, the laying of pads can be made dependent on the distribution of stresses and elongations in the pipeline sections under consideration between compensating elbows.

It is recommended that the design deflection of the compensating pads should not exceed 2/3 of the thickness of the compensation zone. This is more precisely illustrated in the following table.

Table 27: Permissible displacement of pipelines in the compensation zone

1.0	40.0	26.0
3.0	120.0	80.0

12.2. Cooling of pipelines



The stresses obtained in the heated pipelines undergo a change during cooling to the installation temperature, which can be calculated from the formula:

$$\Delta \sigma = | E_T \cdot \alpha_T \cdot (T_{INST} - T) | \quad (124)$$

while the distances from the compensating elbow to the points where the maximum tensile stresses are reached during cooling can be calculated using the following formulae

$$L_{1B} = \frac{\Delta \sigma}{2} \cdot \frac{A_s}{F_1} \quad (125)$$

$$L_{2B} = \frac{\Delta \sigma}{2} \cdot \frac{A_s}{F_2} \quad (126)$$

The limiting minimum length of **LWK** between two compensating elbows, for which there is a variation in the magnitude of elongation during heating and cooling of pipelines, can be determined as the following sum

$$L_{GR} = L_{1B} + L_{2B} \quad (127)$$

The “shortening” of pipeline sections can be calculated from the following formulae

$$\Delta L_{1B} = L_{1B} \cdot \alpha \cdot \Delta T - \frac{F_1 \cdot L_{1B}^2}{2 \cdot A_S \cdot E} \quad (128)$$

$$\Delta L_{2B} = L_{2B} \cdot \alpha \cdot \Delta T - \frac{F_1 \cdot L_{2B}^2}{2 \cdot A_S \cdot E} \quad (129)$$

Taking this into account, it is possible to differentiate the arrangement of compensating pads on the outside and inside of the compensating elbow, but this is not recommended when using bellows compensators, when the compensating elbow is not separated from the compensator by a real fixed point.

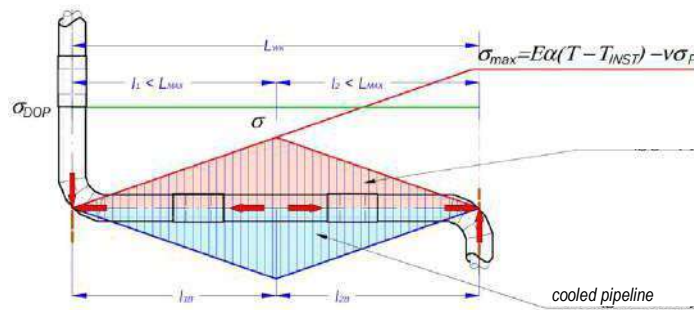


Figure 102: Stress distribution in a short pipeline section during heating and cooling

For shorter sections, the distribution of stresses, elongation and shortening, is more symmetrical and equal in magnitude, so the pads should be laid equally on both sides of the pipelines.

12.3. Compensation of elongations with the “L” type system

12.3.1. Structure

The “L” type pipeline elongation compensation is the simplest self-compensation system used in heat networks.

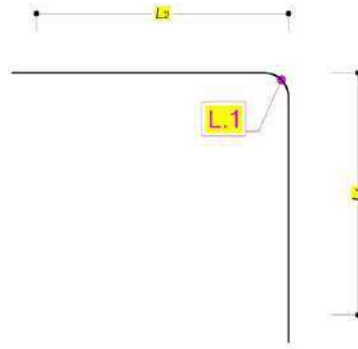


Figure 103: “L” type compensation

It consists of one elbow and two adjacent straight sections of the heat network pipelines.

The characteristic quantities that affect the stresses that occur in the line pipe are:

- the lengths of the adjacent sections and thus the magnitude of their elongation ΔL_1 and ΔL_2 ,
- the elbow bending radius,
- the angle of change of direction (recommended from $\alpha > 75^\circ$), and
- the environment in which the part of the system designed to absorb the elongations of the pipelines is placed.

12.3.2. Action

The following are printouts from **Tadeusz Paszkiewicz’s RC0** programme, which may help to better understand the phenomena occurring at the site of “L” type compensation.

The figure in the part marked **(a)** shows an “L” type compensation which, on one side, absorbs the elongation ΔL_1 , a section of length L_{MAX} , while the other section, adjacent to the elbow, is fixed in the concrete wall. Its length is equal to the minimum length of the compensating arm (marked L_1) required to compensate for the elongation ΔL_1 . The compensation absorbs an elongation of ΔL_2 from this section.

In the case in question, these quantities are equal to

- $\Delta L_1 = 100 \text{ mm}$
- $\Delta L_2 = 10 \text{ mm}$

As can be seen in the figure, the deformation of the pipeline compensation is mainly limited to the deformation of the section that acts as a compensating arm for the section L_{MAX} . The displacement of the top of the elbow δ_{w1} is close to the elongation of the section and is:

- $\delta_{w1} = 100.5 \text{ mm}$

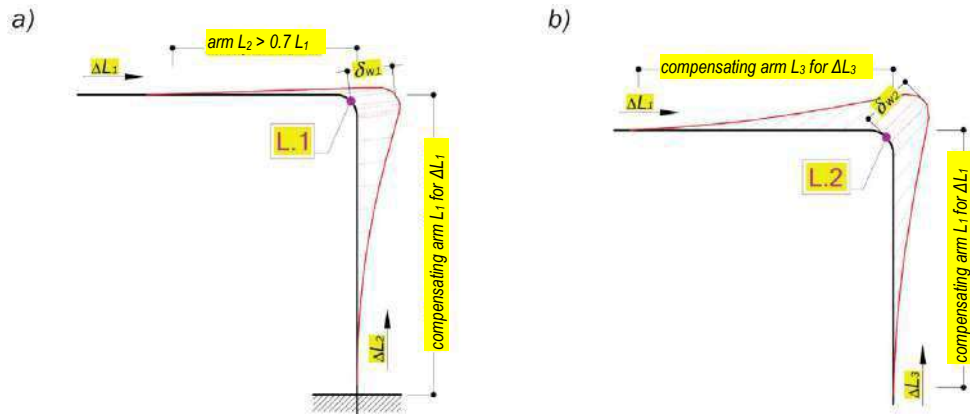


Figure 104: Interaction of the “L” type compensation with the environment at the site of the compensation zone.

(a) a system with a minimum compensating arm L_1 (b) a system with elongation absorption on both sides

The figure in the section marked (b) shows the deformation of pipelines in the “L” type compensation zone when it absorbs similar elongations from both adjacent pipeline sections.

Due to the increase in temperature of the polyethylene jacket and restrictions on the thickness of the compensation zones, the “L” type compensation system should be designed so that the maximum displacement of the top δ_w calculated (for compensation with an angle of $\alpha = 90^\circ$) using the formula:

$$\delta_w = \sqrt{\Delta L_1^2 + \Delta L_2^2} \quad (130)$$

does not exceed the allowable displacement for the maximum possible thickness of the compensation zone (Table 27).

The system shown is designed in such a way that the displacement of the compensation top δ_{w2} is of a similar value as previously δ_{w1} (currently 99 mm in the example). This required a significant reduction in the values of the elongations ΔL_1 and ΔL_2 (in the example, $\Delta L_1 = \Delta L_3 = 70 \text{ mm}$) and this was achieved by shortening the lengths of the sections involved to 70% of the section L_{MAX} .

It results that in many cases, especially for larger pipeline diameters, the “L” type compensation should not be used to absorb elongations from long straight sections.

12.3.3. Contraindications

The next printout from the **RC0** programme shows the deformation of pipelines in the vicinity of an elbow considered to be non-compensating, adjacent to which are pipeline sections with elongations as in the previous example ($\Delta L_1 = \Delta L_3 = 70 \text{ mm}$). The angle of elbow dilation (also known as the angle of deflection of the network route) was changed to $\alpha = 25^\circ$. As can be seen, this resulted in a significant increase in the

displacement of the top δ_{w3} (142 mm in the example in question) compared to compensation with an angle of $\alpha = 90^\circ$. In addition, these actions cause a significant increase in the stresses in the wall of the line pipe, even to a value several times greater than in the case of compensation with an angle of $\alpha = 90^\circ$

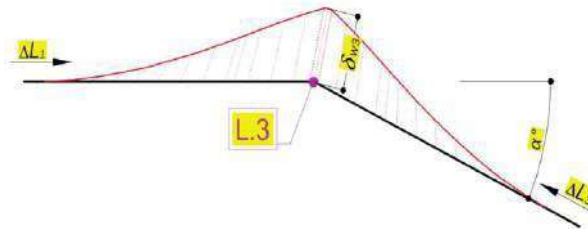


Figure 105: A change of direction that is not an “L” type compensation

These changes occur in the α angle ranges from 5° to 75° , and extreme stress values occur for α angles between 25° and 35° , hence the general conclusion that elbows with angles between 5° and 75° should be avoided when designing heat network route geometries, especially for elongation compensating applications. Their use should be limited, at most, to short sections used in replacement systems.

12.3.4. Rules for the selection of the “L” type compensation size

The selection of the size (length) of the “L” type natural compensating arm for a section with an elongation of ΔL should be made based on the attached table.

The table is designed for easy selection of the arm height “every half metre”:

- for the length of the section L , calculate the magnitudes of the elongation ΔL ,
- for this size, look in the columns for a specific diameter for the closest upper limit of the arm’s compensation capacity,
- read in the column heading the required length of the compensating arm L_1 .
- proceed in the same way for the second adjacent section to determine the compensating arm L_2 .

12.3.5. Use of compensating pads

While the selection of length of the compensating arm is guided by the extent of its compensation capacity, the selection of compensating pads and their distribution can be guided by the exact amount of displacement of the top of the elbow δ_w .

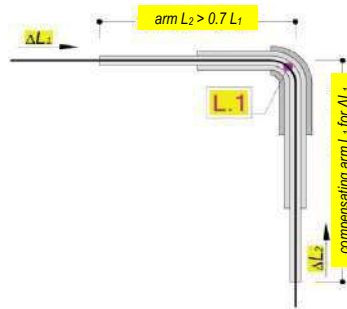


Figure 106: Use of pads in “L” type compensation

As you can see from the **RC0** programme printouts, the deformation curve is very similar to a straight line, so by selecting the pads, while keeping their ability to absorb elongations at **2/3** of their thickness, for “L” type compensation, we can divide the length of the arm by the number of calculated layers of pads, which gives the length of each part.

If there are more layers, the first two parts from the top side should be rounded up to **0.5 m**.

The pipeline should be covered with pads on both sides.

It is important that the elbow is covered over its full length with the thickest compensation zone.

Table 28: Compensation capacity of L-shaped systems

SERIES 1 STANDARD insulation	Steel pipes			Class and number of cycles														
	dn	d _o [mm]	t [mm]		L= 1.5 m	L= 2.0 m	L= 2.5 m	L= 3.0 m	L= 3.5 m	L= 4.0 m	L= 4.5m	L= 5.0 m	L= 5.5 m	L= 6.0 m	L= 6.5 m	L= 7.0 m	L= 7.5 m	L= 8.0 m
DN 25/90	25	33.7	2.6	B 1000	up to 15	up to 40												
DN 40/110	40	48.3	2.9	B1000	up to 10	up to 20	up to 55											
DN 65/140	65	76.1	2.9	B 1000	up to 5	up to 10	up to 25	up to 50	up to 75									
DN 100/200	100	114.3	3.6	C 1000		dc 5	up to 15	up to 25	up to 45	up to 70	up to 95							
DN 150/250	150	168.3	4.0	C 1000			up to 10	up to 20	up to 30	up to 65	up to 85	up to 110						
DN 250/400	250	273.0	5.0	C 1000			up to 15	up to 25	up to 35	up to 45	up to 55	up to 90	up to 105	up to 125				
DN 350/500	350	355.6	5.6	C 1000			up to 10	up to 20	up to 30	up to 40	up to 55	up to 75	up to 95	up to 115	up to 130			
	400	406.4	6.3	C 1000			up to 10	up to 20	up to 30	up to 40	up to 50	up to 65	up to 80	up to 95	up to 115	up to 140		
DN 450/630	450	457.0	6.3	C 1000			up to 10	up to 15	up to 25	up to 35	up to 45	up to 55	up to 65	up to 80	up to 95	up to 135		
DN 500/710	500	508.0	6.3	C 1000			up to 5	up to 10	up to 15	up to 20	up to 35	up to 55	up to 70	up to 90	up to 115	up to 140		
DN 600/800	600	610.0	7.1	C 1000			up to 5	up to 10	up to 15	up to 20	up to 30	up to 40	up to 50	up to 65	up to 80	up to 100	up to 120	up to 160

12.4. Compensation of elongations with the “Z” type system

12.4.1. Structure

Unlike the “L” type natural compensation, the “Z” type natural compensation is made up of two elbows, adjacent to which are sections of pipelines whose elongation will be absorbed by the compensation system, and a section connecting the two elbows. The length of this section determining the compensation capacity of the system.

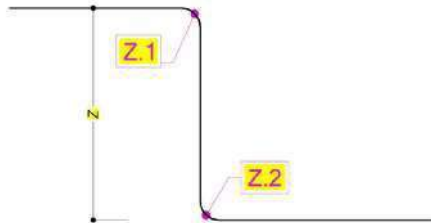


Figure 107: “Z” type compensation

Also important for the functioning and compensation capacity of the system are:

- the lengths of the adjacent sections and thus the magnitude of their elongation ΔZ_1 and ΔZ_2 ,
- the elbow bending radius,
- the angle of change of direction (it is recommended to use “Z” type compensation with elbows
- with bending angles of $\alpha = 90^\circ$), and
- the environment in which the part of the system designed to absorb the elongations of the pipelines is placed.

The characteristic parameter is the height “Z” of the compensation system – see figure.

12.4.2. Action

The RC0 programme printouts below show how the “Z” type natural compensation is subject to deformation in two important cases.

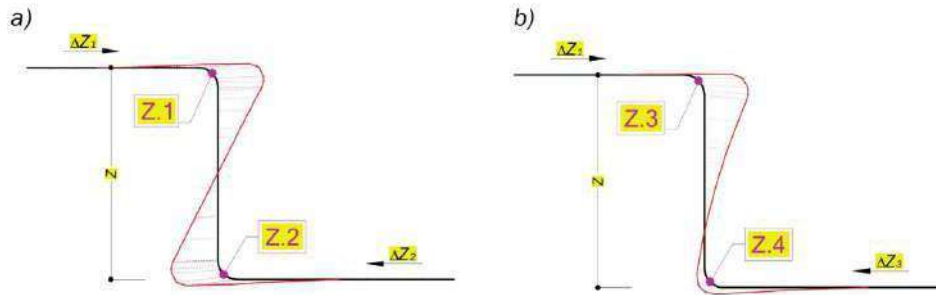


Figure 108: Interaction of “Z” type compensation with the environment at the point of deformation. (a) System with symmetric distribution of absorbed elongations, (b) System with asymmetric distribution of elongations

The part marked **(a)** in the figure illustrates the deformation of a system with a height equal to Z absorbing symmetrically on both sides the same elongations $\Delta Z_1 = \Delta Z_2$ (in the example 120 mm each from the sections of length L_{MAX}).

As can be seen, the deformation that occurs as a result of the absorbed elongations is caused by the displacement of the tops of the compensating elbows. These tops move almost along the axes of the adjacent sections and, therefore, for the purpose of selecting compensation, these displacements are equal to the elongations of the sections. In addition, we can see in the figure that the sections whose elongations are absorbed by the compensation are subject to deformations lateral to their axes. These deformations depend on the diameter of the pipelines and the height of the Z compensation. The system works symmetrically, and the pivot point (zero point) is located at the centre of gravity of the compensation.

The part marked **(b)** in the figure illustrates, in turn, the deformation of a system with an identical height equal to Z absorbing asymmetrically on both sides the elongations of $\Delta Z_1 \neq \Delta Z_2$ (in the example $\Delta Z_1 = 115$ and $\Delta Z_2 = 27$ mm). This effect was achieved by reducing the length of one of the sections to approximately 11% of the length of the other section.

In the figure, we can see the uneven operation of the various parts of the compensation and the change in the location of the “zero point.” We can also see that the deformation of the part of the shorter section near its connection to the elbow is almost the same as in the case of the symmetric system operation.

This means that the decisive influence on the amount of compensation is the maximum unilateral elongation absorbed by the “Z” type compensation system. This has been confirmed by other calculations. In addition, calculations have shown that when the height of the Z compensation increases to a level $> 95\%$ of the sum of the lengths of the compensation zones L_1 for ΔZ_1 and L_2 for ΔZ_2 , it is necessary to start considering such compensations as two independent “L” type natural compensation systems.

12.4.3. Rules for the selection of the “Z” type compensation size

The “Z” type natural compensation can be selected using the table at the end of this chapter in two cases:

- for a symmetric system – by adding the elongations of the sections

$$\Delta Z = \Delta Z_1 + \Delta Z_2 \quad (131)$$

and finding in the table, in the same way as for the selection of the “L” type compensation, the closest upper limit to read the required height of the “Z” type compensation in the column heading.

- for asymmetric systems – by determining the maximum elongation of the section adjacent to the compensation and from this, in the same way as above, finding the required minimum height of the “Z” type compensation. The height selection values for asymmetric systems are shown in red in the table.

For smaller diameters, where the maximum height of compensation is **2.0 m**, symmetric and asymmetric systems are selected in the same way.

12.4.4. Use of compensating pads

Unlike the “L” type compensation systems, in the “Z” type natural compensation the selection of pads and the thickness of compensation zones is made on the basis of the elongations of the individual sections adjacent to the compensating elbows.

Regardless of the elongations absorbed, the first layer of pads should cover the entire “Z” compensation height and adjacent pipeline sections over a length of at least: **0.5** of the height of Z.

in each direction (see figure).

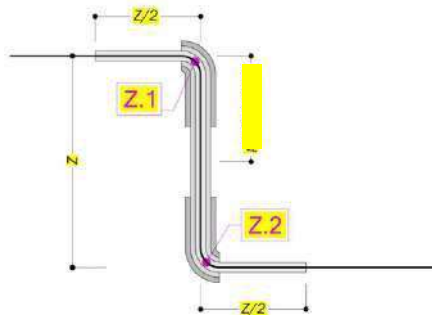


Figure 109: Use of pads in “Z” type compensation with symmetric distribution of elongations

When using multiple layers and symmetric systems, they should be distributed evenly along the transverse compensating arm, making sure that the elbows are covered with the thickest compensation zone over the entire length.

In the case of asymmetric systems, it is necessary to determine the location of the “zero point” from the elbow, which absorbs more elongation. This can be done using the formula:

$$Pkt .0 = \frac{\Delta Z_1}{\Delta Z_1 + \Delta Z_2} \cdot Z \quad (132)$$

After locating the “zero point,” distribute the pads evenly in both directions, also making sure that the elbows are covered with the calculated layer of compensating pads over their entire length (see figure).

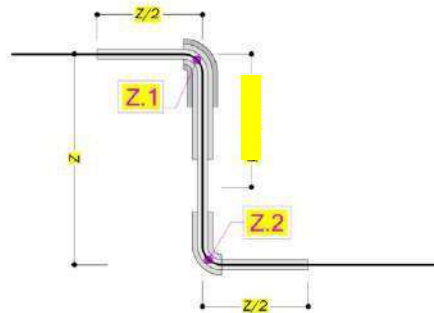


Figure 110: Use of pads in “Z” type compensation with asymmetric distribution of elongations

Table 29: Compensation capacity of Z-shaped systems

SERIES 1 STANDARD insulation	Steel pipes			Class and number of cycles	Elongation absorption capacity (in mm) of "Z" type natural compensation systems with the specified heights, assuming a symmetric elongation distribution of ΔZ_1 ΔZ_1 For larger diameters and asymmetric distributions, the selection of compensation should be made on the basis of the maximum unilateral elongation, the limits of which are shown in red.											
	dn	d ₀ [mm]	t [mm]		Z= 2.0 m	Z= 2.5 m	Z= 3.0 m	Z= 3.5 m	Z= 4.0 m	Z= 4.5 m	Z= 5.0 m	Z= 5.5 m	Z= 6.0 m	Z= 6.5 m	Z= 7.0 m	
DN 20/90	20	26.9	2.6		up to 50											
DN 25/90	25	33.7	2.6	A 1000	up to 70											
DN 32/110	32	42.4	2.6		up to 70											
DN 40/110	40	48.3	2.9	A 1000	up to 90											
DN 50/125	50	60.3	2.9		up to 100											
DN 65/140	65	76.1	2.9	A 1000	up to 110											
DN 80/160	80	88.9	3.2		up to 120											
DN 100/200	100	114.3	3.6	C 1000	up to 32 up to 16	up to 45 up to 22	up to 60 up to 30	up to 75 up to 37	up to 95 up to 47	up to 110 up to 55	up to 140 up to 70					
DN 125/225	125	139.7	3.6		up to 35 up to 17	up to 50 up to 25	up to 65 up to 32	up to 75 up to 37	up to 90 up to 45	up to 105 up to 52	up to 160 up to 80					
DN 150/250	150	168.3	4.0	C 1000	up to 35 up to 17	up to 40 up to 20	up to 55 up to 27	up to 70 up to 35	up to 80 up to 40	up to 95 up to 47	up to 110 up to 55	up to 130 up to 65	up to 190 up to 95			
DN 200/315	200	219.1	4.5		up to 40 up to 20	up to 50 up to 25	up to 65 up to 32	up to 75 up to 37	up to 85 up to 42	up to 95 up to 47	up to 110 up to 55	up to 125 up to 62	up to 215 up to 107			
DN 250/400	250	273.0	5.0	C650	up to 30 up to 15	up to 45 up to 22	up to 60 up to 30	up to 75 up to 37	up to 95 up to 47	up to 115 up to 57	up to 135 up to 67	up to 155 up to 77	up to 230 up to 115			
DN 300/450	300	323.9	5.6			up to 45 up to 22	up to 60 up to 30	up to 75 up to 37	up to 90 up to 45	up to 100 up to 50	up to 120 up to 60	up to 135 up to 67	up to 155 up to 77	up to 180 up to 90	up to 265 up to 132	
DN 350/500	350	355.6	5.6	C650		up to 40 up to 20	up to 60 up to 30	up to 85 up to 42	up to 110 up to 55	up to 135 up to 67	up to 155 up to 77	up to 180 up to 90	up to 260 up to 130			
DN 400/560	400	406.4	6.3				up to 65 up to 32	up to 80 up to 40	dc 100 up to 50	up to 115 up to 57	up to 130 up to 65	up to 150 up to 75	up to 170 up to 85	up to 200 up to 100	up to 290 up to 145	
DN 450/630	450	457.0	6.3	C650			up to 65 up to 32	up to 80 up to 40	up to 100 up to 50	up to 115 up to 57	up to 130 up to 65	up to 150 up to 75	up to 170 up to 85	up to 200 up to 100	up to 290 up to 145	
DN 500/710	500	508.0	6.3				up to 60 up to 30	up to 75 up to 37	up to 95 up to 47	up to 110 up to 55	up to 125 up to 62	up to 140 up to 70	up to 285 up to 142			
DN 600/800	600	610.0	7.1	C650			up to 70 up to 35	up to 90 up to 45	up to 110 up to 55	up to 130 up to 65	up to 150 up to 75	up to 170 up to 85	up to 200 up to 100	up to 240 up to 120	up to 310 up to 155	

12.5. Compensation of elongations with the “U” type system

12.5.1. Structure

The “U” type natural compensation consists of four elbows, two of which are adjacent to pipeline sections whose elongation is to be absorbed by the compensation system. The shape and dimensions of the pipeline section between elbows **U.1** and **U.4** (see figure) determine the compensation capacity of this system.

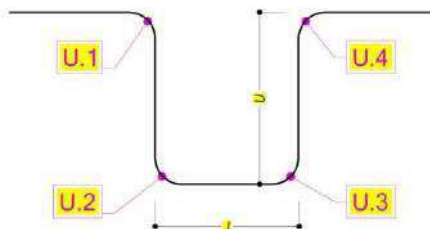


Figure 111: “U” type compensation

As with other natural compensations, the following factors are also important for the functioning and compensation capacity of the system:

- the lengths of the sections adjacent to the first compensating elbows and thus the magnitude of their elongation ΔU_1 and ΔU_2 ,
- the elbow bending radii,
- the angle of change of direction (it is recommended to use “U” type compensation with **U.1** and **U.4** elbows with bending angles of $\alpha = 90^\circ$), and
- the environment in which the part of the system designed to absorb the elongations of the pipelines is placed.

The characteristic parameters are the height of the **U** compensation system (see figure) and its spacing **J**, which in **RADPOL PIPES** technology is based on typical dimensions of pre-insulated elbows produced by the plant. These dimensions are given in the table at the end of this chapter.

12.5.2. Action

As in the case of “Z” type compensation, the RC0 programme printouts below show how “U” type natural compensation is subject to deformation in the ground.

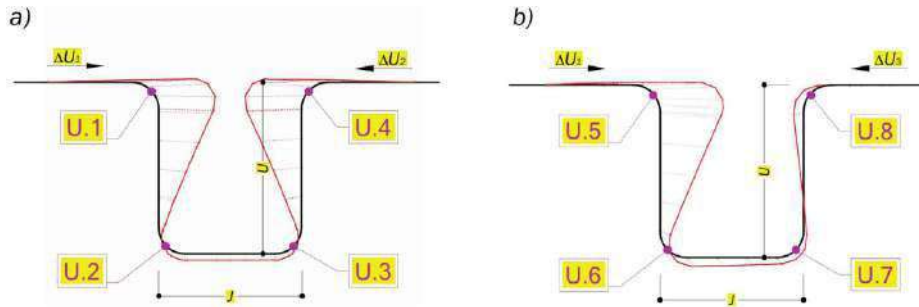


Figure 112: Interaction of “U” type compensation with the environment at the point of deformation. (a) System with symmetric distribution of absorbed elongations, (b) System with asymmetric distribution of elongations

The part marked (a) in the figure illustrates the deformation of a system with a height equal to U absorbing symmetrically on both sides the same elongations $\Delta U_1 = \Delta U_2$ (in the example 110 mm each from the sections of length L_{MAX}).

As can be seen, the deformation that occurs as a result of the absorbed elongations is caused by the displacement of the tops of the compensating elbows U.1 and U.4. These tops move almost along the axes of the adjacent sections and, therefore, for the purpose of selecting compensation, these displacements are equal to the elongations of the sections ΔU_1 and ΔU_2 .

In addition, we can see in the figure that the sections whose elongations are absorbed by the compensation are subject to deformations lateral to their axes. These deformations depend on the diameter of the pipelines and the height of the Z compensation.

The entire compensation system works symmetrically, including the section between elbows U.2 and U.3. It is also subject to displacement.

The part marked (b) in the figure illustrates, in turn, the deformation of a system with an identical height equal to U absorbing asymmetrically on both sides the elongations of $\Delta U_1 \neq \Delta U_2$ (in the example $\Delta U_1 = 120$ and $\Delta U_2 = 21$ mm). As in the case of “Z” compensation, this effect was achieved by reducing the length of one of the sections to approximately 11% of the length of the other section.

In the figure, we can see the uneven work of the different parts of the compensation, but we can also see the continuous work and deformation of the section between elbows U.2 and U.3. This means that, as in the case of the “Z” type systems, when selecting the “U” type compensation, it is necessary to take into account the decisive influence on the amount of compensation of the maximum unilateral elongation absorbed by the “U” compensation system.

12.5.3. Rules for the selection of the “U” type compensation size

The “U” type natural compensation can be selected in the same way as the “Z” type compensation using the table at the end of this chapter.

- for a symmetric system – by adding the elongations of the sections

$$\Delta U = \Delta U_1 + \Delta U_2 \quad (133)$$

and finding in the table the closest upper limit to read the required height of the “U” type compensation in the column heading.

- for asymmetric systems – by determining the maximum elongation of the section adjacent to the compensation and from this, in the same way as above, finding the required minimum height of the “U” type compensation. The height selection values for asymmetric systems are shown in red in the table.

For smaller diameters, where the maximum height of compensation is **2.0 m**, symmetric and asymmetric systems are selected in the same way.

12.5.4. Use of compensating pads

In the case of “U” type compensation, the selection of pads and thickness of compensation zones is based on the elongation of individual sections adjacent to the **U.1** and **U.4** compensating elbows.

Regardless of the elongations absorbed, the first layer of pads should cover the entire compensation system from elbow **U.1** to elbow **U.4** and adjacent pipeline sections over a length of at least:

0.5 of the height of U.

in each direction (see figure)

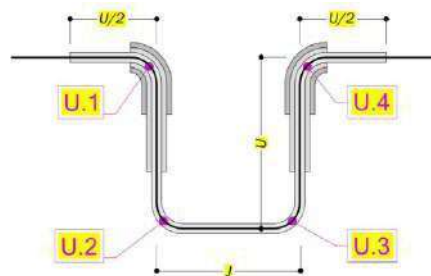


Figure 113: Use of pads in “U” type compensation with symmetric distribution of elongations

When using multiple layers and symmetric systems, they should be distributed evenly along the compensating arms, making sure that the elbows **U.1** and **U.4** are covered with the calculated layer of compensating pads over their entire length (see figure).

In the case of systems operating with asymmetric elongations, cover part of the compensation on the side of the higher elongation with pads, selecting their number according to the calculated elongation.

Proceed in the same way for an arm that absorbs lower elongations, taking into account the lower elongation of the adjacent section when selecting pad thicknesses (see figure).

Cover the arms of the compensator over their entire length.

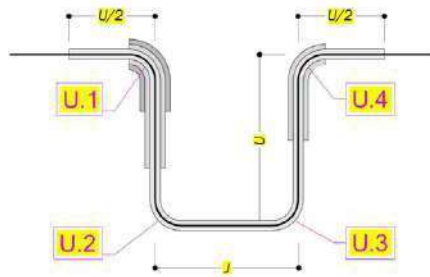


Figure 114: Use of pads in “U” type compensation with asymmetric distribution of elongations

Table 30: Compensation capacity of “L-shaped” systems

SERIES 1 STANDARD insulation	Steel pipes			Spacing J [m]	Class and number of cycles												
	dn	d ₀ [mm]	t [mm]			U= 2.0 m	U= 2.5 m	U= 3.0 m	U= 3.5 m	U= 4.0 m	U= 4.5 m	U= 5.0 m	U= 5.5 m	U= 6.0 m	U= 6.5 m	U= 7.0 m	
DN 25/90	25	33.7	2.6	2.48	B 1000	up to 70											
DN 40/110	40	48.3	2.9	2.52	B 1000	up to 90											
DN 65/140	65	76.1	2.9	2.58	B 1000	up to 110											
DN 100/200	100	114.3	3.6	2.70	C 1000	up to 70 up to 35	up to 140 up to 70										
DN 125/225	125	139.7	3.6	2.75	C 1000	up to 80 up to 40	up to 105 up to 52	up to 155 up to 77									
DN 150/250	150	168.3	4.0	3.00	C 1000	up to 80 up to 40	up to 100 up to 50	up to 180 up to 90									
DN 200/315	200	219.1	4.5	3.13	C 1000	up to 70 up to 35	up to 100 up to 50	00135 up to 67	up to 210 up to 105								
DN 250/400	250	273.0	5.0	3.30	C 1000	up to 75 up to 37	up to 105 up to 52	up to 140 up to 70	up to 225 up to 112								
DN 300/450	300	323.9	5.6	4.40	C 1000		up to 100 up to 50	up to 130 up to 65	up to 165 up to 82	up to 265 up to 132							
DN 350/500	350	355.6	5.6	4.50	C 1000		up to 100 up to 50	up to 125 up to 62	up to 155 up to 77	up to 255 up to 127							
DN 400/560	400	406.4	6.3	4.62	C 1000			up to 115 up to 57	up to 145 up to 72	up to 175 up to 87	up to 290 up to 145						
DN 450/630	450	457.0	6.3	486	C 1000			up to 125 up to 62	up to 160 up to 80	up to 200 up to 100	up to 290 up to 145						
DN 500/710	500	508.0	6.3	5.02	C 1000			up to 130 up to 65	up to 165 up to 82	up to 280 up to 140							
DN 600/800	600	610.0	7.1	5.20	C 1000			up to 125 up to 62	up to 160 up to 80	up to 205 up to 102	up to 310 up to 155						

13. Design of emergency signalling systems

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.

Regardless of the principle of the system, it is important that it can help to detect and locate an incipient failure at the earliest possible stage.

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 specially prepared insulation of the vent stub, drain or valve stem can also be used to disconnect the loop.

13.1. Resistance system

The main advantage of this system is the technical ability to identify incredibly small amounts of liquid in isolation and to locate them immediately with very high precision.

In this way, it is possible to monitor the controlled network preventively, to detect and eliminate at an early stage the cause of a later problem which, if not detected in time, could cause great damage in isolation.

13.1.1. Structure

The base layer of this system consists of a resistive cable (in this case a chromium-nickel alloy with an own resistance of $5.7 \Omega / 1 \text{ m}$). The red active cable – called the sensor cable with the symbol **BS-FA** – acts as the nerve centre of the system and is always marked on the plan with a red line or, in black and white drawings, with a thick continuous line.

This cable, together with the second cable – the return cable – forms a closed measuring circuit, the so-called measuring loop, which is laid in parallel along the entire controlled section and is used by the locator as a reference system.

The return cable – **green** – has the symbol **BS-RA** and is always marked on the plan with a green dotted line, a green continuous line or, in black and white drawings, with a thin dotted line.

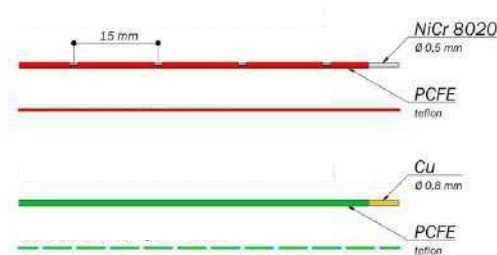


Figure 115: Resistance system cables

13.1.2. Uniform production principles of pre-insulated elements for the BRANDES system

In the **BRANDES** resistance system, there is a well-defined set of principles, the observance of which determines the correct interpretation of the system's indications in the "Location" function.

All prefabricated fittings are manufactured according to the same scheme and any deviation from this scheme is not allowed!

In the prefabricated elbows (bends) pipes are laid as in straight pipes.

Irrespective of the power source-receiver relationship, etc., all pre-insulated tees are manufactured according to the typical "right side up" rule.

This means that the **red** cable is cut off at the tee and routed with a branch to the right, up and to the end of the pipe, where it is “bridged” and with the return cable it is plugged back into the red cable. The **green** cable always passes through the tee.

The necessary changes in orientation of the tee are achieved by rotating it along the symmetry axis of the main pipe and/or the symmetry axis of the branch.

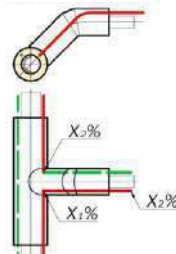


Figure 116: Cables in tees

Crossing of cables in the BRANDES system is fully permitted.

The direction of the cables is adjusted by rotating them around one of the symmetry axes.

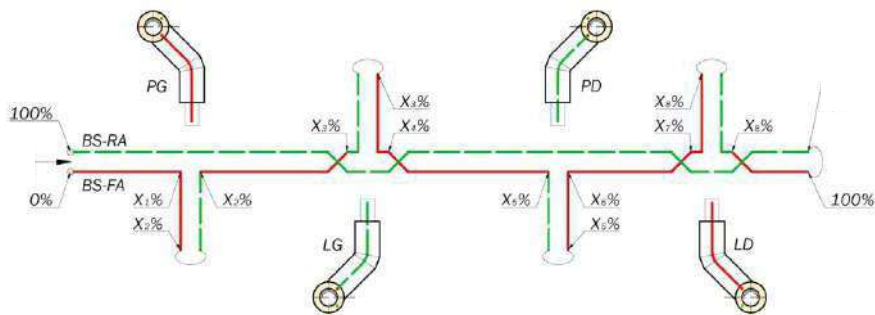


Figure 117: Use of branch tees in different directions

The use of parallel branches absolutely requires marking on the design and special attention from the site supervisor.

The wiring of parallel branches in **RADPOL PIPES** technology is done according to the “**outer bend**” principle, i.e. the sensor cable is cut in a tee and runs in an outer bend towards the discharge.

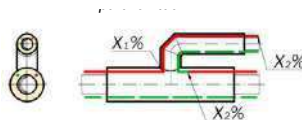


Figure 118: Parallel tee wiring in RADPOL PIPES technology

NOTE!

The wiring of parallel branches in **RADPOL PIPES** technology differs significantly from the recommendations of the developers of the original **BRANDES** resistance system. In the original, parallel branches are wired according to the “**inner bend**” principle, i.e. the sensor cable is cut in a tee and runs in an inner bend towards the discharge.

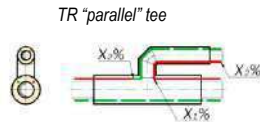


Figure 119: Original BRANDES tee

RADPOL PIPES technology also provides uniform rules for the manufacture of pre-insulated elbows. The way they are wired is shown in the figure below.

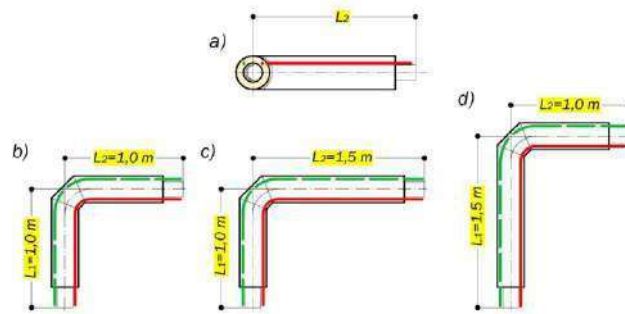


Figure 120: Wiring of elbows in RADPOL PIPES technology
(a) cable position 10:10, (b) symmetric elbow 1.0x1.0,
(c) asymmetrical elbow 1.0x1.5, (d) asymmetrical elbow 1.5x1.0

13.1.3. Principle of operation

Continuous monitoring devices operate in three modes.

(a). checking the condition of the measuring loop – continuity check

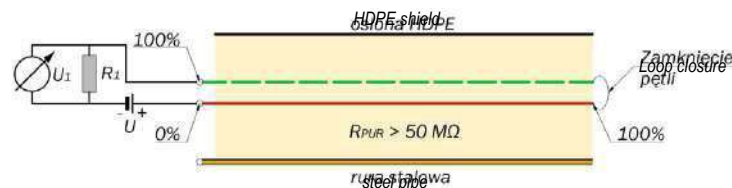


Figure 121: Measuring loop continuity check

In this mode, the condition of the loop is checked and the reaction of the system occurs as a result of the loop interruption.

(b). detection of changes in insulation resistance – detection

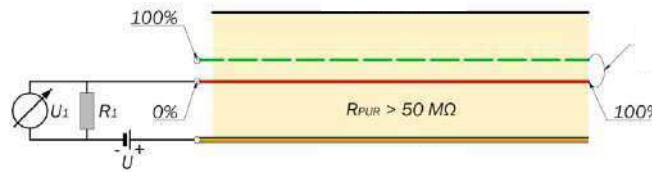


Figure 122: Detection

A specific voltage **U** is applied between a thermally insulated sensor cable placed parallel to the pipe and the pipe itself:

$$U_1 = U \cdot \frac{R_1}{R_1 + R_P} \quad (134)$$

(c). indication of the location of the dangerous anomaly – location

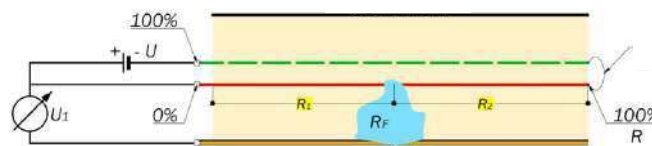


Figure 123: Location

A locating voltage (**U**) is applied to the sensor loop to locate moisture or a short circuit (damage to the system).

At the beginning of the sensor loop, between the sensor cable and the pipe, the partial voltage **U** is measured up to the leakage point. However, the partial voltage measured is not displayed in **V**, but as a percentage of the total voltage and thus represents the location result. As the sensor cable has a very high unit resistance of **5.7 Ω/m**, the value of which is close to zero for the return cable, the following relationship is obtained:

$$X \% = \frac{U_1}{U} \cdot 100 \% = \frac{R_1}{R} \cdot 100 \% = \frac{L_1}{L} \cdot 100 \% \quad (135)$$

Thanks to the appropriate design of the measuring instrument, the intensity of the moisture resulting from the insulation damage does not affect the accuracy of the location.

The distance from the point of damage – and therefore its location – is determined on the basis of the total length of the pipe section, taking into account the serial connection of “sensor/return loops”. It is measured along the sensor cable; the copper return cable is treated as a “zero length” in the calculation.

13.1.4. MH scale

To determine the degree of dryness of the insulation, **BRANDES** has introduced the **MH** scale, where the individual insulation resistances correspond to the respective degrees of the **MH** scale.

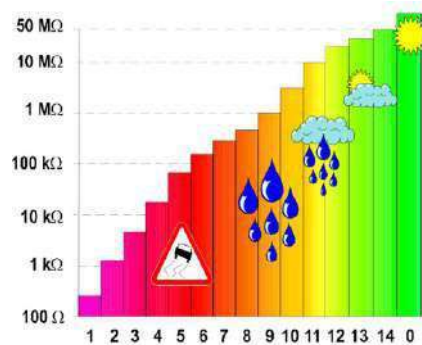


Figure 124: MH scale

To maintain measurement and location accuracy, **BRANDES** recommendations specify the required insulation condition depending on the length of the measuring loop:

- < 300 m – insulation condition **0 MH**
- 300 to 500 m – insulation condition **14 MH**
- 500 to 800 m – insulation condition **13 MH**
- 800 to 1000 m – insulation condition **12 MH**
with **BS-MH 12** corresponding to an insulation resistance of >10 MΩ.

13.1.5. Creating measuring loops

The measuring loop is formed by the two heat-insulated cables laid in parallel lengthwise between the line pipe and the casing pipe.

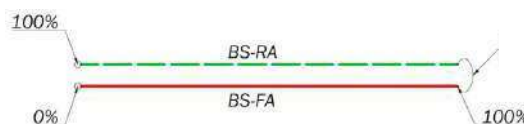


Figure 125: Measuring loop without branches

The loop must always be continuous, i.e. closed at one end with a bridge in the end box and, in the case of branched pipelines, at each pipe end pair.

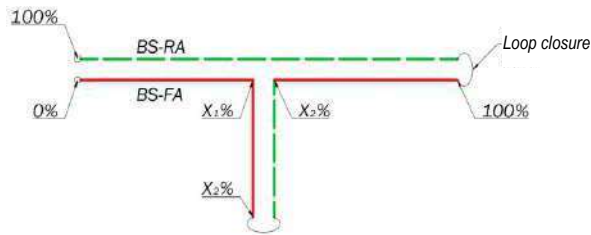


Figure 126: Measuring loop with a branch

The length of the measuring loop is always equal to the length of the pipe and is always 100%. By this term we generally mean only the length of the red cable. Each characteristic point of the route must be marked on the plan: every tee, elbow chamber, fixed point, etc.

The figures above show how to measure loop lengths and mark characteristic points in a resistance system.

Continuous control instruments can be installed in rooms such as a thermal control room, control room, caretaker's apartment, etc. When installing a printer, place it near the central instrument.

The designed district heating network should be divided into measuring sections with a maximum length of **1,000 m** (including branches), i.e. a **1,000 m** section of the heat network means **two independent supply and return measuring loops**, each **1,000 m** long.

13.1.6. Technical part regarding pipeline equipment

The purpose of designing the technical part regarding pipeline equipment is to determine which system elements (and in what quantity) are necessary for efficient control of the district heating network. The table below shows the components of the **BRANDES** system for pre-insulated steel pipes (inner pipe through which the medium flows, made of electrically conductive material) with plastic jacket.

The installation of the various elements must be carried out in accordance with the instructions of the

BRANDES system and the technical regulations in force.

Table 31: BRANDES resistance system components

BRANDES resistance system components	
Name	Quantity
BS BS RA return cable (green)	for dn ≤ 400 mm 1 m per 1 m of pipe or pre-insulated element for dn ≥ 450 mm – 2 m per 1 m of pipe or pre-insulated element
BS-AD (or PPA) junction box	for dn ≤ 400 mm – 1 pc. per end of the pipe pair for dn ≥ 450 mm – 2 pcs per end of the pipe pair
BS-QU collet	for dn ≤ 400 mm – 2 pcs per coupler for dn ≥ 450 mm – 4 pcs per coupler
BS-SL2 (or ME2019K2) two-wire cable	3 m for each loop closure in the measuring box
Measurement report with a drawing of the loop	at least 1 pc. per loop

13.1.7. Design – instrument part

This part involves identifying the instruments that control the various loops, designing their wiring and preparing the documentation.

The part is divided as follows:

- tools and instruments for assembly

Table 32: Tools and instruments for system assembly

Tools and instruments for system assembly	
Name	Tool / Instrument
removal of insulation	BS-AZ stripping pliers
BS SRA shrinking of heat shrinkable sleeves	Air heater, e.g. DT 750
control measurements of active resistance	Digital universal meter

- manual inspection and location instruments

Table 33: Equipment for manual inspection and location purposes

Equipment for manual inspection and location purposes	
Name	Quantity
BS-MD (or PPM) measuring box including the connection cable	1 pc. for the alarm system monitoring unit

- continuous inspection instruments
- control instruments and devices with automatic location

13.1.8. Connecting the devices

The following can be used in pre-insulated pipelines:

- Control instruments without automatic location
- Control instruments with automatic location

The control instruments (route meters) must be installed in dry rooms; the permissible ambient temperature range is **0÷40°C**.

Damp or humid rooms can jeopardise the correct operation of electronic equipment.

Any heat substation along the route can be used as an installation site. It is not necessary to connect instruments at the beginning of the controlled sections (seen from the side of the heating plant). It is possible to connect the appropriate instrument to each end of the pipe.

If it is necessary to install some instruments outdoors, the equipment should be placed in specially designed enclosures.

13.1.9. System components

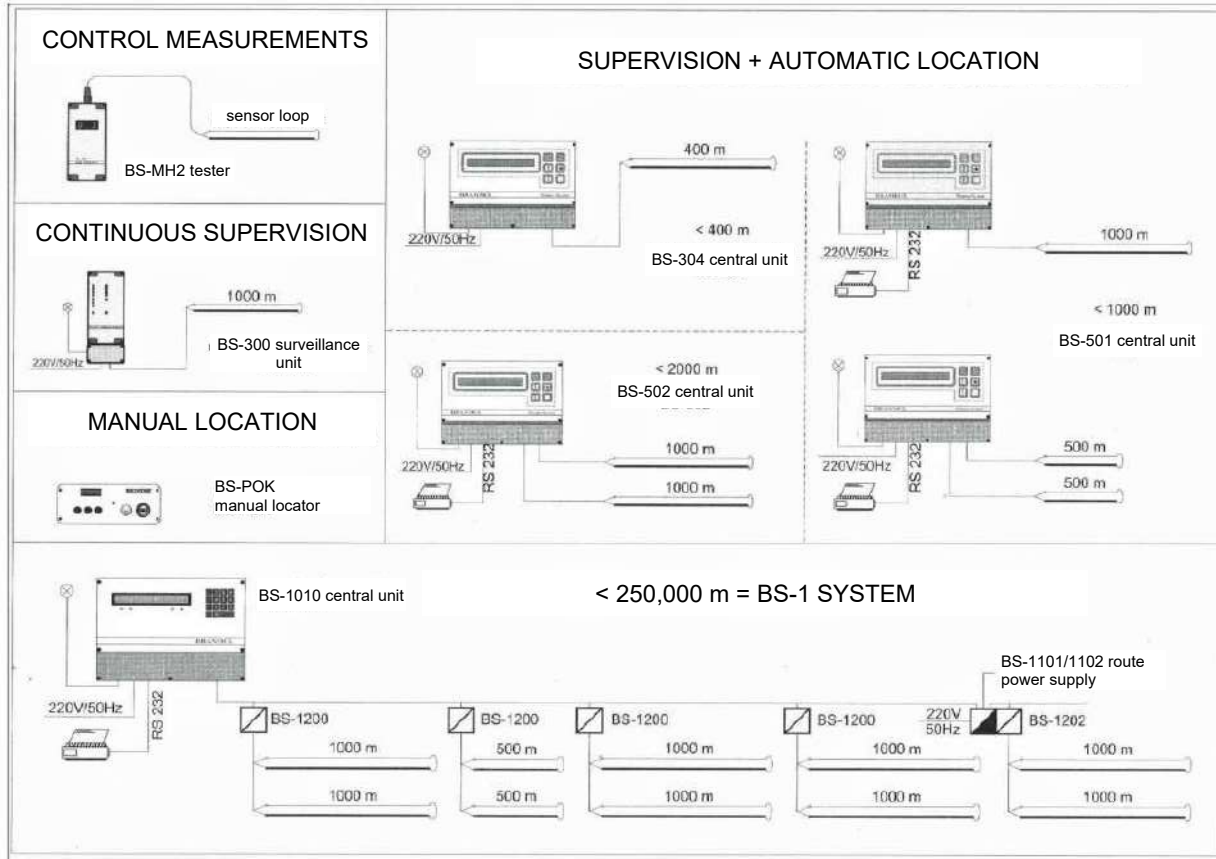


Figure 127: Overview of the BRANDES resistance system elements

13.1.10. Measurement scheme

The following section provides an example of an installation scheme and drawings showing the main ways of installing resistance system instrumentation.

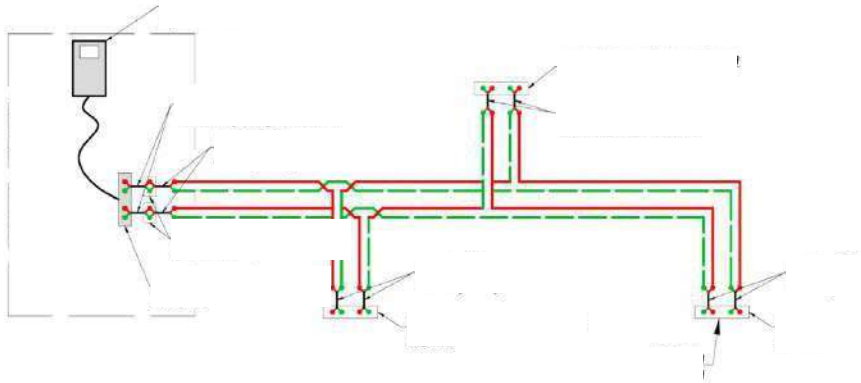


Figure 128: Measurement diagram for BS-MH3

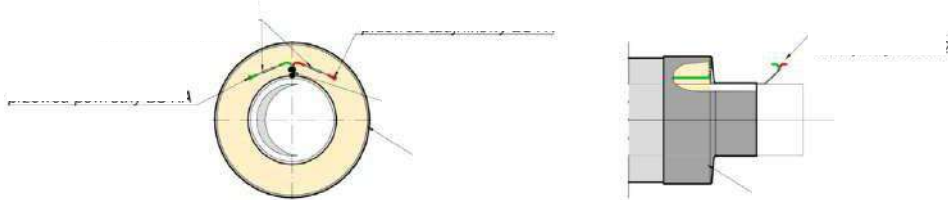


Figure 129: Routing cables from underneath the heat shrinkable end seal – connecting control cables to the two-wire cable

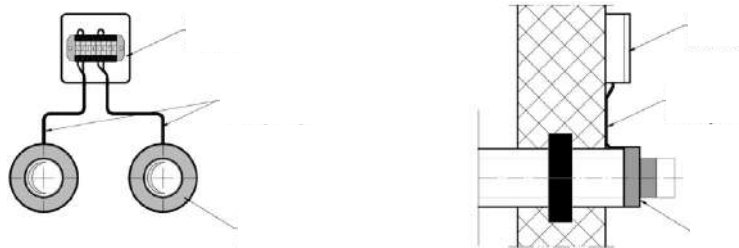


Figure 130: Installation and connection of the junction box

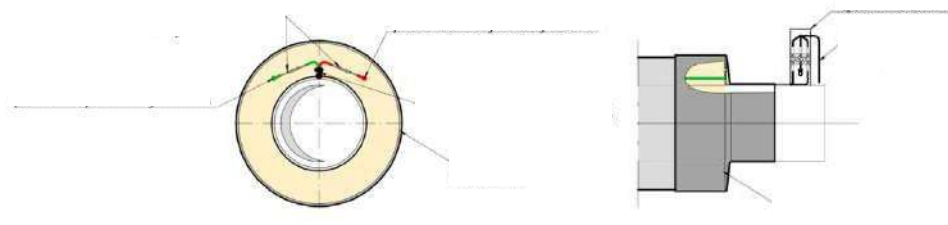


Figure 131: Routing out cables for measurements

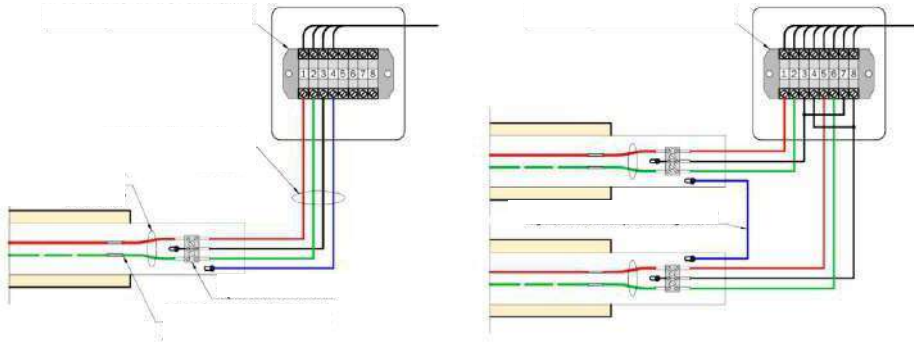


Figure 132: Connection of the BS-MD measuring box for single loop and common loop systems

The marking of the terminals in the measuring box is fixed according to the following description:

- sensor cable – SUPPLY (1)
- return cable – SUPPLY (2)
- connection to the pipe – SUPPLY (3)
- reserve – grounding (4)
- sensor cable – RETURN (5)
- return cable – RETURN (6)
- connection to the pipe – RETURN (7)
- reserve – grounding (8)

13.1.11. System connections in the chambers

In chambers where there is a break in the continuity of the pre-insulation, the cables between the two ends of the pipes should be connected using boxes and two-wire cables.

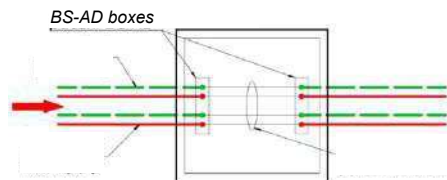


Figure 133: System connections in the chamber

The previously discussed right-hand rule applied to tees should also be applied to the connection of pre-insulated pipelines in chambers.

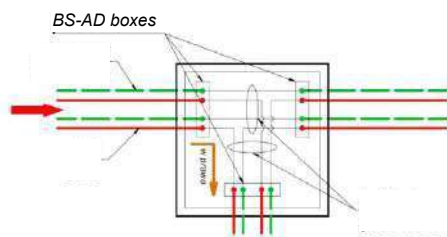


Figure 134: System connections in a chamber with a branch

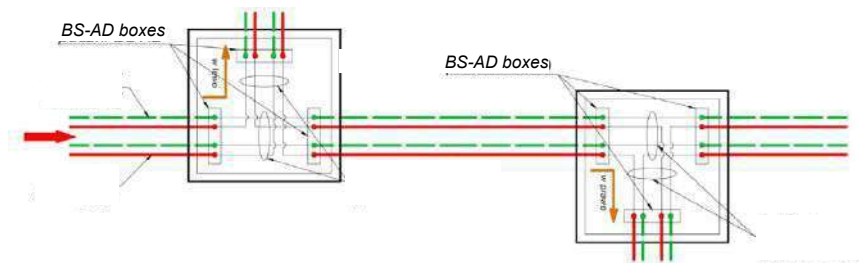


Figure 135: System connection in chambers with “left” and “right” branches

13.2. Impulse system

At the customer’s request, **RADPOL PIPES** equips pipelines and fittings with impulse alarm system cables.

The **impulse** system, also known as the **Nordic** system or **TDR**, as a universal system, is used to control pipeline networks filled with electrically conductive and non-conductive media (that is, media with near-zero conductivity). It is possible to implement comprehensive controls in heat networks.

13.2.1. Structure

The impulse system is based on bare copper cables with a cross-section of **1.5 mm²** each, laid in thermal insulation **15÷20 mm** from the steel pipe, in the “ten and two” position.

One of the cables is tinned (whitened) and is conventionally considered a sensor cable.

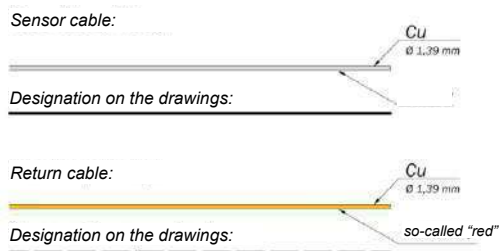


Figure 136: Cables used in the impulse system

Special cables with predetermined impedance are used for connections between devices and the sensor or between different sections of the network.

13.2.2. Uniform production principles of pre-insulated elements for the impulse system

The system uses specific solutions related to the wiring of individual elements. The wiring of elbows and tees is shown in the figures below. All cables used in these fittings are tinned (whitened).



Figure 137: Wiring of the elbow

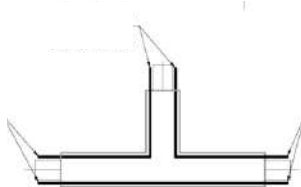


Figure 138: Wiring of the tee

13.2.3. Principle of operation

The system provides continuous monitoring of the dryness of insulation in district heating networks. As the insulating layer becomes wet, the impedance decreases and the alarm system is activated when a pre-set alarm level is reached. Three alarm levels (e.g. 30, 15 and 8k Ω) are set.

The measurement method used here is a combination of impedance and resistance measurement. Measurement in such a system is based on the phenomenon of changes in circuit impedance in a disturbing environment.

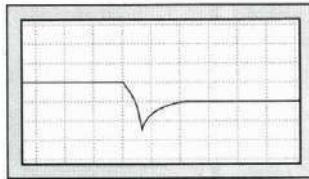


Figure 139: Image of a short circuit on the reflectometer display

This can cause short circuits, interruptions or leaks.

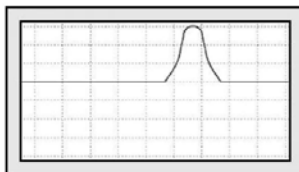


Figure 140: Image of a loop break

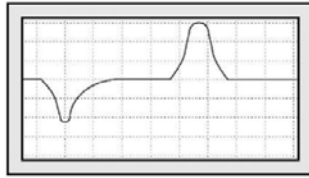


Figure 144: Image of dampness – leakage

Such disturbances cause a change in the characteristics of the electrical impulse sent by the emitter at the site of the disturbance (leakage). For physical reasons, when using electrically conductive media, such as, for example, water, the sensitivity of impulse systems is significantly lower than that of a resistance system.

Such phenomena in pre-insulated pipes are too small to be detected in time, so only more serious leaks are located.

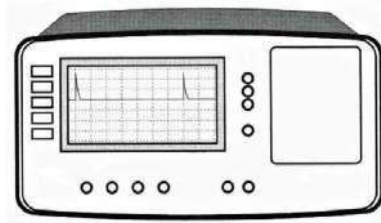


Figure 141: Failure locator – reflectometer

This means that the amount of water causing the “disturbance” must be much greater in order to locate the damage site correctly. This sensitivity also decreases with increasing distance from the damage site.

13.2.4. Creating a measuring loop

These cables in the couplers are connected by special collets and soldering.

The copper cables of the alarm system are connected in loops with a maximum length of **2000 m** (1000 m of pipeline). One of the copper cables is whitened. When installing and laying the pipes in the trench, make sure that the whitened cable is always on the right side, looking in the direction of flow of the medium in the supply pipeline and the red copper cable is on the left side.



Figure 142: Measuring loop without branches

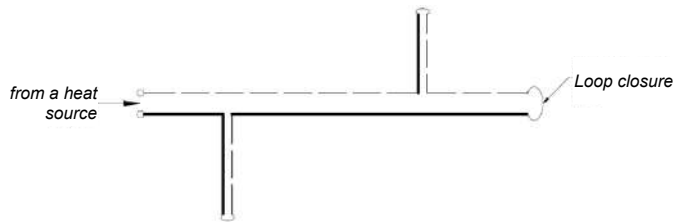


Figure 143: Measuring loop with branches and ways of making branches

Termination of alarm cables at the ends of pipes can be done in two ways:

- closing the loop under a heat shrinkable end seal or in a coupler
- the use of an end box mounted directly on the pipeline or on a wall.

The advantage of this method is direct access to the alarm cables for additional inspection.

Alarm cables must not be crossed!!!

This rule is intended to provide a clear and logical arrangement of alarm cables.

The dry insulation resistance should be – **R_{min} ≥ 10 MΩ per 1000 m** length of cable for systems without felt pads.

For cable sections shorter than **1000 m** a recalculation should be made.

13.2.5. Measurement scheme

The following section provides an example of an installation scheme and drawings showing the main ways of connecting the impulse system installations.

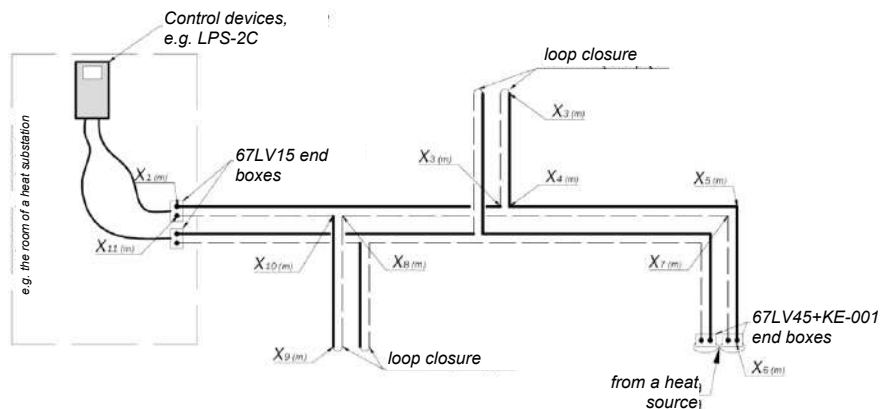


Figure 144: Measurement diagram for LPS-2C

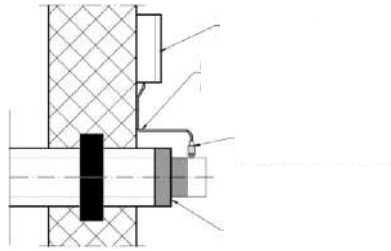


Figure 145: Installation of 67LV15 single end box with a control unit

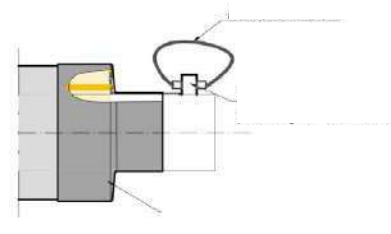


Figure 146: Installation of 67LV45 double end box with KE-001 cable

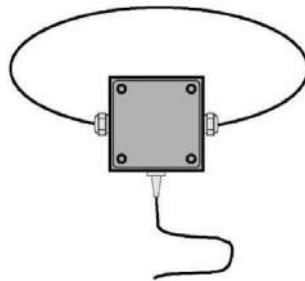


Figure 147: Terminal box 6 7LV45 with KE- cable

13.2.6. General principles of impulse system design

In the initial phase of the impulse system design, the following must be determined:

- the method of controlling the designed network,
- the division of the network into controlled sections (loops),
- the locations for mounting the control devices and closing the loop,
- the method of wiring the control devices.

The controlled sections can have a maximum pipe length of **1000 m**, resulting in **2000 m** of **CWA** copper cables.

The table below can be used to determine the quantities of each impulse system element in a given design.

Table 34: Number of individual elements of the impulse system for the design

Name	Quantity
Cu cable 1.5 mm ² (tinned so-called white)	for dn ≤ 400 mm – 1 m per 1 m of pipe or pre-insulated element for dn ≥ 450 mm – 2 m per 1 m of pipe or pre-insulated element
PKC end box	1 pc per loop

13.3. As-built documentation of the system

During the installation of the heat network, both for control and emergency signaling systems, it is necessary to provide for the execution of as-built documentation, which will include the characteristic parameters of the measuring loop.

Printouts of measurement protocols – as in the figures below – are useful for implementation.

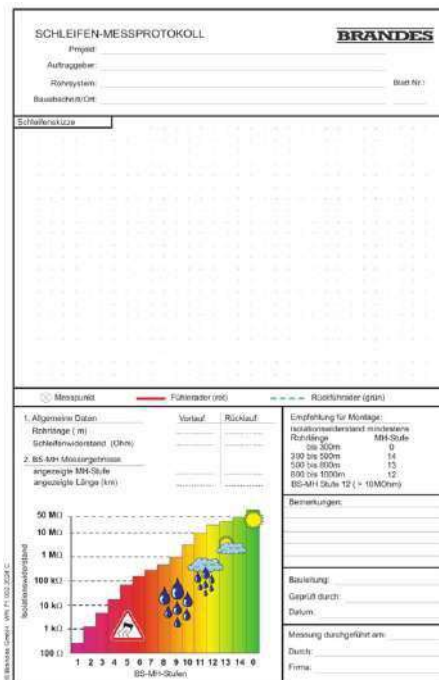


Figure 148: Resistance system measurement report

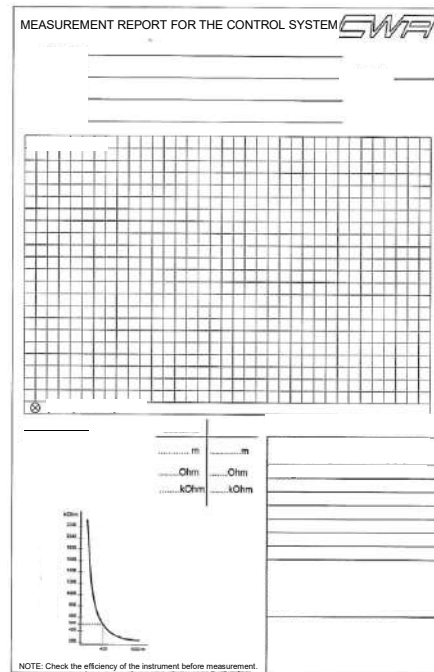


Figure 149: Impulse system measurement report

14. Auxiliary tables

14.1. Series 2 – Insulation +

Table 35: Frictional force values for different sizes of pipeline cover – SERIES 2 – Insulation +

SERIES 2 INSULATION 4	Steel pipes				Jacket							
	dn	d ₀ [mm]	t [mm]	A _s [mm ²]	D _c [mm]	H=0.8 m	1.0 m	1.2 m	1.4 m	1.6 m	1.8 m	2.0 m
DN 25/110	25	33.7	2.6	254.0	110	1.57	1.96	2.34	2.72	3.10	3.48	3.86
DN 40/125	40	48.3	2.9	413.6	125	1.80	2.23	2.67	3.10	3.54	3.97	4.40
DN 65/160	65	76.1	2.9	666.9	160	2.33	2.89	3.44	4.00	4.55	5.11	5.66
DN 100/225	100	114.3	3.6	1252.0	225	3.35	4.13	4.91	5.69	6.47	7.25	8.03
DN 150/280	150	168.3	4.0	2064.7	280	4.26	5.23	6.20	7.17	8.14	9.11	10.08
DN 250/450	250	273.0	5.0	4209.7	450	7.17	8.73	10.29	11.86	13.42	14.98	16.54
DN 350/560	350	355.6	5.6	6157.5	560	9.23	11.17	13.11	15.05	17.00	18.94	20.88
DN 450/710	450	457.0	6.3	8920.3	710	12.18	14.64	17.10	19.57	22.03	24.49	26.95
DN 600/900	600	610.0	7.1	13447.9	900	16.30	19.42	22.54	25.66	28.79	31.91	35.03
DN 800/1100	800	813.0	8.8	22232.9	1100	21.29	25.11	28.92	32.74	36.55	40.37	44.19
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	33.90	38.76	43.62	48.47	53.33	58.18

Table 36: Installation lengths for 125°C/65°C network – SERIES 2 – Insulation +

SERIES 2 INSULATION+	Steel pipes				Jacket Dc [mm]																								
	dn	d _o [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{MAX}	σ _{MAX}	F	L _{MAX}	σ _{MAX}	F	L _{MAX}	σ _{MAX}	F	L _{MAX}	σ _{MAX}	F	L _{MAX}	σ _{MAX}	F	L _{MAX}	σ _{MAX}	F	L _{MAX}	σ _{MAX}			
DN 25/110	25	33.7	2.6	254.0	110	1.57	27.3	27	1.96	21.8	21	2.34	18.3	18	2.72	15.7	15	3.10	13.8	13	3.48	12.3	12	3.86	11.1	11			
DN 40/125	40	48.3	2.9	413.6	125	1.80	38.7	38	2.23	31.3	30	2.67	26.1	25	3.10	22.5	22	3.54	19.7	19	3.97	17.6	17	4.40	15.8	15			
DN 65/160	65	76.1	2.9	666.9	160	2.33	48.2	47	2.89	38.9	38	3.44	32.7	32	4.00	28.1	27	4.55	24.7	24	5.11	22.0	21	5.66	19.9	19			
DN 100/225	100	114.3	3.6	1252.0	225	3.35	63.0	61	4.13	51.1	50	4.91	43.0	42	5.69	37.1	36	6.47	32.6	32	7.25	29.1	28	8.03	26.3	26			
DN 150/280	150	168.3	4.0	2064.7	280	4.26	81.7	80	5.23	66.5	65	6.20	56.1	55	7.17	48.5	47	8.14	42.8	42	9.11	38.2	37	10.08	34.5	34			
DN 250/450	250	273.0	5.0	4209.7	450	7.17	99.0	96	8.73	81.3	79	10.29	69.0	67	11.86	59.8	58	13.42	52.9	52	14.98	47.4	46	16.54	42.9	42			
DN 350/560	350	355.6	5.6	6157.5	560	9.23	112.4	110	11.17	92.9	91	13.11	79.2	77	15.05	69.0	67	17.00	61.0	59	18.94	54.8	53	20.88	49.7	48			
DN 450/710	450	457.0	6.3	8920.3	710	12.18	123.4	120	14.64	102.7	100	17.10	87.9	86	19.57	76.8	75	22.03	68.2	66	24.49	61.4	60	26.95	55.8	54			
DN 600/900	600	610.0	7.1	13447.9	900	16.30	139.1	136	19.42	116.7	114	22.54	100.6	98	25.66	88.3	86	28.79	78.7	77	31.91	71.0	69	35.03	64.7	63			
DN 800/1100	800	813.0	8.8	22232.9	1100	21.29	176.0	171	25.11	149.2	145	28.92	129.6	126	32.74	114.5	112	36.55	102.5	100	40.37	92.8	90	44.19	84.8	83			
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	201.5	196	33.90	172.7	168	38.76	151.0	147	43.62	134.2	131	48.47	120.8	118	53.33	109.8	107	58.18	100.6	98			

Table 37: Bellows compensators in 125°C/65°C network – SERIES 2 – Insulation +

SERIES 2 Insulation +	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	Lkm	δKM	F	Lkm	δKM	F	Lam	&KM	F	Lkm	δKM	F	Lkm	δKM	F	Lkm	Ckm	F	Lkm	OKM			
DN 25/110	25	33.7	2.6	254.0	110	1.57	-	-	1.96	-	-	2.34	-	-	2.72	-	-	3.10	-	-	3.48	-	-	3.86	-	-			
DN 40/125	40	48.3	2.9	413.6	125	1.80	39	39	2.23	31	32	2.67	26	26	3.10	22	23	3.54	20	20	3.97	17	17	4.40	16	16			
DN 65/160	65	76.1	2.9	666.9	160	2.33	47	48	2.89	38	39	3.44	32	33	4.00	27	28	4.55	24	25	5.11	21	22	5.66	19	20			
DN 100/225	100	114.3	3.6	1252.0	225	3.35	59	61	4.13	48	50	4.91	40	42	5.69	35	36	6.47	31	32	7.25	27	28	8.03	25	26			
DN 150/280	150	168.3	4.0	2064.7	280	4.26	74	78	5.23	60	63	6.20	51	54	7.17	44	46	8.14	39	41	9.11	34	36	10.08	31	33			
DN 250/450	250	273.0	5.0	4209.7	450	7.17	84	90	8.73	69	74	10.29	59	63	11.86	51	55	13.42	45	48	14.98	40	43	16.54	37	40			
DN 350/560	350	355.6	5.6	6157.5	560	9.23	92	100	11.17	76	83	13.11	65	71	15.05	57	62	17.00	50	54	18.94	45	49	20.88	41	45			
DN 450/710	450	457.0	6.3	8920.3	710	12.18	97	107	14.64	80	88	17.10	69	76	19.57	60	66	22.03	53	59	24.49	48	53	26.95	44	48			
DN 600/900	600	610.0	7.1	13447.9	900	16.30	103	115	19.42	86	97	22.54	74	83	25.66	65	73	28.79	58	65	31.91	52	58	35.03	48	54			
DN 800/1100	800	813.0	8.8	22232.9	1100	21.29	-	-	25.11	-	-	28.92	-	-	32.74	-	-	36.55	-	-	40.37	-	-	44.19	-	-			
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	-	-	33.90	-	-	38.76	-	-	43.62	-	-	48.47	-	-	53.33	-	-	58.18	-	-			

Table 38: Single-use compensators in 125°C/65°C network – SERIES 2 – Insulation +

SERIES 2 INSULATION*	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u			
DN 25/110	25	33.7	2.6	254.0	110	1.57	-	-	1.96	-	-	2.34	-	-	2.72	-	-	3.10	-	-	3.48	-	-	3.86	-	-			
DN 40/125	40	48.3	2.9	413.6	125	1.80	36.9	25	2.23	29.8	21	2.67	24.9	17	3.10	21.4	15	3.54	18.8	13	3.97	16.7	12	4.40	15.1	10			
DN 65/160	65	76.1	2.9	666.9	160	2.33	46.0	32	2.89	37.1	26	3.44	31.1	21	4.00	26.8	18	4.55	23.5	16	5.11	21.0	14	5.66	18.9	13			
DN 100/225	100	114.3	3.6	1252.0	225	3.35	60.0	41	4.13	48.7	34	4.91	41.0	28	5.69	35.3	24	6.47	31.1	21	7.25	27.7	19	8.03	25.0	17			
DN 150/280	150	168.3	4.0	2064.7	280	4.26	77.8	54	5.23	63.4	44	6.20	53.5	37	7.17	46.3	32	8.14	40.7	28	9.11	36.4	25	10.08	32.9	23			
DN 250/450	250	273.0	5.0	4209.7	450	7.17	94.3	65	8.73	77.5	53	10.29	65.7	45	11.86	57.0	39	13.42	50.4	35	14.98	45.1	31	16.54	40.9	28			
DN 350/560	350	355.6	5.6	6157.5	560	9.23	107.2	74	11.17	88.5	61	13.11	75.4	52	15.05	65.7	45	17.00	58.2	40	18.94	52.2	36	20.88	47.4	33			
DN 450/710	450	457.0	6.3	8920.3	710	12.18	117.6	81	14.64	97.9	68	17.10	83.8	58	19.57	73.2	50	22.03	65.0	45	24.49	58.5	40	26.95	53.2	37			
DN 600/900	600	610.0	7.1	13447.9	900	16.30	132.5	91	19.42	111.2	77	22.54	95.8	66	25.66	84.2	58	28.79	75.0	52	31.91	67.7	47	35.03	61.7	43			
DN 800/1100	800	813.0	8.8	22232.9	1100	21.29	-	-	25.11	-	-	28.92	-	-	32.74	-	-	36.55	-	-	40.37	-	-	44.19	-	-			
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	-	-	33.90	-	-	38.76	-	-	43.62	-	-	48.47	-	-	53.33	-	-	58.18	-	-			

Table 39: Distance of SUCs from a compensating elbow for 125°C/65°C network – SERIES 2 – Insulation +

SERIES 2 INSULATION+							
	H=0.8 m L _{KS}	1.0 m L _{KS}	1.2 m L _{KS}	1.4 m L _{KS}	1.6 m L _{KS}	1.8 m L _{KS}	2.0 m L _{KS}
DN 25/110	-	-	-	-	-	-	-
DN 40/125	57.2	46.2	38.6	33.2	29.1	26.0	23.4
DN 65/160	71.2	57.5	48.3	41.5	36.5	32.5	29.4
DN 100/225	93.0	75.5	63.5	54.8	48.2	43.0	38.8
DN 150/280	120.6	98.2	82.9	71.7	63.2	56.4	51.0
DN 250/450	146.2	120.1	101.9	88.3	78.1	70.0	63.4
DN 350/560	166.0	137.2	116.9	101.9	90.1	80.9	73.4
DN 450/710	182.2	151.7	129.8	113.4	100.7	90.7	82.4
DN 600/900	205.4	172.3	148.5	130.4	116.2	104.9	95.6
DN 800/1100	-	-	-	-	-	-	-
DN 1000/1400	-	-	-	-	-	-	-

Table 40: Calculated heat loss for 125°C/65°C heat network – SERIES 2 – Insulation +

SERIES 2 INSULATION +	Steel pipes		Jacket										
	dn	A _v [mm]	Dc [mm]	Di [mm]	H=0.6 m			H=2.0 m					
					for λs 1.6 W/(mK); λi 0.029 W/(mk and ts=0.0°C						for λs 2.0 W/(mK); λi 0.029 W/(mk and ts=8.0°C		
					q _F	q _R	Σq	q _F	q _R	Σq			
DN 25/110	25	33.7	110	104.0	18.91	9.45	28.36	18.80	9.30	28.10			
DN 40/125	40	48.3	125	119.0	23.33	11.56	34.89	23.15	11.32	34.47			
DN 65/160	65	76.1	160	154.0	29.42	14.44	43.86	29.12	14.04	43.16			
DN 100/225	100	114.3	225	218.2	32.12	15.77	47.89	31.73	15.27	47.00			
DN 150/280	150	168.3	280	272.2	42.39	20.72	63.11	41.67	19.82	61.49			
DN 250/450	250	273.0	450	439.6	43.43	21.39	64.82	42.64	20.46	63.10			
DN 350/560	350	355.6	560	548.0	47.75	23.50	71.25	46.80	22.40	69.20			
DN 450/710	450	457.0	710	695.6	49.45	24.47	73.92	48.46	23.34	71.80			
DN 600/900	600	610.0	900	882.6	56.04	27.67	83.71	54.82	26.31	81.13			
DN 800/1100	800	813.0	1100	1079.6	71.63	35.00	106.63	68.99	32.19	101.18			
DN 1000/1400	1000	1016.0	1400	1375.0	68.20	33.61	101.81	65.76	31.08	96.84			

Table 41: Thermal resistances in 125°C/65°C heat network – SERIES 2 – Insulation +

SERIES 2- INSULATION +	Steel pipes		Jacket															
	dn	d ₀ [mm]	Dc [mm]	Di [mm]	H=0.8 m		1.0 m		1.2 m		1.4 m		1.6 m		1.8 m		2.0 m	
					R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A	R _S	R _A
DN 25/110	25	33.7	110	104.0	6.7439	6.3434	6.7811	6.3436	6.8124	6.3438	6.8395	6.3439	6.8634	6.3440	6.8847	6.3440	6.9040	6.3441
DN 40/125	40	48.3	125	119.0	5.4911	5.1000	5.5280	5.1003	5.5592	5.1005	5.5861	5.1006	5.6099	5.1007	5.6311	5.1008	5.6502	5.1008
DN 65/160	65	76.1	160	154.0	4.3770	4.0058	4.4133	4.0062	4.4440	4.0064	4.4706	4.0065	4.4941	4.0066	4.5151	4.0067	4.5341	4.0068
DN 100/225	100	114.3	225	218.2	4.0100	3.6693	4.0451	3.6698	4.0749	3.6701	4.1009	3.6703	4.1239	3.6705	4.1445	3.6705	4.1632	3.6706
DN 150/280	150	168.3	280	272.2	3.0511	2.7711	3.0849	2.7720	3.1139	2.7726	3.1393	2.7730	3.1618	2.7732	3.1820	2.7734	3.2004	2.7735
DN 250/450	250	273.0	450	439.6	2.9678	2.7248	2.9989	2.7260	3.0259	2.7268	3.0498	2.7274	3.0711	2.7277	3.0904	2.7280	3.1080	2.7282
DN 350/560	350	355.6	560	548.0	2.7010	2.4758	2.7305	2.4772	2.7564	2.4781	2.7793	2.4787	2.7999	2.4792	2.8186	2.4795	2.8357	2.4798
DN 450/710	450	457.0	710	695.6	2.6018	2.4044	2.6292	2.4062	2.6535	2.4074	2.6752	2.4083	2.6948	2.4089	2.7127	2.4094	2.7292	2.4098
DN 600/900	600	610.0	900	882.6	2.2983	2.1179	2.3236	2.1199	2.3463	2.1213	2.3667	2.1223	2.3852	2.1230	2.4023	2.1236	2.4180	2.1241
DN 800/1100	800	813.0	1100	1079.6	1.8670	1.6458	1.8850	1.6468	1.9015	1.6475	1.9168	1.6481	1.9310	1.6485	1.9443	1.6489	1.9568	1.6492
DN 1000/1400	1000	1016.0	1400	1375.0	1.9554	1.7439	1.9710	1.7448	1.9855	1.7456	1.9991	1.7462	2.0119	1.7467	2.0238	1.7471	2.0352	1.7474

14.2. Series 3 – Insulation ++

Table 42: Frictional force values for different sizes of pipeline cover – SERIES 3 – Insulation ++

SERIES 3 - INSULATION ++	Steel pipes				Jacket							
	dn	d ₀ [mm]	t [mm]	A _s [mm ²]	Dc [mm]	H=0.8 m	1.0 m	1.2 m	1.4 m	1.6 m	1.8 m	2.0 m
DN 25/125	25	33.7	2.6	254.0	125	1.79	2.23	2.66	3.09	3.53	3.96	4.40
DN 40/140	40	48.3	2.9	413.6	140	2.02	2.51	2.99	3.48	3.96	4.45	4.93
DN 65/180	65	76.1	2.9	666.9	180	2.63	3.26	3.88	4.50	5.13	5.75	6.38
DN 100/250	100	114.3	3.6	1252.0	250	3.73	4.60	5.46	6.33	7.20	8.06	8.93
DN 150/315	150	168.3	4.0	2064.7	315	4.81	5.90	6.99	8.08	9.18	10.27	11.36
DN 250/500	250	273.0	5.0	4209.7	500	8.01	9.74	11.48	13.21	14.95	16.68	18.42
DN 350/630	350	355.6	5.6	6157.5	630	10.45	12.63	14.82	17.00	19.19	21.38	23.56
DN 450/800	450	457.0	6.3	8920.3	800	13.84	16.61	19.39	22.16	24.94	27.71	30.49
DN 600/1000	600	610.0	7.1	13447.9	1000	18.26	21.72	25.19	28.66	32.13	35.60	39.07
DN 800/1200	800	813.0	8.8	22232.9	1200	23.37	27.53	31.70	35.86	40.02	44.18	48.34
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	33.90	38.76	43.62	48.47	53.33	58.18

Table 43: Installation lengths for 125°C/65°C network – SERIES 3 – Insulation ++

SERIES 3 INSULATION ++	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}	F	L _{MAX}	δ _{MAX}			
DN 25/125	25	33.7	2.6	254.0	125	1.79	23.9	23	2.23	19.2	19	2.66	16.1	16	3.09	13.9	14	3.53	12.1	12	3.96	10.8	11	4.40	9.7	9			
DN 40/140	40	48.3	2.9	413.6	140	2.02	34.5	34	2.51	27.8	27	2.99	23.3	23	3.48	20.0	20	3.96	17.6	17	4.45	15.7	15	4.93	14.1	14			
DN 65/180	65	76.1	2.9	666.9	180	2.63	42.7	42	3.26	34.5	34	3.88	29.0	28	4.50	25.0	24	5.13	21.9	21	5.75	19.5	19	6.38	17.6	17			
DN 100/250	100	114.3	3.6	1252.0	250	3.73	56.6	55	4.60	45.9	45	5.46	38.6	38	6.33	33.3	32	7.20	29.3	29	8.06	26.2	26	8.93	23.6	23			
DN 150/315	150	168.3	4.0	2064.7	315	4.81	72.3	70	5.90	59.0	57	6.99	49.8	49	8.08	43.1	42	9.18	37.9	37	10.2	33.9	33	11.36	30.6	30			
DN 250/500	250	273.0	5.0	4209.7	500	8.01	88.6	86	9.74	72.8	71	11.48	61.8	60	13.21	53.7	52	14.95	47.5	46	16.68	42.5	41	18.42	38.5	38			
DN 350/630	350	355.6	5.6	6157.5	630	10.45	99.3	97	12.63	82.2	80	14.82	70.0	68	17.00	61.0	59	19.19	54.1	53	21.38	48.5	47	23.56	44.1	43			
DN 450/800	450	457.0	6.3	8920.3	800	13.84	108.6	106	16.61	90.5	88	19.39	77.5	76	22.16	67.8	66	24.94	60.3	59	27.71	54.3	53	30.49	49.3	48			
DN 600/1000	600	610.0	7.1	13447.9	1000	18.26	124.1	121	21.72	104.4	102	25.19	90.0	88	28.66	79.1	77	32.13	70.5	69	35.60	63.7	62	39.07	58.0	57			
DN 800/1200	800	813.0	8.8	22232.9	1200	23.37	160.3	156	27.53	136.1	133	31.70	118.2	115	35.86	104.5	102	40.02	93.6	91	44.18	84.8	83	48.34	77.5	76			
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	201.5	196	33.90	172.7	168	38.76	151.0	147	43.62	134.2	131	48.47	120.8	118	53.33	109.8	107	58.18	100.6	98			

Table 44: Bellows compensators in 125°C/65°C network – SERIES 3 – Insulation ++

SERIES 3 Insulation ++	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{KM}	δ _{KM}	F	L _{KM}	δ _{KM}	F	L _{KM}	δ _{KM}	F	L _{KM}	δ _{KM}	F	L _{KM}	δ _{KM}	F	L _{KM}	δ _{KM}	F	L _{KM}	δ _{KM}			
DN 25/125	25	33.7	2.6	254.0	125	1.79			2.23			2.66			3.09			3.53			3.96			4.40					
																								4.93					
DN 40/140	40	48.3	2.9	413.6	140	2.02	34	35	2.51	28	28	2.99	23	23	3.48	20	20	3.96	18	18	4.45	16	16	4.93	14	14			
DN 50/160	50	60.3	2.9	522.9	160	2.32	37	38	2.88	30	31	3.43	25	26	3.99	22	22	4.54	19	19	5.10	17	17	5.66	15	15			
DN 65/180	65	76.1	2.9	666.9	180	2.63	41	42	3.26	33	34	3.88	28	29	4.50	24	25	5.13	21	22	5.75	19	20	6.38	17	17			
DN 80/200	80	88.9	3.2	861.6	200	2.94	47	49	3.64	38	39	4.33	32	33	5.02	28	29	5.72	24	25	6.41	22	23	7.11	20	20			
DN 100/250	100	114.3	3.6	1252.0	250	3.73	53	55	4.60	43	45	5.46	36	38	6.33	31	32	7.20	27	28	8.06	25	26	8.93	22	23			
DN 125/280	125	139.7	3.6	1539.3	280	4.22	56	59	5.19	46	48	6.16	38	40	7.13	33	35	8.10	29	31	9.08	26	27	10.05	24	25			
DN 150/315	150	168.3	4.0	2064.7	315	4.81	65	69	5.90	53	56	6.99	45	47	8.08	39	41	9.18	34	36	10.27	31	33	11.36	28	29			
DN 200/400	200	219.1	4.5	3033.8	400	6.25	71	76	7.64	58	62	9.02	49	52	10.41	43	46	11.80	38	40	13.18	34	36	14.57	31	33			
DN 250/500	250	273.0	5.0	4209.7	500	8.01	76	82	9.74	62	67	11.48	53	57	13.21	46	49	14.95	41	44	16.68	36	39	18.42	33	35			
DN 300/560	300	323.9	5.6	5599.8	560	9.15	87	94	11.10	72	78	13.04	61	66	14.98	53	57	16.92	47	51	18.87	42	45	20.81	38	41			
DN 350/630	350	355.6	5.6	6157.5	630	10.45	32	89	12.63	68	74	14.82	58	63	17.00	50	54	19.19	44	48	21.38	40	43	23.56	36	39			
DN 400/710	400	406.4	6.3	7918.8	710	12.03	90	98	14.50	75	82	16.96	64	70	19.42	56	61	21.88	50	54	24.35	45	49	26.81	41	45			
DN 450/800	450	457.0	6.3	8920.3	800	13.84	85	94	16.61	71	78	19.39	61	67	22.16	53	59	24.94	47	52	27.71	43	47	30.49	39	43			
DN 500/900	500	508.0	6.3	9929.7	900	15.90	79	88	19.02	66	74	22.14	57	64	25.26	50	56	28.38	45	50	31.50	40	45	34.63	36	40			
DN 600/1000	600	610.0	7.1	13447.9	1000	18.26	92	103	21.72	77	86	25.19	66	74	28.66	58	65	32.13	52	58	35.60	47	53	39.07	43	48			
DN 700/1100	700	711.0	8.0	17668.3	1100	20.75			24.56			28.38			32.20			36.01			39.83			43.64					
DN 800/1200	800	813.0	8.8	22232.9	1200	23.37			27.53			31.70			35.86			40.02			44.18			48.34					
DN 900/1400	900	914.0	10.0	28400.0	1400	28.34		-	33.20		-	38.06			42.91			47.77			52.62			57.48					
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05			33.90			38.76			43.62			48.47			53.33			58.18					

Table 45: Single-use compensators in 125°C/65°C network – SERIES 3 – Insulation ++

SERIES 3 INSULATION++	Steel pipes				Jacket Dc [mm]																								
	dn	d ₀ [mm]	t [mm]	A _s [mm]		H=0.8 m			1.0 m			1.2 m			1.4 m			1.6 m			1.8 m			2.0 m					
						F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u	F	L _{ALL}	2 u			
DN 25/125	25	33.7	2.6	254.0	125	1.79	-	-	2.23	-	-	2.66	-	-	3.09	-	-	3.53	-	-	3.96	-	-	4.40	-	-			
DN 40/140	40	48.3	2.9	413.6	140	2.02	32.9	23	2.51	26.5	18	2.99	22.2	15	3.48	19.1	13	3.96	16.8	12	4.45	14.9	10	4.93	13.5	9			
DN 65/180	65	76.1	2.9	666.9	180	2.63	40.7	28	3.26	32.9	23	3.88	27.6	19	4.50	23.8	16	5.13	20.9	14	5.75	18.6	13	6.38	16.8	12			
DN 100/250	100	114.3	3.6	1252.0	250	3.73	53.9	37	4.60	43.7	30	5.46	36.8	25	6.33	31.8	22	7.20	27.9	19	8.06	24.9	17	8.93	22.5	16			
DN 150/315	150	168.3	4.0	2064.7	315	4.81	68.9	48	5.90	56.2	39	6.99	47.4	33	8.08	41.0	28	9.18	36.1	25	10.27	32.3	22	11.36	29.2	20			
DN 250/500	250	273.0	5.0	4209.7	500	8.01	84.4	58	9.74	69.4	48	11.48	58.9	41	13.21	51.2	35	14.95	45.2	31	16.68	40.5	28	18.42	36.7	25			
DN 350/630	350	355.6	5.6	6157.5	630	10.45	94.6	65	12.63	78.3	54	14.82	66.7	46	17.00	58.2	40	19.19	51.5	36	21.38	46.3	32	23.56	42.0	29			
DN 450/800	450	457.0	6.3	8920.3	800	13.84	103.5	71	16.61	86.3	60	19.39	73.9	51	22.16	64.7	45	24.94	57.4	40	27.71	51.7	36	30.49	47.0	32			
DN 600/1000	600	610.0	7.1	13447.9	1000	18.26	118.3	82	21.72	99.4	69	25.19	85.7	59	28.66	75.4	52	32.13	67.2	46	35.60	60.7	42	39.07	55.3	38			
DN 800/1200	800	813.0	8.8	22232.9	1200	23.37	-	-	27.53	-	-	31.70	-	-	35.86	-	-	40.02	-	-	44.18	-	-	48.34	-	-			
DN 1000/1400	1000	1016.0	11.0	34730.3	1400	29.05	-	-	33.90	-	-	38.76	-	-	43.62	-	-	48.47	-	-	53.33	-	-	58.18	-	-			

Table 46: Distance of SUCs from a compensating elbow for 125°C/65°C network – SERIES 3 – Insulation ++

SERIES 3 INSULATION++							
	H=0.8 m L _{KS}	1.0 m L _{KS}	1.2 m L _{KS}	1.4 m L _{KS}	1.6 m L _{KS}	1.8 m L _{KS}	2.0 m L _{KS}
DN 25/125	-	-	-	-	-	-	-
DN 40/140	51.0	411	34.4	29.6	26.0	23.2	20.9
DN 65/180	63.1	51.0	42.8	36.9	32.4	28.8	26.0
DN 100/250	83.6	67.8	57.0	49.2	43.3	38.7	34.9
DN 150/315	106.8	87.1	73.5	63.6	56.0	50.1	45.2
DN 250/500	130.8	107.5	91.3	79.3	70.1	62.8	56.9
DN 350/630	146.6	121.4	103.4	90.1	79.9	71.7	65.1
DN 450/800	160.4	133.7	114.5	100.2	89.0	80.2	72.8
DN 600/1000	183.3	154.1	132.9	116.8	104.1	94.1	85.7
DN 800/1200	-	-	-	-	-	-	-
DN 1000/1400	-	-	-	-	-	-	-

Table 47: Calculated heat loss for 125°C/65°C heat network – SERIES 3 – Insulation ++

SERIES 3 INSULATION ++	Steel pipes		Jacket							
	dn	d _o [mm]	D _c [mm]	D _i [mm]	H=0.6 m			H=2.0m		
					for λs 1.6 W/(mK); λi 0.029 W/(mk and ts=0.0°C					
					q _F	q _R	Σq	q _F	q _R	Σq
DN 25/125	25	33.7	125	119.0	17.04	8.56	25.60	16.95	8.43	25.38
DN 40/140	40	48.3	140	134.0	20.84	10.40	31.24	20.70	10.20	30.90
DN 65/180	65	76.1	180	174.0	25.47	12.62	38.09	25.24	12.32	37.56
DN 100/250	100	114.3	250	242.8	28.04	14.00	42.04	27.72	13.60	41.32
DN 150/315	150	168.3	315	306.8	34.78	17.23	52.01	34.28	16.62	50.90
DN 250/500	250	273.0	500	488.8	36.21	18.04	54.25	35.66	17.39	53.05
DN 350/630	350	355.6	530	616.8	38.37	19.14	57.51	37.77	18.44	56.21
DN 450/800	450	457.0	800	784.2	39.36	19.72	59.08	38.73	19.01	57.74
DN 600/1000	600	610.0	1000	981.2	44.58	22.29	66.87	43.81	21.45	65.26
DN 800/1200	800	813.0	1200	1178.0	56.35	27.97	84.32	55.21	26.73	81.94
DN 1000/1400	1000	1016.0	1400	1375.0	68.20	33.61	101.81	66.62	31.92	98.54

Table 48: Thermal resistances for 125°C/65°C heat network – SERIES 3 – Insulation ++

SERIES 3 INSULATION++	Steel pipes		Jacket															
	dn	d ₀ [mm]	Dc [mm]	Di [mm]	H=0.8 m		1.0 m		1.2 m		1.4 m		1.6 m		1.8 m		2.0 m	
					R _s	R _A	R _s	R _A	R _s	R _A	R _s	R _A	R _s	R _A	R _s	R _A	R _s	R _A
DN 25/125	25	33.7	125	119	7.4666	7.0755	7.5035	7.0758	7.5347	7.0760	7.5616	7.0761	7.5854	7.0762	7.6066	7.0763	7.6258	7.0763
DN 40/140	40	48.3	140	134	6.1272	5.7449	6.1638	5.7453	6.1947	5.7455	6.2215	5.7456	6.2452	5.7457	6.2663	5.7457	6.2854	5.7458
DN 65/180	65	76.1	180	174	5.0312	4.6702	5.0671	4.6706	5.0975	4.6708	5.1240	4.6710	5.1473	4.6711	5.1682	4.6712	5.1871	4.6712
DN 100/250	100	114.3	250	243	4.5612	4.2730	4.5956	4.2738	4.6249	4.2744	4.6506	4.2747	4.6733	4.2749	4.6937	4.2751	4.7122	4.2752
DN 150/315	150	168.3	315	307	3.6930	3.4218	3.7262	3.4228	3.7547	3.4234	3.7798	3.4238	3.8020	3.4241	3.8221	3.4243	3.8403	3.4244
DN 250/500	250	273.0	500	489	3.5381	3.3036	3.5684	3.3049	3.5949	3.3058	3.6183	3.3064	3.6393	3.3068	3.6583	3.3071	3.6757	3.3073
DN 350/630	350	355.6	630	617	3.3369	3.1212	3.3655	3.1227	3.3906	3.1237	3.4130	3.1244	3.4332	3.1250	3.4516	3.1253	3.4684	3.1256
DN 450/800	450	457.0	800	784	3.2466	3.0578	3.2729	3.0597	3.2964	3.0610	3.3175	3.0619	3.3366	3.0626	3.3541	3.0631	3.3702	3.0635
DN 600/1000	600	610.0	1000	981	2.8687	2.6955	2.8930	2.6976	2.9148	2.6991	2.9346	2.7001	2.9526	2.7010	2.9692	2.7016	2.9846	2.7021
DN 800/1200	800	813.0	1200	1178	2.2783	2.1172	2.3009	2.1194	2.3212	2.1210	2.3398	2.1223	2.3569	2.1232	2.3727	2.1239	2.3874	2.1245
DN 1000/1400	1000	1016.0	1400	1375	1.8895	1.7380	1.9105	1.7403	1.9296	1.7421	1.9472	1.7434	1.9634	1.7444	1.9784	1.7452	1.9924	1.7459

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