A new pipe-Standard EN 13941

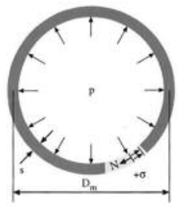
The standard EN 13941:2009 provides regulations for calculation, design and installation of pre-insulated pipes layed in trenches and covered by soil.
The standard is not harmonized with Pressure Equipment Directive (PED) and may only be used for buried district heating pipes.

The standard requires the calculation of the pipes in three respects:

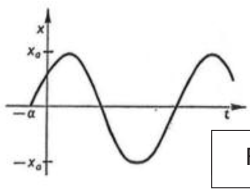
1. Stresses due to internal pressure (force controlled action) Limitations is listed in the "Limit State A"

2. Stresses resulting from repeated loads, "Fatigue." The restriction is specified in the "Limit State B".
   This applies to:
   Main lines shall be capable of 100 cycles.
   Distribution lines shall be capable of 250 cycles.
   Service pipes shall be capable of 1000 cycles.
   Each cycle is based on a change of temperature of 110°C.

3. Stresses which may lead to instability or deformation. (dilation controlled action).
   The limitations are specified in the "Limit-state C".
   The pipelines are divided into three project classes:
   Project class A (secondary plant)
   Project class B (primary plant with DN ≤300)
   Project class C (primary plant with DN >300)

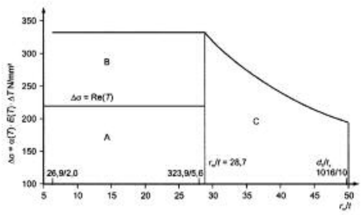


Internal pressure



Fatigue

Projet class	Weld Inspection at installation	Safety factor fatigue	Documentation
A	≥ 5%	5	Generalized
B	≥10%	6,67	Generalized
C	≥ 20%	10	Specific

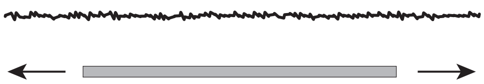


Project classes

The generalized documentation can be business standards or manufacturer manuals. The specific doumentationen shall include:

- Calculated pressure and temperature and the number of expected cycles including estimates related to "Limit State A-C."
- Pipe line information such as, drawings, dimensions, material specifications, installation prerequisites, relational drawings.
- Quality assurance.

Forces, movements and expansion types



The pipe will expand when temperatur rises.

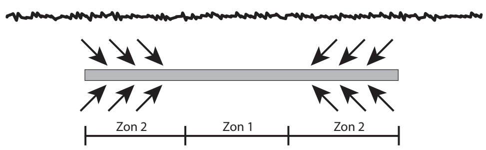
<u>Expansion</u>
When a buried pipeline is exposed to temperature increase, this will lead to an expansion of the pipe.

The expansion is counter acted by friction that occurs between the moving pipe and the surrounding sand (soil).

The friction builds up an axial stress in the pipe and counteract free expansion.

You get two different zones of the district heating pipe:

1. The part that is fixed (may be in the middleton of a straight length) (zone 1).
2 The part of the pipe that moves (in both ends of a straight length) (Zone 2).



Movement counter acted by friction.

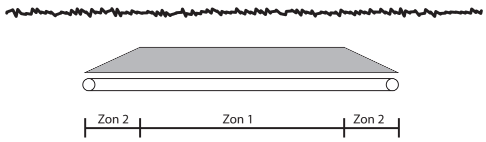
The stress in the fixed part depends only on the temperature change from the temperature when the trench was filled. The force in the pipe can be calculated as the stress multiplied by the steel pipes cross area.

$$\sigma = E \cdot \alpha \cdot \Delta T$$

σ = Stress
E = Modulus of elasticity
α = Koefficient of thermal expansion
ΔT = Temperature Change

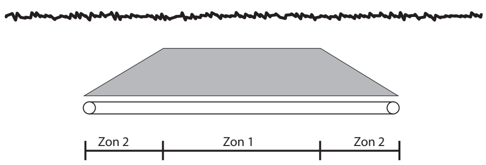
The part of the pipe that moves is called "Friction Length". It acts as a fixative for the fixed part.

<u>Preheating</u>
To limit tensions and movements, it is common that the pipes are heat-preloaded.
This means that you get compressive stresses in the pipe at high temperatures and tensile stresses at low temperatures.



Tension in a preladed pipe

<u>Cold Laying</u>
Small and medium-sized dimensions can be layed cold. This means that you may get exremly high (but in term of norms acceptable) axial stresses. The movements e.g. of a bend can be up to four times as large as by pre-heating.



Stresses in a cold layed pipe

<u>Table of friction lengths and movements</u>
Table of friction length and movements are shown on the next page. Shown values are based on a number of conditions, as indicated. When change in the conditions, of course, specified data will change.

Assumptions for calculations

Maximum axiell stress is 150 Mpa for single pipes (equivalent ΔT=60°C). Maximum axiell stress is 150+50 Mpa for double pipes (temperature difference between supply and returning line is 40°C, soil covering 0,6 m; Bending Radius 3s. Number of full cycles: 1000 cycles for DN 25-65; 250 cycles for DN80-300; 100 cycles for DN 350-900.

Series 1

Dimension	Friction force N/m	Friction length m	Movement mm	Length L-bend mm
25	956	36	13	0,7
32	1189	42	15	0,8
40	1192	48	18	1,0
50	1376	58	22	1,2
65	1565	65	24	1,6
80	1822	72	27	1,6
100	2359	81	30	1,9
125	2719	87	32	2,4
150	3102	102	38	2,9
200	4130	113	42	3,6
250	5584	116	43	4,2
300	6556	131	48	4,5
350	7524	125	46	5,0
400	8808	138	51	5,6
450	8958	153	56	6,5
500	10516	145	54	6,9
600	12252	163	60	8,2
700	15152	179	66	9,4
800	181216	188	70	10,4

Series 2

Dimension	Friction force N/m	Friction length m	Movement mm	Length L-bend mm
25	1185	29	11	0,5
32	1365	36	13	0,7
40	1368	42	15	0,9
50	1556	52	19	1,2
65	1811	56	21	1,5
80	2075	64	24	1,5
100	2693	71	26	1,8
125	3064	77	28	2,2
150	3530	90	33	2,7
200	4749	98	36	3,4
250	6439	100	37	4,0
300	7449	115	43	4,2
350	8652	109	40	4,6
400	10201	119	44	5,2
450	10351	132	49	6,1
500	12211	125	46	6,4
600	14664	141	52	7,6
700	17568	154	57	8,7
800	20711	165	61	9,8

Series 3

Dimension	Friction force N/m	Friction length m	Movement mm	Length L-bend mm
25	1361	26	9	0,6
32	1545	32	12	0,7
40	1548	37	14	0,9
50	1801	44	16	1,1
65	2063	50	18	1,4
80	2334	57	21	1,6
100	3038	63	23	1,7
125	3492	68	25	2,1
150	4049	78	29	2,5
200	5478	85	31	3,2
250	7326	88	33	3,7
300	8577	100	37	4,4
350	10045	94	35	4,8
400	11897	102	38	5,4
450	12046	113	42	5,6
500	14249	107	40	6,0
600	17080	121	45	7,1
700	20152	134	50	8,2
800	23466	145	54	9,2

Series 4

Dimension	Friction force N/m	Friction length m	Movement mm	Length L-bend mm
25	1539	23	9	0,6
32	1784	28	10	0,7
40	1790	32	12	0,8
50	2062	39	14	1,0
65	2320	44	17	1,3
80	2654	50	19	1,4
100	3461	55	21	1,7
125	4005	59	22	2,0
150	4648	68	25	2,4
200	6204	75	28	3,0
250	8487	76	28	3,5
300	9950	86	32	3,9
350	11621	81	30	4,0
400	13843	88	33	4,5
450	13920	98	37	5,3
500	16612	92	34	5,8
600	19645	105	39	6,6
700	23012	117	44	7,7

Double, standard

Dimension	Friction force N/m	Friction length m	Movement mm	Length L-bend mm
2*20	1550	23	9	0,4
2*25	1552	33	12	0,6
2*32	1805	36	14	0,9
2*40	1811	41	15	0,8
2*50	2338	45	17	1,1
2*65	2691	50	19	1,4
2*80	3058	56	21	1,4
2*100	4052	62	23	1,7
2*125	5445	57	21	1,9
2*150	6370	65	24	2,3
2*200	8544	71	27	2,9

Double+

Dimension	Friction force N/m	Friction length m	Movement mm	Length L-bend mm
2*20	1805	20	8	0,4
2*25	1805	28	11	0,6
2*32	2319	28	11	0,7
2*40	2328	32	12	0,8
2*50	2675	39	15	1,0
2*65	3040	44	17	1,3
2*80	3402	51	19	1,3
2*100	4523	55	21	1,6
2*125	6234	49	18	1,8
2*150	7116	58	22	2,2

Backfilling with alternative materials

Shown below are the guidelines and potential limitations for the use of alternative backfill materials. If coarse grain materials are used as backfill around culvert pipes, special attention must be paid to controll during the operation. Extreme caution must be exercised when handling the backfill mass to avoid damage to pipes and fittings.

	Not congested traffic area	Traffic Congested paved surface	Traffic Congested not paved surface
Comments	No exterior load on the pipes	The pipline assumes to be below the paved surface, ie. in earlier existing hard packed soil.The upper level distributes the traffic loads so that point loads not occurs on the pipes. Surrounding material must be possible to be compacted.	Risk of point load on the pipes due to insufficient overfilling belived missing. Surrounding material must be possible to be compacted.
Friction Fixed distance	Existing natural and/or mixed material with largest grain size 50 mm Joints are enclosed with protection net of HDPE.	Existing natural and/or mixed material with largest grain size 50 mm Joints are enclosed with protection net of HDPE.	Existing not sharp-edged nature-natural material and/or mixed material with largest grain size 50 mm Joints are enclosed with protection net of HDPE.
Expansion distance (axiell movement)	Existing not sharp-edged natural material and/or mixed material with largest grain size 50 mm or mixed material 4-32 mm grain size. Joints are enclosed with mech mat of polyethylene.	Existing not sharp-edged natural material and/or mixed material with largest grain size 50 mm or mixed material 4-32 mm grain size. Joints are enclosed with mech mat of polyethylene.	Not sharp-edged trench gravel according to AMA tableCEC/1 with the largest grain size 32 mm. Joints are enclosed with mech mat of polyethylene.
Expansion-device (radiell movement). For limited movement at preheated systems.	Not sharp-edged trench gravel according to AMA tableCEC/1 with the largest grain size 32 mm.	Not sharp-edged trench gravel according to AMA tableCEC/1 with the largest grain size 32 mm + foam pads that absorbe the expansion that exceeds 20 mm.	Not sharp-edged trench gravel according to AMA tableCEC/1 with the largest grain size 32 mm.
Expansions-device (radiell movement). For limited movement at cold layed systems.	Not sharp-edged trench gravel according to AMA table CEC/1 with the largest grain size 32 mm + foam pads with thickness = least equal to the estimated movement or natural and/or mixed material with largest grain size 50 mm. Foam pads with thickness approx 1,6 times the estimated movement.	Not sharp-edged trench gravel according to AMA table CEC/1 with the largest grain size 32 mm + foam pads with thickness = least equal to the estimated movement or natural and/or mixed material with largest grain size 50 mm. Foam pads with thickness approx 1,6 times the estimated movement.	Not sharp-edged trench gravel according to AMA table CEC/1 with the largest grain size 32 mm + foam pads with thickness = least equal to the estimated movement or natural and/or mixed material with largest grain size 50 mm. Foam pads with thickness approx 1,6 times the estimated movement.

Calculating the pressure-drop for flexible pipes

Required flow

Each connected house has a power requirement according the design-temperature.
This power requirement with available temperature-drop determines the required flow.

Ex. Power Requiremen	Q	12kW.	
Temperature drop	ΔT	40°C	
Required flow	m	258 kg/h	m = Q*860/ΔT

Required dimension

For copper pipes see calculation chart 9:102
With a pressure-drop of 1 mbar/m (10 mm vp/m) the required dimension for the above-stated example is, 18*1 mm.

Total pressure-drop

The available pressure drop is divided on the longest pipe line from the connection point to the district heating central located farthest.

Ex: Average pressure-drop can be calculated in terms of type of 1mbar/m.
The pressure-drop on the connecting pipe (Copper-Flex 18*1) if it is 14 m it will be 2*14 * 1 = 28 mbar

Higher pressure-drops can be calculated on the connecting lines located closer to the connection points. However, water flow should not exceed 2 m/s in a copper pipe.

Steel flexible pipes

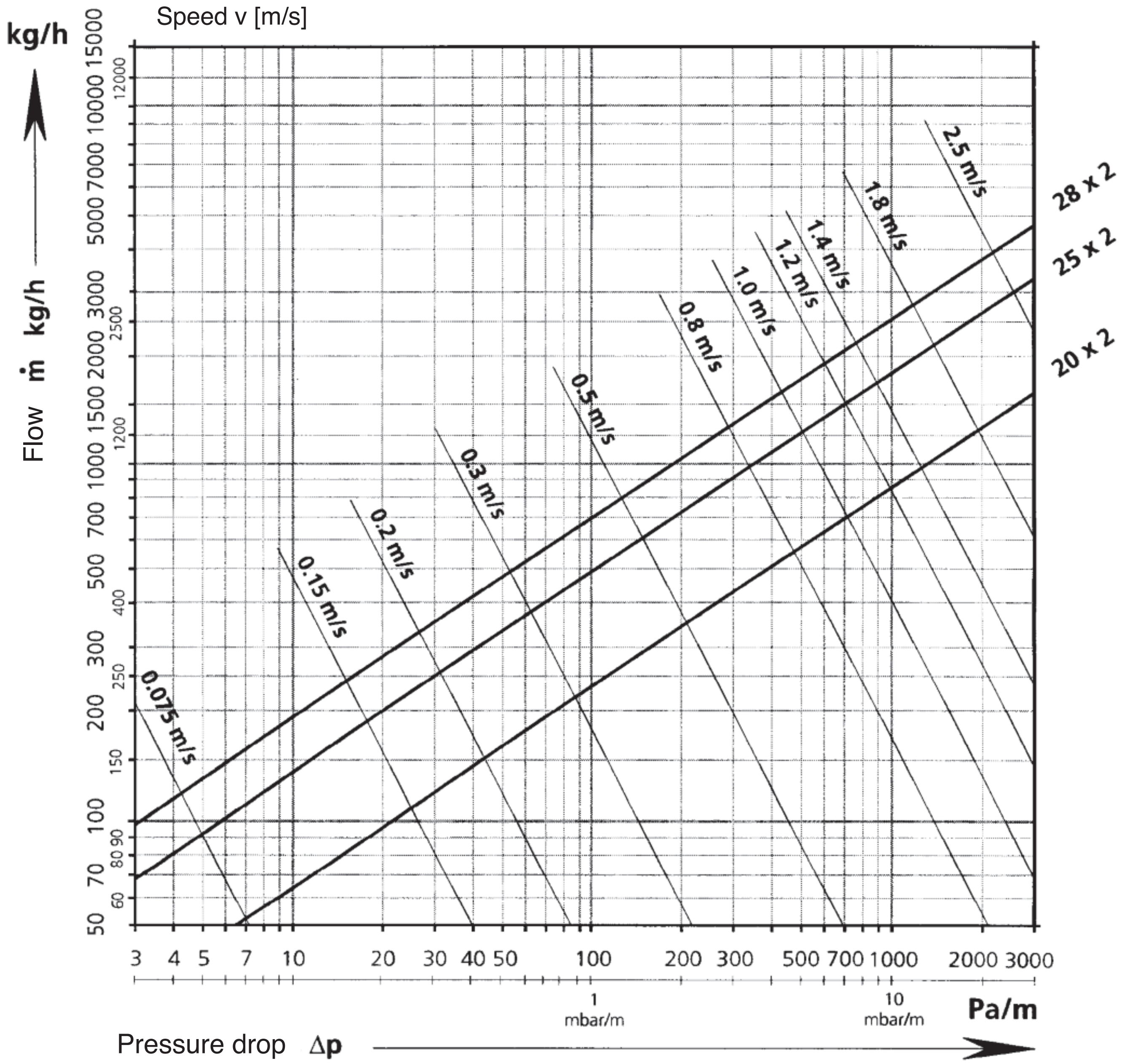
Average Temperature, water 80°C

Roughness ε = 0.0016 mm steelflex
(1 mm vp = 9.81 Pa)

$$\dot{m} \approx \frac{Q \cdot 860}{\Delta T}$$

$\dot{m}$ = flow in kg/h
Q = effect kW
ΔT = temperature difference °C

Example: Power needs 30kW
ΔT = 40°C
Required flow = $\frac{30 \times 860}{40}$ = 645 kg/h



Copper flexible pipes

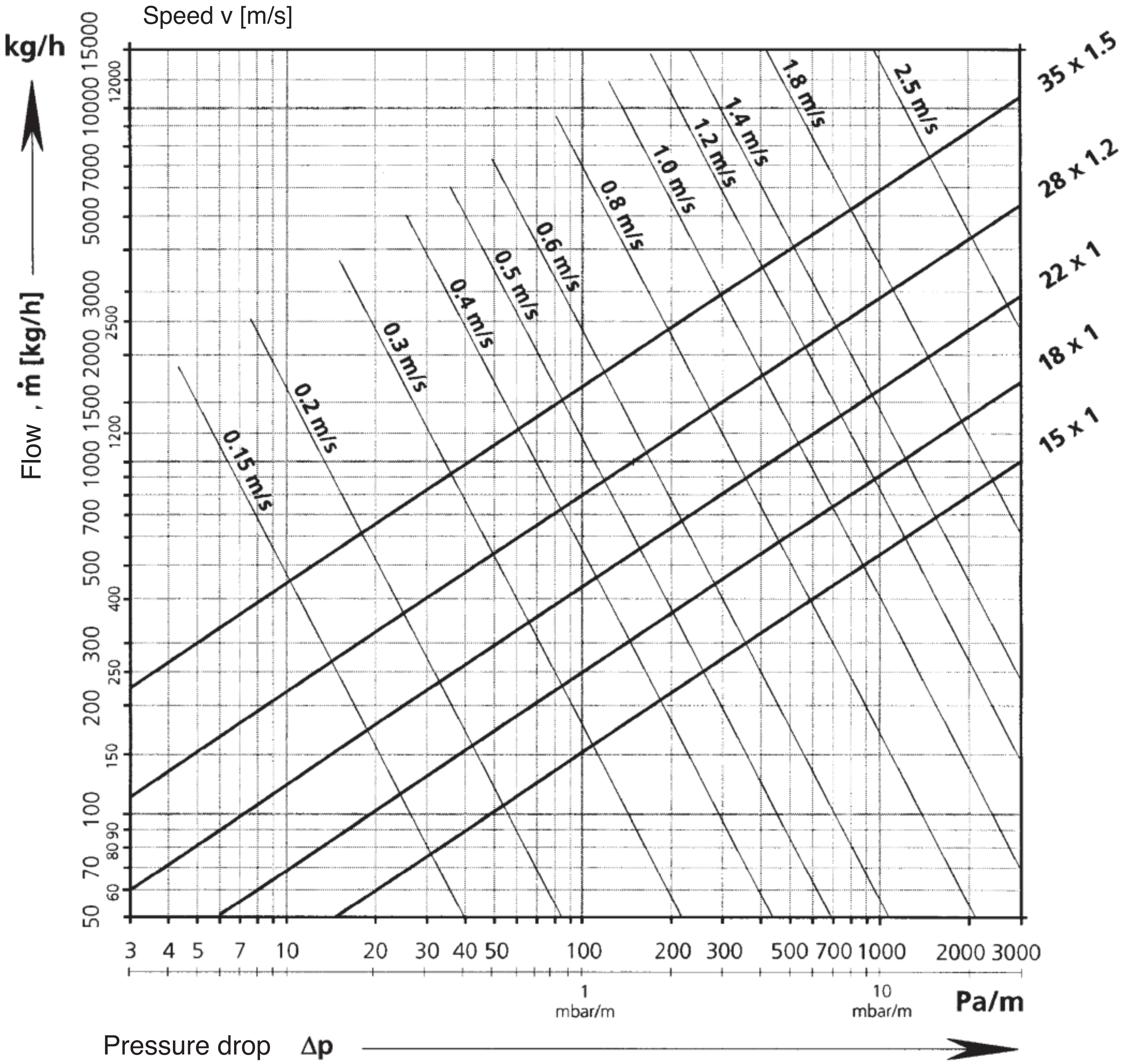
Average Temperature, water 80°C

Roughness ε = 0.0015 mm copper
(1 mm vp = 9.81 Pa)

$$\dot{m} \approx \frac{Q \cdot 860}{\Delta T}$$

$\dot{m}$ = flow in kg/h
Q = effect kW
ΔT = temperature difference °C

Example: Power needs 30kW
ΔT = 40°C
Required flow = $\frac{30 \times 860}{40}$ = 645 kg/h



Heat losses

Calculation prerequisites for single and double pipe systems

Conditions of installation

Height of back-filling	0,80 m	
Distance between pipes	0,20 m	Ø 110≤Dy≤ Ø 180
	0,25 m	Ø 200≤Dy≤ Ø 500
	0,30 m	Ø 630≤Dy≤ Ø 900

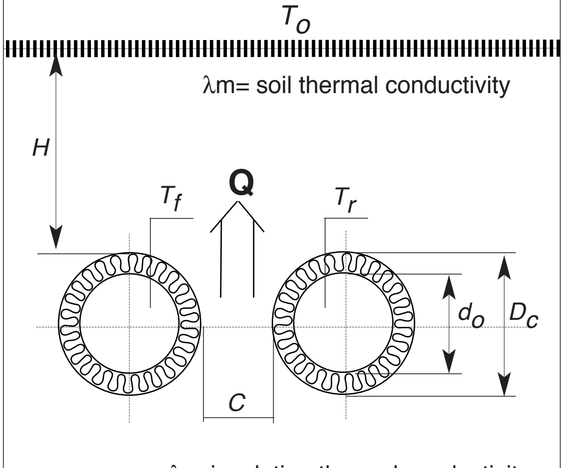
Ground

Thermal conductivity: λ m = 1,5 W/m° K

PUR foam insulation:

Thermal conductivity λ i = 0,026 W/m° K

Heat loss Q



Temperatures, yearly average (primary system):

Flow pipelines	Tf	= 85° C
Return pipelines	Tr	= 55° C
Ambient temperature	To	= 5° C
	ΔT	= 65° C

$$\Delta T = \frac{T_f + Tr}{2} - To$$

If ΔT is changed 10°, the heat losses are influenced by $\frac{10}{65} = 15\%$

Heat Losses in district heating pipes in the ground depends on:

1-Thermal resistance of soil: $$Rm = \frac{1}{2\pi\lambda_m} \ln\left(\frac{4Z_c}{D_c}\right)$$

2- Thermal resistance of pipe insulation $$Rr = \frac{1}{2\pi\lambda_i} \ln\left(\frac{D_{pur}}{d_o}\right)$$

3- The interactions between the supply and return line $$R_2 = \frac{1}{4\pi\lambda_s} \ln\left(1+\left(\frac{2Z_c}{C}\right)^2\right)$$

For calculation see EN 13941

Single pipe systems

Heat losses at Δ T = 65° C (includes supply and return lines)

DN	Series 1 W/m	Series 1 kWh/m.year	Series 2 W/m	Series 2 kWh/m.year	Series 3 W/m	Series 3 kWh/m.year	Series 4 W(m	Series 4 kWh/m.year
20			14,6	128	13,4	117	12,5	109
25	20,8	182	17,3	151	15,6	137	14,4	126
32	21,3	186	18,8	164	17,0	149	15,3	134
40	24,5	214	21,2	186	19,0	167	17,0	148
50	27,3	239	23,7	208	20,6	180	18,5	162
65	32,1	281	26,6	233	23,1	203	20,7	182
80	33,0	289	27,8	244	24,4	214	21,5	188
100	34,5	302	29,0	254	25,3	221	22,3	195
125	39,9	350	33,4	292	28,2	247	24,4	214
150	47,1	413	37,8	331	31,1	272	26,5	232
200	51,1	448	39,8	349	32,4	284	27,5	241
250	49,2	431	38,8	340	32,4	284	27,8	243
300	56,4	494	44,2	387	35,7	312	29,9	262
350	54,8	480	42,6	373	34,3	301	28,8	253
400	58,1	509	44,1	387	35,2	308	29,5	258
450	85,5	749	58,4	511	43,7	383	35,2	309
500	82,2	720	56,5	495	42,7	374	34,6	303
600	109,8	962	68,4	599	49,3	432	39,8	349
700	134,6	1179	77,7	681	55,8	488	44,8	392
800	152,0	1332	87,3	765	62,4	546		

Double pipe systems

Heat losses at Δ T = 65° C

DN	STANDARD W/m	STANDARD kWh/m.year	DOUBLE+ W/m	DOUBLE+ kWh/m.year	DOUBLE++ W/m	DOUBLE++ kWh/m.year
2 x 20	10,1	88	8,9	78	8,1	71
2 x 25	13,2	116	11,2	97	9,9	87
2 x 32	14,6	128	12,2	107	10,8	95
2 x 40	16,6	145	14,3	125	12,4	109
2 x 50	16,4	144	13,8	121	12,2	107
2 x 65	20,2	177	16,3	143	13,7	120
2 x 80	22,8	200	17,8	156	14,6	128
2 x 100	22,9	201	17,4	152	14,4	126
2 x 125	20,8	182	16,7	146	13,6	119
2 x 150	25,6	224	19,7	173	16,1	141
2 x 200	30,5	267	21,8	191	17,3	152

When calculating the heat consumption, the computer program "Ekodim", has EN13941 and the ISO-value λ = 0.026 W / moC been used, and consideration has been taken that jacket pipes expanded 1%.
When calculating future heat loss confirm the computerized program «Ekodim».

Heat losses, flexible pipes

Conditions of installation

Filling Height	0,6 m
Free distance between the pipes	0,1 m
Ground	
Thermal conductivity:	λ_m=1,5 W/m°K
Insulation PUR foam	
Thermal conductivity:	λ_i=0,024 W/m°K

Temperatures, annual average

	Primary-system	Secondary-system
Supply pipe temp.	85°C	70°C
Return pipe temp.	55°C	40°C
Ambient temp.	5°C	5°C
ΔT	65°C	50°C

Heat losses, copper flexible pipes, single

Dimension	Primary System W/m	kWh/m, year	Secondary System W/m	kWh/m, year
22/91	13,4	118	10,3	90
28/91	16,1	141	12,4	108
35/91	19,7	172	15,1	133

Heat losses, copper flexible pipes, double

2*15/91	7,4	64	5,7	50
2*18/91	9,3	81	7,2	63
2*22/91	11,5	101	8,9	78
2*28/91	14,9	130	11,5	101
2*18/110	7,5	66	5,8	51
2*22/110	8,7	76	6,7	59
2*28/110	10,2	89	7,8	68

Heat losses, Steel flexible pipes, single

20/78	14,0	122	10,8	94
28/91	16,1	141	12,4	108

The heat losses above are both supply and return direction. If ΔT is changed, the heat losses are affected linearly.
OBS! Heat losses increases with time for all District Heating pipes. Ask Powerpipe for optimization.

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