PIPE SYSTEMS

Planning Information

Calculations & measurements

ductile iron solutions
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Structural Design of Concrete Thrust Blocks

DVGW data-sheet summary GW 310-Appendix C

This summary for handling on construction sites only applies to force absorption at termination fittings, changes of direction and horizontal branch fittings. The thrust block must be symmetrical to the plane passing through the axis of the pipe bend and have a square base.

⚠ For further explanations, see the DVGW data sheet GW 310.

⚠ No concrete thrust blocks are required for restrained locking systems!

Terms / Calculation methods:

R = resulting force [kN]
N = longitudinal force due to internal pressure [kN]
d_a = external pipe diameter [cm]
p = internal pressure (test pressure) [bar]
α = bend or angle of curvature [°]
a = conversion factor, see table below.

Calculation of longitudinal force:

$N = p * (\pi * d_a 2) / 400$ [kN]

Calculation of resulting force:

$R = 2\ N * \sin(\alpha / 2) = N * a$ [kN] when $a = 2 * \sin(\alpha / 2)$, which can be taken from the "Conversion factor" table.

⚠ Values for longitudinal force and resulting force can be taken from the "Forces at the bend" table for simplification.

Calculation of thrust block area:

$A = R / \sigma_{h,w}$ [m^2] $A = b * h$ [m^2]
A = minimum thrust-block surface area at the trench wall
b = minimum thrust-block width at the trench wall
h = minimum thrust-block height at the trench wall
$\sigma_{h,w}$ = horizontal ground pressure for thrust blocks [kN/m^2]

The horizontal ground pressure depends on the soil group and the foundation depth of the thrust block and is shown in the following diagrams.

Non-cohesive soil NB:

NB1: natural gravel sharp-edged; dense gravel or sand
NB2: medium dense sandy gravel or sand
NB3: loose sandy gravel or sand

Cohesive soil B:

B1: Boulder clay, loam or clay, at least semi-solid (non-workable)
B2: Loam, silt or clay, at least stiff (difficult to work)
B3: Loam, silt or clay, at least soft (easy to work)

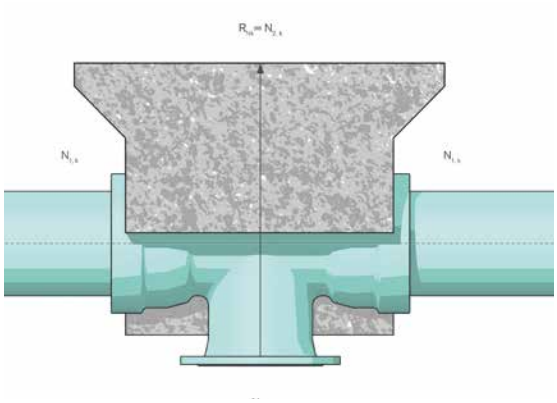
⚠ The soils must be clearly classifiable in the above soil groups. For layered soils, the value for the most unfavorable soil layer is to be used for $\sigma_{h,w}$. Concrete thrust blocks should not be installed in very soft or highly organic soils.

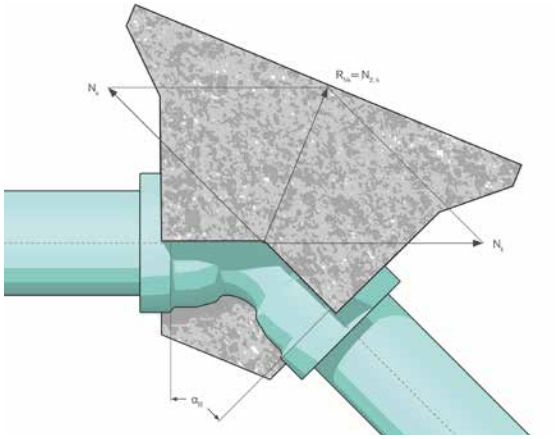
Example calculation:

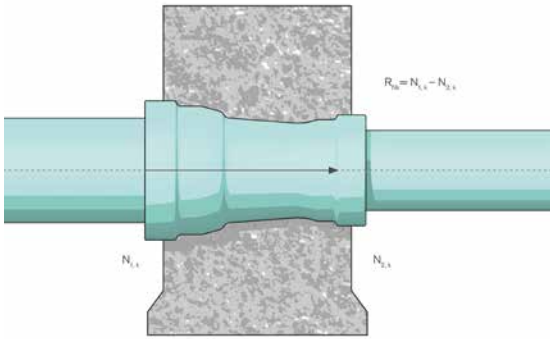
Pipe DN 300 = d_a = 32.6 cm
Test pressure p = 21 bar
MMK 30° = α_R = 30 ° --> a = 0.52
Thrust-block foundation depth h = 2.0 m
Soil group NB1 --> $\sigma_{h,w}$ = 130 kN/m^2

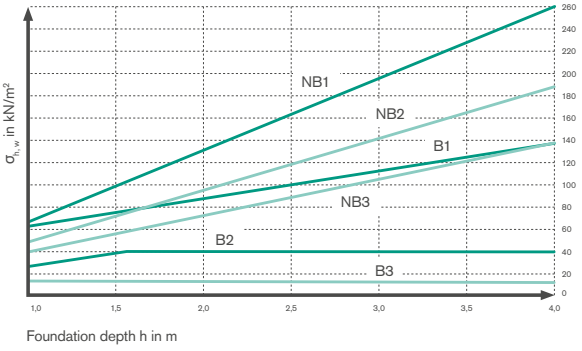
$N = p * (\pi * d_a 2) / 400 = 21 * (\pi * 32.6^2) / 400 = 175.28$ kN
$R = N * a = 175.28 * 0.52 = 91.15$ kN
$A = R / \sigma_{h,w} = 91.15 / 130 = 0.70\ m^2$
$b = h = \sqrt{A} = \sqrt{0.70} = 0.83$ m

⚠ All data are taken from the detailed tables in DVGW data sheet GW310.









Calculated value of the horizontal soil pressure $\sigma_{h,w}$ as a function of soil group and foundation depth for level terrain

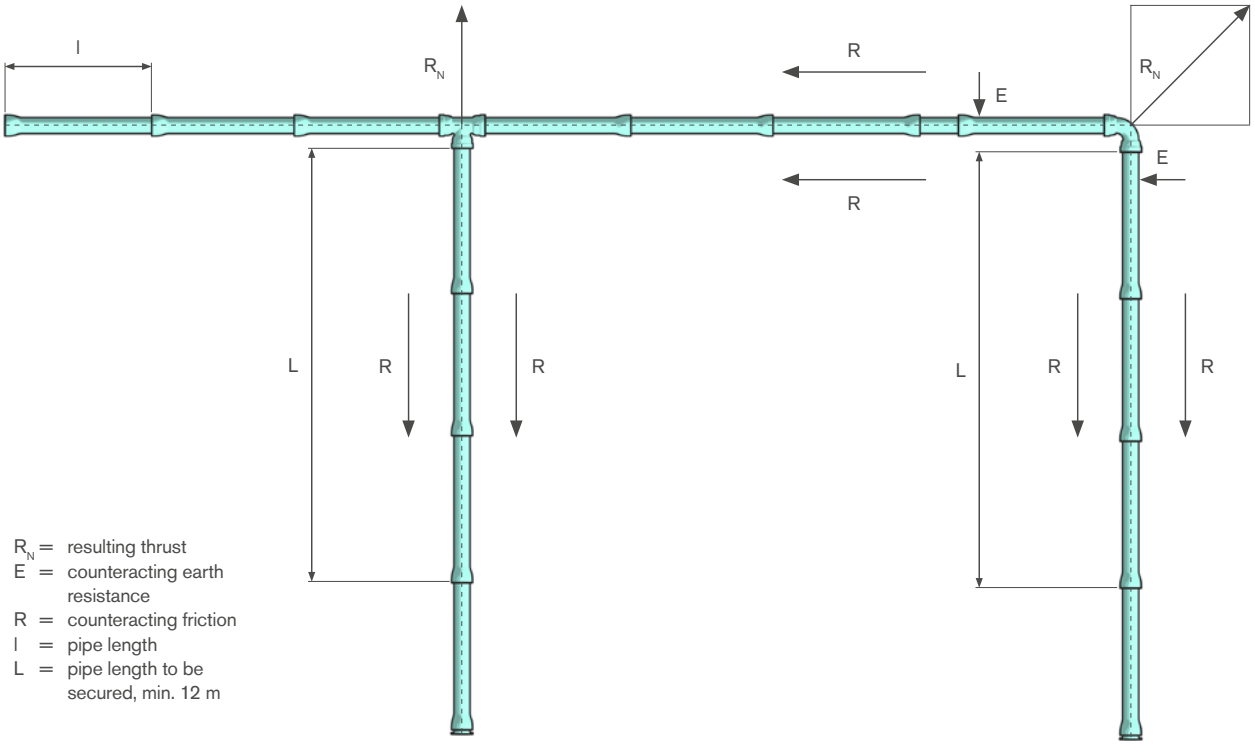
Pipe bend conversion factor

α	11° Bend	22.5° Bend	30° Bend	45° Bend	90° Bend	Termination fitting Branch fitting
a	0.2	0.3	0.52	0.77	1.41	1

Forces at bend at 1 bar (=10^5 Pa) [a]

DN	Angle of curvature	1°	2°	3°	4°	5°	11 1/4°	22 1/2°	30°	45°	90°
	Longitudinal force N	Resulting force R									
	[N]										
80	754	13	26	39	53	66	148	294	390	577	1,066
100	1,094	19	38	57	76	95	214	427	566	837	1,547
125	1,629	28	57	85	114	142	319	636	843	1,247	2,304
150	2,270	40	79	119	158	198	445	886	1,175	1,737	3,210
200	3,871	68	135	203	270	338	759	1,510	2,004	2,963	5,474
250	5,897	103	203	309	412	514	1,156	2,301	3,053	4,513	8,340
300	8,347	146	291	437	583	728	1,636	3,257	4,321	6,389	11,804
400	14,455	252	505	757	1,009	1,261	2,834	5,640	7,482	11,063	20,442
500	22,229	388	776	1,164	1,552	1,939	4,358	8,673	11,507	17,013	31,437
600	31,669	553	1,105	1,658	2,211	2,763	6,208	12,357	16,393	24,238	44,786
700	42,776	747	1,493	2,240	2,986	3,732	8,386	16,690	22,143	32,739	60,494
800	55,682	972	1,944	2,915	3,887	4,858	10,916	21,726	28,823	42,617	78,746
900	70,138	1,224	2,448	3,672	4,896	6,119	13,750	27,367	36,306	53,681	99,190
1,000	86,261	1,506	3,011	4,516	6,021	7,525	16,910	33,657	44,652	66,021	121,992

[a] Multiply the above values by the actual test pressure STP.



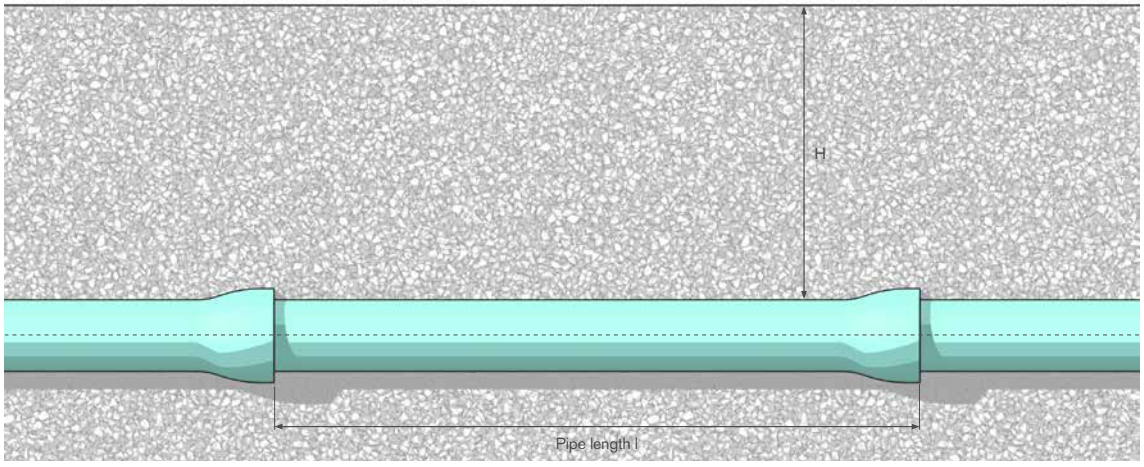
R_N = resulting thrust
E = counteracting earth resistance
R = counteracting friction
l = pipe length
L = pipe length to be secured, min. 12 m

Pipe Lengths to Be Secured

Avoiding concrete thrust blocks

Forces occur at bends, branch fittings, termination fittings and pipe reducers, and the size of these forces can be determined. In pipes with restrained locking systems e.g. welded or flanged joints, these forces are transmitted through the pipe joint; in pipes with non-restrained locking systems, e.g. plug-in sockets (TYTON® joints) or screw sockets, these forces must be transmitted:

+ by being absorbed by concrete thrust blocks (see GW 310) or
+ by producing the axial restraint of several sockets (socket securing) and transmitting it to the surrounding soil.



Soil groups according to DVGW GW 310[a]

Soil group		NB 1	NB 2	NB 3	B 1
Above groundwater	μ		0.5		0.25
	alwbl. $\sigma_{h,w}$ in kN/m²	40		30	
Below groundwater	μ		0.4		0
	alwbl. $\sigma_{h,w}$ in kN/m²	25		20	

[a] A friction coefficient of μ = 0.5 is used for cement-mortar coatings

The pipe lengths to be secured are calculated in accordance with DVGW Code of Practice GW 368. The number of pipe joints to be secured depends on:

+ the nominal pipe diameter
+ the test pressure
+ the soil group of the area around the pipe according to DVGW GW 310
+ the friction coefficient (pipe/soil) μ
+ the soil pressure
+ the pipe covering (height of pipe trench)
+ the bend angle (11°, 22°, 30°, 45°, 90°)
+ the branch fitting, termination fitting and reducer (180°)

Friction coefficient μ

The friction coefficient μ for the soil/pipe interface depends on the type of coating and the soil and is between μ = 0.1 and 0.6 if compacted properly around the pipe.

⚠ See table of soil groups according to DVGW GW 310.

The soil pressure

The possible soil pressure depends heavily on the degree of compaction of the trench filling in the immediate vicinity of the pipe. The compaction of the trench filling should be at least Dpr = 95%. In this case, the allowable horizontal soil pressure (allowable $\sigma_{h,w}$) can be reduced by 50% according to diagram GW 310 (see thrust-block calculation sheet).

⚠ For safety reasons, it is recommended to secure at least 2 pipe lengths on both sides of a bend or sectional valve, or 2 pipe lengths for a branch, termination fitting or a change in cross-section.

In the following tables, the pipe lengths L to be secured are given on the basis of the values in the "Soil groups" table.

Minimum pipe length to be secured above groundwater level depending on test pressure in m for ductile iron pipes according to EN 545

Pipe bedding	above groundwater level																	
Test pressure (STP)	15 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.50						μ = 0.50						μ = 0.25					
Soil pressure	σ_h = 40 kN/m²						σ_h = 30 kN/m²						σ_h = 30 kN/m²					
DN	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]
80	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
100	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13
125	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	16
150	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	20
200	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	26
250	12	12	12	12	12	15	12	12	12	12	12	15	12	12	12	17	26	32
300	12	12	12	12	13	18	12	12	12	12	15	18	12	12	12	23	31	38
400	12	12	12	14	19	23	12	12	13	16	21	24	12	19	27	34	43	49
500	12	12	14	19	25	29	12	14	18	22	26	29	12	30	38	45	54	59
600	12	15	19	24	30	34	12	20	23	27	31	34	12	41	48	56	64	69
700	12	20	25	30	35	39	12	25	29	32	36	39	23	52	59	66	74	79
800	12	25	30	35	40	43	16	30	34	37	41	44	34	62	69	76	83	89
900	12	30	35	39	44	48	21	35	38	42	45	48	44	71	78	85	92	98
1,000	17	35	39	44	48	52	26	39	43	46	50	52	53	80	87	94	101	106
1,200	26	43	48	52	57	60	35	48	51	54	58	60	71	97	103	110	117	122

[a] End fittings, branches, sectional valves

Pipe bedding	above groundwater level																	
Test pressure (STP)	21 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.50						μ = 0.50						μ = 0.25					
Soil pressure	σ_h = 40 kN/m²						σ_h = 30 kN/m²						σ_h = 30 kN/m²					
DN	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]
80	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	16
100	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	19
125	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	17	24
150	12	12	12	12	12	13	12	12	12	12	12	13	12	12	12	13	22	28
200	12	12	12	12	13	17	12	12	12	12	14	18	12	12	13	22	31	37
250	12	12	12	12	17	21	12	12	12	14	19	22	12	14	22	30	39	45
300	12	12	12	16	21	25	12	12	14	18	23	26	12	23	31	39	47	53
400	12	13	18	24	29	33	12	19	23	27	31	34	12	39	47	55	63	69
500	12	21	26	31	37	41	12	27	30	34	38	41	25	55	62	70	78	84
600	12	29	34	39	44	48	20	34	38	41	45	48	40	69	77	84	92	98
700	17	36	41	46	51	55	27	41	45	48	52	55	55	85	91	98	106	112
800	25	43	48	53	58	61	34	48	52	55	59	62	70	98	105	112	119	125
900	32	50	54	59	64	67	41	55	58	62	65	68	83	111	117	124	132	137
1,000	38	56	60	65	70	73	48	61	64	68	71	74	96	123	131	136	144	149
1,200	51	68	72	77	81	85	60	72	76	79	82	85	121	146	153	159	166	171

[a] End fittings, branches, sectional valves

Pipe bedding	above groundwater level																	
Test pressure (STP)	30 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.50						μ = 0.50						μ = 0.25					
Soil pressure	σ_h = 40 kN/m²						σ_h = 30 kN/m²						σ_h = 30 kN/m²					
DN	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]
80	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	17	23
100	12	12	12	12	12	13	12	12	12	12	12	13	12	12	12	13	22	28
125	12	12	12	12	12	16	12	12	12	12	13	16	12	12	12	19	28	35
150	12	12	12	12	15	19	12	12	12	12	16	20	12	12	17	26	35	41
200	12	12	12	15	21	25	12	12	14	18	23	26	12	22	30	38	47	53
250	12	12	16	21	27	31	12	16	20	24	29	32	12	34	42	50	59	65
300	12	17	22	27	33	37	12	22	26	31	34	38	15	46	54	62	72	77
400	12	28	34	39	44	48	19	34	38	42	46	49	39	69	77	85	93	99
500	20	40	45	50	55	59	30	45	49	52	57	59	61	91	99	106	115	120
600	31	50	55	60	65	69	41	55	59	63	67	69	83	112	119	127	135	140
700	41	60	65	70	75	79	51	65	69	73	77	79	104	132	140	147	155	160
800	51	70	75	80	85	88	61	75	79	82	86	89	124	152	159	166	174	179
900	61	79	84	89	94	97	71	84	88	91	95	98	143	170	177	184	191	197
1,000	70	88	93	97	102	106	80	93	96	100	103	106	161	187	194	201	208	213
1,200	88	105	109	113	118	121	97	109	113	116	119	122	195	220	226	233	240	245

[a] End fittings, branches, sectional valves

Pipe bedding	above groundwater level																	
Test pressure (STP)	45 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.50						μ = 0.50						μ = 0.25					
Soil pressure	σ_h = 40 kN/m²						σ_h = 30 kN/m²						σ_h = 30 kN/m²					
DN	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]
80	12	12	12	12	12	16	12	12	12	12	14	17	12	12	12	20	29	36
100	12	12	12	12	16	20	12	12	12	13	18	21	12	12	19	28	37	43
125	12	12	12	15	21	25	12	12	14	18	22	26	12	21	29	37	46	53
150	12	12	14	20	25	30	12	14	18	23	27	30	12	30	38	47	56	62
200	12	18	23	29	35	39	12	24	28	32	36	40	17	49	57	66	74	81
250	12	27	33	38	44	48	17	33	37	41	45	48	36	67	75	83	92	98
300	15	36	41	47	53	57	26	42	46	0	54	57	54	85	93	101	110	116
400	33	54	59	64	70	73	44	59	63	67	71	74	89	120	127	135	143	149
500	50	70	75	80	86	89	60	75	79	83	87	90	122	152	160	167	175	181
600	66	85	90	95	101	104	76	91	94	98	102	105	154	183	190	198	206	211
700	82	101	106	110	116	119	92	106	109	113	117	120	185	213	220	228	235	241

[a] End fittings, branches, sectional valves

Minimum pipe length to be secured below groundwater level depending on test pressure in m for ductile iron pipes according to EN 545

Pipe bedding	below groundwater level																	
Test pressure (STP)	15 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.40						μ = 0.40						μ = 0					
Soil pressure	σ_h = 25 kN/m²						σ_h = 20 kN/m²						σ_h = 20 kN/m²					
DN	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]
80	12	12	12	12	12	12	12	12	12	12	12	12	the entire pipe should be secured with restrained locking systems					
100	12	12	12	12	12	12	12	12	12	12	12	12						
125	12	12	12	12	12	12	12	12	12	12	12	12						
150	12	12	12	12	12	12	12	12	12	12	12	12						
200	12	12	12	12	13	16	12	12	12	12	13	16						
250	12	12	12	12	16	20	12	12	12	14	17	20						
300	12	12	12	16	20	23	12	12	14	17	21	23						
400	12	15	19	23	27	30	12	18	21	24	28	30						
500	12	22	26	30	34	37	13	25	28	31	35	37						
600	13	28	32	36	40	43	19	32	35	38	41	43						
700	20	35	39	42	46	49	26	38	41	44	47	50						
800	27	41	45	48	52	55	33	44	47	50	53	55						
900	33	47	50	54	58	61	39	50	53	56	59	61						
1,000	39	52	55	59	63	66	44	55	58	61	64	66						
1,200	50	63	66	70	73	76	55	66	68	71	74	76						

[a] End fittings, branches, sectional valves

Pipe bedding	below groundwater level																	
Test pressure (STP)	21 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.40						μ = 0.40						μ = 0					
Soil pressure	σ_h = 25 kN/m²						σ_h = 20 kN/m²						σ_h = 20 kN/m²					
DN	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]	11°	22°	30°	45°	90°	180°[a]
80	12	12	12	12	12	12	12	12	12	12	12	12	the entire pipe should be secured with restrained locking systems					
100	12	12	12	12	12	12	12	12	12	12	12	12						
125	12	12	12	12	12	14	12	12	12	12	12	15						
150	12	12	12	12	14	17	12	12	12	12	15	18						
200	12	12	12	15	19	23	12	12	13	17	20	23						
250	12	12	16	20	25	28	12	15	19	22	26	28						
300	12	17	21	25	30	33	12	20	24	27	31	33						
400	12	27	31	35	40	42	18	31	34	37	41	43						
500	21	37	41	45	49	52	28	40	43	46	50	52						
600	31	46	50	54	58	61	37	49	52	55	59	61						
700	40	55	59	63	67	70	46	58	61	64	67	70						
800	49	64	67	71	75	78	55	67	70	73	76	78						
900	57	72	75	79	83	85	63	75	77	80	83	86						
1,000	65	79	83	86	90	93	71	82	85	88	91	93						
1,200	80	94	97	100	104	107	86	97	99	102	105	107						

[a] End fittings, branches, sectional valves

Pipe bedding	below groundwater level																	
Test pressure (STP)	30 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.40						μ = 0.40						μ = 0					
Soil pressure	σ_h = 25 kN/m²						σ_h = 20 kN/m²						σ_h = 20 kN/m²					
DN	11°	22°	30°	45°	90°	180° [a]	11°	22°	30°	45°	90°	180° [a]	11°	22°	30°	45°	90°	180° [a]
80	12	12	12	12	12	14	12	12	12	12	12	14	the entire pipe should be secured with restrained locking systems					
100	12	12	12	12	14	17	12	12	12	12	15	18						
125	12	12	12	13	18	21	12	12	12	15	19	22						
150	12	12	13	17	22	25	12	12	16	19	23	25						
200	12	17	21	25	30	33	12	20	23	27	31	33						
250	12	24	28	33	37	40	15	28	31	34	38	41						
300	15	32	36	40	44	48	22	35	38	42	45	48						
400	30	46	50	54	59	62	37	49	53	56	59	62						
500	44	60	64	68	72	75	51	63	66	69	73	75						
600	58	73	76	80	84	87	64	76	79	82	85	88						
700	71	85	89	93	97	100	77	88	91	94	98	100						
800	83	97	101	105	109	112	89	100	103	106	110	112						
900	95	109	112	116	120	123	100	112	115	117	121	123						
1,000	106	119	123	127	130	133	111	122	125	128	131	133						
1,200	127	140	143	147	150	153	132	143	145	148	151	153						

[a] End fittings, branches, sectional valves

Pipe bedding	below groundwater level																	
Test pressure (STP)	45 bar																	
Pipe covering	H = 1.00 m																	
Soil group	NB1						NB2 / NB3						B1					
Friction coefficient	μ = 0.40						μ = 0.40						μ = 0					
Soil pressure	σ_h = 25 kN/m²						σ_h = 20 kN/m²						σ_h = 20 kN/m²					
DN	11°	22°	30°	45°	90°	180° [a]	11°	22°	30°	45°	90°	180° [a]	11°	22°	30°	45°	90°	180° [a]
80	12	12	12	14	19	22	12	12	12	16	20	22	the entire pipe should be secured with restrained locking systems					
100	12	12	14	19	23	27	12	13	17	20	24	27						
125	12	16	20	25	29	33	12	20	23	26	30	33						
150	12	22	26	31	35	38	12	25	29	32	36	39						
200	17	34	38	42	47	50	24	37	41	44	48	50						
250	29	45	49	53	58	61	35	49	52	55	59	61						
300	40	56	60	64	69	72	47	59	63	66	70	72						
400	62	78	82	86	90	93	68	81	84	87	91	93						
500	82	98	102	106	110	113	89	101	104	107	111	113						
600	102	117	121	125	129	132	108	120	123	126	130	132						
700	121	136	140	143	147	150	127	139	142	145	148	151						

[a] End fittings, branches, sectional valves

Hydraulic Calculation

Pipe efficiency

A calculation is necessary to ensure the hydraulic performance of the pipe. High flow velocities lead to considerable pressure losses. Particularly with long pressure lines, the flow velocity has a major influence on the efficiency of the entire supply system. Low flow velocities result in long retention times (stagnation). Here, for hygienic reasons, care must be taken to ensure sufficient water exchange (water turbidity, microbial contamination).

The hydraulic calculation for drinking-water pipes is governed by DVGW Code of Practice GW 303-1. The flow velocities are primarily between 1.0 m/s and 2.0 m/s. Among other things, GW 303-1 specifies the operational roughness (k_2 – integral roughness) of pipe networks. The integral roughness combines all resistance-forming parts of a pipe or network such as wall roughness, socket transitions, deposits and the effect of pipe installations (valves, bends, branch fittings, reductions, etc.). The following values have been defined for all pipe materials:

k_2 = 0.1 mm for long-distance and feeder pipes
k_2 = 0.4 mm for main pipes
k_2 = 1.0 mm for supply pipes

⚠ A program based on the DVGW Code of Practice GW 303-1 can be downloaded free of charge from **www.eadips.org** in the "Calculation tools" section.

Pressure loss table DN 80

Q [l/s]	DN 80			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
0.5	0.1	0.232	0.258	0.303
0.6	0.12	0.32	0.36	0.427
0.7	0.14	0.42	0.477	0.572
0.8	0.16	0.532	0.61	0.737
0.9	0.18	0.656	0.758	0.924
1	0.2	0.791	0.992	1.13
1.25	0.25	1.181	1.4	1.738
1.5	0.3	1.641	1.975	2.474
1.75	0.35	2.171	2.645	3.339
2	0.4	2.77	3.412	4.334
2.25	0.45	3.438	4.274	5.457
2.5	0.5	4.173	5.233	6.71
2.75	0.55	4.976	6.287	8.091
3	0.6	5.846	7.437	9.601
3.25	0.65	6.784	8.683	11.24
3.5	0.7	7.788	10.03	13.01
3.75	0.75	8.859	11.46	14.91
4	0.8	9.996	13	16.93
4.25	0.85	11.2	14.63	19.09
4.5	0.9	12.47	16.35	21.37
4.75	0.94	13.81	18.17	23.78
5	0.99	15.21	20.09	26.33
5.25	1.04	16.68	22.1	29
5.5	1.09	18.21	24.21	31.8
5.75	1.14	19.81	26.41	34.72
6	1.19	21.48	28.71	37.78
6.25	1.24	23.21	31.1	40.97
6.5	1.29	25.01	33.59	44.28
6.75	1.34	26.87	36.18	47.73
7	1.39	28.8	38.86	51.3
7.25	1.44	30.8	41.64	55.01
7.5	1.49	32.86	44.51	58.84
7.75	1.54	34.98	47.48	62.8
8	1.59	37.18	50.54	66.89
8.25	1.64	39.43	53.7	71.1
8.5	1.69	41.76	56.96	75.45
8.75	1.74	44.15	60.31	79.93
9	1.79	46.6	63.76	84.53
9.25	1.84	49.12	67.3	89.27
9.5	1.89	51.71	70.94	94.13
9.75	1.94	54.36	74.67	99.12
10	1.99	57.07	78.5	104.2
10.25	2.04	59.86	82.43	109.5
10.5	2.09	62.71	86.45	114.9
10.75	2.14	65.62	90.57	120.4
11	2.19	68.6	94.78	126
11.5	2.29	74.75	103.5	137.7

Pressure loss table DN 80

Q [l/s]	DN 80			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
12	2.39	81.17	112.6	149.9
12.5	2.49	87.85	122.1	162.5
13	2.59	94.79	131.9	175.8
13.5	2.69	102	142.2	189.5
14	2.79	109.5	152.8	203.7
14.5	2.88	117.2	163.8	218.5
15	2.98	125.2	175.2	233.7
15.5	3.08	133.4	187	249.5
16	3.18	141.9	199.1	265.8
16.5	3.28	150.7	211.7	282.6
17	3.38	159.7	224.6	300
17.5	3.48	169	237.9	317.8
18	3.58	178.6	251.6	336.2
18.5	3.68	188.4	265.6	355.1
19	3.78	198.5	280.1	374.5
19.5	3.88	208.8	294.9	394.4
20	3.98	219.4	310.2	414.8
20.5	4.08	230.3	325.8	435.8
21	4.18	241.4	341.7	457.2
21.5	4.28	252.8	358.1	479.2
22	4.38	264.5	374.9	–
22.5	4.48	276.4	392	–
23	4.58	288.6	409.5	–
23.5	4.68	301	427.4	–
24	4.77	313.7	445.7	–
24.5	4.87	326.6	464.3	–
25	4.97	339.9	483.4	–
25.5	5.07	353.3	–	–
26	5.17	367.1	–	–
26.5	5.27	381.1	–	–
27	5.37	395.4	–	–
27.5	5.47	409.9	–	–
28	5.57	424.7	–	–
28.5	5.67	439.7	–	–
29	5.77	455	–	–
29.5	5.87	470.6	–	–
30	5.97	486.5	–	–

Pressure loss table DN 100

Q [l/s]	DN 100			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
0.6	0.08	0.11	0.12	0.137
0.7	0.09	0.144	0.158	0.183
0.8	0.1	0.182	0.201	0.235
0.9	0.11	0.224	0.249	0.293
1	0.13	0.269	0.302	0.357
1.25	0.16	0.4	0.456	0.546
1.5	0.19	0.554	0.639	0.774
1.75	0.22	0.73	0.852	1.041
2	0.25	0.929	1.095	1.347
2.25	0.29	1.149	1.367	1.693
2.5	0.32	1.392	1.669	2.077
2.75	0.35	1.656	2	2.501
3	0.38	1.941	2.361	2.964
3.25	0.41	2.247	2.751	3.466
3.5	0.45	2.575	3.171	4.007
3.75	0.48	2.924	3.62	4.587
4	0.51	3.294	4.099	5.207
4.25	0.54	3.684	4.607	5.865
4.5	0.57	4.096	5.144	6.563
4.75	0.6	4.528	5.71	7.3
5	0.64	4.982	6.306	8.076
5.25	0.67	5.456	6.932	8.891
5.5	0.7	5.95	7.587	9.745
5.75	0.73	6.466	8.271	10.64
6	0.76	7.002	8.984	11.57
6.25	0.8	7.558	9.727	12.54
6.5	0.83	8.136	10.5	13.55
6.75	0.86	8.733	11.3	14.6
7	0.89	9.352	12.13	15.69
7.25	0.92	9.991	12.99	16.82
7.5	0.95	10.65	13.88	17.99
7.75	0.99	11.33	14.8	19.19
8	1.02	12.03	15.75	20.44
8.25	1.05	12.75	16.73	21.72
8.5	1.08	13.49	17.73	23.05
8.75	1.11	14.25	18.77	24.41
9	1.15	15.04	19.84	25.81
9.25	1.18	15.84	20.93	27.25
9.5	1.21	16.66	22.05	28.73
9.75	1.24	17.51	23.21	30.25
10	1.27	18.37	24.39	31.81
10.25	1.31	19.26	25.6	33.41
10.5	1.34	20.16	26.85	35.05
10.75	1.37	21.09	28.12	36.72
11	1.4	22.03	29.42	38.44
11.5	1.46	23.98	32.11	41.98
12	1.53	26.02	34.91	45.69
12.5	1.59	28.13	37.84	49.55

Pressure loss table DN 100

Q [l/s]	DN 100			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
13	1.66	30.33	40.88	53.57
13.5	1.72	32.61	44.03	57.74
14	1.78	34.97	47.31	62.07
14.5	1.85	37.41	50.7	66.55
15	1.91	39.93	54.21	71.2
15.5	1.97	42.53	57.84	76
16	2.04	45.22	61.59	80.95
16.5	2.1	47.99	65.45	86.07
17	2.16	50.83	69.43	91.33
17.5	2.23	53.76	73.52	96.76
18	2.29	56.77	77.74	102.3
18.5	2.36	59.86	82.07	108.1
19	2.42	63.04	86.52	114
19.5	2.48	66.29	91.09	120
20	2.55	69.63	95.77	126.2
20.5	2.61	73.04	100.6	132.6
21	2.67	76.54	105.5	139.1
21.5	2.74	80.12	110.5	145.8
22	2.8	83.78	115.7	152.6
22.5	2.86	87.52	120.9	159.6
23	2.93	91.34	126.3	166.8
23.5	2.99	95.24	131.8	174.1
24	3.06	99.23	137.5	181.5
24.5	3.12	103.3	143.2	189.1
25	3.18	107.4	149.1	196.9
25.5	3.25	111.7	155	204.9
26	3.31	116	161.1	212.9
26.5	3.37	120.4	167.3	221.2
27	3.44	124.8	173.7	229.6
27.5	3.5	129.4	180.1	238.1
28	3.57	134	186.7	246.8
28.5	3.63	138.7	193.3	255.7
29	3.69	143.5	200.1	264.7
29.5	3.76	148.4	207.1	273.9
30	3.82	153.4	214.1	283.3
30.5	3.88	158.4	221.2	292.8
31	3.95	163.5	228.5	302.4
31.5	4.01	168.7	235.9	312.2
32	4.07	174	243.4	322.2
32.5	4.14	179.4	251	332.3

Pressure loss table DN 125

Q [l/s]	DN 125			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
1	0.08	0.9	0.098	0.112
1.25	0.1	0.134	0.147	0.17
1.5	0.12	0.184	0.205	0.24
1.75	0.14	0.242	0.272	0.321
2	0.16	0.307	0.348	0.414
2.25	0.18	0.379	0.433	0.518
2.5	0.2	0.458	0.527	0.635
2.75	0.22	0.544	0.63	0.762
3	0.24	0.636	0.742	0.902
3.25	0.26	0.736	0.862	1.053
3.5	0.28	0.841	0.992	1.216
3.75	0.3	0.954	1.13	1.39
4	0.32	1.073	1.277	1.576
4.25	0.34	1.198	1.433	1.773
4.5	0.36	1.33	1.598	1.983
4.75	0.38	1.468	1.772	2.203
5	0.4	1.613	1.954	2.436
5.25	0.42	1.765	2.146	2.68
5.5	0.44	1.922	2.346	2.935
5.75	0.46	2.086	2.555	3.203
6	0.48	2.257	2.772	3.481
6.25	0.5	2.434	2.999	3.772
6.5	0.52	2.617	3.234	4.074
6.75	0.54	2.806	3.479	4.387
7	0.56	3.002	3.732	4.713
7.25	0.59	3.204	3.993	5.049
7.5	0.61	3.413	4.264	5.398
7.75	0.63	3.628	4.543	5.758
8	0.65	3.849	4.831	6.13
8.25	0.67	4.076	5.128	6.513
8.5	0.69	4.31	5.434	6.908
8.75	0.71	4.55	5.749	7.314
9	0.73	4.796	6.072	7.732
9.25	0.75	5.048	6.404	8.162
9.5	0.77	5.307	6.745	8.603
9.75	0.79	5.572	7.095	9.056
10	0.81	5.843	7.454	9.521
10.5	0.85	6.404	8.197	10.48
11	0.89	6.99	8.976	11.49
11.5	0.93	7.601	9.79	12.55
12	0.97	8.237	10.64	13.65
12.5	1.01	8.897	11.52	14.8
13	1.05	9.583	12.44	16
13.5	1.09	10.29	13.4	17.24
14	1.13	11.03	14.39	18.53
14.5	1.17	11.79	15.41	19.87
15	1.21	12.57	16.47	21.25
15.5	1.25	13.38	17.57	22.68

Pressure loss table DN 125

Q [l/s]	DN 125			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
16	1.29	14.22	18.7	24.15
16.5	1.33	15.07	19.86	25.67
17	1.37	15.96	21.06	27.24
17.5	1.41	16.87	22.3	28.85
18	1.45	17.8	23.57	30.51
18.5	1.49	18.76	24.88	32.22
19	1.53	19.74	26.22	33.97
19.5	1.57	20.75	27.59	35.77
20	1.61	21.78	29.01	37.62
20.5	1.65	22.83	30.45	39.51
21	1.69	23.91	31.93	41.45
21.5	1.74	25.02	33.45	43.44
22	1.78	26.15	35	45.47
22.5	1.82	27.31	36.59	47.54
23	1.86	28.49	38.21	49.67
23.5	1.9	29.69	39.87	51.84
24	1.94	30.92	41.56	54.06
24.5	1.98	32.17	43.29	56.32
25	2.02	33.45	45.06	58.63
25.5	2.06	34.75	46.85	60.99
26	2.1	36.08	48.69	63.39
26.5	2.14	37.43	50.56	65.84
27	2.18	38.81	52.46	68.34
27.5	2.22	40.21	54.4	70.88
28	2.26	41.64	56.37	73.47
28.5	2.3	43.09	58.38	76.1
29	2.34	44.56	60.43	78.78
29.5	2.38	46.06	62.51	81.51
30	2.42	47.59	64.62	84.29
30.5	2.46	49.13	66.77	87.11
31	2.5	50.71	68.96	89.97
31.5	2.54	52.31	71.18	92.89
32	2.58	53.93	73.43	95.85
32.5	2.62	55.58	75.72	98.85
33	2.66	57.25	78.05	101.9
33.5	2.7	58.94	80.41	105
34	2.74	60.67	82.81	108.2
34.5	2.78	62.41	85.24	111.3
35	2.82	64.18	87.7	114.6
35.5	2.87	65.98	90.21	117.9
36	2.91	67.8	92.74	121.2
36.5	2.95	69.64	95.31	124.6
37	2.99	71.51	97.92	128
37.5	3.03	73.4	100.6	131.5
38	3.07	75.32	103.2	135
38.5	3.11	77.26	106	138.6
39	3.15	79.23	108.7	142.2
39.5	3.19	81.22	111.5	145.8

Pressure loss table DN 125

Q [l/s]	DN 125			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
40	3.23	83.24	114.3	149.5
40.5	3.27	85.28	117.2	153.3
41	3.31	87.34	120	157.1
41.5	3.35	89.43	123	160.9
42	3.39	91.55	125.9	164.8
42.5	3.43	93.69	128.9	168.7
43	3.47	95.85	131.9	172.7
43.5	3.51	98.04	135	176.7
44	3.55	100.3	138.1	180.8
44.5	3.59	102.5	141.2	184.9
45	3.63	104.8	144.4	189.1
45.5	3.67	107	147.6	193.3
46	3.71	109.3	150.9	197.6
46.5	3.75	111.7	154.1	201.9
47	3.79	114	157.4	206.2
47.5	3.83	116.4	160.8	210.6
48	3.87	118.8	164.2	215.1
48.5	3.91	121.3	167.6	219.6
49	3.95	123.7	171	224.1
49.5	4	126.2	174.5	228.7
50	4.04	128.7	178	233.3
51	4.12	133.8	185.2	242.7
52	4.2	139	192.5	252.3
53	4.28	144.3	199.9	262.1
54	4.36	149.7	207.5	272.1
55	4.44	155.2	215.2	282.2
56	4.52	160.7	223	292.5
57	4.6	166.4	231	303
58	4.68	172.2	239.2	313.7
59	4.76	178.1	247.4	324.6
60	4.84	184	255.8	335.7
62	5	196.3	273.1	358.4
64	5.17	208.9	290.9	381.9
66	5.33	221.9	309.3	406
68	5.49	235.4	328.2	431
70	5.65	249.2	347.7	456.7
72	5.81	263.4	367.8	483.1
74	5.97	278	388.4	–

Pressure loss table DN 150

Q [l/s]	DN 150			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
1.5	0.08	0.076	0.083	0.094
1.75	0.1	0.1	0.109	0.125
2	0.11	0.127	0.139	0.161
2.25	0.13	0.156	0.173	0.201
2.5	0.14	0.188	0.21	0.246
2.75	0.15	0.223	0.25	0.295
3	0.17	0.26	0.294	0.348
3.25	0.18	0.301	0.341	0.406
3.5	0.2	0.343	0.392	0.468
3.75	0.21	0.389	0.446	0.534
4	0.22	0.437	0.503	0.605
4.25	0.24	0.487	0.564	0.68
4.5	0.25	0.54	0.628	0.76
4.75	0.27	0.596	0.695	0.843
5	0.28	0.654	0.766	0.932
5.25	0.29	0.715	0.84	1.024
5.5	0.31	0.778	0.917	1.121
5.75	0.32	0.844	0.998	1.222
6	0.34	0.912	1.082	1.328
6.25	0.35	0.983	1.17	1.438
6.5	0.36	1.056	1.26	1.552
6.75	0.38	1.131	1.355	1.671
7	0.39	1.209	1.452	1.794
7.25	0.4	1.29	1.553	1.922
7.5	0.42	1.373	1.657	2.053
7.75	0.43	1.458	1.764	2.19
8	0.45	1.546	1.875	2.33
8.25	0.46	1.637	1.989	2.475
8.5	0.47	1.729	2.107	2.624
8.75	0.49	1.824	2.228	2.778
9	0.5	1.922	2.352	2.936
9.25	0.52	2.022	2.479	3.098
9.5	0.53	2.125	2.61	3.265
9.75	0.54	2.229	2.744	3.436
10	0.56	2.337	2.882	3.611
10.5	0.59	2.559	3.166	3.975
11	0.61	2.79	3.465	4.356
11.5	0.64	3.031	3.776	4.755
12	0.67	3.282	4.101	5.171
12.5	0.7	3.542	4.439	5.604
13	0.73	3.812	4.791	6.055
13.5	0.75	4.091	5.155	6.523
14	0.78	4.38	5.533	7.009
14.5	0.81	4.678	5.925	7.512
15	0.84	4.986	6.329	8.033
15.5	0.87	5.303	6.747	8.571
16	0.89	5.63	7.179	9.126
16.5	0.92	5.967	7.623	9.699

Pressure loss table DN 150

Q [l/s]	DN 150			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
17	0.95	6.313	8.081	10.29
17.5	0.98	6.668	8.552	10.9
18	1.01	7.033	9.037	11.52
18.5	1.03	7.407	9.535	12.17
19	1.06	7.791	10.05	12.83
19.5	1.09	8.184	10.57	13.5
20	1.12	8.587	11.11	14.2
20.5	1.14	8.999	11.66	14.91
21	1.17	9.421	12.22	15.64
21.5	1.2	9.852	12.8	16.39
22	1.23	10.29	13.39	17.15
22.5	1.26	10.74	14	17.93
23	1.28	11.2	14.61	18.73
23.5	1.31	11.67	15.24	19.55
24	1.34	12.15	15.89	20.38
24.5	1.37	12.64	16.55	21.24
25	1.4	13.13	17.22	22.1
25.5	1.42	13.64	17.9	22.99
26	1.45	14.16	18.6	23.89
26.5	1.48	14.68	19.31	24.82
27	1.51	15.22	20.03	25.75
27.5	1.54	15.76	20.77	26.71
28	1.56	16.31	21.52	27.68
28.5	1.59	16.88	22.28	28.68
29	1.62	17.45	23.06	29.68
29.5	1.65	18.03	23.85	30.71
30	1.68	18.62	24.65	31.75
30.5	1.7	19.22	25.47	32.81
31	1.73	19.83	26.3	33.89
31.5	1.76	20.45	27.14	34.99
32	1.79	21.08	28	36.1
32.5	1.81	21.72	28.87	37.23
33	1.84	22.37	29.75	38.38
33.5	1.87	23.02	30.65	39.54
34	1.9	23.69	31.56	40.73
34.5	1.93	24.37	32.49	41.93
35	1.95	25.05	33.42	43.15
35.5	1.98	25.75	34.37	44.38
36	2.01	26.45	35.33	45.63
36.5	2.04	27.16	36.31	46.9
37	2.07	27.89	37.3	48.19
37.5	2.09	28.62	38.3	49.49
38	2.12	29.36	39.32	50.82
38.5	2.15	30.11	40.35	52.16
39	2.18	30.87	41.39	53.51
39.5	2.21	31.64	42.45	54.89
40	2.23	32.42	43.52	56.28
40.5	2.26	33.21	44.6	57.69

Pressure loss table DN 150

Q [l/s]	DN 150			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
41	2.29	34.01	45.7	59.12
41.5	2.32	34.82	46.81	60.56
42	2.35	35.63	47.93	62.02
42.5	2.37	36.46	49.07	63.5
43	2.4	37.29	50.22	65
43.5	2.43	38.14	51.38	66.51
44	2.46	38.99	52.55	68.04
44.5	2.48	39.86	53.74	69.59
45	2.51	40.73	54.95	71.16
45.5	2.54	41.61	56.16	72.74
46	2.57	42.5	57.39	74.34
46.5	2.6	43.4	58.63	75.96
47	2.62	44.31	59.89	77.59
47.5	2.65	45.23	61.16	79.25
48	2.68	46.16	62.44	80.92
48.5	2.71	47.1	63.74	82.61
49	2.74	48.05	65.04	84.31
49.5	2.76	49.01	66.37	86.03
50	2.79	49.98	67.7	87.78
51	2.85	51.94	70.41	91.31
52	2.9	53.94	73.18	94.91
53	2.96	55.97	75.99	98.58
54	3.02	58.05	78.86	102.3
55	3.07	60.16	81.79	106.1
56	3.13	62.31	84.76	110
57	3.18	64.5	87.79	114
58	3.24	66.72	90.88	118
59	3.29	68.98	94.01	122.1
60	3.35	71.28	97.2	126.2
62	3.46	75.99	103.7	134.8
64	3.57	80.85	110.5	143.6
66	3.69	85.86	117.5	152.7
68	3.8	91.03	124.6	162
70	3.91	96.34	132	171.7
72	4.02	101.8	139.6	181.6
74	4.13	107.4	147.4	191.8

Pressure loss table DN 200

Q [l/s]	DN 200			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
2.5	0.08	0.045	0.048	0.054
3	0.09	0.062	0.067	0.076
3.5	0.11	0.081	0.089	0.102
4	0.12	0.103	0.114	0.131
4.5	0.14	0.127	0.141	0.164
5	0.15	0.154	0.172	0.2
5.5	0.17	0.183	0.205	0.24
6	0.18	0.214	0.241	0.284
6.5	0.2	0.247	0.28	0.331
7	0.22	0.282	0.321	0.382
7.5	0.23	0.319	0.366	0.436
8	0.25	0.359	0.413	0.494
8.5	0.26	0.401	0.463	0.556
9	0.28	0.445	0.516	0.621
10	0.31	0.539	0.63	0.762
11	0.34	0.642	0.755	0.917
12	0.37	0.753	0.892	1.087
13	0.4	0.872	1.039	1.271
14	0.43	1	1.197	1.47
15	0.46	1.136	1.367	1.682
16	0.49	1.28	1.548	1.909
17	0.52	1.432	1.74	2.151
18	0.55	1.593	1.942	2.407
19	0.58	1.762	2.156	2.677
20	0.62	1.938	2.381	2.961
21	0.65	2.123	2.618	3.26
22	0.68	2.316	2.865	3.573
23	0.71	2.517	3.123	3.901
24	0.74	2.726	3.392	4.242
25	0.77	2.943	3.673	4.598
26	0.8	3.168	3.964	4.969
27	0.83	3.402	4.267	5.354
28	0.86	3.643	4.581	5.753
29	0.89	3.892	4.905	6.166
30	0.92	4.149	5.241	6.594
31	0.95	4.414	5.588	7.036
32	0.98	4.688	5.946	7.493
33	1.02	4.969	6.315	7.964
34	1.05	5.258	6.695	8.449
35	1.08	5.555	7.086	8.948
36	1.11	5.86	7.488	9.462
37	1.14	6.174	7.901	9.99
38	1.17	6.495	8.326	10.53
39	1.2	6.824	8.761	11.09
40	1.23	7.161	9.208	11.66
41	1.26	7.506	9.665	12.25
42	1.29	7.859	10.13	12.85
43	1.32	8.219	10.61	13.46

Pressure loss table DN 200

Q [l/s]	DN 200			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
44	1.35	8.588	11.1	14.09
45	1.38	8.965	11.61	14.73
46	1.42	9.35	12.12	15.39
47	1.45	9.742	12.64	16.06
48	1.48	10.14	13.18	16.75
49	1.51	10.55	13.72	17.45
50	1.54	10.97	14.28	18.16
52.5	1.62	12.04	15.72	20.01
55	1.69	13.17	17.23	21.95
57.5	1.77	14.34	18.81	23.98
60	1.85	15.57	20.46	26.09
62.5	1.92	16.84	22.18	28.3
65	2	18.17	23.97	30.6
70	2.15	20.96	27.75	35.46
75	2.31	23.96	31.8	40.68
80	2.46	27.15	36.14	46.26
85	2.62	30.54	40.75	52.2
90	2.77	34.12	45.64	58.49
95	2.92	37.91	50.8	65.15
100	3.08	41.89	56.24	72.16
105	3.23	46.07	61.96	79.53
110	3.39	50.44	67.95	87.26
115	3.54	55.02	74.23	95.35
120	3.69	59.79	80.77	103.8
125	3.85	64.76	87.6	112.6
130	4	69.93	94.7	121.8
135	4.15	75.29	102.1	131.3
140	4.31	80.85	109.7	141.2
145	4.46	86.61	117.7	151.4
150	4.62	92.57	125.9	162
155	4.77	98.72	134.3	173
160	4.92	105.1	143.1	184.3
165	5.08	111.6	152.1	195.9
170	5.23	118.4	161.5	208
175	5.39	125.3	171	220.4
180	5.54	132.5	180.9	233.1
185	5.69	139.8	191.1	246.2
190	5.85	147.3	201.5	259.7
195	6	155.1	212.2	273.5
200	6.16	163	223.1	287.7
205	6.31	171.1	234.4	302.2

Pressure loss table DN 250

Q [l/s]	DN 250			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
4	0.08	0.035	0.038	0.042
4.5	0.09	0.043	0.047	0.053
5	0.1	0.052	0.057	0.064
5.5	0.11	0.062	0.068	0.077
6	0.12	0.072	0.079	0.09
6.5	0.13	0.084	0.092	0.105
7	0.14	0.095	0.105	0.121
7.5	0.15	0.108	0.12	0.138
8	0.16	0.121	0.135	0.156
8.5	0.17	0.135	0.151	0.176
9	0.18	0.15	0.168	0.196
10	0.2	0.181	0.204	0.24
11	0.22	0.215	0.244	0.288
12	0.24	0.252	0.288	0.341
13	0.26	0.292	0.334	0.398
14	0.28	0.334	0.385	0.459
15	0.3	0.379	0.438	0.525
16	0.31	0.426	0.496	0.596
17	0.33	0.476	0.556	0.67
18	0.35	0.529	0.62	0.749
19	0.37	0.584	0.688	0.833
20	0.39	0.642	0.758	0.92
21	0.41	0.702	0.833	1.013
22	0.43	0.765	0.91	1.109
23	0.45	0.831	0.992	1.21
24	0.47	0.899	1.076	1.315
25	0.49	0.97	1.164	1.425
26	0.51	1.043	1.256	1.539
27	0.53	1.119	1.35	1.658
28	0.55	1.197	1.449	1.781
29	0.57	1.278	1.55	1.908
30	0.59	1.361	1.655	2.039
31	0.61	1.447	1.764	2.176
32	0.63	1.536	1.876	2.316
33	0.65	1.627	1.991	2.461
34	0.67	1.72	2.11	2.61
35	0.69	1.816	2.232	2.763
36	0.71	1.915	2.357	2.921
37	0.73	2.016	2.486	3.084
38	0.75	2.119	2.619	3.25
39	0.77	2.225	2.754	3.421
40	0.79	2.334	2.894	3.597
41	0.81	2.445	3.036	3.777
42	0.83	2.558	3.182	3.961
43	0.85	2.674	3.332	4.15
44	0.87	2.792	3.484	4.343
45	0.89	2.913	3.641	4.54
46	0.9	3.037	3.8	4.742

Pressure loss table DN 250

Q [l/s]	DN 250			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
47	0.92	3.163	3.963	4.948
48	0.94	3.291	4.13	5.158
49	0.96	3.422	4.3	5.373
50	0.98	3.556	4.473	5.592
52.5	1.03	3.9	4.921	6.16
55	1.08	4.26	5.391	6.755
57.5	1.13	4.635	5.882	7.377
60	1.18	5.026	6.394	8.026
62.5	1.23	5.433	6.927	8.703
65	1.28	5.854	7.482	9.408
70	1.38	6.745	8.655	10.9
75	1.48	7.696	9.914	12.5
80	1.57	8.71	11.26	14.21
85	1.67	9.785	12.69	16.03
90	1.77	10.92	14.2	17.96
95	1.87	12.12	15.8	20
100	1.97	13.38	17.49	22.14
105	2.07	14.7	19.26	24.4
110	2.16	16.09	21.11	26.77
115	2.26	17.53	23.05	29.25
120	2.36	19.04	25.08	31.83
125	2.46	20.6	27.19	34.53
130	2.56	22.23	29.39	37.33
135	2.66	23.92	31.67	40.25
140	2.75	25.68	34.03	43.27
145	2.85	27.49	36.49	46.41
150	2.95	29.36	39.02	49.65
155	3.05	31.3	41.65	53.01
160	3.15	33.3	44.35	56.47
165	3.25	35.36	47.15	60.04
170	3.34	37.48	50.02	63.72
175	3.44	39.66	52.99	67.51
180	3.54	41.9	56.04	71.42
185	3.64	44.21	59.17	75.43
190	3.74	46.58	62.39	79.55
195	3.84	49	65.69	83.78
200	3.93	51.49	69.08	88.12
205	4.03	54.04	72.56	92.57

Pressure loss table DN 300

Q [l/s]	DN 300			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
6	0.08	0.03	0.032	0.036
7	0.1	0.039	0.043	0.048
8	0.11	0.05	0.054	0.061
9	0.12	0.062	0.067	0.077
10	0.14	0.075	0.082	0.094
11	0.15	0.089	0.098	0.113
12	0.16	0.104	0.115	0.133
13	0.18	0.12	0.133	0.155
14	0.19	0.137	0.153	0.179
15	0.2	0.155	0.174	0.204
16	0.22	0.174	0.197	0.231
17	0.23	0.194	0.22	0.26
18	0.25	0.216	0.246	0.29
19	0.26	0.238	0.272	0.322
20	0.27	0.261	0.3	0.356
22	0.3	0.311	0.359	0.428
24	0.33	0.365	0.424	0.507
26	0.35	0.423	0.493	0.593
28	0.38	0.485	0.568	0.685
30	0.41	0.551	0.649	0.784
32	0.44	0.62	0.734	0.889
34	0.46	0.694	0.825	1.002
36	0.49	0.772	0.921	1.121
38	0.52	0.853	1.022	1.246
40	0.55	0.939	1.128	1.378
42	0.57	1.028	1.24	1.517
44	0.6	1.121	1.357	1.663
46	0.63	1.218	1.479	1.815
48	0.65	1.319	1.606	1.974
50	0.68	1.424	1.738	2.139
52.5	0.72	1.561	1.911	2.355
55	0.75	1.703	2.092	2.582
57.5	0.78	1.852	2.281	2.819
60	0.82	2.006	2.479	3.066
62.5	0.85	2.167	2.684	3.324
65	0.89	2.333	2.898	3.592
70	0.95	2.684	3.349	4.159
75	1.02	3.059	3.833	4.768
80	1.09	3.458	4.35	5.418
85	1.16	3.88	4.899	6.11
90	1.23	4.327	5.481	6.844
95	1.3	4.797	6.095	7.619
100	1.36	5.291	6.741	8.435
105	1.43	5.808	7.421	9.294
110	1.5	6.35	8.132	10.19
115	1.57	6.915	8.877	11.13
120	1.64	7.504	9.654	12.12
125	1.7	8.116	10.46	13.14

Pressure loss table DN 300

Q [l/s]	DN 300			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
130	1.77	8.752	11.3	14.21
135	1.84	9.412	12.18	15.31
140	1.91	10.1	13.09	16.46
145	1.98	10.8	14.03	17.65
150	2.05	11.53	15	18.89
155	2.11	12.29	16	20.16
160	2.18	13.07	17.04	21.48
165	2.25	13.87	18.11	22.83
170	2.32	14.69	19.21	24.23
175	2.39	15.54	20.34	25.67
180	2.45	16.41	21.51	27.15
185	2.52	17.31	22.71	28.67
190	2.59	18.23	23.94	30.24
195	2.66	19.17	25.21	31.84
200	2.73	20.14	26.51	33.49
205	2.79	21.13	27.84	35.18
210	2.86	22.15	29.2	36.91
215	2.93	23.18	30.59	38.68
220	3	24.25	32.02	40.5
225	3.07	25.33	33.48	42.35
230	3.14	26.44	34.97	44.25
235	3.2	27.57	36.5	46.19
240	3.27	28.73	38.05	48.17
245	3.34	29.91	39.64	50.19
250	3.41	31.11	41.27	52.25
255	3.48	32.34	42.92	54.36
260	3.54	33.59	44.61	56.5
265	3.61	34.86	46.33	58.69
270	3.68	36.16	48.08	60.92
280	3.82	38.82	51.68	65.5
290	3.95	41.59	55.42	70.25
300	4.09	44.44	59.28	75.17
310	4.23	47.39	63.27	80.25
320	4.36	50.43	67.39	85.5
330	4.5	53.57	71.65	90.91
340	4.64	56.8	76.03	96.49
350	4.77	60.13	80.54	102.2
360	4.91	63.55	85.19	108.1
370	5.04	67.06	89.96	114.2
380	5.18	70.67	94.86	120.5
390	5.32	74.38	99.9	126.9

Pressure loss table DN 400

Q [l/s]	DN 400			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
9	0.07	0.016	0.017	0.019
10	0.08	0.02	0.021	0.023
12.5	0.1	0.029	0.032	0.035
15	0.12	0.041	0.044	0.05
17.5	0.14	0.054	0.059	0.067
20	0.16	0.068	0.075	0.086
25	0.2	0.102	0.114	0.132
30	0.24	0.142	0.161	0.188
35	0.27	0.189	0.215	0.253
40	0.31	0.241	0.277	0.328
45	0.35	0.3	0.347	0.413
50	0.39	0.364	0.424	0.508
55	0.43	0.434	0.509	0.612
60	0.47	0.51	0.602	0.726
65	0.51	0.592	0.703	0.849
70	0.55	0.679	0.811	0.982
75	0.59	0.773	0.926	1.125
80	0.63	0.872	1.05	1.277
85	0.67	0.977	1.181	1.44
90	0.71	1.088	1.319	1.611
95	0.75	1.204	1.466	1.793
100	0.78	1.326	1.62	1.984
105	0.82	1.454	1.781	2.185
110	0.86	1.587	1.95	2.395
115	0.9	1.726	2.127	2.615
120	0.94	1.871	2.312	2.845
125	0.98	2.022	2.504	3.085
130	1.02	2.178	2.704	3.334
135	1.06	2.339	2.911	3.593
140	1.1	2.507	3.126	3.861
145	1.14	2.68	3.349	4.14
150	1.18	2.859	3.579	4.427
155	1.22	3.043	3.817	4.725
160	1.26	3.233	4.063	5.032
165	1.29	3.429	4.316	5.349
170	1.33	3.63	4.577	5.675
175	1.37	3.837	4.846	6.012
180	1.41	4.05	5.122	6.358
185	1.45	4.268	5.406	6.713
190	1.49	4.492	5.697	7.078
195	1.53	4.721	5.996	7.453
200	1.57	4.956	6.303	7.838
205	1.61	5.197	6.617	8.232
210	1.65	5.443	6.939	8.636
215	1.69	5.695	7.269	9.049
220	1.73	5.953	7.606	9.473
225	1.77	6.216	7.951	9.905
230	1.8	6.484	8.303	10.35

Pressure loss table DN 400

Q [l/s]	DN 400			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
235	1.84	6.759	8.664	10.8
240	1.88	7.039	9.031	11.26
245	1.92	7.324	9.407	11.73
250	1.96	7.616	9.79	12.21
260	2.04	8.215	10.58	13.21
270	2.12	8.837	11.4	14.24
280	2.2	9.481	12.25	15.31
290	2.28	10.15	13.13	16.41
300	2.35	10.84	14.04	17.56
310	2.43	11.55	14.98	18.74
320	2.51	12.28	15.95	19.97
330	2.59	13.04	16.96	21.23
340	2.67	13.82	17.99	22.53
350	2.75	14.62	19.05	23.87
360	2.83	15.44	20.15	25.25
370	2.9	16.29	21.27	26.67
380	2.98	17.15	22.43	28.12
390	3.06	18.05	23.62	29.62
400	3.14	18.96	24.83	31.15
410	3.22	19.89	26.08	32.72
420	3.3	20.85	27.36	34.33
430	3.37	21.83	28.67	35.98
440	3.45	22.83	30	37.67
450	3.53	23.86	31.37	39.39
460	3.61	24.91	32.77	41.16
470	3.69	25.98	34.2	42.96
480	3.77	27.07	35.67	44.8
490	3.85	28.18	37.16	46.69
500	3.92	29.32	38.68	48.61
525	4.12	32.26	42.62	53.57
550	4.32	35.34	46.75	58.78
575	4.51	38.56	51.07	64.24
600	4.71	41.92	55.58	69.93
625	4.9	45.42	60.28	75.87
650	5.1	49.06	65.17	82.04
675	5.3	52.84	70.26	88.46
700	5.49	56.76	75.53	95.12
725	5.69	60.82	81	102
750	5.89	65.01	86.66	109.2
775	6.08	69.35	92.5	116.6
800	6.28	73.83	98.54	124.2

Pressure loss table DN 500

Q [l/s]	DN 500			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
15	0.08	0.014	0.015	0.016
17.5	0.09	0.018	0.019	0.022
20	0.1	0.023	0.025	0.028
25	0.13	0.035	0.037	0.042
30	0.15	0.048	0.052	0.06
35	0.18	0.063	0.07	0.08
40	0.2	0.081	0.09	0.104
45	0.23	0.1	0.112	0.13
50	0.25	0.121	0.137	0.16
55	0.28	0.145	0.164	0.192
60	0.3	0.17	0.193	0.227
65	0.33	0.197	0.225	0.266
70	0.35	0.225	0.259	0.307
75	0.38	0.256	0.296	0.351
80	0.4	0.288	0.335	0.398
85	0.43	0.323	0.376	0.449
90	0.45	0.359	0.42	0.502
95	0.48	0.397	0.466	0.558
100	0.5	0.436	0.514	0.617
105	0.53	0.478	0.565	0.679
110	0.55	0.521	0.618	0.744
115	0.58	0.566	0.674	0.812
120	0.6	0.613	0.732	0.883
125	0.63	0.662	0.792	0.957
130	0.65	0.713	0.854	1.034
135	0.68	0.765	0.919	1.114
140	0.7	0.819	0.987	1.197
145	0.73	0.875	1.056	1.283
150	0.75	0.932	1.128	1.372
155	0.78	0.992	1.203	1.463
160	0.8	1.053	1.28	1.558
165	0.83	1.116	1.359	1.656
170	0.85	1.181	1.44	1.757
175	0.88	1.247	1.524	1.86
180	0.9	1.316	1.61	1.967
185	0.93	1.386	1.699	2.076
190	0.95	1.457	1.79	2.189
195	0.98	1.531	1.883	2.304
200	1	1.606	1.979	2.423
205	1.03	1.683	2.077	2.544
210	1.05	1.762	2.177	2.669
215	1.08	1.843	2.28	2.796
220	1.1	1.925	2.385	2.927
225	1.13	2.009	2.492	3.06
230	1.15	2.095	2.602	3.196
235	1.18	2.183	2.714	3.335
240	1.2	2.272	2.829	3.478
245	1.23	2.364	2.946	3.623

Pressure loss table DN 500

Q [l/s]	DN 500			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
250	1.25	2.457	3.065	3.771
260	1.3	2.648	3.311	4.076
270	1.35	2.846	3.566	4.393
280	1.4	3.051	3.83	4.722
290	1.45	3.263	4.104	5.063
300	1.5	3.482	4.387	5.416
310	1.55	3.709	4.68	5.78
320	1.6	3.942	4.982	6.157
330	1.65	4.182	5.294	6.545
340	1.7	4.429	5.615	6.945
350	1.75	4.683	5.945	7.358
360	1.8	4.945	6.285	7.782
370	1.85	5.213	6.635	8.217
380	1.9	5.488	6.994	8.665
390	1.95	5.77	7.362	9.125
400	2	6.059	7.74	9.596
410	2.06	6.355	8.127	10.08
420	2.11	6.659	8.523	10.57
430	2.16	6.969	8.929	11.08
440	2.21	7.286	9.345	11.6
450	2.26	7.61	9.77	12.13
460	2.31	7.941	10.2	12.67
470	2.36	8.279	10.65	13.23
480	2.41	8.624	11.1	13.79
490	2.46	8.976	11.56	14.37
500	2.51	9.335	12.04	14.96
525	2.63	10.26	13.26	16.49
550	2.76	11.23	14.54	18.09
575	2.88	12.25	15.88	19.77
600	3.01	13.31	17.28	21.52
625	3.13	14.41	18.73	23.34
650	3.26	15.56	20.25	25.24
675	3.38	16.75	21.83	27.21
700	3.51	17.98	23.46	29.26
725	3.63	19.26	25.15	31.38
750	3.76	20.58	26.91	33.58
775	3.88	21.94	28.72	35.84
800	4.01	23.35	30.59	38.19

Pressure loss table DN 600

Q [l/s]	DN 600			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
25	0.09	0.014	0.015	0.017
30	0.1	0.02	0.021	0.024
35	0.12	0.026	0.028	0.032
40	0.14	0.033	0.036	0.041
45	0.16	0.041	0.045	0.051
50	0.17	0.05	0.055	0.063
55	0.19	0.059	0.066	0.075
60	0.21	0.069	0.077	0.089
65	0.23	0.08	0.09	0.104
70	0.24	0.092	0.103	0.12
75	0.26	0.104	0.118	0.137
80	0.28	0.118	0.133	0.155
85	0.3	0.131	0.149	0.174
90	0.31	0.146	0.166	0.195
95	0.33	0.161	0.184	0.216
100	0.35	0.177	0.203	0.239
110	0.38	0.212	0.244	0.288
120	0.42	0.249	0.288	0.342
130	0.45	0.288	0.336	0.4
140	0.49	0.331	0.388	0.462
150	0.52	0.376	0.443	0.529
160	0.56	0.425	0.501	0.601
170	0.59	0.476	0.564	0.677
180	0.63	0.529	0.63	0.758
190	0.66	0.586	0.7	0.843
200	0.7	0.645	0.773	0.933
210	0.73	0.707	0.85	1.027
220	0.76	0.772	0.93	1.126
230	0.8	0.84	1.015	1.229
240	0.83	0.91	1.102	1.337
250	0.87	0.983	1.194	1.45
260	0.9	1.059	1.289	1.567
270	0.94	1.137	1.388	1.688
280	0.97	1.218	1.49	1.814
290	1.01	1.302	1.596	1.945
300	1.04	1.389	1.705	2.08
310	1.08	1.478	1.819	2.219
320	1.11	1.57	1.935	2.363
330	1.15	1.665	2.056	2.512
340	1.18	1.763	2.18	2.665
350	1.22	1.863	2.308	2.823
360	1.25	1.966	2.439	2.985
370	1.29	2.071	2.574	3.152
380	1.32	2.18	2.712	3.324
390	1.36	2.291	2.854	3.499
400	1.39	2.405	3	3.68
410	1.43	2.521	3.15	3.865
420	1.46	2.64	3.303	4.054

Pressure loss table DN 600

Q [l/s]	DN 600			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
430	1.49	2.762	3.459	4.248
440	1.53	2.887	3.62	4.447
450	1.56	3.014	3.783	4.65
460	1.6	3.144	3.951	4.857
470	1.63	3.277	4.122	5.07
480	1.67	3.412	4.297	5.286
490	1.7	3.55	4.475	5.507
500	1.74	3.691	4.657	5.733
520	1.81	3.981	5.032	6.198
540	1.88	4.282	5.422	6.681
560	1.95	4.593	5.825	7.183
580	2.02	4.915	6.244	7.702
600	2.09	5.248	6.676	8.24
625	2.17	5.679	7.238	8.937
650	2.26	6.127	7.822	9.663
675	2.35	6.592	8.429	10.42
700	2.43	7.074	9.058	11.2
725	2.52	7.573	9.71	12.01
750	2.61	8.089	10.38	12.85
775	2.69	8.621	11.08	13.72
800	2.78	9.17	11.8	14.61
825	2.87	9.736	12.54	15.54
850	2.95	10.32	13.31	16.49
875	3.04	10.92	14.1	17.47
900	3.13	11.54	14.91	18.48
925	3.22	12.17	15.74	19.52
950	3.3	12.82	16.6	20.58
975	3.39	13.49	17.47	21.68
1,000	3.48	14.17	18.37	22.8
1,050	3.65	15.59	20.24	25.13
1,100	3.82	17.07	22.2	27.57
1,150	4	18.63	24.26	30.13
1,200	4.17	20.25	26.4	32.8
1,250	4.35	21.93	28.63	35.58
1,300	4.52	23.69	30.95	38.48
1,350	4.69	25.51	33.36	41.49
1,400	4.87	27.4	35.87	44.61
1,450	5.04	29.35	38.46	47.85
1,500	5.21	31.38	41.15	51.19
1,550	5.39	33.47	43.92	54.66
1,600	5.56	35.63	46.79	58.23

Pressure loss table DN 700

Q [l/s]	DN 700			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
30	0.08	0.01	0.01	0.011
35	0.09	0.013	0.013	0.015
40	0.1	0.016	0.017	0.019
45	0.12	0.02	0.021	0.024
50	0.13	0.024	0.026	0.029
55	0.14	0.028	0.031	0.035
60	0.15	0.033	0.036	0.041
65	0.17	0.038	0.042	0.048
70	0.18	0.044	0.048	0.055
75	0.19	0.05	0.055	0.063
80	0.21	0.056	0.062	0.071
85	0.22	0.063	0.07	0.08
90	0.23	0.07	0.077	0.089
95	0.24	0.077	0.086	0.099
100	0.26	0.084	0.095	0.11
110	0.28	0.101	0.113	0.132
120	0.31	0.118	0.134	0.156
130	0.33	0.137	0.156	0.182
140	0.36	0.157	0.179	0.211
150	0.38	0.178	0.205	0.241
160	0.41	0.201	0.232	0.274
170	0.44	0.225	0.26	0.308
180	0.46	0.25	0.291	0.345
190	0.49	0.277	0.323	0.383
200	0.51	0.304	0.356	0.424
210	0.54	0.333	0.391	0.467
220	0.56	0.364	0.428	0.511
230	0.59	0.395	0.467	0.558
240	0.62	0.428	0.507	0.607
250	0.64	0.462	0.549	0.658
260	0.67	0.497	0.592	0.711
270	0.69	0.534	0.637	0.766
280	0.72	0.572	0.684	0.822
290	0.74	0.611	0.732	0.881
300	0.77	0.651	0.782	0.943
310	0.8	0.693	0.834	1.006
320	0.82	0.736	0.887	1.071
330	0.85	0.78	0.942	1.138
340	0.87	0.825	0.998	1.207
350	0.9	0.871	1.056	1.278
360	0.92	0.919	1.116	1.352
370	0.95	0.968	1.177	1.427
380	0.98	1.019	1.241	1.504
390	1	1.07	1.305	1.584
400	1.03	1.123	1.372	1.665
410	1.05	1.177	1.44	1.749
420	1.08	1.232	1.509	1.834
430	1.1	1.288	1.58	1.922

Pressure loss table DN 700

Q [l/s]	DN 700			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
440	1.13	1.346	1.653	2.011
450	1.15	1.405	1.728	2.103
460	1.18	1.465	1.804	2.197
470	1.21	1.527	1.882	2.293
480	1.23	1.589	1.961	2.39
490	1.26	1.653	2.042	2.49
500	1.28	1.718	2.125	2.592
520	1.33	1.852	2.295	2.802
540	1.39	1.991	2.472	3.02
560	1.44	2.134	2.656	3.246
580	1.49	2.283	2.846	3.48
600	1.54	2.437	3.042	3.723
625	1.6	2.635	3.297	4.037
650	1.67	2.842	3.562	4.365
675	1.73	3.056	3.838	4.705
700	1.8	3.278	4.123	5.058
725	1.86	3.507	4.419	5.423
750	1.92	3.745	4.725	5.802
775	1.99	3.989	5.042	6.193
800	2.05	4.242	5.368	6.597
825	2.12	4.502	5.705	7.014
850	2.18	4.77	6.052	7.443
875	2.25	5.045	6.409	7.885
900	2.31	5.329	6.777	8.34
925	2.37	5.619	7.154	8.808
950	2.44	5.918	7.542	9.288
975	2.5	6.224	7.941	9.781
1,000	2.57	6.538	8.349	10.29
1,050	2.69	7.188	9.197	11.34
1,100	2.82	7.869	10.09	12.44
1,150	2.95	8.58	11.01	13.59
1,200	3.08	9.323	11.98	14.79
1,250	3.21	10.1	13	16.05
1,300	3.34	10.9	14.05	17.35
1,350	3.46	11.73	15.14	18.71
1,400	3.59	12.6	16.28	20.12
1,450	3.72	13.49	17.45	21.58
1,500	3.85	14.42	18.67	23.08
1,550	3.98	15.37	19.92	24.64
1,600	4.11	16.36	21.22	26.26

Pressure loss table DN 800

Q [l/s]	DN 800			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
40	0.08	0.008	0.009	0.01
50	0.1	0.012	0.013	0.015
60	0.12	0.017	0.019	0.021
70	0.14	0.023	0.025	0.028
80	0.16	0.029	0.032	0.036
90	0.18	0.036	0.039	0.045
100	0.2	0.044	0.048	0.055
110	0.22	0.052	0.057	0.066
120	0.23	0.061	0.068	0.078
130	0.25	0.071	0.079	0.091
140	0.27	0.081	0.091	0.105
150	0.29	0.092	0.103	0.12
160	0.31	0.103	0.117	0.136
170	0.33	0.116	0.131	0.153
180	0.35	0.128	0.146	0.171
190	0.37	0.142	0.162	0.19
200	0.39	0.156	0.179	0.21
210	0.41	0.171	0.197	0.231
220	0.43	0.186	0.215	0.253
230	0.45	0.202	0.234	0.277
240	0.47	0.219	0.254	0.301
250	0.49	0.236	0.275	0.326
260	0.51	0.254	0.297	0.352
270	0.53	0.273	0.319	0.379
280	0.55	0.292	0.342	0.407
290	0.57	0.312	0.366	0.436
300	0.59	0.332	0.391	0.466
310	0.61	0.354	0.417	0.497
320	0.63	0.375	0.443	0.529
330	0.65	0.398	0.471	0.562
340	0.67	0.421	0.499	0.597
350	0.68	0.444	0.528	0.632
375	0.73	0.506	0.603	0.724
400	0.78	0.571	0.684	0.822
425	0.83	0.641	0.77	0.927
450	0.88	0.714	0.861	1.038
475	0.93	0.791	0.957	1.155
500	0.98	0.872	1.058	1.278
525	1.03	0.956	1.164	1.408
550	1.08	1.045	1.275	1.544
575	1.13	1.137	1.391	1.686
600	1.17	1.233	1.512	1.835
625	1.22	1.333	1.638	1.99
650	1.27	1.437	1.77	2.151
675	1.32	1.544	1.906	2.318
700	1.37	1.656	2.047	2.491
725	1.42	1.771	2.194	2.671
750	1.47	1.89	2.345	2.857

Pressure loss table DN 800

Q [l/s]	DN 800			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
775	1.52	2.013	2.502	3.05
800	1.57	2.139	2.663	3.248
825	1.61	2.27	2.83	3.453
850	1.66	2.404	3.001	3.664
875	1.71	2.542	3.178	3.881
900	1.76	2.684	3.359	4.105
925	1.81	2.829	3.546	4.335
950	1.86	2.979	3.738	4.571
975	1.91	3.132	3.935	4.814
1,000	1.96	3.289	4.137	5.062
1,050	2.05	3.614	4.555	5.578
1,100	2.15	3.954	4.994	6.12
1,150	2.25	4.31	5.453	6.686
1,200	2.35	4.68	5.933	7.277
1,250	2.45	5.066	6.432	7.893
1,300	2.54	5.467	6.952	8.535
1,350	2.64	5.883	7.492	9.201
1,400	2.74	6.315	8.052	9.893
1,450	2.84	6.761	8.632	10.61
1,500	2.94	7.222	9.232	11.35
1,550	3.03	7.699	9.852	12.12
1,600	3.13	8.191	10.49	12.91
1,650	3.23	8.698	11.15	13.73
1,700	3.33	9.22	11.83	14.57
1,750	3.42	9.757	12.54	15.43
1,800	3.52	10.31	13.26	16.33
1,850	3.62	10.88	14	17.24
1,900	3.72	11.46	14.76	18.18
1,950	3.82	12.06	15.54	19.15
2,000	3.91	12.67	16.34	20.14
2,050	4.01	13.3	17.17	21.16
2,100	4.11	13.94	18.01	22.2
2,150	4.21	14.6	18.87	23.27
2,200	4.31	15.27	19.75	24.36
2,250	4.4	15.96	20.66	25.48
2,300	4.5	16.66	21.58	26.62
2,350	4.6	17.38	22.52	27.79
2,400	4.7	18.11	23.49	28.98
2,450	4.79	18.86	24.47	30.2
2,500	4.89	19.63	25.47	31.44
2,550	4.99	20.41	26.5	32.71
2,600	5.09	21.2	27.54	34

Pressure loss table DN 900

Q [l/s]	DN 900			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
50	0.08	0.007	0.007	0.008
60	0.09	0.01	0.01	0.011
70	0.11	0.013	0.014	0.015
80	0.12	0.016	0.018	0.02
90	0.14	0.02	0.022	0.025
100	0.15	0.025	0.027	0.03
110	0.17	0.029	0.032	0.036
120	0.19	0.034	0.038	0.043
130	0.2	0.04	0.044	0.05
140	0.22	0.045	0.05	0.057
150	0.23	0.052	0.057	0.065
160	0.25	0.058	0.065	0.074
170	0.26	0.065	0.072	0.083
180	0.28	0.072	0.081	0.093
190	0.29	0.08	0.089	0.104
200	0.31	0.087	0.099	0.114
210	0.32	0.096	0.108	0.126
220	0.34	0.104	0.118	0.138
230	0.36	0.113	0.129	0.15
240	0.37	0.123	0.14	0.163
250	0.39	0.132	0.151	0.177
260	0.4	0.142	0.163	0.191
270	0.42	0.152	0.175	0.206
280	0.43	0.163	0.188	0.221
290	0.45	0.174	0.201	0.236
300	0.46	0.185	0.214	0.253
310	0.48	0.197	0.228	0.27
320	0.49	0.209	0.243	0.287
330	0.51	0.222	0.258	0.305
340	0.53	0.234	0.273	0.323
350	0.54	0.247	0.289	0.342
375	0.58	0.281	0.33	0.392
400	0.62	0.318	0.374	0.445
425	0.66	0.356	0.421	0.501
450	0.7	0.396	0.47	0.561
475	0.73	0.439	0.522	0.624
500	0.77	0.484	0.577	0.691
525	0.81	0.53	0.634	0.761
550	0.85	0.579	0.695	0.834
575	0.89	0.63	0.758	0.911
600	0.93	0.683	0.824	0.991
625	0.97	0.738	0.892	1.074
650	1	0.795	0.963	1.161
675	1.04	0.854	1.037	1.251
700	1.08	0.915	1.114	1.345
725	1.12	0.979	1.193	1.442
750	1.16	1.044	1.275	1.542
775	1.2	1.111	1.36	1.646

Pressure loss table DN 900

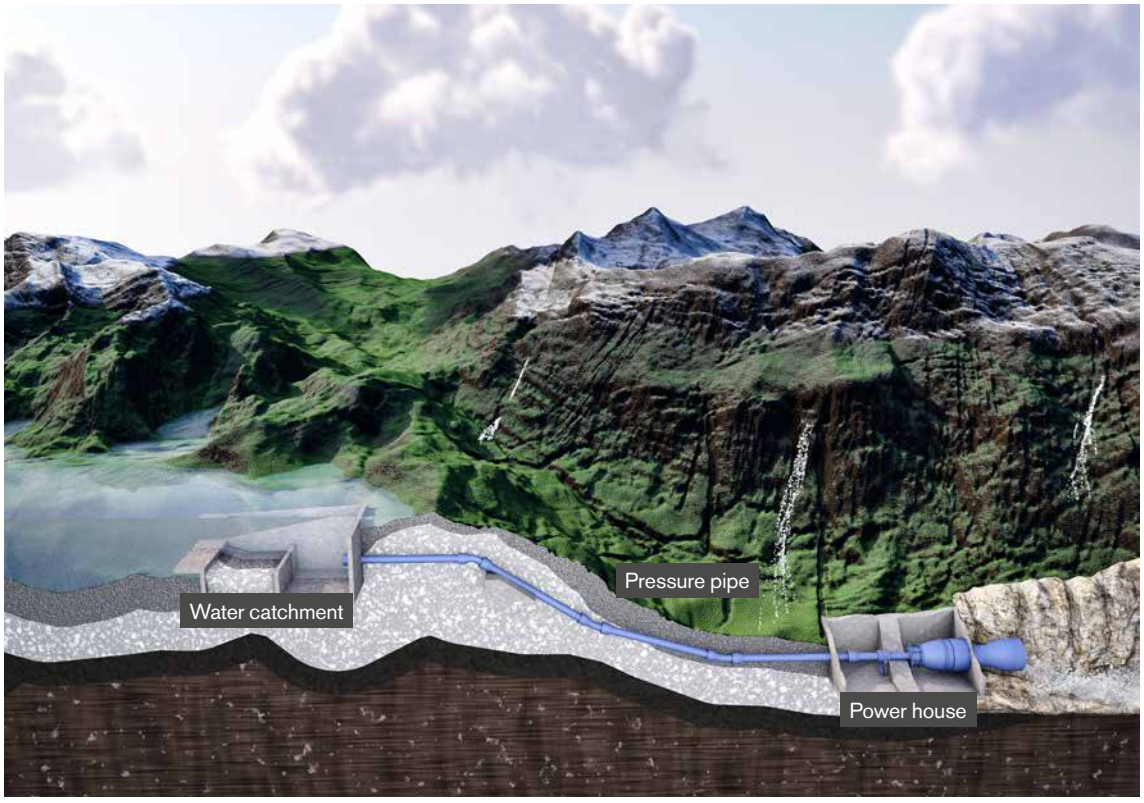
Q [l/s]	DN 900			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
800	1.24	1.181	1.447	1.753
825	1.27	1.252	1.538	1.863
850	1.31	1.326	1.63	1.977
875	1.35	1.402	1.726	2.094
900	1.39	1.479	1.825	2.214
925	1.43	1.559	1.926	2.338
950	1.47	1.641	2.029	2.465
975	1.51	1.725	2.136	2.596
1,000	1.55	1.811	2.245	2.73
1,050	1.62	1.989	2.472	3.008
1,100	1.7	2.175	2.709	3.299
1,150	1.78	2.37	2.958	3.604
1,200	1.85	2.572	3.217	3.922
1,250	1.93	2.783	3.487	4.254
1,300	2.01	3.003	3.768	4.6
1,350	2.09	3.23	4.06	4.958
1,400	2.16	3.466	4.363	5.331
1,450	2.24	3.709	4.677	5.716
1,500	2.32	3.961	5.001	6.115
1,550	2.39	4.221	5.337	6.528
1,600	2.47	4.49	5.683	6.954
1,650	2.55	4.766	6.04	7.394
1,700	2.63	5.051	6.409	7.847
1,750	2.7	5.344	6.787	8.313
1,800	2.78	5.645	7.177	8.793
1,850	2.86	5.954	7.578	9.287
1,900	2.94	6.272	7.99	9.794
1,950	3.01	6.598	8.412	10.31
2,000	3.09	6.931	8.845	10.85
2,050	3.17	7.274	9.29	11.4
2,100	3.24	7.624	9.745	11.96
2,150	3.32	7.982	10.21	12.53
2,200	3.4	8.349	10.69	13.12
2,250	3.48	8.724	11.18	13.72
2,300	3.55	9.107	11.67	14.33
2,350	3.63	9.498	12.18	14.96
2,400	3.71	9.897	12.7	15.6
2,450	3.79	10.3	13.23	16.26
2,500	3.86	10.72	13.78	16.93
2,550	3.94	11.14	14.33	17.61
2,600	4.02	11.58	14.89	18.3

Pressure loss table DN 1000

Q [l/s]	DN 1000			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
60	0.08	0.006	0.006	0.007
70	0.09	0.008	0.008	0.009
80	0.1	0.01	0.01	0.012
90	0.11	0.012	0.013	0.014
100	0.13	0.015	0.016	0.018
110	0.14	0.018	0.019	0.021
120	0.15	0.021	0.022	0.025
130	0.16	0.024	0.026	0.029
140	0.18	0.027	0.03	0.033
150	0.19	0.031	0.034	0.038
160	0.2	0.035	0.038	0.043
170	0.21	0.039	0.043	0.049
180	0.23	0.043	0.047	0.054
190	0.24	0.047	0.053	0.06
200	0.25	0.052	0.058	0.067
210	0.26	0.057	0.064	0.073
220	0.28	0.062	0.069	0.08
230	0.29	0.067	0.076	0.087
240	0.3	0.073	0.082	0.095
250	0.31	0.079	0.089	0.103
260	0.33	0.085	0.095	0.111
270	0.34	0.091	0.103	0.119
280	0.35	0.097	0.11	0.128
290	0.36	0.104	0.118	0.137
300	0.38	0.11	0.126	0.146
325	0.41	0.128	0.146	0.171
350	0.44	0.147	0.169	0.198
375	0.47	0.167	0.193	0.227
400	0.5	0.188	0.218	0.257
425	0.53	0.211	0.245	0.29
450	0.56	0.235	0.274	0.324
475	0.59	0.26	0.304	0.361
500	0.63	0.286	0.336	0.399
525	0.66	0.314	0.37	0.44
550	0.69	0.342	0.405	0.482
575	0.72	0.372	0.441	0.526
600	0.75	0.403	0.479	0.572
625	0.78	0.436	0.519	0.62
650	0.81	0.469	0.56	0.67
675	0.84	0.504	0.603	0.722
700	0.88	0.54	0.647	0.776
725	0.91	0.577	0.693	0.832
750	0.94	0.615	0.741	0.889
775	0.97	0.655	0.79	0.949
800	1	0.696	0.84	1.011
825	1.03	0.738	0.893	1.074
850	1.06	0.781	0.946	1.14
875	1.09	0.825	1.002	1.207

Pressure loss table DN 1000

Q [l/s]	DN 1000			
	v [m/s]	$k_2 = 0.1$	$k_2 = 0.4$	$k_2 = 1.0$
		J [m/km]		
900	1.13	0.87	1.059	1.276
925	1.16	0.917	1.117	1.348
950	1.19	0.965	1.177	1.421
1,000	1.25	1.064	1.302	1.573
1,050	1.31	1.169	1.433	1.733
1,100	1.38	1.278	1.57	1.901
1,150	1.44	1.391	1.714	2.076
1,200	1.5	1.51	1.864	2.259
1,250	1.56	1.633	2.02	2.45
1,300	1.63	1.761	2.182	2.649
1,350	1.69	1.893	2.351	2.855
1,400	1.75	2.031	2.526	3.069
1,450	1.81	2.173	2.707	3.291
1,500	1.88	2.32	2.894	3.52
1,550	1.94	2.472	3.088	3.758
1,600	2	2.628	3.288	4.003
1,650	2.06	2.789	3.494	4.255
1,700	2.13	2.955	3.707	4.516
1,750	2.19	3.126	3.926	4.784
1,800	2.25	3.301	4.151	5.06
1,850	2.31	3.481	4.382	5.344
1,900	2.38	3.666	4.619	5.635
1,950	2.44	3.855	4.863	5.935
2,000	2.5	4.05	5.113	6.242
2,050	2.56	4.249	5.37	6.556
2,100	2.63	4.453	5.632	6.879
2,150	2.69	4.661	5.901	7.209
2,200	2.75	4.874	6.176	7.547
2,250	2.81	5.092	6.458	7.892
2,300	2.88	5.315	6.745	8.246
2,350	2.94	5.542	7.039	8.607
2,400	3	5.775	7.34	8.976
2,450	3.06	6.011	7.646	9.352
2,500	3.13	6.253	7.959	9.736
2,600	3.25	6.75	8.603	10.53
2,700	3.38	7.267	9.272	11.35
2,800	3.5	7.802	9.967	12.2
2,900	3.63	8.356	10.69	13.09
3,000	3.75	8.929	11.43	14.01
3,100	3.88	9.521	12.2	14.95
3,200	4	10.13	12.99	15.93
3,300	4.13	10.76	13.81	16.94



Water catchment, pressure pipe and power house with 4.6 km pipe length

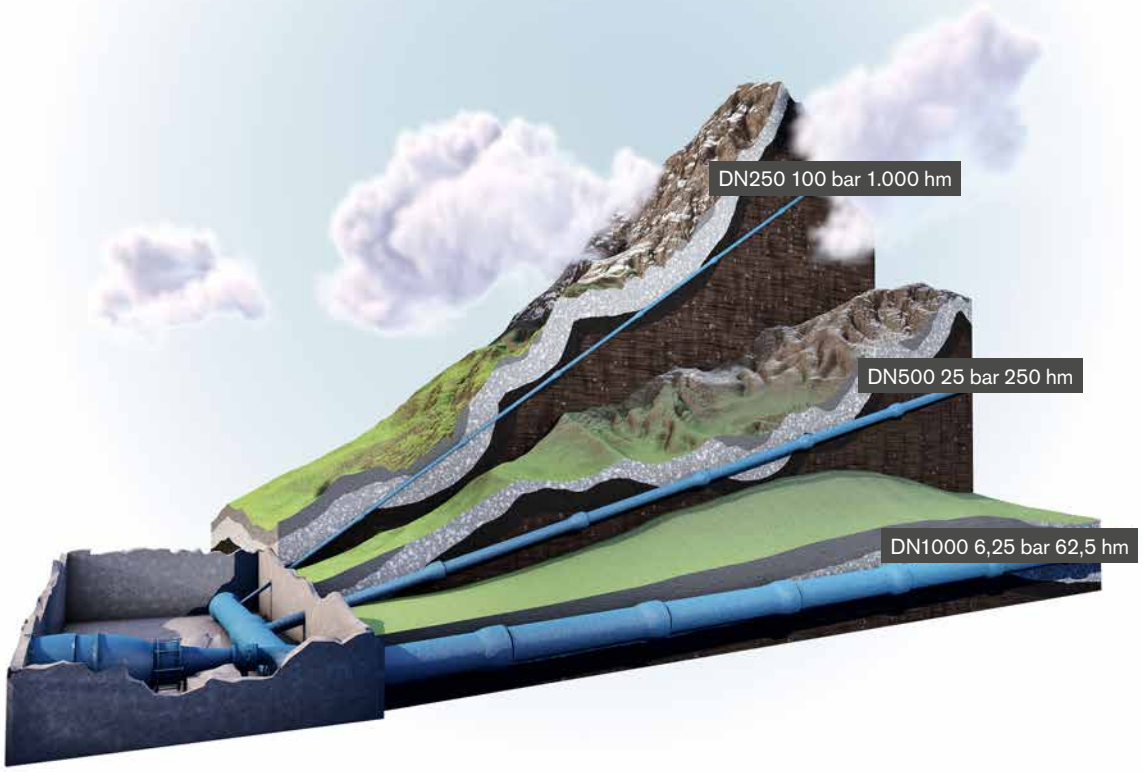
Sustainable High Performance

Combined with safety

The technical and financial superiority of ductile iron is particularly clearly demonstrated in pipe systems that are subject to high pressure.

In the pipe shown in the diagram with a length of 4.6 km, a diameter of 250 mm and an operating pressure of 100 bar; the resulting cover pressure is approx. 491 kN. Ductile iron has the necessary material properties to counteract this huge load with a high degree of safety and durability.

Cover pressure	Volume at length 4.6 km
$F_D = (d^2 * \pi) / 4 * p_i$	$V = (d^2 * \pi) / 4 * l_{pipe}$
$F_D = 490.87$ kN ~ 50 to	$V = 225.80$ m³
$_D$ Resulting forces	$_i$ Internal pressure



Various pipes: DN 250 100 bar 1,000 hm; DN 500 25 bar 250 hm; DN 1000 6.25 bar 62.5 hm

Pressure and Hazard Potential

Ductile iron for large-volume pipes

For pipes with high pressure, ductile iron pipes are the obvious choice for planners. However, the safety reserves of our pipe systems are also worthwhile for lower pressures and larger nominal widths.

The following example shows how important the safety reserves of our ductile iron pipes are, if we examine the potential risk of a large diameter pipe: Let's assume three pipes of the same length with the same cover pressure. To create these, the smallest pipe with DN 250 is subject to 100 bar internal pressure, the DN 500 pipe is subject to 25 bar and the largest cross-section of DN 1000 is subject to just 6.25 bar.

However, the potential risk, i.e. the pipe volume which could escape in case of damage, is 16 times greater – a good reason for choosing iron pipes for this pipe. If damage does occur, our pipe systems feature a leak-before-break concept whereby consequential damage is greatly reduced.

	Diameter d	Area $A_e=d^{2*}\pi/4$	K class	Wall thickness s_{min}	Pressure PFA	Cover pressure $F_D=A_e*PFA*10^2$		Volume[1] $V=A_e*l$	
	[mm]	[m²]		[mm]	[bar]	[kN]	[to]	[m³]	
x2	250	0.049	K16	10.5	100	490.87	50.04	225.8	x4
	500	0.196	K9	7.2	25			903.21	
x2	1,000	0.785	K9	11.2	6.25			3,612.83	x4

[1] for pipe length of 4.6 km

System Loads and Component Resistances

Design of the pipe system

The relevant guideline for the design of "water supply systems and their components outside buildings" is ÖNORM EN 805. This prescribes a planned operating life of at least 50 years and specifies requirements concerning planning, hydraulic design, choice of materials, installation and commissioning.

This standard requires that all system pressures are smaller than the permitted component-related pressures approved by the manufacturer. Iron pipes are produced in accordance with the relevant product standards and already incorporate a 20% reserve for pressure-surge testing and a reference for the test pressure. This makes it very easy to design a pipework system on PFA (see table). Pressure surges must be limited to 1.2 times the value, for example by specifying closing times for valves.

- ⚠ Please contact our application engineering department if you require products or solutions with higher pressures than those stated in our documentation.
- ⚠ Depending on the product and application standard, there are various terms for nominal pressure PN. In other words, PN ≠ PN!

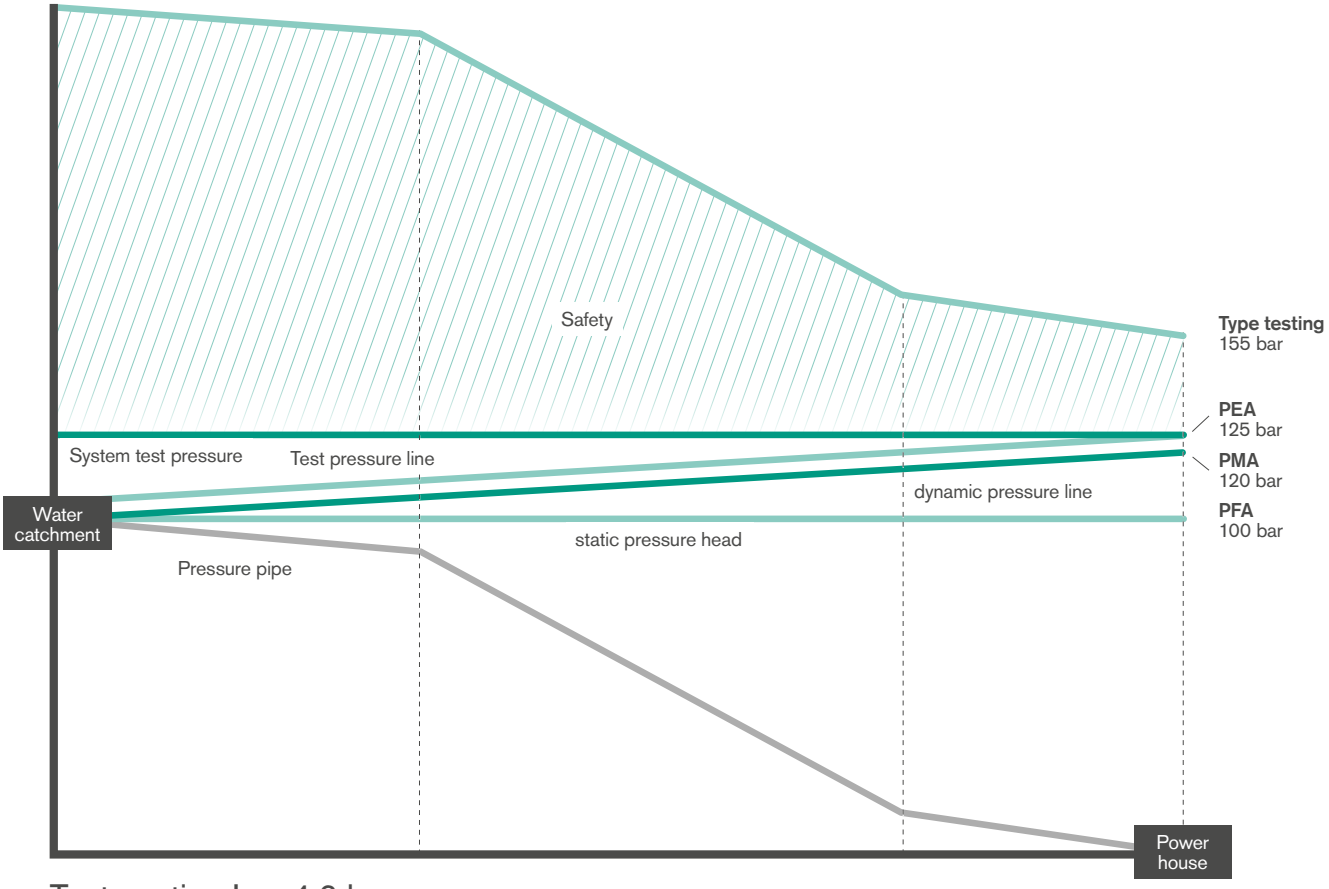
Pressure conditions for the selection of pipe parts in accordance with ÖNORM EN 805.

Pipe parts[a]			System design[b]	
PFA	allowable operating pressure, without pressure surge	≥	DP	System pressure
PMA = PFA x 1.2	allowable maximum operating pressure, including pressure surge	≥	MDP	maximum System pressure
PEA = PMA + 5 bar	allowable test pressure	≥	STP	system test pressure
≥ 80 kPa[c] negative pressure		–	≤ 80 kPa[c] negative pressure	

[a] to be specified by the manufacturer

[b] to be determined by the planner

[c] 100 kPa = 1 bar



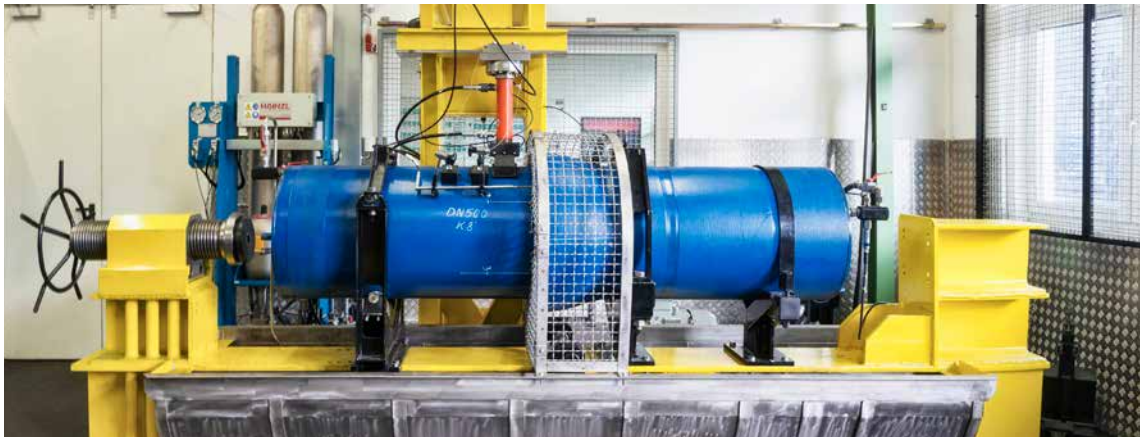
Schematic representation of pressures in a iron pipe DN 250 PFA 100; safety type test 155 bar; system test pressure PEA 125 bar; test pressure line; dynamic pressure line PMA 120 bar; static pressure head PFA 100 bar; test section L = 4.6 km

System Pressures and Terms

Test process and overview of results

The example illustrated above shows a pipe system of 4,600 m in length and an operating pressure of 100 bar. At a nominal diameter of DN 250, the pipe contains 225.80 m^3 of water. Tiroler Rohre GmbH pipe systems undergo type testing of 155 bar hydraulic internal pressure.

The already high specification for the system test pressure of 125 bar is greatly exceeded with our type testing. This allows us to offer extraordinary safety and minimize potential risks.



Type testing in the laboratory on the works premises.

Type Tests

The robustness of ductile iron put to the test

ductile iron pipes undergo type testing at Tiroler Rohre GmbH's factory under the most unfavorable conditions at 1.5 x PFA + 5 bar (worst-case testing). In addition, they have a 3-fold safety reserve against internal pressure.

Ductile iron pipes must be produced in accordance with the minimum standard ÖNORM EN 545. In addition, more extensive requirements from the relevant standards (e.g. ÖNORM B 2599-1, ÖNORM B 2597 and ÖNORM B 2560) must also be observed. The pipes manufactured must be tested under the unfavorable conditions required by these standards. Proof of the tests must be provided by the manufacturer at the customer's request.

⚠ Tiroler Rohre GmbH is one of the few manufacturers which has a corresponding test facility at their premises and are permitted to carry out the required certifications for all relevant nominal diameters in collaboration with a nationally accredited testing institute.

Example:

Requirements for type-testing certification for ductile iron pipes for water supply with a VRS®-T joint DN 250, nominal pressure PFA 100 bar (K 16)

Joint	Test	Test pressure	Duration of test	Test conditions
VRS®-T joint				
DN 250 K 16 PFA 100	Positive hydrostatic internal pressure	155 bar	2 hrs	under shearing load max. bending greatest annular gap min. wall thickness
	Negative internal pressure	-0.9 bar		under shearing load max. bending greatest annular gap
	Positive hydrostatic External pressure	2 bar		under shearing load greatest annular gap
	Cyclic hydrostatic internal pressure	Between PMA and (PMA-5) bar	24,000 pressure cycles	under shearing load greatest annular gap

Checklist

For constructors and planners

+ **Texts for use in invitations to tender adapted to the relevant standards**

+ **Defined award criteria**

+ Production and storage in Austria
+ Type testing, testing laboratory & evidence
+ Fast delivery and high availability
+ More than 20 different types of fittings stocked in Austria
+ AutoCAD libraries for pipes and fittings
+ Pipe-laying training & supervision on site
+ Technical assistance with planning and implementation
+ System supplier (pipes and fittings)

+ **Special products & solutions**

+ **Sustainability**

+ Short transport distances, recycled raw materials and eco-friendly production
+ Durability and high safety reserves
+ Environmental protection and hygiene

+ **Consistently high quality**

+ Complete documentation and testing at every stage of production

+ **Key data for planners**

+ Hydraulic measurement: Roughness and flow velocity
+ Static measurement: Internal and external forces of the pipe; geometric measurement of the trench/dam; bedding, backfill and trench building conditions; composition of the soil and backfill material
+ System measurement: System pressure (DP), maximum System pressure (MDP) & system test pressure (STP) taking all relevant flow conditions into account.

PIPE SYSTEMS

Tiroler Rohre GmbH
Innsbrucker Strasse 51
6060 Hall in Tirol
Austria
T +43 5223 503 0
F +43 5223 436 19
E office@trm.at
www.trm.at

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