TECHNICAL DATA, FORMULAS AND CHARTS

Diagram for local district heating plants connected to a heating and power plant.

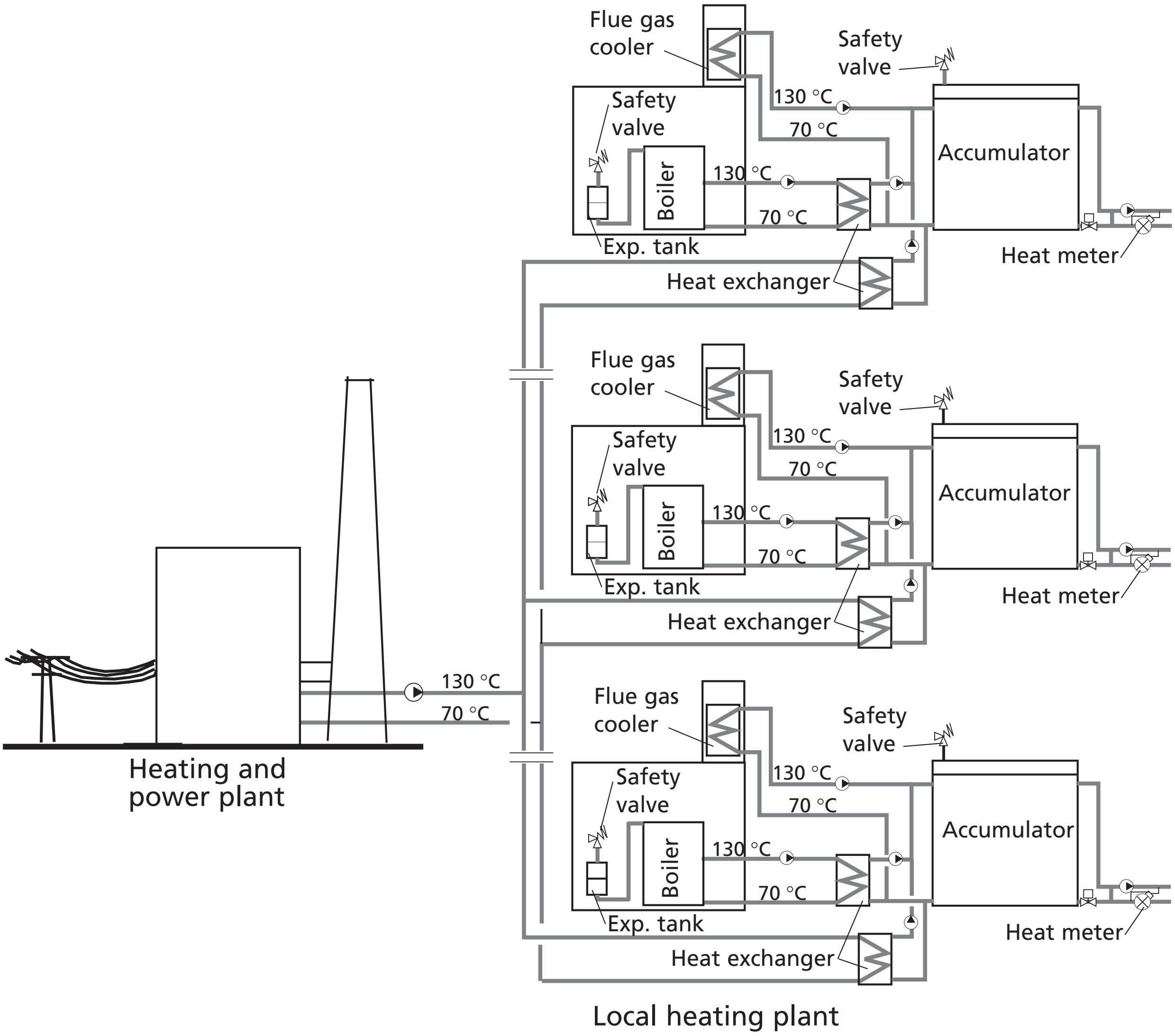
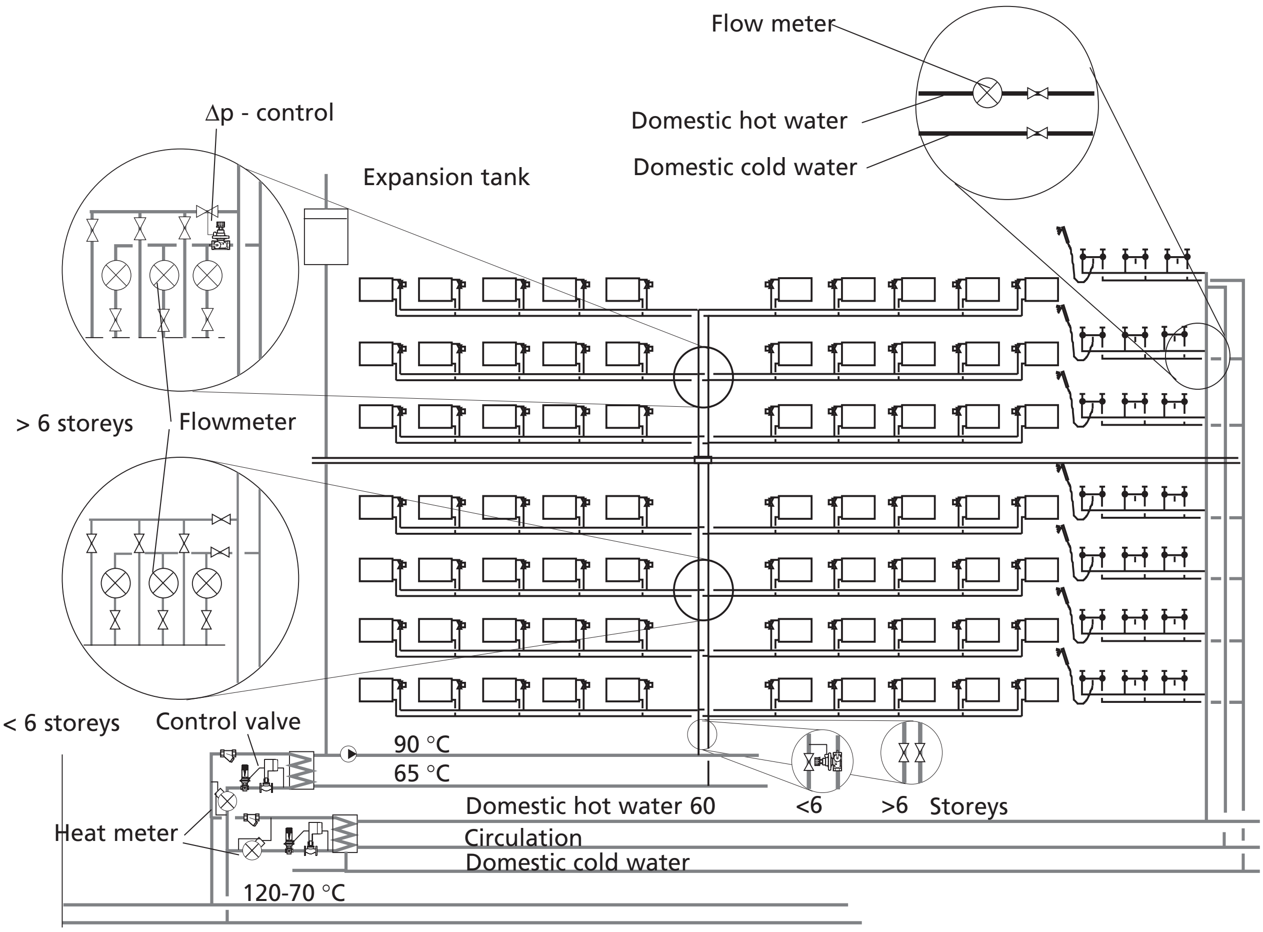


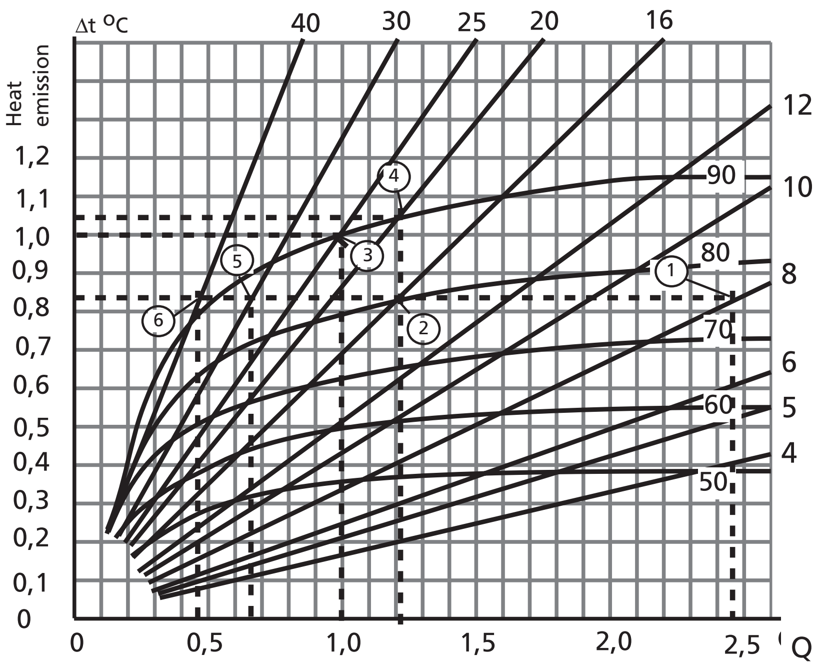
Diagram for heating and domestic hot and cold water.



Heat emission from radiators.

Two-pipe system with thermostatic valves.
Measured ① : t_{flow} 75 ºC, Δt 8 ºC
Heat requirement : 0,83, Q = 2,47
t_{flow} 80 ºC : ② Δt 16 ºC, Q = 1,23
Every point along the horizontal line 0,83 gives the same heat emission.

n = 1,3 t_{room} = 20 ºC t_{flow} = 90 ºC Δt = 25 ºC

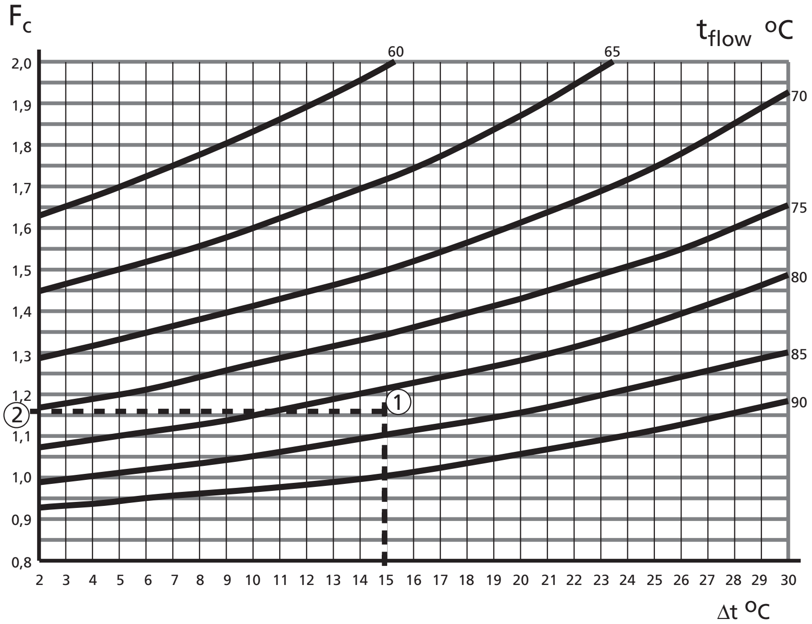


The influence of gravity forces on heat emission from a radiator in a two-pipe system
For a correctly sized radiator ③ (with manual radiator valve in a two-pipe system) the heat emission will increases only by 5% when the flow increases by 23%, ④, depending on gravity forces. The temperature drop across the radiator however will decrease by 5 ºC and that is significant, because it reduces the capacity of the whole system all the way down to the heating and power plant.

Resuls Δt for one- and two - pipe circuits, and required pump capacity when thermostatic valves utilize internal and external heat gains.

Point	Heat gain %	Two-pipe circuit Flow %	Δt ºC	Circuit resistance %	Pump capacity %	One-pipe circuit Flow %	Δt ºC	Pump capacity %
③	0	100	25	100	100	100	25	100
⑤	10	66	33	44	29	100	22,5	100
⑥	20	47	39	22	10	100	20	100

Conversion chart for radiators in one-pipe circuits.



Conversion chart for panel and section radiators in one-pipe circuits. Enter the current t_{flow} and temperature drop and find the conversion factor, F_c.

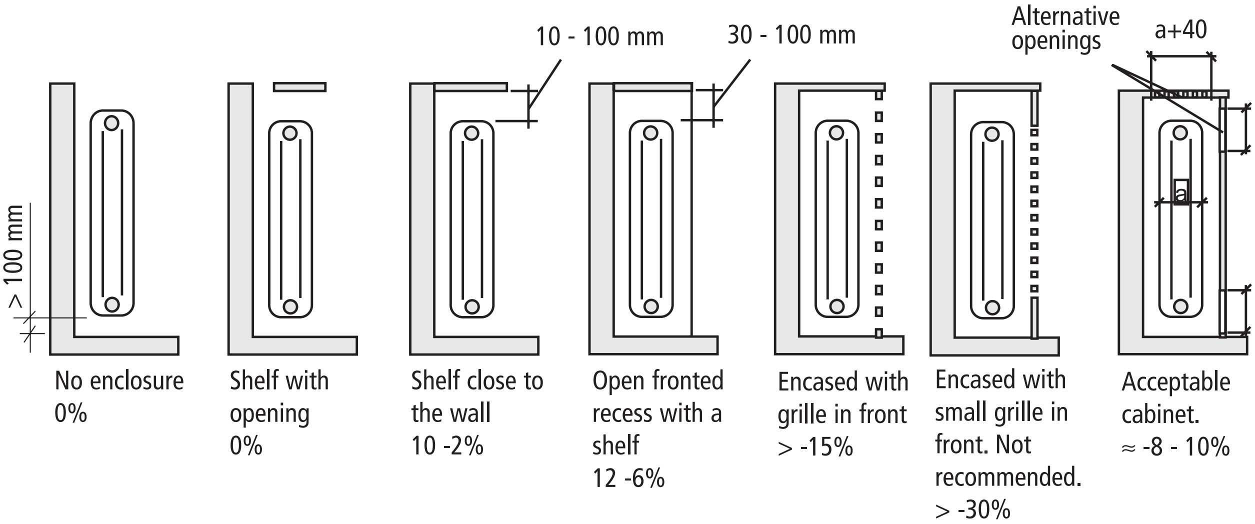
Multiply the heat requirement by F_c and select size of the radiator according to the new value.

Example.
Calculated heat requirement: 1.230 W.
t_{flow} : 82 °C, Δt: 15 °C, ①
F_c = 1,16 ②
Converted heat requirement: 1.230 x 1,16 = 1.427 W.
Formula for calculating F_c:

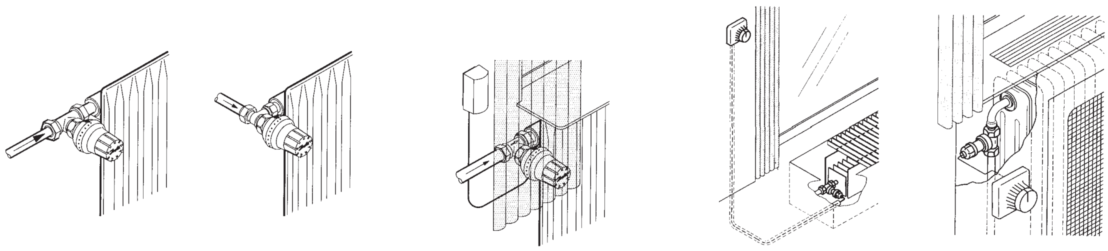
$$F = \left[\frac{49{,}33 \times \ln\left(\frac{t_1 - t_r}{t_2 - t_r}\right)}{t_1 - t_2} \right]^n$$

	n
Panel radiator	1,28
Section radiator	1,29
Convector	1,3 - 1,33

Reduction of heat emission from radiators fixed in some type of enclosure



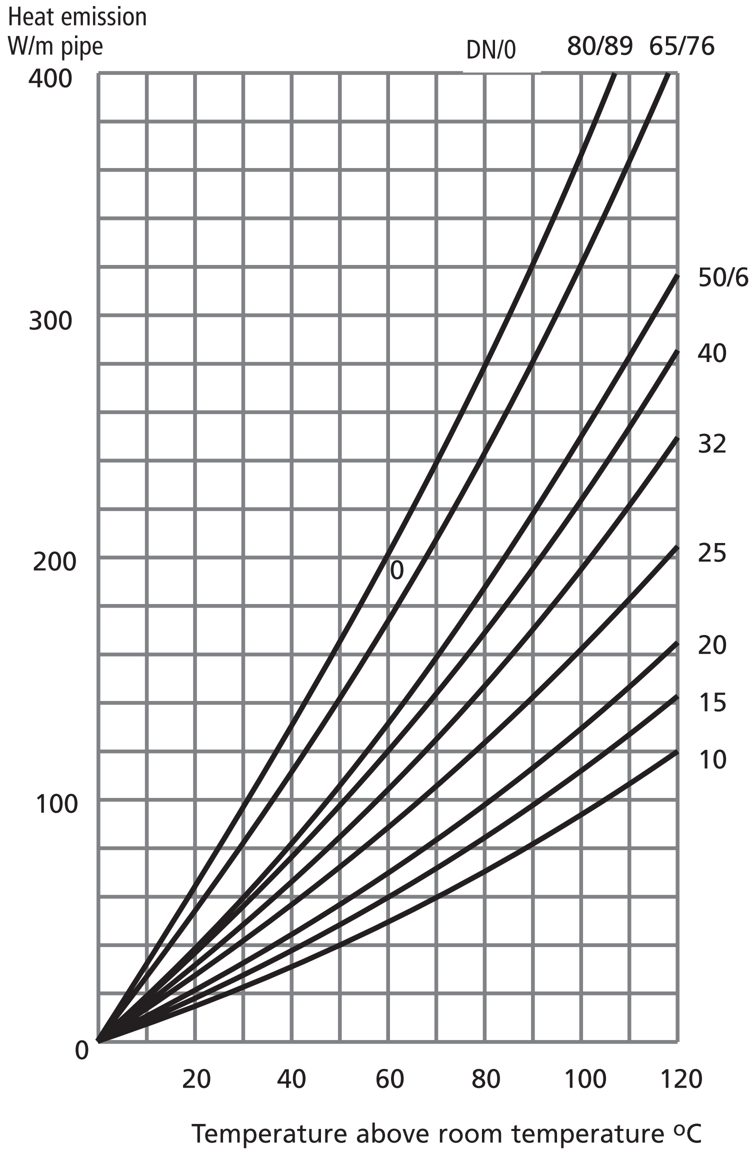
The control unit has to sense the room temperature to be able to control it.



Radiation from a radiator depending on the treatment of the surface.

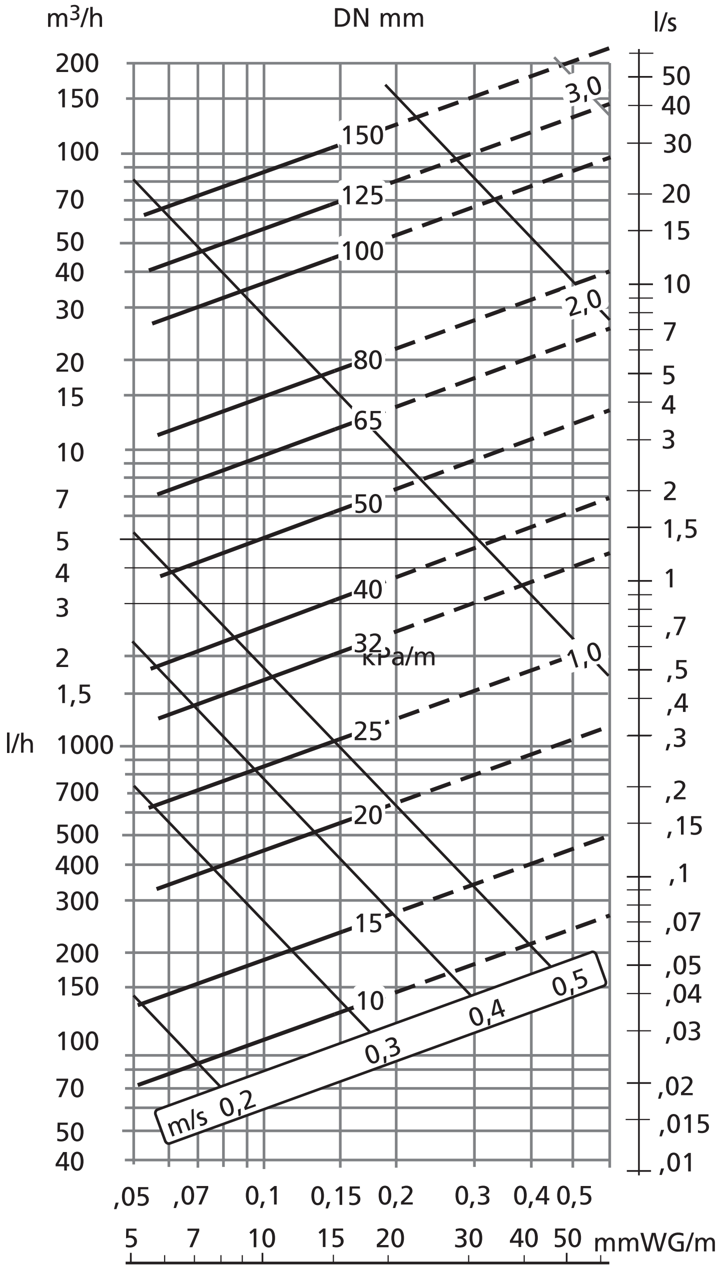
Material	Surface treatment	Radiation %
Steel, cast iron		100
	Oil paint	100
	Aluminium or copper bronzes	75
	Zinc white	101
	Lead white	99
Enamelled	White	101
	Matt green	96
Aluminium		8

Heat losses from uninsulated horizontal pipe.



For vertical pipe reduce by 20%
One-pipe above another reduce by 12%
Three pipes above each other reduce by 20%

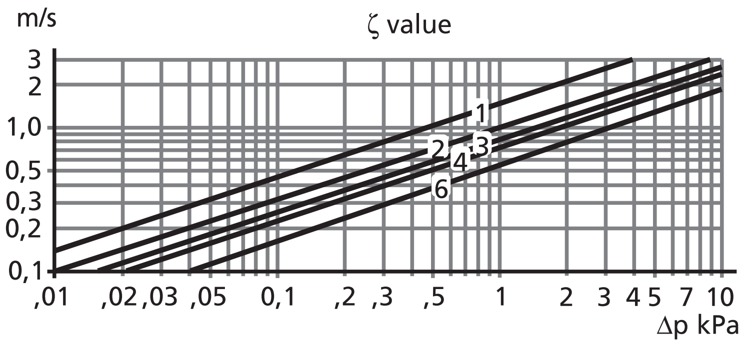
Pressure drop in steel pipes for heating installations.



k = 0,00003 m
Density = 1.000 kg/m^3

Δp for ζ values at differnt rates.

Symbol	Units	Coefficient of resistance, ζ
	Branch tee	1
	Through tee	1
	Elbow, smooth	0,2
	Bend	1



The values for the coefficient of resistance for tees, elbows and bends.

The pressure drop is calculated from:
$\Delta p = \zeta \, 0{,}5 \, \rho \, v^2$,

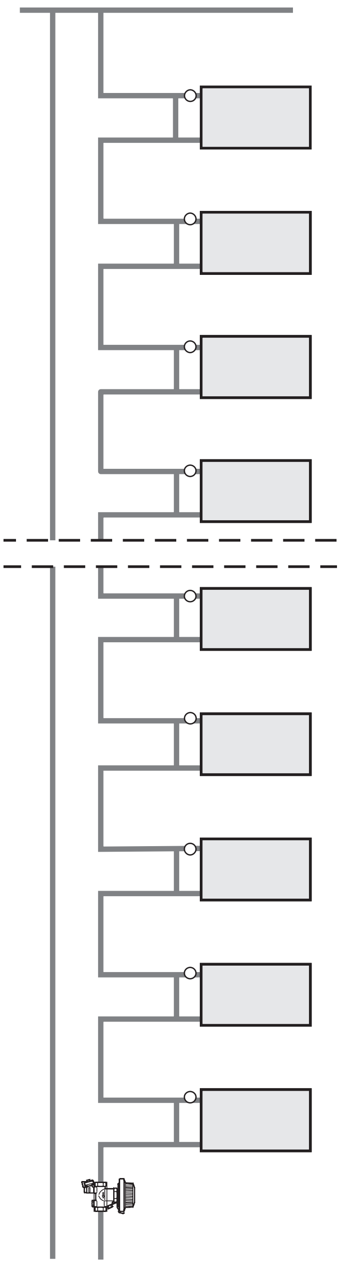
Recommended portion of pipe losses for different systems or part of systems.

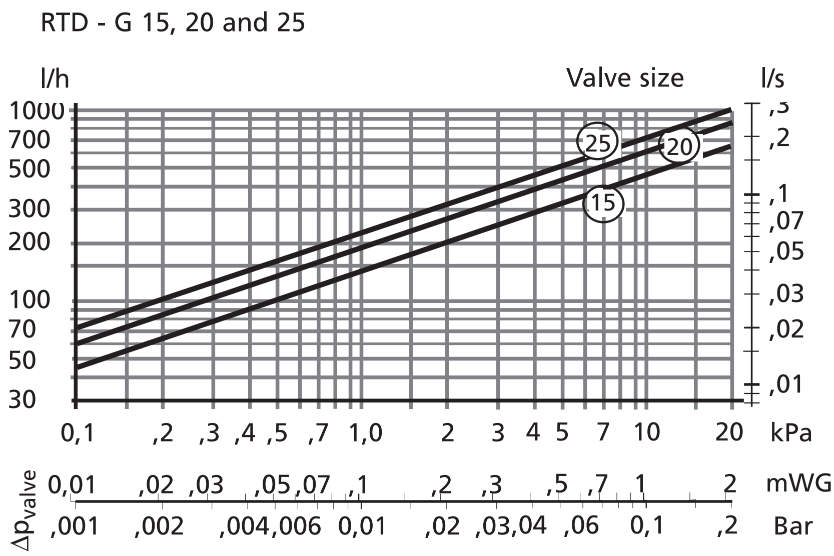
Type of system	Unit	Friction %
Heating	Small buildings	50 - 60
	Large buildings	60 - 70
Sub-stations	Primary and secondary side	20 - 30
Distribution pipe net work	Primary side	80 - 90

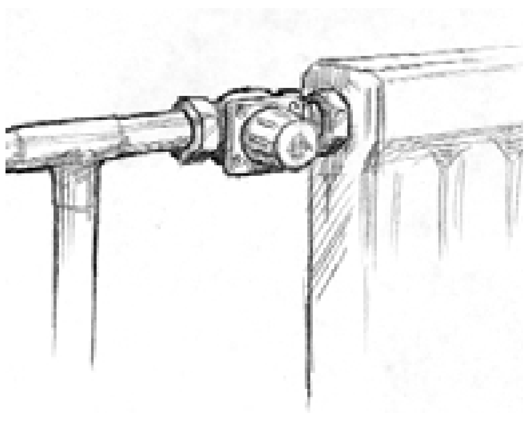
Sizes of steel pipes for heating systems. Working pressure 1,0 MPa (10 bar)

Nominal diameter	External diameter		Wall thickness	Internal diameter
mm	inch	mm	mm	mm
8	1/4	13,50	2,25	9
10	3/8	17,00	2,25	12,5
15	1/2	21,25	2,75	15,75
20	3/4	26,75	2,75	21,25
25	1	33,50	3,25	27,00
32	1 1/4	42,25	3,25	35,75
40	1 1/2	48,00	3,50	41,00
50	2	60,00	3,50	53,00
65	2 1/2	75,50	3,75	68,00
80	3	88,50	4,00	80,50
100	4	114,00	4,00	106,00
125	5	140,00	4,50	131,00
150	6	165,00	4,50	156,00

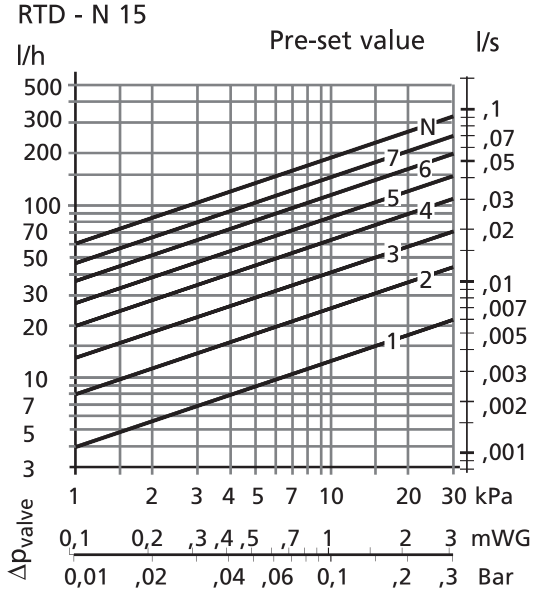
Flow chart for RTD-G 15, 20 and 25

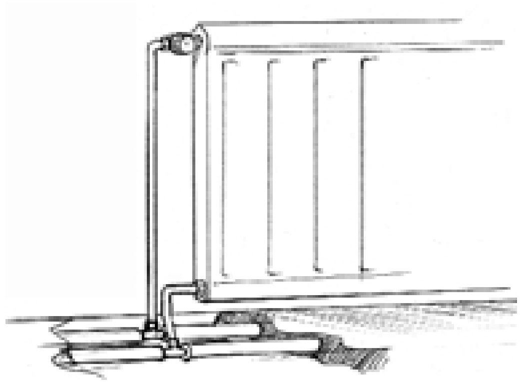




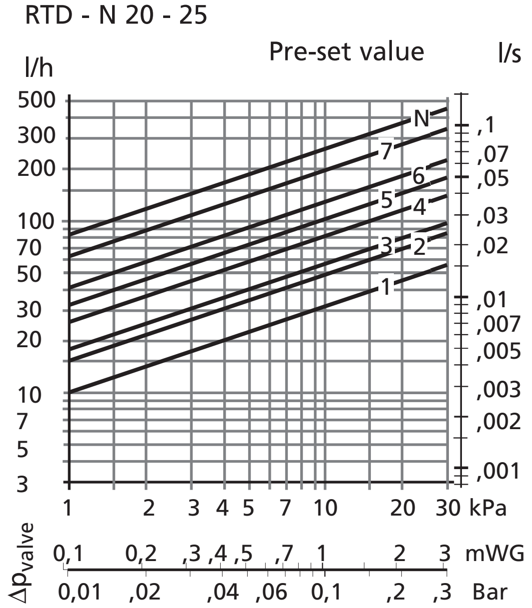


Flow chart for thermostatic valves in two-pipe system



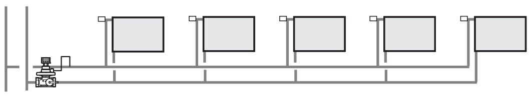


Pre-set value	1	2	3	4	5	6	7	N
kv values	0,04	0,08	0,12	0,20	0,27	0,36	0,45	0,60

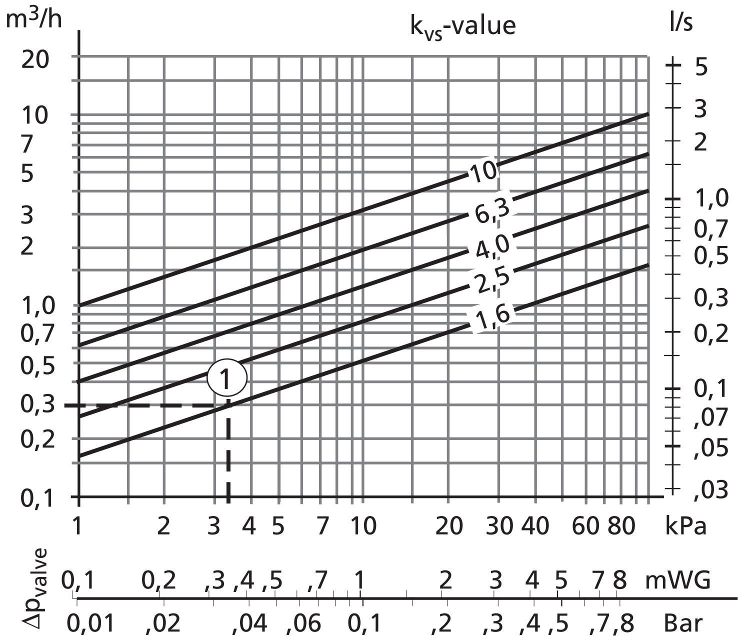


Pre-set value	1	2	3	4	5	6	7	N
kv values	0,10	0,15	0,17	0,25	0,32	0,41	0,62	0,83

Flow chart for Δp control valves for riser or circuit in heating systems.



ASV-P, PV 15-40 and ASV-M 15-40



Working range:

ASV-P 10 kPa

ASV-PV 5 - 25 kPa.

Minimum available Δp for good functioning: 8 kPa.

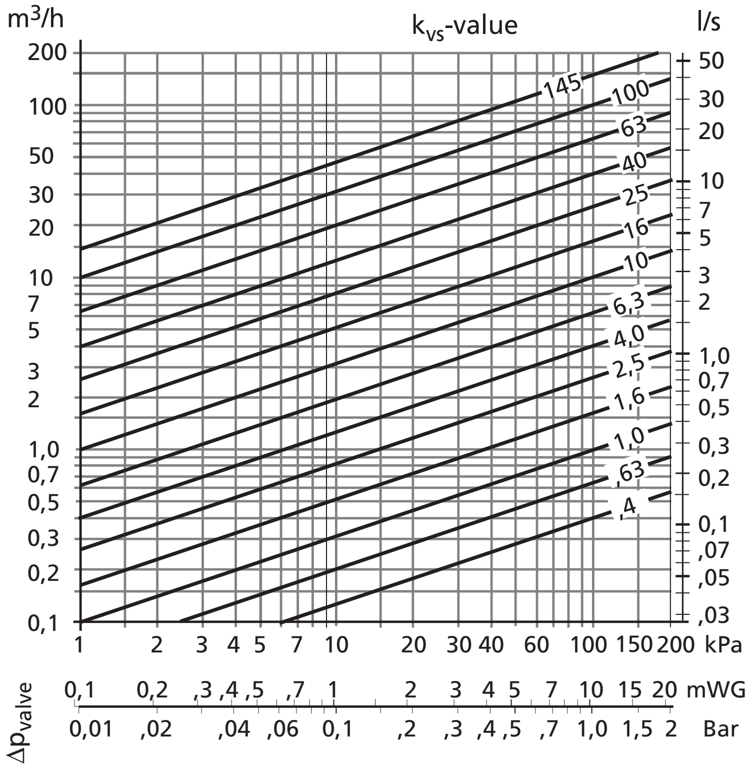
Example

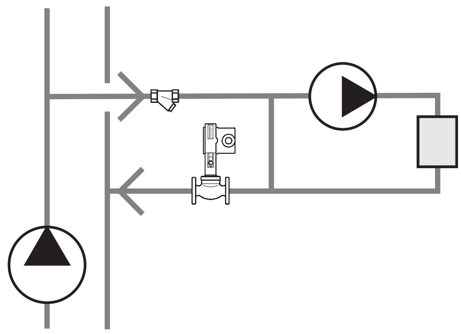
Q: 300 l/h. Δp riser: 7kPa. Δp radiator including valve: 5 kPa.

Δp-control kv 1,6. Δp_{vp} = 3,4 kPa, (1)

Necessary Δp = 7+5+8 = 20 kPa.

Flow chart for control valves in heating systems.





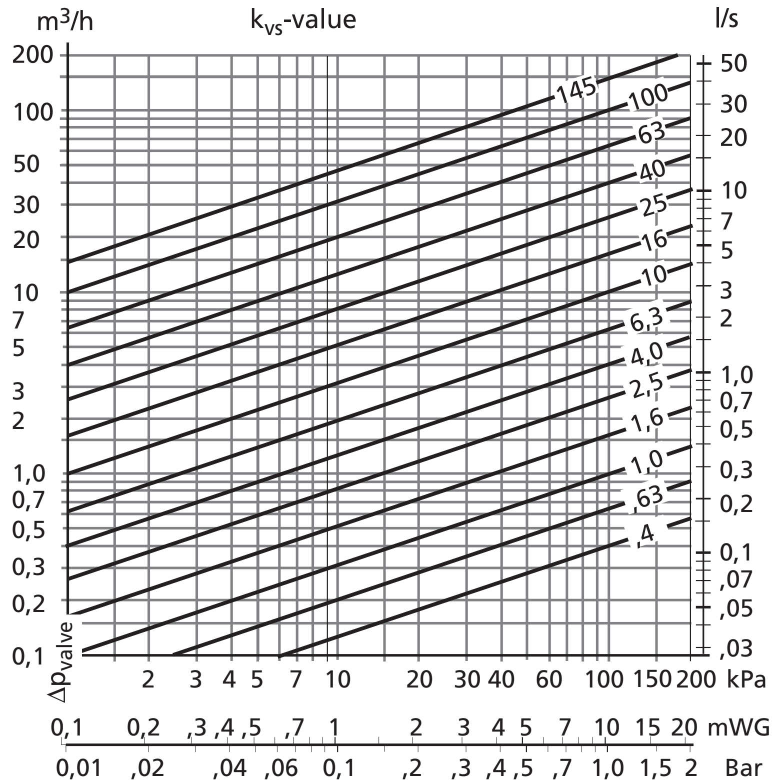
Formulas.

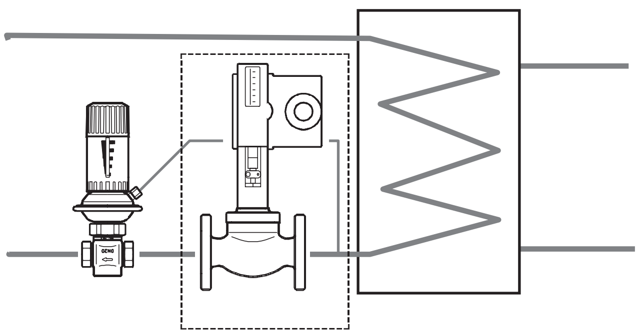
Δp : **bar.** Q: **m³/h.** $k_v = \frac{Q}{\sqrt{\Delta p}}$; $\Delta p = \left(\frac{Q}{k_v}\right)^2$; $Q = kv \frac{Q}{\sqrt{\Delta p}}$;

Δp : **kPa.** Q: **l/h.** $k_v = 0{,}01\frac{Q}{\sqrt{\Delta p}}$; $\Delta p = \left(0{,}01\frac{Q}{k_v}\right)^2$; $Q = 100x\ k_V \frac{Q}{\sqrt{\Delta p}}$;

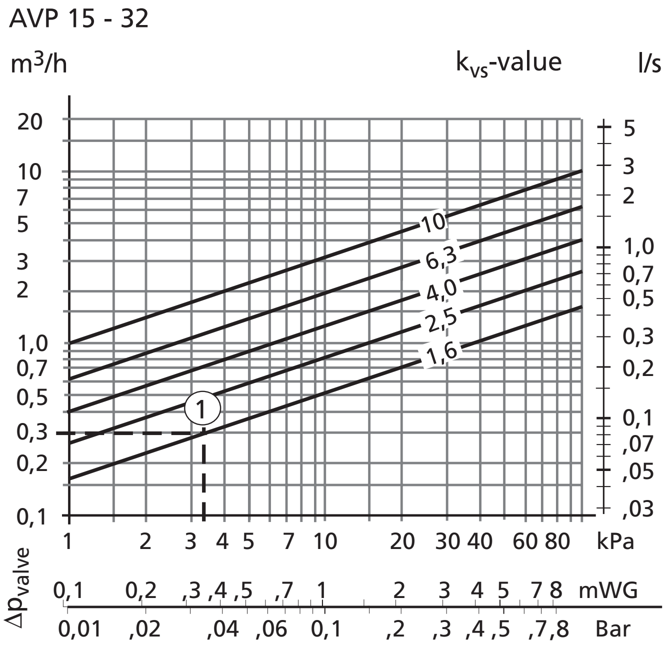
Δp : **kPa.** Q: **l/s.** $k_v = 36\frac{Q}{\sqrt{\Delta p}}$; $\Delta p = \left(36\frac{Q}{k_v}\right)^2$; $Q = \frac{k_v}{36} \frac{Q}{\sqrt{\Delta p}}$;

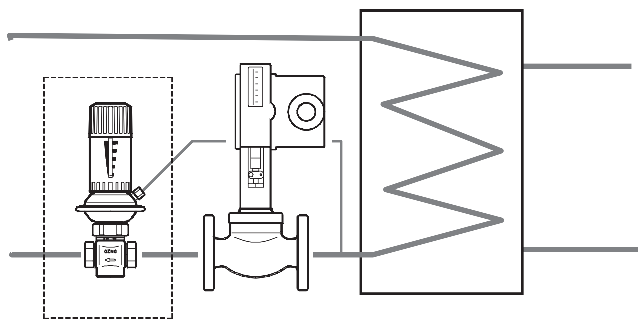
Flow chart for valves in district heating systems.



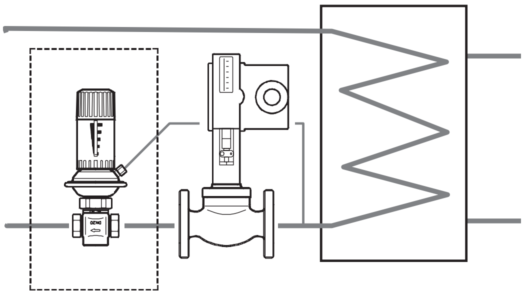


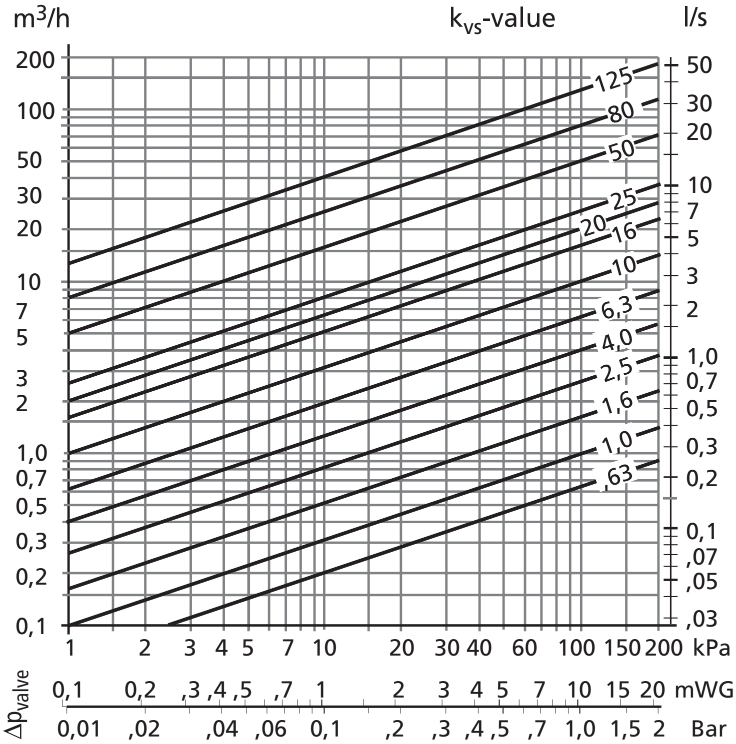
Flow chart for ∆p control valves in district heating systems.





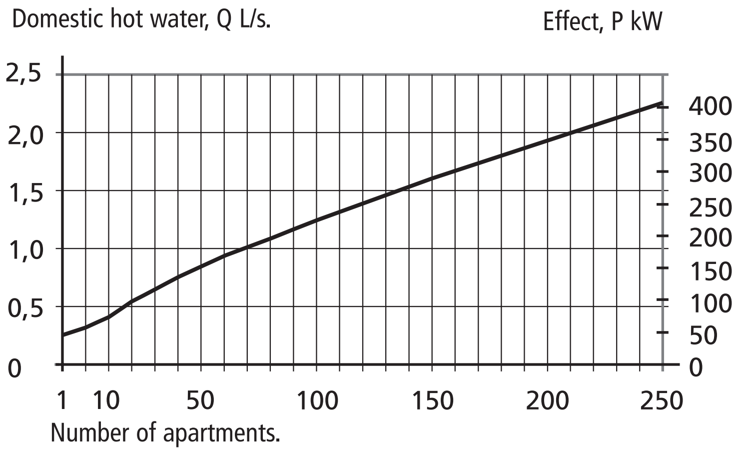
Flow chart for Δp control valves in district heating systems.



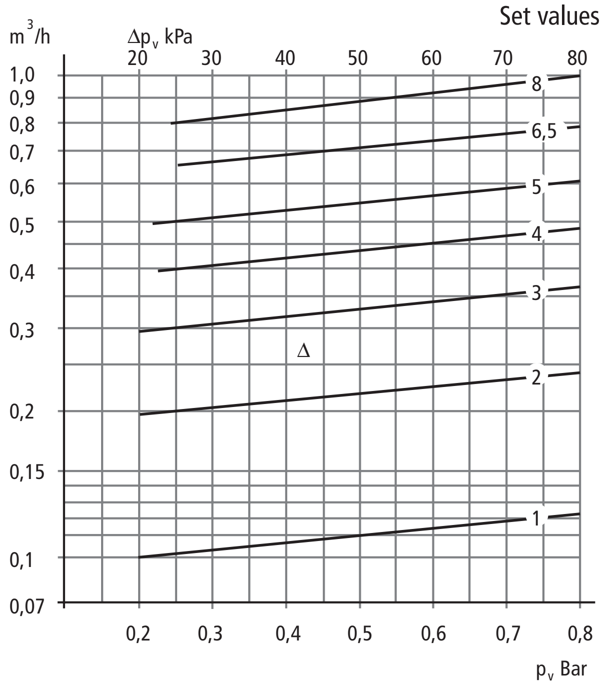


Δp-regulator, working range:	IVD 5 - 50 and 20 - 250 kPa. AFP 20 - 120 and 50 - 250 kPa
Maximum Δp valve IVF k_{vs}:	0,63 and 1,0 = 1.000 kPa 2,5 = 630 kPa 4,0 - 25 = 800 kPa
Maximum Δp valve AFP:	1.200 kPa

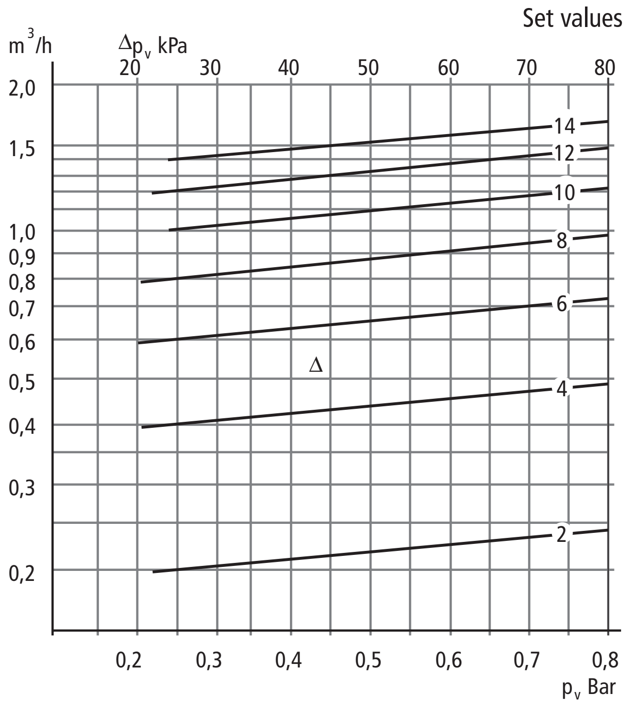
Heat requirement for hot water according to the Swedish Board of District Heating



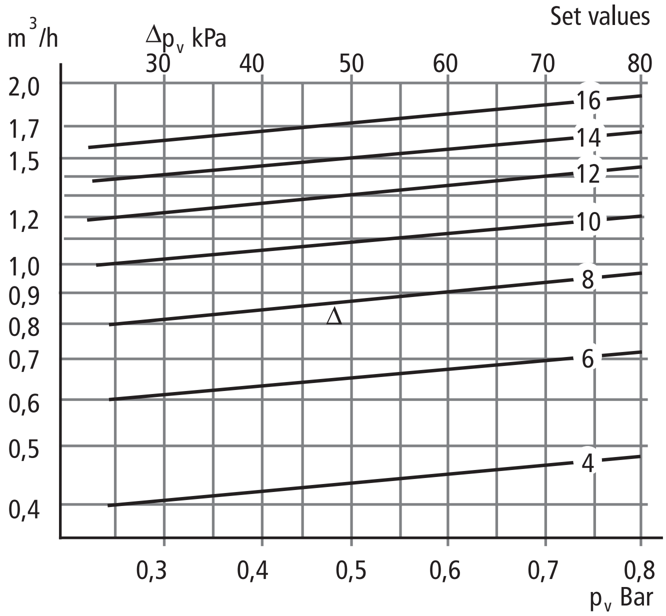
Flow limiter, ASV-Q 15, Flow limiter, ASV-Q 20

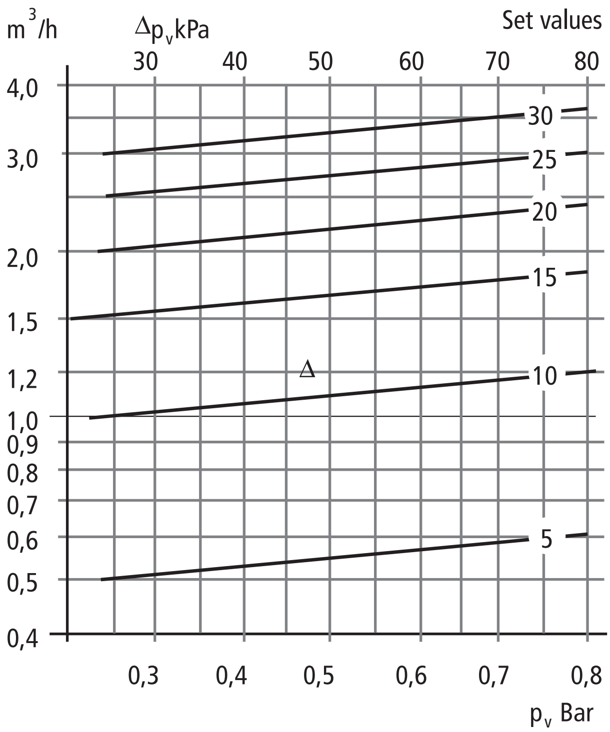


ASV-Q	Capacity l/h	Set value
15	100 - 800	1 - 8
20	200 - 1400	2 - 14
25	400 - 1600	4 - 16
32	500 - 2500	5 - 30

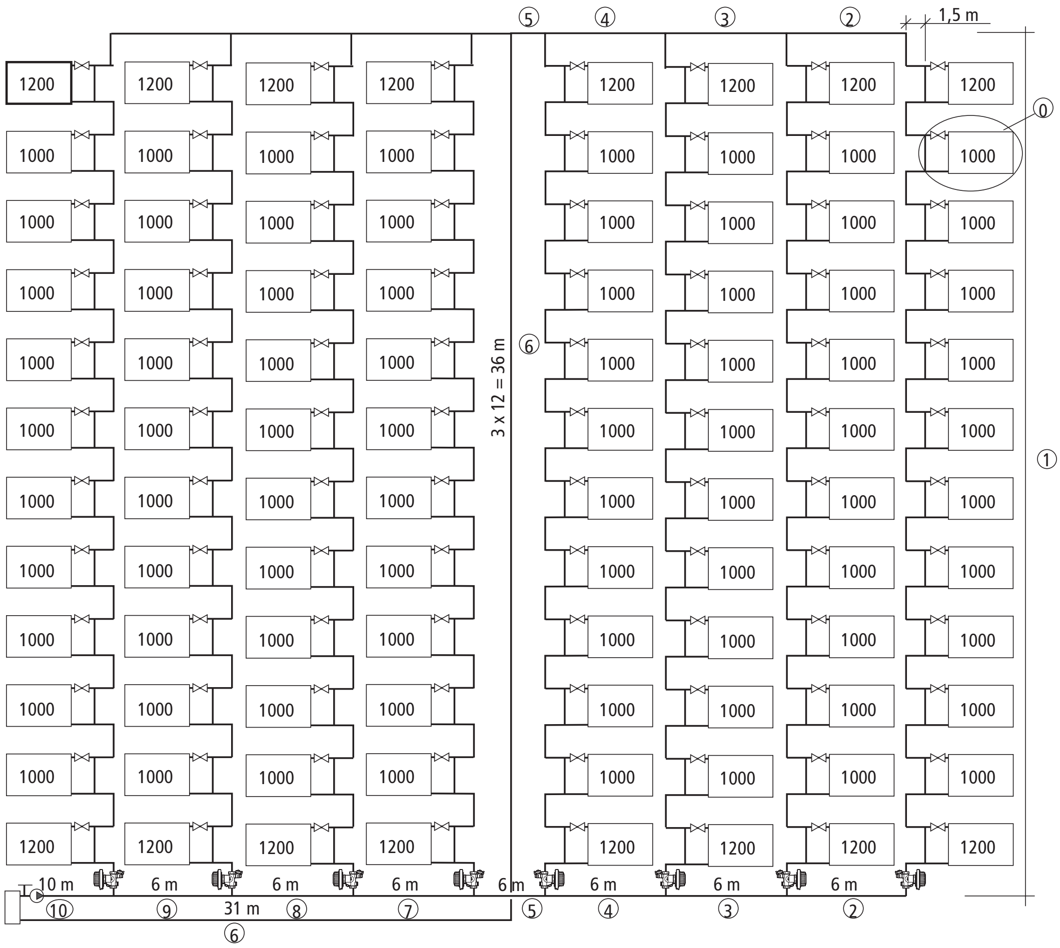


Flow limiter, ASV-Q 25, Flow limiter, ASV-Q 32





Calculation of one-pipe system



Calculation of one-pipe system

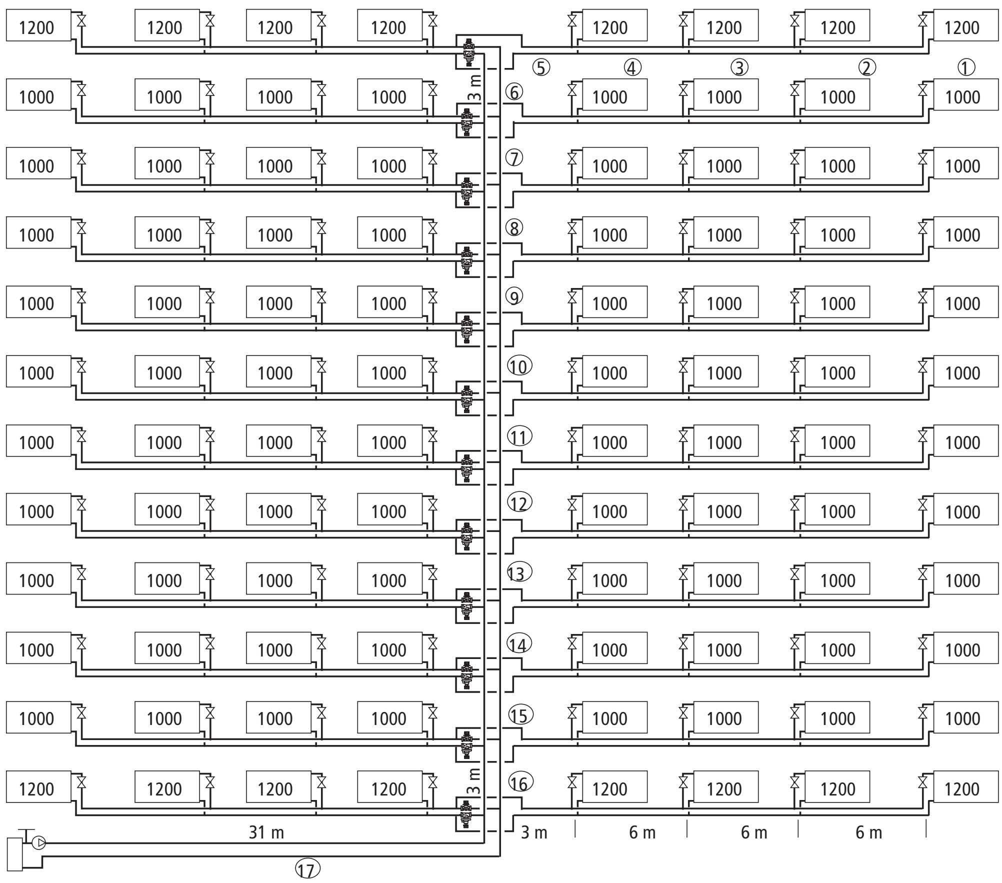
Pos. no	Heat load W	Flow l/h Δt 25 °C	Pipe length l m	Pipe size	Velocity m/s	R/m kPa	Σ ζ	R x l kPa	Z	R x l +Z kPa	Accum kPa
0	Resistance across 1 radiator (kv=2) at 30 % flow (427x0,3=128 l/h)			Δp_{rad} =(0,128/2)^2; Δp=0,0041 bar=0,41 kPa Valve 20. Δp_{valve}=0,48 kPa Σ ζ = 4; Gives 0,2 kPa						1,1x12 = 13,2	
1	12400	427	12x3+12x3=72	20	0,33	0,1		7,2	13,2	20,4	20,4
ASV-Q	12400	427		20						45	65,4*
2	12400	427	12	20	0,33	0,1	2	1,2	0,1	1,3	66,7
3	24800	854	12	25	0,41	0,1	2	1,2	0,1	1,3	68,0
4	37200	1281	12	32	0,37	0,06	2	0,7	0,2	0,9	68,9
5	49600	1708	9	32	0,52	0,11	2	1	0,3	1,3	70,2
6	99200	3413	67	50	0,44	0,05	2	3,4	0,2	3,6	73,8
7	62000	2133	6	40	0,48	0,06	1	0,4	0,12	0,5	74,3
8	74400	2559	6	40	0,55	0,12	1	0,7	0,13	0,8	75,1
9	86800	2986	6	40	0,7	0,14	1	0,8	0,2	1,0	76,1
10	99200	3413	10	50	0,44	0,05	1	0,5	0,1	0,6	76,7
Heat exchanger										15	91,7
Pump: Q= 3.413 l/h, pump head=92 kPa.											
15 % through the radiators give:											
0	Resistance across 1 radiator (kv=2) at 15 % flow (427x0,15=64 l/h)			Δp_{rad} =(0,064/2)^2; Δp=0,001 bar=0,1 kPa Valve 20. Δp_{valve}=0,2 kPa Σ ζ = 4; Gives 0,01 kPa						0,3x12 =3,6	

* The flow limiting valve ASV-Q keeps the flow constant, independent of varying available pressure.

Required pump capacity for the calculated system two- and one-pipe types respectively when thermostatic valves utilizes internal and external heat gains.

	Two-pipe circuit				One-pipe circuit		
Heat gain %	Flow %	Δt °C	Circuit resistance %	Pump capacity %	Flow %	Δt °C	Pump capacity %
0	100	25	100	100	100	25	100
10	66	33	44	29	100	22,5	100
20	47	39	22	10	100	20	100

Calculation of two-pipe system



Calculation of two-pipe system

Pos. no	Heat load W	Flow l/h Δt 25°C	Pipe length l m	Pipe size	Velocity m/s	R/m kPa	Σ ζ	R x l kPa	Z kPa	R x l +Z kPa	Accum. kPa
1	1200	41,3		15						1,2	1,2
2	1200	41,3	12	15	< 0,1	0,01	< 1	0,1	0,01	0,1	1,3
3	2400	82,6	12	15	< 0,1	0,02	2	0,2	0,02	0,2	1,5
4	3600	124	12	15	< 0,2	0,05	2	0,6	0,04	0,6	2,1
5	4800	165	6	15	0,24	0,08	2	0,5	0,06	0,6	2,7
ASV-P	9600	330		15						18	18,0 *
6	9600	330	6	20	0,25	0,08	2	0,5	0,06	0,6	18,6
7	17600	605	6	20	0,45	0,17	2	1	0,2	1,2	19,8
8	25600	880	6	25	0,41	0,11	2	0,7	0,15	0,9	20,7
9	33600	1156	6	25	0,5	0,13	2	0,8	0,25	1	21,7
10	41600	1431	6	32	0,4	0,07	2	0,4	0,15	0,7	22,4
11	49600	1706	6	32	0,5	0,1	2	0,6	0,25	0,9	23,3
12	57600	1981	6	40	0,41	0,06	2	0,4	0,15	0,6	23,9
13	65600	2257	6	40	0,5	0,09	2	0,5	0,25	0,8	24,7
14	73600	2532	6	40	0,55	0,11	2	0,7	0,30	1	25,7
15	81600	2807	6	40	0,6	0,13	2	0,8	0,35	1,2	26,9
16	89600	3082	6	40	0,65	0,16	2	1	0,4	1,4	28,3
17	99200	3413	62	50	0,45	0,05	4	3,1	0,4	3,5	31,8
Heat exchanger										15	46,8
Pump: Q = 3.413 l/h, pump head 47 kPa.											
Resistance in the smal circuit with 1000 W per radiator.											
1	1000	34		15							
2	1000	34	12	15	< 0,1	0,01	2	0,1	-	0,1	
3	2000	69	12	15	< 0,1	0,015	2	0,2	-	0,2	
4	3000	103	12	15	0,15	0,03	2	0,4	0,02	0,4	
5	4000	138	6	15	0,2	0,05	2	0,3	0,04	0,3	

* The differential pressure valve ASV-P keep Δp across the radiator circuits at 10 kPa and need another 8 kPa minimum for good functioning.

Pre-set values for the radiators in the calculated circuit.			Pre-set values for the smal circuits with 1000 W per radiator.		
Radiator no	Available Δp kPa	Pre-set value	Radiator no	Available Δp kPa	Pre-set value
4	10 - 0,6 = 9,4	3	4	10 - 0,3 = 9,7	2,5
3	9,4 - 0,6 = 8,8	3	3	9,7 - 0,4 = 9,3	2,5
2	8,8 - 0,2 = 8,6	3	2	9,3 - 0,2 = 9,1	3,0
1	8,6 - 0,1 = 8,5	3	1	9,1 - 0,1 = 9,0	3,0

Thanks to the differential pressure valve ASV-P all circuits have the same Δp available, 10 kPa.

SI-units.

Effect, P.

W	kcal/h
1	0,85985
1,163	1

Pressure, p.

Pa	kPa	bar	mWG
1	0,001	0,00001	0,0001
1.000	1	0,01	0,1
100.000	100	1	10
10.000	10	0,1	1

Flow, Q (φ).

l/s	m^3/h
1	3,6
0,278	1

Temperature, t (θ).

Kelvin K	Celsius °C
0	-273,15
273,15	± 0
373,15	100

Greek alphabet.

Α α	Β β	Γ γ	Δ δ	Ε ε	Ζ ζ	Η η	Θ θ	Ι τ
alfa	beta	gamma	delta	epsilon	seta	eta	theta	iota
Κ κ	Λ λ	Μ μ	Ν ν	Ξ ξ	Ο ο	Π π	Ρ ρ	Σ σ
kappa	lamda	my	ny	xi	omikron	pi	ro	sigma
Τ τ	Υ υ	ϑ φ	Χ χ	Ψ ψ	Ω ω			
tau	ypsilon	phi	chi	psi	omega			

Physical properties for water.

Temperature υ °C	Pressure p kPa	Density ρ kg/m^3	Isobaric heat capacitivity c_p J/ (kg x K)
0	-	999,84	4218
10	-	999,70	4192
20	-	998,205	4182
30	-	995,65	4178
40	-	992,2	4178
50	-	998,14	4181
60	-	983,21	4184
70	-	977,78	4190
80	-	971,80	4196
90	-	965,33	4205
100	1,3	958,35	4216
110	43,26	951,0	-
120	98,54	943,1	4245
130	170,11	934,8	-
140	261,36	926,1	4287
150	375,97	916,9	-