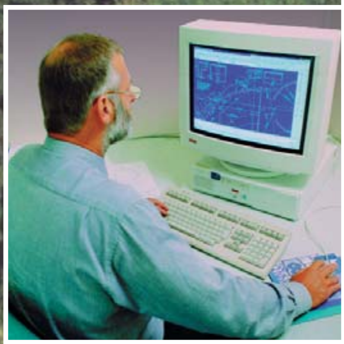
PAM Worldwide

Pipe & Fittings Water & Sewer



Design Guide

SAINT-GOBAIN PIPELINES

A World of Choice

Saint-Gobain Pipelines is the UK's leading supplier of ductile iron pipe systems for potable water and sewerage applications.

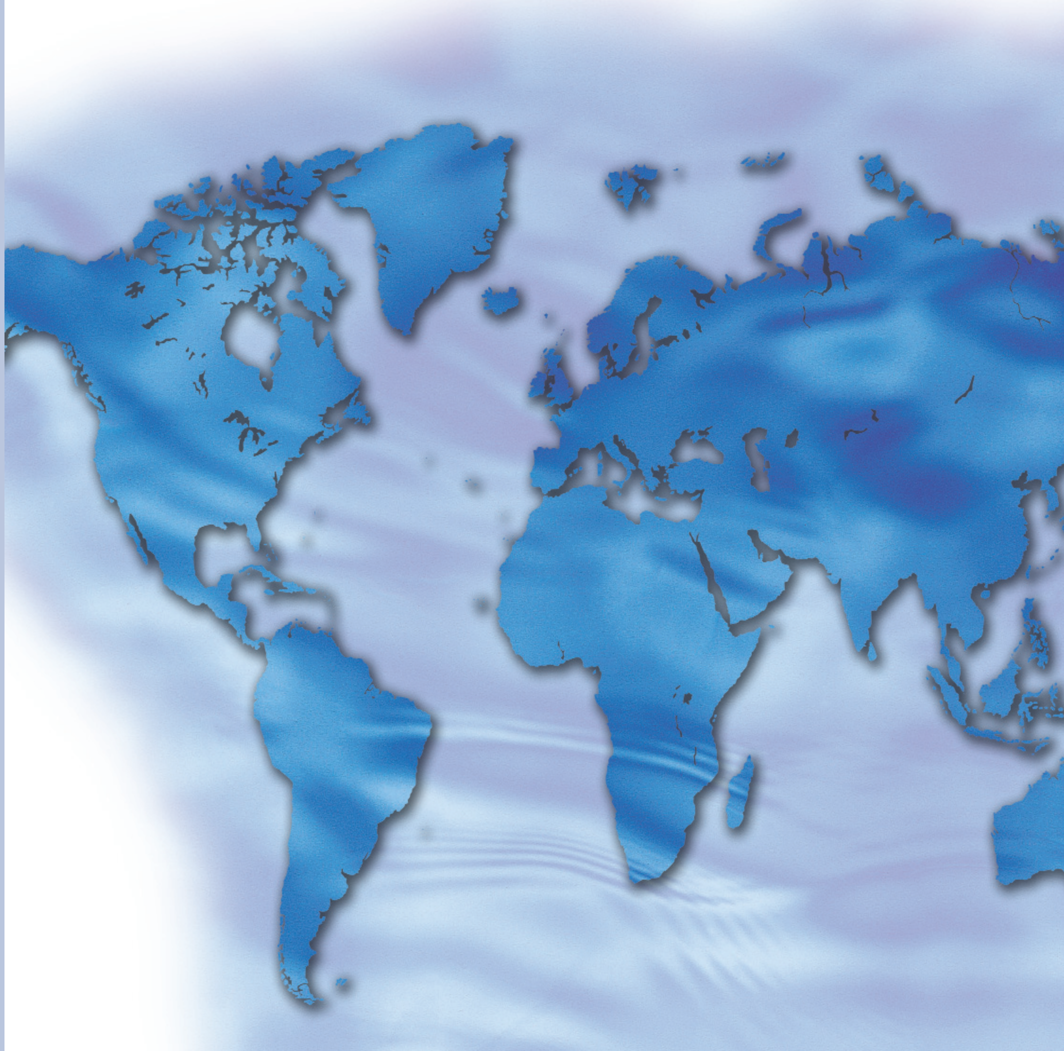
Saint-Gobain Pipelines is part of the Saint-Gobain Pipe Division, a global company with a presence in Europe, Asia, South America and the Far East. The pipe division has over 9000 employees, and sells product in 120 different countries with approximately 100,000km of ductile iron pipes being installed worldwide per year.

The Saint-Gobain Pipe Division is part of the Saint-Gobain Group, one of the world's leading multi-nationals, which currently employs over 180,000 people in 48 countries and over 1200 consolidated companies.

Everyone at Saint-Gobain Pipelines is dedicated to meeting customer expectations. We encourage open communication between staff, customers and related organisations to make a positive impact on the future of the marketplace and help improve the quality of life for people worldwide.

UK customers benefit from the global network of the Pipe Division through our long term commitment to improve and develop innovative products and processes. We achieve this through continual investment in Research and Development on a global scale. In excess of £10million per annum is spent on R&D programmes worldwide, meaning an unrivalled product range of next-generation, ductile iron pipe systems being constantly developed and delivered to the UK market.

For further information on Saint-Gobain Pipelines visit
www.saint-gobain-pipelines.co.uk



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Section 1

Design Introduction

This section of the catalogue provides design information specific to ductile iron (DI) pipelines. The benefits of using ductile iron are apparent through all stages of design, from selection of the required pipe diameter through to the determination of embedment and the selection of the appropriate anchorage. The information is provided in four main sections:

Hydraulic Performance

The hydraulic performance of DI pipes and selection of DN

Designing Below Ground

Design information specific for below ground installations

Designing Above Ground

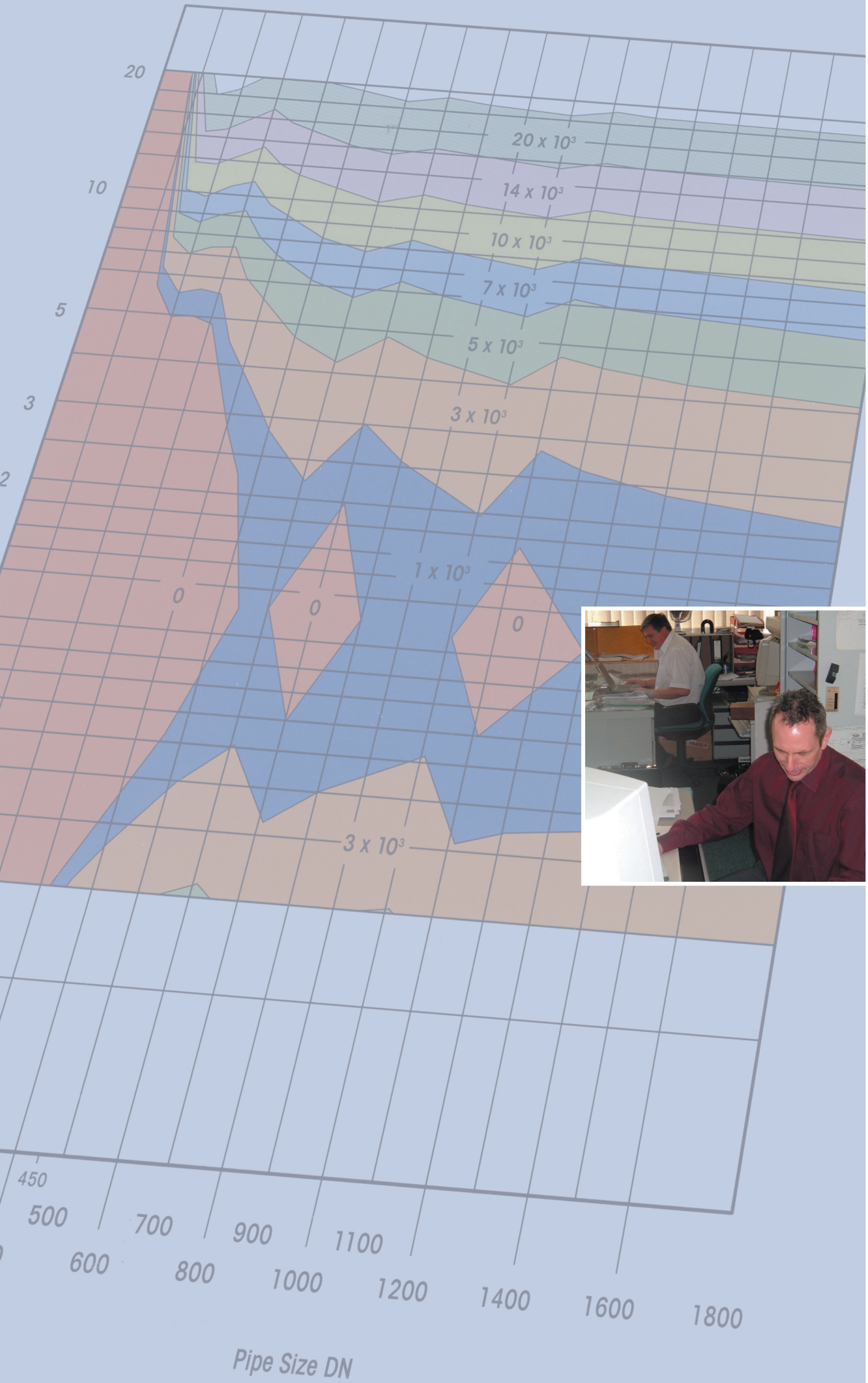
Design information specific to flanged pipe and above ground applications

Typical Installations

Solutions to special design requirements and typical installations

A table showing some of the mechanical and physical properties of ductile iron is included at the end of the design section on page 54.

Section 1



20
10
5
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20 x 10³
14 x 10³
10 x 10³
7 x 10³
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0
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0
3 x 10³
450
500
600
700
800
900
1000
1100
1200
1400
1600
1800
Pipe Size DN

Hydraulic Performance

Introduction

The following method can be used to determine the discharge for Saint-Gobain Pipelines' water and Integral pipe. It also includes allowances for the additional losses due to fittings.

The hydraulic calculations in this section can be performed using the PipeSpec software.

Full bore discharge

The flow in a ductile iron pipeline can be calculated by using the Colebrook-White equation. This has been used for many years and provides an accurate basis for flow calculations.

Colebrook-White Equation

The equation expressed in terms of velocity is:-

$$V = -2\sqrt{2gDi}\,.\,\log_{10}\left[\frac{Ks}{3.7D} + \frac{2.51\vartheta}{D\sqrt{2gDi}}\right]$$

Where:

V = velocity (m/s)

g = gravitational acceleration (9.81 m/s^2)

D = internal diameter of pipe (m)

i = hydraulic gradient (m/m)

Ks = effective roughness value (m)

ϑ = Kinematic viscosity of fluid (m^2/s)

The full bore discharge is given by:-

$$Q = 785.4\, D^2 V$$

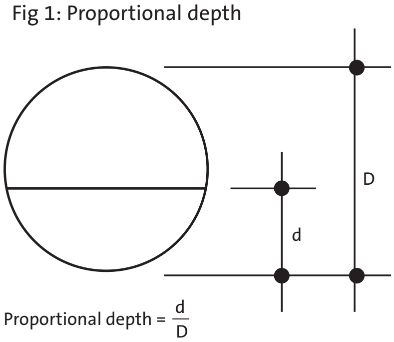
Where: Q = discharge (l/s)

Water Pipe

The effective roughness Ks, for cement mortar lined ductile iron pipes is 0.03mm as recommended in "Tables for the hydraulic design of pipes and sewers" seventh edition H.R. Wallingford and D.I.H. Barr. There is no significant deterioration with time of the measure of effective roughness Ks where cement mortar lined pipes are conveying treated potable water. However, conveying certain raw waters can lead to a build up of slime in the bores of all pipes and this will cause an increase in the value of Ks. The formation of these slimes is not deleterious to the linings of ductile iron pipes and periodic cleaning of this type of main will restore the hydraulic performance to that of the pipeline in its new condition.

Table 2 gives the full bore discharge for water pipe as a function of DN and hydraulic gradients with a effective roughness of 0.03mm and kinematic viscosity of 1.31 x $10^{-6} m^2/s$ - this value is for water at 10°C.

Fig 1: Proportional depth



Integral Pipe

The Water Services Association publication ‘Sewer for Adoption’ (4th Edition) states the following effective roughness values:-

foul and combined sewers: Ks = 1.5mm
surface water sewers: Ks = 0.6mm
rising mains: Ks = 0.3mm (velocity ≤ 1.1m/s)
rising mains: Ks = 0.15mm (velocity = 1.1 - 1.8m/s)

The effective roughness for PAM Integral pipes readily satisfies the above requirements with Ks = 0.06mm.

‘Tables for the hydraulics design of pipes, sewers and channels’ (Seventh Edition, HR Wallingford and D.I.H Barr) provides more specific recommendations on effective surface roughness values.

Table 3 giveS the full bore discharge for Integral pipe as a function of DN, effective surface roughness and hydraulic gradient for a kinematic viscosity of $1.31 \times 10^{-6} m^2/s$ - this value is for water or sewage at 10°C.

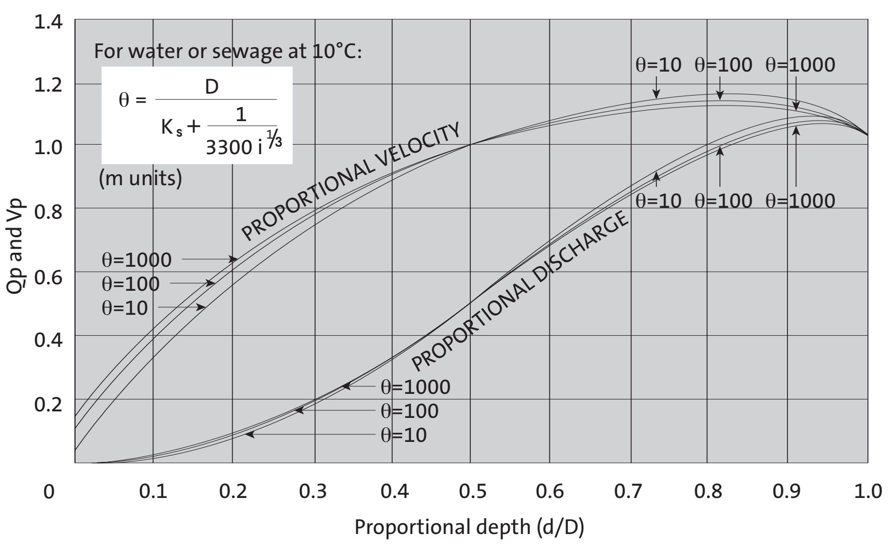
It is recommended that the velocity for Saint-Gobain Pipelines’ water and Integral pipe is limited to a maximum of 7.0m/s. For higher velocities, please contact Pipelines Technical Sales Department, Tel: 0115 930 0700.

Part-full Discharge

Foul water gravity systems are normally designed to flow at a maximum of three-quarters full bore to encourage air flow in the system at peak discharge. When a system is designed to function at less than full bore (see Fig 1), the proportional velocity and proportional discharge should be evaluated. The Water Services Association publication “Sewers for Adoption” (4th edition) states a minimum velocity of 0.75 m/s at 1/3rd the design flow and for combined sewers of 1 m/s at the pipe-full flow.

The proportional discharge and velocity as a function of proportional depth are given in Fig 2.

Fig 2: Proportional discharge and velocity in part full circular pipes



Allowance for Fittings

Allowance for the additional losses due to fittings can be made by adding the equivalent lengths given in Table 1 to the actual length of the main. For fittings not covered in the table please consult our Pipelines Technical Sales Department, Tel: 0115 930 0700.

The values given for the flow through the branches of tees and angle branches relate to the branch diameter.

The value given for the flow through tapers relates to the diameter at the small end. There is negligible resistance to flow towards the smaller end of tapers.

Table 1: Fittings head losses, equivalent length of main (m)

DN	90°	45°	22.5°	11.25°	Tee Main	Tee Branch	45° Angle	Taper
80	2.8	1	0.6	0.2	1.3	2.9	2.2	0.5
100	3.7	1.3	0.7	0.3	1.6	3.6	2.7	0.6
150	5.4	1.9	1.2	0.5	2.4	5.4	4	0.9
200	7.6	2.8	1.6	0.7	3.2	7.2	5.4	1.2
250	8.7	3.3	1.6	0.9	4	9	6.8	1.5
300	10.4	4	1.9	1.2	4.8	10.8	8.1	1.8
350	12.1	4.9	2.8	1.7	5.6	12.6	9.4	2.1
400	13.8	5.7	3.1	2	6.4	14.4	10.8	2.4
450	15.6	6.3	3.5	2.2	7.2	16.2	12.2	2.7
500	17.2	7	3.9	2.5	8	18	13.5	3
600	20.7	8.4	4.5	2.7	9.6	21.6	16.2	3.6
700	24.3	9.6	5.2	3.6	11.2	25.2	18.9	4.2
800	27.7	11.1	5.9	4.1	12.8	28.8	21.6	4.8
900	31.2	12.6	6.6	4.6	14.4	32.4	24.3	5.4
1000	34.6	14.2	7.3	4.9	16	36	27	6
1100	38.1	14.7	7.7	5.6	17.6	39.6	29.7	6.6
1200	41.5	16.8	8.8	6.4	19.2	43.2	32.4	7.2
1400	54.4	21.1	10.5	6.8	22.4	50.4	37.8	8.4
1600	65.6	24.6	12.3	8	25.6	57.6	43.2	9.6
1800	-	28.2	14.1	9.2	28.8	64.8	48.6	10.8
2000	-	32.6	15.7	10.3	32	72	54	12

Worked Examples - Water Pipes

Example one:

A DN1200 gravity ductile iron main 5000m long has a difference of 50m between the top of the water level at the intake and the level at discharge. The pipeline includes 10 x 45° bends, 8 x 22.5° bends and 5 x 11.25° bends. Determine the discharge assuming an effective surface roughness value of 0.03mm, neglect inlet and outlet losses and a kinematic viscosity of 1.31 x 10^{-6}m^2/s.

The head loss due to the various fittings needs to be accounted for when calculating the hydraulic gradient, from Table 1:

Equivalent length due to 45° bends = 10 x 16.8m = 168m
Equivalent length due to 22.5° bends = 8 x 8.8m = 70m
Equivalent length due to 11.25° bends = 5 x 6.4m = 32m
The equivalent length of main = 5000 + 270 = 5270m
The hydraulic gradient is : i = 50/5270 = 9.49m/1000m
From Table 2 interpolation for i = 9.49m/1000m gives a discharge of 5350 l/s and a velocity of 4.65m/s

Example two:

A cement mortar lined ductile iron raw water rising main is required to deliver approximately 100 l/s at a velocity of approximately 1.0 m/s. The main is 800m long and rises 20m. Determine the size of pipe and pumping head required assuming an effective surface roughness of 0.03mm and a kinematic viscosity of 1.31 x 10^{-6}m^2/ss. Tables 2 shows that a DN350 main is needed to provide the required discharge and velocity of flow i.e. a DN350 main will discharge 100 l/s at a velocity of 1.03 m/s. The value of the hydraulic gradient is 2.41m/1000m; this value is used to determine the required pumping head.

Head to produce the flow neglecting the rise or fall of the main	$= \frac{2.41 \times 800}{1000} = 1.93$m
Static head	= 20m
Total pumping head required neglecting inlet and outlet losses	= 1.93 + 20 = 21.93

Water pipe

Table 2: Full bore discharge DN80-2000

	DN80 D = 75mm		DN100 D = 95mm		DN150 D = 147mm	
Q (l/s)	V (m/s)	i m/1000	V (m/s)	i m/1000	V (m/s)	i m/1000
3	0.68	7.4	0.43	2.36	0.18	0.29
4	0.91	12.48	0.57	3.96	0.24	0.48
5	1.14	18.77	0.71	5.93	0.3	0.72
6	1.37	26.25	0.85	8.27	0.36	0.99
7	1.59	34.9	0.99	10.96	0.41	1.31
8	1.82	44.73	1.14	14	0.47	1.67
9	2.05	55.71	1.28	17.39	0.53	2.06
10	2.28	67.84	1.42	21.12	0.59	2.5
12	2.73	95.55	1.70	29.61	0.71	3.34
14	3.19	127.8	1.99	39.47	0.83	4.61
16	3.64	164.6	2.27	50.67	0.95	5.89
18	4.1	206	2.56	63.22	1.07	7.31
20	4.55	251.9	2.84	77.1	1.18	8.87
22	5.01	302.3	3.12	92.31	1.3	10.58
24	5.46	357.2	3.41	108.9	1.42	12.43
26	5.92	416.6	3.69	126.7	1.54	14.42
28	6.37	480.5	3.98	145.9	1.66	16.55
30	6.83	548.9	4.26	166.4	1.78	18.82
35			4.97	223.5	2.07	25.11
40			5.68	288.8	2.37	32.26
45			6.39	362.4	2.67	40.27
50			7.1	444.2	2.96	49.14
55					3.26	58.87
60					3.55	69.44
65					3.85	80.87
70					4.15	93.15
75					4.44	106.3
80					4.74	120.2
85					5.04	135.1
90					5.33	150.7
95					5.63	167.3
100					5.92	184.6
110					6.52	221.9
120					7.11	262.5

	DN200 D = 198mm		DN250 D = 249mm		DN300 D = 300mm	
Q (l/s)	V (m/s)	i m/1000	V (m/s)	i m/1000	V (m/s)	i m/1000
15	0.49	1.21				
20	0.65	2.05				
25	0.81	3.07	0.51	1.01		
30	0.97	4.3	0.62	1.41		
35	1.14	5.71	0.72	1.87	0.5	0.76
40	1.3	7.31	0.82	2.39	0.57	0.96
45	1.46	9.09	0.93	2.97	0.64	1.19
50	1.62	11.06	1.03	3.61	0.71	1.45
60	1.95	15.55	1.24	5.05	0.85	2.02
70	2.27	20.76	1.44	6.73	0.99	2.69
80	2.6	26.7	1.65	8.63	1.13	3.44
90	2.92	33.35	1.85	10.75	1.27	4.28
100	3.25	40.73	2.06	13.1	1.42	5.21
120	3.9	57.62	2.47	18.46	1.7	7.32
140	4.55	77.35	2.88	24.7	1.98	9.76
160	5.2	99.93	3.29	31.82	2.27	12.55
180	5.85	125.3	3.71	39.81	2.55	15.67
200	6.5	153.6	4.12	48.68	2.83	19.12
220	7.15	184.7	4.53	58.41	3.12	22.91
240			4.94	69.02	3.4	27.03
260			5.35	80.49	3.68	31.48
280			5.76	92.84	3.97	36.26
300			6.18	106	4.25	41.37
320			6.59	120.1	4.53	46.82
340			7	135.1	4.82	52.59
360					5.1	58.69
380					5.38	65.12
400					5.67	71.87
420					5.95	78.96
440					6.23	86.37
460					6.52	94.12
480					6.8	102.2
500					7.08	110.6

Table 2: Full bore discharge DN80-2000

	DN350 D = 351mm		DN400 D = 401mm		DN450 D = 451mm	
Q (l/s)	V (m/s)	i m/1000	V (m/s)	i m/1000	V (m/s)	i m/1000
50	0.52	0.68	0.4	0.35		
75	0.78	1.42	0.59	0.74	0.47	0.42
100	1.03	2.41	0.79	1.25	0.63	0.71
125	1.29	3.64	0.99	1.89	0.78	1.07
150	1.55	5.11	1.19	2.65	0.94	1.49
175	1.81	6.82	1.39	3.53	1.1	1.99
200	2.07	8.76	1.58	4.53	1.25	2.54
225	2.33	10.94	1.78	5.65	1.41	3.17
250	2.59	13.35	1.98	6.88	1.57	3.86
275	2.85	15.98	2.18	8.23	1.72	4.61
300	3.1	18.85	2.38	9.7	1.88	5.43
325	3.36	21.95	2.57	11.28	2.04	6.31
350	3.62	25.27	2.77	12.98	2.19	7.25
375	3.88	28.83	2.97	14.8	2.35	8.26
400	4.14	32.61	3.17	16.73	2.51	9.33
425	4.4	36.63	3.37	18.77	2.66	10.46
450	4.66	40.87	3.56	20.93	2.82	11.66
475	4.91	45.33	3.76	23.2	2.98	12.92
500	5.17	50.03	3.96	25.59	3.13	14.24
550	5.69	60.1	4.36	30.71	3.45	17.07
600	6.21	71.09	4.75	36.28	3.76	20.15
650	6.73	82.98	5.15	42.31	4.07	23.48
700	7.24	95.77	5.55	48.8	4.39	27.05
750			5.94	55.74	4.7	30.88
800			6.34	63.14	5.01	34.96
850			6.73	70.99	5.33	39.28
900			7.13	79.29	5.64	43.85
950					5.95	48.67
1000					6.27	53.73
1050					6.58	59.05
1100					6.89	64.61
1150					7.21	70.41
1200						

	DN500 D = 502mm		DN600 D = 603mm		DN700 D = 702mm	
Q (l/s)	V (m/s)	i m/1000	V (m/s)	i m/1000	V (m/s)	i m/1000
100	0.5	0.42				
150	0.76	0.88	0.53	0.36		
200	1.01	1.5	0.7	0.61	0.52	0.29
250	1.26	2.27	0.88	0.93	0.65	0.44
300	1.52	3.19	1.05	1.3	0.77	0.62
350	1.77	4.26	1.23	1.73	0.9	0.82
400	2.02	5.47	1.4	2.21	1.03	1.05
450	2.27	6.83	1.58	2.76	1.16	1.3
500	2.53	8.33	1.75	3.36	1.29	1.59
600	3.03	11.77	2.1	4.74	1.55	2.23
700	3.54	15.79	2.45	6.34	1.81	2.98
800	4.04	20.37	2.8	8.16	2.06	3.83
900	4.55	25.53	3.15	10.2	2.32	4.78
1000	5.05	31.25	3.5	12.47	2.58	5.83
1100	5.56	37.54	3.85	14.96	2.84	6.99
1200	6.06	44.4	4.2	17.67	3.1	8.24
1300	6.57	51.83	4.55	20.6	3.35	9.6
1400	7.07	59.82	4.9	23.75	3.61	11.06
1500			5.25	27.11	3.87	12.61
1600			5.6	30.7	4.13	14.27
1700			5.95	34.51	4.39	16.03
1800			6.3	38.54	4.65	17.89
1900			6.65	42.79	4.9	19.84
2000			7	47.25	5.16	21.9
2100					5.42	24.06
2200					5.68	26.31
2300					5.94	28.67
2400					6.19	31.13
2500					6.45	33.68
2600					6.71	36.34
2700					6.97	39.09

Water pipe

Table 2: Full bore discharge DN80-2000

	DN800 D = 804mm		DN900 D = 906mm		DN1000 D = 1007mm	
Q (l/s)	V (m/s)	i m/1000	V (m/s)	i m/1000	V (m/s)	i m/1000
250	0.49	0.23	0.39	0.13	0.31	0.08
300	0.59	0.32	0.47	0.18	0.38	0.11
350	0.69	0.42	0.54	0.24	0.44	0.14
400	0.79	0.54	0.62	0.3	0.5	0.18
450	0.89	0.67	0.7	0.38	0.57	0.22
500	0.98	0.82	0.78	0.46	0.63	0.27
550	1.08	0.97	0.85	0.54	0.69	0.32
600	1.18	1.14	0.93	0.64	0.75	0.38
650	1.28	1.33	1.01	0.74	0.82	0.44
700	1.38	1.53	1.09	0.85	0.88	0.51
750	1.48	1.74	1.16	0.97	0.94	0.58
800	1.57	1.96	1.24	1.09	1	0.65
850	1.67	2.19	1.32	1.22	1.07	0.73
900	1.77	2.44	1.4	1.36	1.13	0.81
950	1.87	2.7	1.47	1.5	1.19	0.89
1000	1.97	2.98	1.55	1.66	1.26	0.98
1250	2.46	4.54	1.94	2.52	1.57	1.49
1500	2.95	6.41	2.33	3.55	1.88	2.1
1750	3.44	8.6	2.72	4.76	2.2	2.81
2000	3.94	11.1	3.1	6.13	2.51	3.62
2250	4.43	13.9	3.49	7.67	2.83	4.53
2500	4.92	17.02	3.88	9.38	3.14	5.53
2750	5.41	20.45	4.27	11.26	3.45	6.64
3000	5.9	24.19	4.65	13.31	3.77	7.84
3250	6.4	28.23	5.04	15.52	4.08	9.13
3500	6.89	32.58	5.43	17.91	4.39	10.53
3750			5.82	20.45	4.71	12.02
4000			6.21	23.17	5.02	13.61
4250			6.59	26.05	5.34	15.29
4500			6.98	29.1	5.65	17.07
4750					5.96	18.95
5000					6.28	20.93
5250					6.59	23

	DN1100 D = 1109mm		DN1200 D = 1210mm		DN1400 D = 1407mm	
Q (l/s)	V (m/s)	i m/1000	V (m/s)	i m/1000	V (m/s)	i m/1000
500	0.52	0.17	0.43	0.11		
750	0.78	0.36	0.65	0.24	0.48	0.11
1000	1.04	0.61	0.87	0.4	0.64	0.19
1250	1.29	0.93	1.09	0.61	0.8	0.29
1500	1.55	1.31	1.3	0.85	0.96	0.41
1750	1.81	1.75	1.52	1.14	1.13	0.54
2000	2.07	2.24	1.74	1.46	1.29	0.69
2250	2.33	2.8	1.96	1.82	1.45	0.87
2500	2.59	3.42	2.17	2.22	1.61	1.06
2750	2.85	4.1	2.39	2.66	1.77	1.26
3000	3.11	4.84	2.61	3.13	1.93	1.49
3250	3.36	5.64	2.83	3.65	2.09	1.73
3500	3.62	6.49	3.04	4.21	2.25	1.99
3750	3.88	7.41	3.26	4.8	2.41	2.27
4000	4.14	8.39	3.48	5.43	2.57	2.56
4250	4.4	9.42	3.7	6.09	2.73	2.87
4500	4.66	10.51	3.91	6.8	2.89	3.2
4750	4.92	11.66	4.13	7.54	3.06	3.55
5000	5.18	12.87	4.35	8.32	3.22	3.92
5500	5.69	15.47	4.78	9.99	3.54	4.7
6000	6.21	18.3	5.22	11.81	3.86	5.55
6500	6.73	21.37	5.65	13.78	4.18	6.47
7000	7.25	24.67	6.09	15.9	4.5	7.46
7500			6.52	18.17	4.82	8.51
8000			6.96	20.59	5.15	9.64
8500					5.47	10.83
9000					5.79	12.1
9500					6.11	13.43
10000					6.43	14.83
10500					6.75	16.3
11000					7.07	17.84

Table 2: Full bore discharge DN80-2000

	DN1600 D = 1609mm	
Q (l/s)	V (m/s)	i m/1000
1000	0.49	0.1
1250	0.61	0.15
1500	0.74	0.21
1750	0.86	0.28
2000	0.98	0.36
2250	1.11	0.45
2500	1.23	0.54
2750	1.35	0.65
3000	1.48	0.77
3250	1.6	0.89
3500	1.72	1.02
3750	1.84	1.17
4000	1.97	1.32
4250	2.09	1.48
4500	2.21	1.65
4750	2.34	1.82
5000	2.46	2.01
5500	2.7	2.41
6000	2.95	2.84
6500	3.2	3.31
7000	3.44	3.81
7500	3.69	4.35
8000	3.93	4.92
8500	4.18	5.53
9000	4.43	6.17
9500	4.67	6.84
10000	4.92	7.55
10500	5.16	8.29
11000	5.41	9.07
11500	5.65	9.89
12000	5.9	10.73
12500	6.15	11.61
13000	6.39	12.53
13500	6.64	13.48
14000	6.88	14.16

	DN1800 D = 1812mm	
Q (l/s)	V (m/s)	i m/1000
1750	0.68	0.16
2000	0.78	0.2
2250	0.87	0.25
2500	0.97	0.3
2750	1.07	0.36
3000	1.16	0.43
3250	1.26	0.5
3500	1.36	0.57
3750	1.45	0.65
4000	1.55	0.73
4250	1.65	0.82
4500	1.75	0.92
4750	1.84	1.01
5000	1.94	1.12
5500	2.13	1.34
6000	2.33	1.58
6500	2.52	1.83
7000	2.71	2.11
7500	2.91	2.41
8000	3.1	2.72
8500	3.3	3.06
9000	3.49	3.41
9500	3.68	3.78
10000	3.88	4.17
10500	4.07	4.58
11000	4.27	5
11500	4.46	5.45
12000	4.65	5.91
12500	4.85	6.4
13000	5.04	6.9
13500	5.24	7.42
14000	5.43	7.96
15000	5.82	9.09
16000	6.2	10.3
17000	6.59	11.58

	DN2000 D = 2015mm	
Q (l/s)	V (m/s)	i m/1000
2000	0.63	0.12
2250	0.71	0.15
2500	0.78	0.18
2750	0.86	0.22
3000	0.94	0.25
3250	1.02	0.3
3500	1.1	0.34
3750	1.18	0.39
4000	1.25	0.43
4250	1.33	0.49
4500	1.41	0.54
4700	1.49	0.6
5000	1.57	0.66
5500	1.72	0.79
6000	1.88	0.93
6500	2.04	1.08
7000	2.2	1.25
7500	2.35	1.42
8000	2.51	1.61
8500	2.67	1.8
9000	2.82	2.01
9500	2.98	2.23
10000	3.14	2.45
10500	3.29	2.69
11000	3.45	2.94
12000	3.76	3.48
13000	4.08	4.05
14000	4.39	4.67
15000	4.7	5.34
16000	5.02	6.04
17000	5.33	6.79
18000	5.64	7.58
19000	5.96	8.42
20000	6.27	9.3
21000	6.59	10.22

Integral pipe

Worked Example

A storm water sewer 1000m long with a head of 6.52m is constructed using PAM Integral DN1200 pipe. The sewer includes 10 x 45° bends, 8 x 22.5° bends and 5 x 11.25° bends. Neglect inlet and outlet losses.

Calculate the discharge and velocity at 10°C when the pipe is:
 i) running full,
 ii) running at 1/4 full.
Roughness value Ks = 0.06mm

1 Calculate i

The headloss due to the various fittings needs to be accounted for when calculating the hydraulic gradient:

From Table 1:
Equivalent length due to 45° bends = 10 x 16.8 = 168m

Equivalent length due to 22.5° bends = 8 x 8.8 = 71m

Equivalent length due to 11.25° bends = 5 x 6.4 = 32m

The equivalent length of main = 1000+271 = 1271m

Giving a hydraulic gradient i = 6.52/1271 = 5.13m per 1000m

2 Determine V and Q

From Table 3 Interpolation, for i = 5.13:

The full bore discharge of a DN1200 Integral pipe = 3720 l/s

The velocity of a DN1200 Integral pipe running full = 3.25 m/s

3 Calculate proportional discharge and velocity

Using the equation shown in Fig 2, q = 664
From Fig 2, a proportional depth of 1/4 (0.25) gives:

proportional discharge = 0.14

proportional velocity = 0.71

Therefore:
The discharge of a DN1200 Integral pipe running 1/4 full = 0.14 x 3720 = 521 l/s

The velocity of a DN1200 Integral pipe running 1/4 full = 0.71 x 3.25 = 2.31 m/s

Table 3: Full bore discharge DN80

DN80: D=77mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
1	0.21	0.92	0.97	1.05	1.2	1.54
2	0.43	3.17	3.46	3.86	4.52	5.98
3	0.64	6.63	7.37	8.38	9.94	13.33
4	0.85	11.27	12.71	14.59	17.47	23.57
5	1.07	17.05	19.45	22.51	27.1	36.71
6	1.28	23.98	27.6	32.13	38.83	52.75
7	1.5	32.04	37.15	43.44	52.66	71.69
8	1.71	41.23	48.11	56.46	68.59	93.52
9	1.92	51.54	60.47	71.17	86.63	118.26
10	2.14	62.98	74.23	87.58	106.76	145.9
11	2.35	75.54	89.39	105.69	129	176.43
12	2.56	89.22	105.96	125.49	153.34	209.86
13	2.78	104.02	123.92	147	179.78	246.2
14	2.99	119.94	143.29	170.2	208.32	285.43
15	3.2	136.97	164.06	195.1	238.96	327.56
16	3.42	155.12	186.23	221.7	271.7	372.59
17	3.63	174.39	209.8	250	306.55	420.51
18	3.85	194.78	234.77	280	345.5	471.34
19	4.06	216.28	261.14	311.69	382.54	525.07
20	4.27	238.9	288.91	345.08	423.69	581.69
21	4.49	262.63	318.08	380.17	466.94	641.22
22	4.7	287.48	348.66	416.96	512.29	703.64
23	4.91	313.44	380.63	455.44	559.75	768.96
24	5.13	340.52	414.01	495.63	609.3	837.18
25	5.34	368.71	448.79	537.51	660.96	908.3
26	5.55	398.02	484.96	581.09	714.71	982.32
27	5.77	428.45	522.54	626.37	770.57	1059.24
28	5.98	459.98	561.52	673.35	828.53	1139.05
29	6.2	492.64	601.9	722.02	888.59	1221.77
30	6.41	526.4	643.68	772.39	950.75	1307.38
31	6.62	561.29	686.86	824.46	1015.02	1395.9
32	6.84	597.28	731.44	878.23	1081.38	1487.31
33	7.05	634.4	777.42	933.7	1149.85	1581.62

Note: Discharge for DN100-1800 continued on the following pages.

Integral pipe

Table 3: Full bore discharge DN100-2000

DN100: D=97mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
1	0.13	0.30	0.32	0.34	0.37	0.46
2	0.27	1.04	1.10	1.20	1.37	1.76
3	0.40	2.15	2.33	2.58	3.00	3.91
4	0.54	3.63	3.98	4.47	5.24	6.90
5	0.67	5.46	6.05	6.85	8.09	10.72
6	0.81	7.64	8.55	9.75	11.57	15.39
7	0.94	10.17	11.47	13.14	15.66	20.90
8	1.08	13.04	14.80	17.04	20.37	27.25
9	1.21	16.25	18.55	21.44	52.69	34.44
10	1.35	19.80	22.72	26.34	31.64	42.47
11	1.48	23.69	27.31	31.74	38.20	51.35
12	1.62	27.93	32.32	37.65	45.37	61.06
13	1.75	32.49	37.74	44.06	53.17	71.61
14	1.89	37.40	43.58	50.97	61.58	83.01
15	2.02	42.64	49.84	58.39	70.61	95.24
16	2.16	48.22	56.52	66.31	80.26	108.3
18	2.43	60.38	71.12	83.65	101.4	137.0
20	2.70	73.89	87.39	103.0	125.0	169.0
22	2.96	88.73	105.3	124.4	151.1	204.4
24	3.23	104.9	124.9	147.7	179.6	243.2
26	3.50	122.4	146.2	173.1	210.7	285.3
28	3.77	141.3	169.2	200.5	244.2	330.8
30	4.04	161.5	193.8	229.9	280.1	379.7
32	4.31	183.0	220.1	261.3	318.5	431.9
34	4.58	205.9	248.0	294.7	359.4	487.5
36	4.85	230.1	277.6	330.2	402.8	546.4
38	5.12	255.7	308.9	367.6	448.6	608.7
40	5.39	282.6	341.8	407.0	496.9	674.4
42	5.66	310.8	376.5	448.5	547.7	743.4
44	5.93	340.3	412.7	492.0	600.9	815.8
46	6.20	371.2	450.7	537.4	656.6	891.6
48	6.47	403.4	490.3	584.9	714.8	970.7
50	6.74	437.0	531.6	634.4	775.4	1053

DN150: D=149mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
3	0.17	0.27	0.28	0.30	0.33	0.41
4	0.23	0.45	0.48	0.51	0.58	0.72
5	0.29	0.68	0.72	0.78	0.88	1.11
6	0.34	0.94	1.01	1.10	1.25	1.59
7	0.40	1.24	1.34	1.47	1.69	2.16
8	0.46	1.59	1.72	1.90	2.19	2.81
9	0.52	1.97	2.14	2.37	2.75	3.54
10	0.57	2.38	2.61	2.91	3.37	4.36
11	0.63	2.84	3.12	3.49	4.06	5.27
12	0.69	3.34	3.67	4.13	4.82	6.26
13	0.74	3.87	4.28	4.81	5.63	7.33
14	0.80	4.44	4.92	5.56	6.52	8.49
15	0.86	5.04	5.61	6.35	7.46	9.74
16	0.92	5.68	6.35	7.20	8.47	11.07
17	0.97	6.36	7.13	8.10	9.54	12.48
18	1.03	7.08	7.95	9.05	10.58	13.98
19	1.09	7.83	8.82	10.06	11.88	15.57
20	1.15	8.62	9.73	11.11	13.14	17.24
22	1.26	10.31	11.68	13.39	15.86	20.84
24	1.37	12.14	13.82	15.87	18.84	24.78
26	1.49	14.12	16.13	18.57	22.07	29.06
28	1.60	16.25	18.62	21.47	25.56	33.68
30	1.72	18.52	21.28	24.59	29.30	38.64
40	2.29	32.02	37.25	43.32	51.84	68.56
50	2.86	49.12	57.63	67.32	80.76	107.0
60	3.44	69.80	82.42	96.57	116.1	154.0
70	4.01	94.05	111.6	131.1	157.8	209.4
80	4.58	121.9	145.2	170.9	205.8	273.4
90	5.15	153.3	183.3	215.9	260.3	345.9
100	5.73	188.3	225.7	266.2	321.1	426.9
110	6.30	226.8	272.6	321.8	388.4	516.5
120	6.87	269.0	323.8	382.6	462.0	614.5

Table 3: Full bore discharge DN100-2000

DN200: D=200mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
10	0.32	0.56	0.60	0.65	0.73	0.92
12	0.38	0.78	0.84	0.92	1.04	1.31
14	0.44	1.04	1.12	1.23	1.40	1.78
16	0.51	1.33	1.44	1.58	1.82	2.31
18	0.57	1.65	1.79	1.99	2.29	2.92
20	0.63	2.00	2.18	2.43	2.81	3.60
22	0.70	2.38	2.62	2.92	3.39	4.35
24	0.76	2.80	3.09	3.46	4.02	5.16
26	0.82	3.25	3.59	4.04	4.70	6.05
28	0.89	3.73	4.14	4.66	5.44	7.01
30	0.95	4.24	4.72	5.33	6.23	8.04
35	1.11	5.66	6.34	7.19	8.44	10.92
40	1.27	7.27	8.20	9.34	10.98	14.24
45	1.43	9.08	10.29	11.76	13.86	18.01
50	1.59	11.08	12.61	14.45	17.07	22.21
60	1.90	15.66	17.97	20.68	24.50	31.93
70	2.22	21.02	24.26	28.02	33.26	43.42
80	2.54	27.14	31.49	36.47	43.37	56.67
90	2.85	34.03	39.66	46.03	54.81	71.68
100	3.17	41.68	48.76	56.70	67.58	88.45
110	3.49	50.11	58.81	68.49	81.69	107.0
120	3.80	59.29	69.79	81.38	97.14	127.3
130	4.12	69.25	81.70	95.38	113.9	149.3
140	4.44	79.97	94.55	110.5	132.1	173.1
150	4.76	91.45	108.3	126.7	151.5	198.7
160	5.07	103.7	123.1	144.1	172.3	226.1
170	5.39	116.7	138.7	162.5	194.5	255.2
180	5.71	130.5	155.3	182.0	217.9	286.0
190	6.02	145.0	172.9	202.7	242.7	318.6
200	6.34	160.3	191.3	224.5	268.9	353.0
220	6.97	193.2	231.1	271.4	325.2	427.1
240	7.61	229.2	274.6	322.7	386.8	508.2

DN250: D=251mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
14	0.28	0.35	0.37	0.39	0.44	0.55
16	0.32	0.44	0.47	0.51	0.57	0.71
18	0.36	0.55	0.58	0.63	0.72	0.89
20	0.4	0.66	0.71	0.77	0.88	1.10
22	0.44	0.79	0.85	0.93	1.06	1.33
24	0.49	0.93	1.00	1.10	1.25	1.58
26	0.53	1.07	1.16	1.28	1.46	1.84
28	0.57	1.23	1.33	1.47	1.69	2.14
30	0.61	1.40	1.52	1.68	1.93	2.45
35	0.71	1.86	2.03	2.26	2.61	3.32
40	0.81	2.38	2.62	2.93	3.39	4.33
45	0.91	2.97	3.28	3.68	4.28	5.47
50	1.01	3.61	4.01	4.52	5.26	6.74
60	1.21	5.08	5.70	6.45	7.54	9.69
70	1.41	6.80	7.67	8.72	10.23	13.16
80	1.62	8.75	9.93	11.33	13.32	17.17
90	1.82	10.95	12.48	14.28	16.82	21.71
100	2.02	13.38	15.32	17.58	20.72	26.79
120	2.43	18.96	21.86	25.18	29.76	38.53
140	2.83	25.49	29.56	34.15	40.43	52.40
160	3.23	32.97	38.41	44.48	52.73	68.40
180	3.64	41.39	48.41	56.16	66.66	86.53
200	4.04	50.77	59.57	69.22	82.22	106.8
220	4.45	61.09	71.89	83.63	99.41	129.2
240	4.85	72.36	85.36	99.40	118.2	153.7
260	5.25	84.57	99.98	116.5	138.7	180.3
280	5.66	97.73	115.8	135.0	160.8	209.1
300	6.06	111.8	132.7	154.9	184.5	240.0
320	6.47	126.9	150.8	176.1	209.8	273.0
340	6.87	142.9	170.0	198.7	236.8	308.2
360	7.28	159.8	190.4	222.6	265.4	345.4

Integral pipe

Table 3: Full bore discharge DN100-2000

DN300: D=302mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
15	0.21	0.16	0.17	0.18	0.20	0.24
20	0.28	0.27	0.28	0.31	0.34	0.42
25	0.35	0.40	0.43	0.46	0.52	0.65
30	0.42	0.56	0.60	0.66	0.74	0.92
35	0.49	0.75	0.80	0.88	1.00	1.25
40	0.56	0.96	1.03	1.14	1.30	1.63
45	0.63	1.19	1.29	1.43	1.63	2.06
50	0.7	1.45	1.58	1.75	2.01	2.54
60	0.84	2.03	2.23	2.49	2.87	3.64
70	0.98	2.71	2.99	3.36	3.89	4.94
80	1.12	3.48	3.87	4.35	5.06	6.45
90	1.26	4.34	4.85	5.48	6.38	8.15
100	1.4	5.29	5.94	6.74	7.86	10.05
110	1.53	6.34	7.15	8.12	9.49	12.15
120	1.67	7.47	8.46	9.63	11.28	14.45
130	1.81	8.70	9.88	11.27	13.22	16.95
140	1.95	10.02	11.42	13.04	15.31	19.64
150	2.09	11.43	13.06	14.94	17.56	22.54
160	2.23	12.93	14.81	16.97	19.95	25.63
180	2.51	16.20	18.64	21.41	25.21	32.42
200	2.79	19.84	22.91	26.37	31.09	40.00
220	3.07	23.84	27.62	31.84	37.57	48.38
240	3.35	28.19	32.77	37.83	44.67	57.56
260	3.63	32.91	38.35	44.33	52.39	67.53
280	3.91	38.00	44.37	51.35	60.72	78.29
300	4.19	43.44	50.83	58.88	69.66	89.86
320	4.46	49.24	57.73	66.92	79.22	102.2
340	4.74	55.41	65.07	75.49	89.39	115.4
360	5.02	61.93	72.84	84.56	100.2	129.3
380	5.3	68.82	81.06	94.15	111.6	144.1
400	5.58	76.06	89.71	104.3	123.6	159.6
450	6.28	95.75	113.3	131.8	156.3	202.0
500	6.98	117.7	139.5	162.5	192.9	249.3

DN350: D=353mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
30	0.31	0.26	0.28	0.30	0.33	0.41
35	0.36	0.35	0.37	0.40	0.45	0.55
40	0.41	0.45	0.48	0.52	0.58	0.72
45	0.46	0.55	0.59	0.65	0.73	0.91
50	0.51	0.67	0.72	0.79	0.90	1.12
60	0.61	0.94	1.02	1.12	1.28	1.60
80	0.82	1.60	1.76	1.95	2.25	2.83
100	1.02	2.43	2.69	3.01	3.48	4.41
120	1.22	3.43	3.82	4.30	4.99	6.33
140	1.43	4.58	5.14	5.81	6.77	8.60
160	1.63	5.90	6.66	7.56	8.81	11.22
180	1.84	7.39	8.37	9.52	11.13	14.19
200	2.04	9.03	10.28	11.72	13.72	17.51
220	2.25	10.83	12.37	14.14	16.57	21.17
240	2.45	12.80	14.67	16.79	19.70	25.18
260	2.65	14.92	17.15	19.67	23.10	29.54
280	2.86	17.21	19.83	22.77	26.76	34.25
300	3.06	19.66	22.71	26.10	30.70	39.30
320	3.27	22.27	25.78	29.66	34.90	44.71
340	3.47	25.03	29.04	33.45	39.38	50.46
360	3.67	27.96	32.49	37.46	44.12	56.56
380	3.88	31.05	36.14	41.70	49.14	63.00
400	4.08	34.30	39.98	46.16	54.42	69.80
420	4.29	37.71	44.02	50.86	59.98	76.94
440	4.49	41.27	48.25	55.78	65.80	84.43
460	4.69	45.00	52.67	60.92	71.89	92.26
480	4.9	48.89	57.29	66.30	78.26	100.5
500	5.1	52.94	62.10	71.90	84.89	109.0
550	5.61	63.76	74.98	86.89	102.7	131.8
600	6.12	75.58	89.06	103.3	122.1	156.9
650	6.63	88.40	104.4	121.1	143.2	184.1
700	7.14	102.2	120.9	140.4	166.1	213.4

Table 3: Full bore discharge DN100-2000

DN400: D=403mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
40	0.31	0.23	0.25	0.26	0.29	0.36
50	0.39	0.35	0.37	0.40	0.45	0.56
60	0.47	0.49	0.52	0.57	0.65	0.80
70	0.55	0.65	0.70	0.77	0.87	1.08
80	0.63	0.83	0.90	0.99	1.13	1.41
90	0.70	1.04	1.13	1.25	1.42	1.78
100	0.78	1.26	1.38	1.53	1.75	2.19
110	0.86	1.51	1.65	1.84	2.11	2.65
120	0.94	1.78	1.95	2.18	2.50	3.15
130	1.02	2.06	2.27	2.54	2.93	3.69
140	1.10	2.37	2.62	2.94	3.39	4.28
160	1.25	3.05	3.39	3.81	4.41	5.58
180	1.41	3.81	4.26	4.80	5.57	7.05
200	1.57	4.65	5.22	5.90	6.86	8.69
220	1.72	5.57	6.28	7.12	8.29	10.51
240	1.88	6.57	7.44	8.45	9.85	12.50
260	2.04	7.66	8.69	9.89	11.54	14.66
280	2.19	8.82	10.04	11.44	13.37	17.00
300	2.35	10.07	11.49	13.11	15.33	19.51
350	2.74	13.53	15.53	17.78	20.83	26.53
400	3.13	17.50	20.18	23.16	27.16	34.62
450	3.52	21.98	25.44	29.24	34.34	43.80
500	3.91	26.95	31.30	36.04	42.35	54.05
550	4.31	32.43	37.77	43.54	51.20	65.38
600	4.70	38.41	44.85	51.75	60.89	77.79
650	5.09	44.89	52.53	60.67	71.43	91.28
700	5.48	51.88	60.81	70.29	82.80	105.8
750	5.87	59.36	69.70	80.63	95.01	121.5
800	6.26	67.35	79.20	91.67	108.1	138.2
850	6.65	75.84	89.30	103.4	122.0	156.0
900	7.05	84.83	100.0	115.9	136.7	174.9

DN450: D=453mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
30	0.19	0.08	0.08	0.09	0.09	0.11
50	0.31	0.20	0.21	0.22	0.25	0.30
70	0.43	0.37	0.39	0.42	0.48	0.59
90	0.56	0.58	0.63	0.69	0.78	0.96
110	0.68	0.85	0.92	1.01	1.15	1.43
130	0.81	1.16	1.26	1.40	1.60	1.99
150	0.93	1.51	1.66	1.84	2.11	2.65
170	1.05	1.91	2.11	2.35	2.71	3.40
190	1.18	2.35	2.61	2.92	3.37	4.24
210	1.30	2.84	3.16	3.55	4.11	5.17
230	1.42	3.38	3.77	4.25	4.92	6.20
250	1.55	3.95	4.43	5.00	5.80	7.32
270	1.67	4.58	5.14	5.82	6.75	8.53
290	1.80	5.24	5.91	6.69	7.78	9.83
240	1.49	3.66	4.09	4.61	5.35	6.74
260	1.61	4.26	4.78	5.40	6.26	7.91
280	1.73	4.90	5.52	6.25	7.26	9.17
300	1.86	5.59	6.31	7.15	8.32	10.52
350	2.17	7.50	8.52	9.69	11.29	14.30
400	2.48	9.69	11.06	12.61	14.72	18.66
450	2.79	12.16	13.93	15.92	18.61	23.61
500	3.10	14.89	17.13	19.61	22.94	29.13
550	3.41	17.90	20.66	23.68	27.73	35.23
600	3.72	21.19	24.51	28.14	32.98	41.92
700	4.34	28.57	33.21	38.21	44.83	57.02
800	4.95	37.05	43.23	49.81	58.49	74.45
900	5.57	46.63	54.56	62.95	73.97	94.20
1000	6.19	57.29	67.20	77.62	91.27	116.3
1100	6.81	69.05	81.16	93.83	110.4	140.7
1200	7.43	81.89	96.44	111.6	131.3	167.4

Integral pipe

Table 3: Full bore discharge DN100-2000

DN500: D=505mm

Q (l/s)	V (m/s)	i (m/1000m) ks=0.06 mm	ks=0.15 mm	ks=0.3 mm	ks=0.6 mm	ks=1.5 mm
50	0.25	0.12	0.12	0.13	0.14	0.17
75	0.38	0.25	0.26	0.28	0.32	0.38
100	0.50	0.42	0.45	0.49	0.55	0.68
125	0.63	0.64	0.68	0.75	0.85	1.05
150	0.75	0.89	0.97	1.07	1.22	1.51
175	0.88	1.19	1.30	1.44	1.65	2.05
200	1.00	1.53	1.68	1.87	2.14	2.68
225	1.13	1.90	2.10	2.35	2.70	3.38
250	1.25	2.32	2.58	2.88	3.32	4.17
275	1.38	2.78	3.10	3.48	4.01	5.04
300	1.50	3.28	3.66	4.12	4.77	5.99
325	1.63	3.82	4.28	4.82	5.59	7.03
350	1.75	4.39	4.94	5.58	6.47	8.15
375	1.88	5.01	5.65	6.39	7.42	9.35
400	2.00	5.67	6.40	7.26	8.43	10.63
450	2.25	7.10	8.06	9.15	10.65	13.44
500	2.50	8.69	9.90	11.27	13.13	16.59
550	2.75	10.44	11.93	13.61	15.87	20.06
600	3.00	12.34	14.15	16.16	18.86	23.87
650	3.25	14.40	16.56	18.94	22.12	28.00
700	3.50	16.62	19.16	21.93	25.64	32.46
750	3.75	19.00	21.94	25.15	29.41	37.25
800	4.00	21.53	24.92	28.58	33.44	42.38
850	4.25	24.22	28.08	32.24	37.74	47.83
900	4.50	27.06	31.43	36.11	42.29	53.61
950	4.75	30.07	34.97	40.20	47.10	59.73
1000	5.00	33.23	38.70	44.51	52.17	66.17
1050	5.25	36.54	42.61	49.05	57.49	72.94
1100	5.50	40.02	46.72	53.80	63.08	80.04
1150	5.75	43.65	51.01	58.77	68.93	87.48
1200	6.00	47.44	55.49	63.96	75.03	95.24
1300	6.50	55.48	65.02	75.00	88.02	111.8
1400	7.00	64.15	75.30	86.92	102.1	129.6

DN600: D=606mm

Q (l/s)	V (m/s)	i (m/1000m) ks=0.06 mm	ks=0.15 mm	ks=0.3 mm	ks=0.6 mm	ks=1.5 mm
50	0.17	0.05	0.05	0.05	0.06	0.07
75	0.26	0.10	0.11	0.11	0.12	0.15
100	0.35	0.17	0.18	0.19	0.22	0.26
125	0.43	0.26	0.28	0.30	0.33	0.41
150	0.52	0.36	0.39	0.42	0.47	0.58
175	0.61	0.48	0.52	0.57	0.64	0.79
200	0.69	0.62	0.67	0.73	0.83	1.03
225	0.78	0.77	0.84	0.92	1.05	1.30
250	0.87	0.94	1.02	1.13	1.29	1.60
275	0.95	1.12	1.23	1.36	1.55	1.93
300	1.04	1.32	1.45	1.61	1.84	2.29
325	1.13	1.54	1.69	1.88	2.16	2.69
350	1.21	1.77	1.95	2.18	2.50	3.12
375	1.30	2.01	2.23	2.49	2.86	3.57
400	1.39	2.27	2.52	2.83	3.25	4.06
450	1.56	2.84	3.17	3.56	4.11	5.14
500	1.74	3.47	3.89	4.38	5.06	6.34
550	1.91	4.16	4.68	5.29	6.11	7.66
600	2.08	4.92	5.55	6.27	7.27	9.11
650	2.26	5.73	6.48	7.35	8.52	10.69
700	2.43	6.60	7.50	8.50	9.87	12.39
750	2.60	7.54	8.58	9.74	11.32	14.22
800	2.78	8.54	9.73	11.07	12.87	16.17
900	3.12	10.71	12.26	13.98	16.26	20.46
1000	3.47	13.13	15.09	17.22	20.05	25.25
1100	3.82	15.80	18.20	20.80	24.24	30.54
1200	4.16	18.70	21.60	24.72	28.83	36.33
1300	4.51	21.85	25.30	28.97	33.81	42.63
1400	4.86	25.24	29.28	33.57	39.19	49.43
1600	5.55	32.75	38.12	43.77	51.15	64.53
1800	6.25	41.24	48.13	55.32	64.69	81.65
2000	6.94	50.69	59.30	68.23	79.82	100.8

Table 3: Full bore discharge DN100-2000

DN700: D=703mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
50	0.13	0.02	0.02	0.03	0.03	0.03
75	0.19	0.05	0.05	0.05	0.06	0.07
100	0.26	0.08	0.09	0.09	0.10	0.12
125	0.32	0.13	0.13	0.14	0.16	0.19
150	0.39	0.18	0.19	0.20	0.22	0.27
175	0.45	0.23	0.25	0.27	0.30	0.36
200	0.52	0.30	0.32	0.34	0.39	0.47
225	0.58	0.37	0.40	0.43	0.49	0.59
250	0.64	0.45	0.48	0.53	0.60	0.73
275	0.71	0.54	0.58	0.64	0.72	0.88
300	0.77	0.63	0.69	0.75	0.85	1.05
325	0.84	0.74	0.80	0.88	1.00	1.23
350	0.90	0.84	0.92	1.02	1.15	1.43
375	0.97	0.96	1.05	1.16	1.32	1.64
400	1.03	1.08	1.19	1.32	1.50	1.86
450	1.16	1.35	1.49	1.66	1.89	2.35
500	1.29	1.65	1.82	2.04	2.33	2.90
550	1.42	1.98	2.19	2.45	2.82	3.50
600	1.55	2.33	2.60	2.91	3.35	4.17
650	1.67	2.72	3.03	3.41	3.92	4.88
700	1.80	3.13	3.50	3.94	4.54	5.66
800	2.06	4.04	4.54	5.12	5.92	7.39
900	2.32	5.06	5.72	6.46	7.48	9.34
1000	2.58	6.19	7.02	7.96	9.22	11.53
1200	3.09	8.80	10.04	11.41	13.24	16.59
1400	3.61	11.85	13.60	15.49	18.00	22.56
1600	4.12	15.36	17.69	20.19	23.48	29.45
1800	4.64	19.31	22.31	25.51	29.69	37.27
2000	5.15	23.71	27.47	31.44	36.63	45.99
2200	5.67	28.56	33.17	38.00	44.29	55.64
2400	6.18	33.86	39.40	45.18	52.68	66.20
2600	6.70	39.60	46.17	52.98	61.80	77.68
2800	7.21	45.79	53.47	61.40	71.65	90.08

DN800: D=805mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
100	0.20	0.04	0.04	0.05	0.05	0.06
125	0.25	0.07	0.07	0.07	0.08	0.09
150	0.29	0.09	0.09	0.10	0.11	0.13
175	0.34	0.12	0.13	0.14	0.15	0.18
200	0.39	0.15	0.16	0.17	0.19	0.23
225	0.44	0.19	0.20	0.22	0.24	0.29
250	0.49	0.23	0.25	0.27	0.30	0.36
275	0.54	0.28	0.30	0.32	0.36	0.44
300	0.59	0.33	0.35	0.38	0.42	0.52
325	0.64	0.38	0.40	0.44	0.50	0.61
350	0.69	0.43	0.47	0.51	0.57	0.70
375	0.74	0.49	0.53	0.58	0.66	0.80
400	0.79	0.56	0.60	0.66	0.75	0.91
450	0.88	0.69	0.75	0.83	0.94	1.16
500	0.98	0.84	0.92	1.02	1.16	1.42
550	1.08	1.01	1.10	1.22	1.39	1.72
600	1.18	1.19	1.31	1.45	1.66	2.05
650	1.28	1.38	1.52	1.70	1.94	2.40
700	1.38	1.59	1.76	1.96	2.25	2.78
750	1.47	1.81	2.01	2.25	2.57	3.19
800	1.57	2.05	2.28	2.55	2.97	3.63
850	1.67	2.30	2.56	2.87	3.30	4.09
900	1.77	2.56	2.86	3.21	3.69	4.59
950	1.87	2.84	3.18	3.57	4.11	5.11
1000	1.96	3.14	3.52	3.95	4.55	5.66
1250	2.46	4.81	5.43	6.14	7.09	8.83
1500	2.95	6.83	7.77	8.80	10.18	12.70
2000	3.93	11.91	13.67	15.57	18.05	22.55
2500	4.91	18.39	21.23	24.24	28.16	35.21
3000	5.89	26.25	30.45	34.83	40.50	50.69
3500	6.88	35.50	41.32	47.33	55.08	68.96

Table 3: Full bore discharge DN100-2000

DN900: D=903mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
100	0.16	0.02	0.03	0.03	0.03	0.03
125	0.20	0.04	0.04	0.04	0.04	0.05
150	0.23	0.05	0.05	0.06	0.06	0.07
175	0.27	0.07	0.07	0.08	0.08	0.10
200	0.31	0.09	0.09	0.10	0.11	0.13
225	0.35	0.11	0.11	0.12	0.13	0.16
250	0.39	0.13	0.14	0.15	0.17	0.20
275	0.43	0.16	0.17	0.18	0.20	0.24
300	0.47	0.19	0.20	0.21	0.24	0.28
325	0.51	0.21	0.23	0.25	0.28	0.33
350	0.55	0.25	0.26	0.28	0.32	0.39
375	0.59	0.28	0.30	0.32	0.36	0.44
400	0.62	0.32	0.34	0.37	0.41	0.50
450	0.70	0.39	0.42	0.46	0.52	0.63
500	0.78	0.48	0.52	0.57	0.64	0.78
550	0.86	0.57	0.62	0.68	0.77	0.94
600	0.94	0.67	0.73	0.81	0.91	1.12
650	1.02	0.78	0.85	0.94	1.07	1.32
700	1.09	0.90	0.98	1.09	1.24	1.52
750	1.17	1.03	1.12	1.25	1.42	1.75
800	1.25	1.16	1.27	1.41	1.61	1.99
850	1.33	1.30	1.43	1.59	1.82	2.24
900	1.41	1.45	1.60	1.78	2.04	2.51
950	1.48	1.60	1.78	1.98	2.27	2.80
1000	1.56	1.77	1.96	2.19	2.51	3.10
1250	1.95	2.70	3.03	3.40	3.90	4.84
1500	2.34	3.83	4.32	4.87	5.60	6.96
2000	3.12	6.67	7.59	8.59	9.93	12.35
2500	3.91	10.28	11.77	13.37	15.48	19.28
3000	4.69	14.65	16.86	19.21	22.26	27.74
3500	5.47	19.79	22.87	26.09	30.27	37.74
4000	6.25	25.69	29.78	34.02	39.50	49.28
4500	7.03	32.36	37.61	43.01	49.96	62.36

DN1000: D=1004mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
150	0.19	0.03	0.03	0.03	0.04	0.04
175	0.22	0.04	0.04	0.04	0.05	0.06
200	0.25	0.05	0.05	0.06	0.06	0.07
225	0.28	0.07	0.07	0.07	0.08	0.09
250	0.32	0.08	0.08	0.09	0.10	0.11
275	0.35	0.09	0.10	0.11	0.12	0.14
300	0.38	0.11	0.12	0.12	0.14	0.16
325	0.41	0.13	0.13	0.14	0.16	0.19
350	0.44	0.15	0.15	0.17	0.18	0.22
375	0.47	0.17	0.18	0.19	0.21	0.25
400	0.51	0.19	0.20	0.21	0.24	0.29
450	0.57	0.23	0.25	0.27	0.30	0.36
500	0.63	0.28	0.30	0.33	0.37	0.45
550	0.69	0.34	0.36	0.40	0.45	0.54
600	0.76	0.40	0.43	0.47	0.53	0.64
650	0.82	0.46	0.50	0.55	0.62	0.76
700	0.88	0.53	0.58	0.63	0.72	0.87
750	0.95	0.61	0.66	0.72	0.82	1.00
800	1.01	0.68	0.74	0.82	0.93	1.14
850	1.07	0.77	0.84	0.92	1.05	1.29
900	1.14	0.85	0.93	1.03	1.17	1.44
950	1.20	0.95	1.04	1.15	1.31	1.60
1000	1.26	1.04	1.14	1.27	1.45	1.78
1250	1.58	1.59	1.76	1.97	2.25	2.77
1500	1.89	2.25	2.51	2.81	3.23	3.98
2000	2.53	3.91	4.40	4.96	5.71	7.07
2500	3.16	6.01	6.82	7.72	8.90	11.04
3000	3.79	8.55	9.76	11.07	12.79	15.88
3500	4.42	11.53	13.23	15.04	17.39	21.60
4000	5.05	14.96	17.22	19.60	22.69	28.21
4500	5.68	18.83	21.74	24.77	28.69	35.69
5000	6.32	23.13	26.78	30.55	35.40	44.05
5500	6.95	27.89	32.34	36.93	42.82	53.29

Table 3: Full bore discharge DN100-2000

DN1200: D=1207mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
225	0.20	0.03	0.03	0.03	0.03	0.04
250	0.22	0.03	0.03	0.04	0.04	0.04
275	0.24	0.04	0.04	0.04	0.05	0.05
300	0.26	0.05	0.05	0.05	0.05	0.06
325	0.28	0.05	0.05	0.06	0.06	0.07
350	0.31	0.06	0.06	0.07	0.07	0.09
375	0.33	0.07	0.07	0.08	0.08	0.10
400	0.35	0.08	0.08	0.09	0.09	0.11
450	0.39	0.09	0.10	0.11	0.12	0.14
500	0.44	0.12	0.12	0.13	0.14	0.17
550	0.48	0.14	0.15	0.16	0.17	0.21
600	0.52	0.16	0.17	0.18	0.21	0.25
650	0.57	0.19	0.20	0.22	0.24	0.29
700	0.61	0.21	0.23	0.25	0.28	0.33
750	0.66	0.24	0.26	0.28	0.32	0.38
800	0.70	0.28	0.30	0.32	0.36	0.44
850	0.74	0.31	0.33	0.36	0.41	0.49
900	0.79	0.34	0.37	0.40	0.45	0.55
950	0.83	0.38	0.41	0.45	0.50	0.61
1000	0.87	0.42	0.45	0.50	0.56	0.68
1250	1.09	0.64	0.69	0.76	0.87	1.06
1500	1.31	0.90	0.99	1.09	1.24	1.52
2000	1.75	1.55	1.72	1.92	2.19	2.69
2500	2.18	2.38	2.66	2.98	3.41	4.20
3000	2.62	3.38	3.80	4.27	4.90	6.05
3500	3.06	4.54	5.14	5.80	6.66	8.22
4000	3.50	5.88	6.68	7.55	8.69	10.73
4500	3.93	7.39	8.43	9.54	10.99	13.58
5000	4.37	9.07	10.37	11.76	13.59	16.76
5500	4.81	10.92	12.52	14.21	16.39	20.27
6000	5.24	12.94	14.87	16.89	19.49	24.12
7000	6.12	17.49	20.17	22.95	26.51	32.82
8000	6.99	22.72	26.28	29.93	34.60	42.85

DN1400: D=1407mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
325	0.21	0.02	0.03	0.03	0.03	0.03
350	0.23	0.03	0.03	0.03	0.03	0.04
375	0.24	0.03	0.03	0.04	0.04	0.04
400	0.28	0.04	0.04	0.04	0.04	0.05
450	0.29	0.04	0.05	0.05	0.05	0.06
500	0.32	0.05	0.06	0.06	0.07	0.08
550	0.35	0.06	0.07	0.07	0.08	0.09
600	0.39	0.08	0.08	0.09	0.09	0.11
650	0.42	0.09	0.09	0.10	0.11	0.13
700	0.45	0.10	0.11	0.11	0.13	0.15
750	0.48	0.12	0.12	0.13	0.14	0.17
800	0.51	0.13	0.14	0.15	0.16	0.20
850	0.55	0.15	0.15	0.17	0.18	0.22
900	0.58	0.16	0.17	0.19	0.21	0.25
950	0.61	0.18	0.19	0.21	0.23	0.28
1000	0.64	0.20	0.21	0.23	0.25	0.31
1250	0.8	0.30	0.32	0.35	0.39	0.47
1500	0.96	0.42	0.46	0.50	0.56	0.68
2000	1.29	0.72	0.79	0.87	0.99	1.21
2500	1.61	1.10	1.22	1.36	1.54	1.88
3000	1.93	1.56	1.74	1.94	2.21	2.71
3500	2.25	2.10	2.35	2.63	3.00	3.68
4000	2.57	2.72	3.05	3.42	3.92	4.81
4500	2.89	3.41	3.84	4.32	4.95	6.08
5000	3.22	4.18	4.72	5.32	6.10	7.50
5500	3.54	5.02	5.70	6.43	7.38	9.08
6000	3.86	5.95	6.76	7.64	8.77	10.80
6500	4.18	6.95	7.92	8.95	10.29	12.67
7000	4.5	8.02	9.16	10.37	11.93	14.69
8000	5.15	10.41	11.93	13.52	15.56	19.18
9000	5.79	13.10	15.06	17.08	19.68	24.27
10000	6.43	16.10	18.55	21.07	24.28	29.95
11000	7.07	19.41	22.41	25.47	29.37	36.24

Integral pipe

Table 3: Full bore discharge DN100-2000

DN1600: D=1609mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
500	0.25	0.03	0.03	0.03	0.03	0.04
550	0.27	0.03	0.04	0.04	0.04	0.05
600	0.30	0.04	0.04	0.04	0.05	0.06
650	0.32	0.05	0.05	0.05	0.06	0.07
700	0.34	0.05	0.06	0.06	0.06	0.08
750	0.37	0.06	0.06	0.07	0.07	0.09
800	0.39	0.07	0.07	0.08	0.08	0.10
850	0.42	0.08	0.08	0.08	0.09	0.11
900	0.44	0.08	0.09	0.09	0.10	0.12
950	0.47	0.09	0.10	0.10	0.12	0.14
1000	0.49	0.10	0.11	0.12	0.13	0.15
1250	0.61	0.15	0.16	0.18	0.20	0.24
1500	0.74	0.22	0.23	0.25	0.28	0.34
2000	0.98	0.37	0.40	0.44	0.50	0.60
2500	1.23	0.57	0.62	0.68	0.77	0.93
3000	1.48	0.80	0.88	0.97	1.10	1.34
3500	1.72	1.07	1.19	1.32	1.50	1.83
4000	1.97	1.39	1.54	1.71	1.95	2.38
4500	2.21	1.74	1.94	2.16	2.47	3.01
5000	2.46	2.13	2.38	2.66	3.04	3.72
5500	2.70	2.55	2.87	3.21	3.67	4.50
6000	2.95	3.02	3.40	3.82	4.37	5.35
6500	3.20	3.53	3.98	4.47	5.12	6.28
7000	3.44	4.07	4.60	5.18	5.94	7.28
7500	3.69	4.65	5.27	5.94	6.81	8.35
8000	3.93	5.27	5.99	6.75	7.74	9.50
8500	4.18	5.93	6.75	7.61	8.74	10.72
9000	4.43	6.63	7.55	8.53	9.79	12.02
9500	4.67	7.37	8.41	9.50	10.90	13.39
10000	4.92	8.14	9.30	10.52	12.08	14.83
11000	5.41	9.81	11.23	12.71	14.60	17.94
12000	5.90	11.62	13.34	15.11	17.37	21.35
13000	6.39	13.60	15.63	17.72	20.38	25.05

DN1800: D=1812mm

Q (l/s)	V (m/s)	i (m/1000m) ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
650	0.25	0.03	0.03	0.03	0.03	0.04
700	0.27	0.03	0.03	0.03	0.03	0.04
750	0.29	0.03	0.03	0.04	0.04	0.05
800	0.31	0.04	0.04	0.04	0.05	0.05
850	0.33	0.04	0.04	0.05	0.05	0.06
900	0.35	0.05	0.05	0.05	0.06	0.07
950	0.37	0.05	0.05	0.06	0.06	0.07
1000	0.39	0.06	0.06	0.06	0.07	0.08
1250	0.48	0.09	0.09	0.10	0.11	0.13
1500	0.58	0.12	0.13	0.14	0.15	0.18
2000	0.78	0.21	0.22	0.24	0.27	0.32
2500	0.97	0.31	0.34	0.37	0.42	0.50
3000	1.16	0.44	0.48	0.53	0.60	0.72
3500	1.36	0.59	0.65	0.72	0.81	0.98
4000	1.55	0.77	0.84	0.93	1.06	1.28
4500	1.75	0.96	1.06	1.17	1.33	1.62
5000	1.94	1.17	1.30	1.45	1.64	2.00
5500	2.13	1.41	1.56	1.74	1.98	2.42
6000	2.33	1.66	1.85	2.07	2.36	2.88
6500	2.52	1.94	2.17	2.42	2.76	3.37
7000	2.71	2.24	2.51	2.81	3.20	3.91
7500	2.91	2.56	2.87	3.22	3.67	4.49
8000	3.10	2.90	3.26	3.66	4.18	5.10
8500	3.30	3.26	3.67	4.12	4.71	5.76
9000	3.49	3.64	4.11	4.62	5.28	6.46
9500	3.68	4.04	4.57	5.14	5.88	7.19
10000	3.88	4.46	5.06	5.69	6.51	7.97
11000	4.27	5.37	6.10	6.87	7.87	9.64
12000	4.65	6.36	7.24	8.17	9.36	11.47
13000	5.04	7.43	8.48	9.58	10.98	13.45
14000	5.43	8.59	9.82	11.10	12.73	15.60
15000	5.82	9.83	11.26	12.73	14.61	17.91

Table 3: Full bore discharge DN100-2000
DN2000: D=2015mm

Q (l/s)	V (m/s)	i (m/1000m)				
		ks= 0.06 mm	ks= 0.15 mm	ks= 0.3 mm	ks= 0.6 mm	ks= 1.5 mm
1000	.31	.03	.04	.04	.04	.05
1250	.39	.05	.05	.06	.06	.07
1500	.47	.07	.08	.08	.09	.11
2000	.63	.12	.13	.14	.16	.19
2500	.78	.19	.2	.22	.24	.29
3000	.94	.26	.28	.31	.35	.42
3500	1.1	.35	.38	.42	.47	.56
4000	1.25	.45	.49	.54	.61	.74
4500	1.41	.56	.62	.68	.77	.93
5000	1.57	.69	.76	.84	.95	1.15
5500	1.72	.83	.91	1.01	1.14	1.39
6000	1.88	.98	1.08	1.2	1.36	1.65
6500	2.04	1.14	1.26	1.4	1.59	1.94
7000	2.2	1.31	1.46	1.62	1.85	2.24
7500	2.35	1.5	1.67	1.86	2.12	2.58
8000	2.51	1.7	1.89	2.11	2.41	2.93
8500	2.67	1.91	2.13	2.38	2.71	3.31
9000	2.82	2.13	2.39	2.67	3.04	3.7
9500	2.98	2.36	2.65	2.97	3.39	4.13
10000	3.14	2.61	2.93	3.29	3.75	4.57
11000	3.45	3.14	3.54	3.97	4.53	5.53
12000	3.76	3.71	4.2	4.72	5.39	6.58
13000	4.08	4.34	4.92	5.53	6.32	7.72
14000	4.39	5.01	5.69	6.41	7.33	8.95
15000	4.7	5.73	6.52	7.35	8.41	10.27
16000	5.02	6.5	7.41	8.35	9.56	11.68
17000	5.33	7.32	8.35	9.42	10.79	13.19
18000	5.64	8.18	9.35	10.56	12.09	14.78
19000	5.96	9.1	10.41	11.75	13.47	16.47
20000	6.27	10.06	11.52	13.02	14.92	18.25

Embedment Designing Below Ground

Introduction

Saint-Gobain Pipelines' water and Integral pipes behave as semi-rigid conduits and withstand external loading through a combination of the inherent strength of ductile iron and the support from the pipe embedment. The embedment regime depends on several variables including earth/vehicle loading, pipe stiffness and pipe support (bedding and sidefill).

The embedment calculations in this section can be performed using the PipeSpec software.

$$\Delta = \frac{100K\,(Pe + Pt)}{8S + 0.061\,E^{1}/DL}$$

Where:
Δ = ovalisation (%)
K = bedding coefficient
Pe = earth load (kN/m²)
Pt = traffic load (kN/m²)
S = pipe diametral stiffness (kN/m²)
E^{1} = modulus of soil reaction (kN/m²)
DL = deflection lag factor

Ovalisation

The design method adopted in the European Standards for ductile iron pipes (BS EN 545 and BS EN 598) utilises the modified Spangler Iowa formula, which calculates the ovalisation (diametral deflection) of the pipe barrel.

The ovalisation calculated from this formula should not exceed the allowable ovalisation in Table 4.

Table 4: Allowable Ovalisation (Δ)

DN	Water		Integral	
	Pipe Class	Ovalisation (%)	DN	Ovalisation (%)
80	40	1.1	80	1.4
100	40	1.3	100	1.6
150	40	1.85	150	2.1
200	40	2.25	200	2.4
250	40	2.6	250	2.7
300	40	2.9	300-2000	3.0
350	40	2.95		
400	40	3.0		
450-2000	K9	3.0		

The allowable ovalisation increases with DN whilst:

-remaining well below the value that internal linings e.g. cement mortar can withstand without cracking.
-providing a minimum safety factor of 2.0 with respect to the ultimate bending stress, and
-ensuring a leak-tight joint at all times under the most adverse conditions.

The earth load (Pe) is based upon the prism load:

$$Pe = f \gamma H$$

Where:
f = loading factor
γ = unit weight of backfill (kN/m^3)
H = height of cover (m)

Note: Embankment conditions are possible in trench installations. A narrow trench loading condition prevails when:

$$\frac{H}{Bd} > 0.733 \left[\frac{H}{De}\right]^{0.735}$$

Where:
Bd = trench width (m)
De = pipe external diameter (m)

Earth Load, Pe

Values for the loading factor f are given for Narrow Trench and Embankment conditions in Table 5.

Table 5: Earth Loading Factor (f)

DN	Loading Factor	
	Narrow Trench	Embankment
80	1	1.8
100	1	1.8
150	1	1.7
200	1	1.7
250	1	1.6
300	1	1.6
350	1	1.4
400	1	1.4
450	1	1.3
500	1	1.3
600	1	1.2
700	1	1.1
800-2000	1	1

In the absence of other data, the unit weight of soil is taken as being equal to 20 kN/m^2 in order to cover the vast majority of cases. If a geotechnical survey confirms the actual unit weight, then this value must be used if this is shown to be greater than 20 kN/m^2.

Traffic Load, Pt

$$Pt = 40 \frac{ß}{H}\left[1 - (2DN \times 10^{-4})\right]$$

Where:
ß = traffic load factor

Traffic load

The traffic load (Pt) is assumed to be uniformly distributed at the top of the pipe over a distance equal to the external diameter and is given by:
Note: This formula is not valid for H<0.3m

ß has 4 main values:
- ß = 0.5 – rural areas
- ß = 0.75 – access roads (no HGV traffic)
- ß = 1.5 – main roads
- ß = 2.0 – high traffic loads

Pipe Stiffness

The stiffness (S) of a ductile iron pipe is a measure of its ability to resist ovalisation when subjected to external loading. The minimum diametral stiffness is given in Table 6.

Table 6: Minimum Diametral Stiffness (S)

DN	Water		Integral
	Pipe Class	Min. Stiffness (kN/m^2)	Min. Stiffness (kN/m^2)
80	40	1200	450
100	40	680	250
150	40	250	80
200	40	130	60
250	40	91	54
300	40	68	47
350	40	67	36
400	40	63	30
450	K9	61	26
500	K9	52	22
600	K9	41	18
700	K9	34	24
800	K9	30	20
900	K9	26	18
1000	K9	24	16
1100	K9	22	-
1200	K9	20	20
1400	K9	18	18
1600	K9	17	17
1800	K9	16	16
2000	K9	16	16

Bedding Coefficient

The bedding coefficient (K) reflects the angle of support at the invert and the quality of the bedding and sidefill material and varies from 0.11 for bedding angle = 20° to 0.09 for bedding angle = 120°. A value of 20° corresponds to a ductile iron pipe simply laid on a trimmed flat bottom trench with excavations for the joints (joint holes).

Modulus of soil reaction

The modulus of soil reaction (E^1) is an empirical factor and is related to the degree of compaction applied to the pipe surround material on installation. Values have been established for various types of soil and vary from 0 to 20,000 kN/m^2, see Table 7. Low values correspond to the poorer soils with little or no compaction and the higher values to imported granular materials with compaction. Ductile iron pipe in the smaller sizes can usually be laid in very poor soils (where E^1 is assumed to be zero) without the need to import granular material for the embedment. This advantage, compared with other materials, is due to the pipe having sufficient stiffness to withstand the imposed earth and traffic loads without support from the sidefill.

Deflection Lag Factor

The deflection lag factor (DL) is influenced by the nature of the native soil and sidefill, and the working pressure. It is assumed that for pressure pipelines DL= 1 and for non-pressure pipelines DL = 1.5.

Design Charts

Water Pipe

Figures 4 and 5 are provided for determining the soil modulus for water pipes laid in fields and under roads: -

Fig 4, is for fields with a traffic factor (ß) of 0.75.
Fig 7, is for roads with a traffic factor (ß) of 2.0.

Sewer Pipe

Figures 6 and 7 are provided for determining the soil modulus for sewer pipes laid in fields and under roads: -

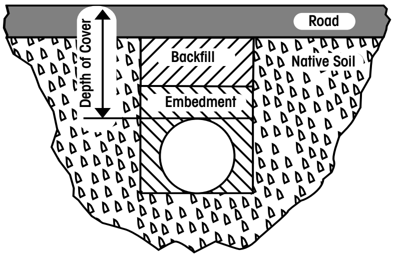
Fig 6, is for fields with a traffic factor (ß) of 0.75.
Fig 7, is for roads with a traffic factor (ß) of 2.0.

The following criteria were used in their preparation: -

i) allowable ovalisation D, as given in Table 4
ii) stiffness S, as given in Table 6
iii) bedding coefficient K = 0.11
iv) unit weight of backfill = 20 kN/m^3
v) narrow trench earth loading

To use Figs 4, 5, 6 and 7 for embankment conditions, the actual laid depths need to be increased by the factors given in Table 5 in order to obtain a theoretical depth of cover to compensate for the increased loading, see Example 3 for water pipelines.

Fig 3: Typical Trench Cross-Section



Soil classification

Table 7, shows the classification of soils together with the range of modulus (E^1) which can be obtained for various compactions (expressed as % Standard Proctor Density). Table 8 shows the compaction method needed to obtain the required densities.

Practical considerations

Fig 3 shows a typical trench for a ductile iron pipe installation, with the pipe laid on a trimmed flat bottom trench. The trench should be as narrow as is practical taking into consideration the type of native soil and backfill and, where necessary, the required compaction.

Special consideration should be given to the minimum depth of cover:

-to avoid any frost penetration (UK recommendation of 0.9m minimum), and

-to withstand any surcharge loading at the surface (e.g. traffic, railways etc.).

Joint holes should be provided to ensure that the pipe rests on the barrel.

In rocky ground, the trench should be excavated at least 100mm deeper than normally required and then made up to the level with the addition of a suitable bedding material.

Where necessary suitable precautions should be taken to avoid any risk of pipe floatation prior to backfilling.

The embedment should be compacted as required (see Table 8). Where compaction of the embedment is required, this should be carried out in layers and any trench sheeting must be pulled progressively to enable the specified compaction to be achieved.

Shallow Road Trenches

Where Saint-Gobain Pipelines' water pipe installations of DN600 and above are designed with a minimum depth of cover under highways, the majority of total load acting on the pipe is vehicular loading. In this situation higher E^1 values may be required from the pipe surround to prevent deterioration of the road surface.

Narrow Trenching

In the range DN ≤ 300, because of its high inherent strength, Saint-Gobain Pipelines' water pipes are ideal for narrow trenching installations. In the case of narrow trench installations for larger sizes it may be necessary, in very poor ground, to use soil stabilisation matting during compaction in order to obtain the required E^1.

Exceptional Cases

Should conditions more severe than those covered by Table 7 occur e.g. exceptionally weak native soil, or buried pipes laid on intermittent supports (piers) please contact Pipelines Technical Sales Department, Tel: 0115 930 0700.

Sp = Standard Proctor Density
LL = Liquid Limit

Table 7: Soil Classification and Embedment Class

Soil Type/Embedment Material	Casagrande Group Symbol	Embedment Class (E^1) kN/m²				
		Uncompacted	Lightly Consolidated >80% SP	Light Compaction >85% SP	Medium Compaction >90% SP	High Compaction >95% SP
Gravel, single size	GU	5000	7000	7000	10000	14000
Gravel, graded	GW	3000	5000	7000	10000	20000
Sand & coarse grained soil with <12% fines	GP, SW, SP	1000	3000	5000	7000	14000
Fine grain with >12% fines Fine grain soil LL <50% with medium to no plasticity and containing >25% coarse grained particles	GM, GC, SM CL, ML mixtures ML/CL ML/MH	0	1000	3000	5000	10000
Fine grained soil LL <50% with medium to no plasticity and containing <25% coarse grained particles	CL, ML mixtures ML/CL CL/CH ML/MH	0	0	1000	3000	7000

Table 8: Soil Compaction Requirements

Description	Casagrande Group Symbol	Degree of Compaction % Sp	No. of Passes with Standard Vibroplate	Thickness of Layer
Gravel	GW, GU	80	1	450
		85	1	450
		90	1	300
		95	2	300
Gravel, Sand and coarse grained soil with <12% fines	GP, SW, SP	80	1	450
		85	1	300
		90	2	300
		95	3	300
Coarse grained soil with >12% fines	GM, GC, SM	80	1	450
		85	1	300
		90	2	150
		95	3	150
Fine grained soil LL <50% with medium to no plasticity and containing >25% coarse grained particles	CL, ML, ML/CL ML/MH	80	1	450
		85	2	300
		90	2	150
		95	3	150
Fine grained soil LL <50% with medium to no plasticity and containing <25% coarse grained particles	CL, ML, CL/CH ML/MH	80	1	300
		85	3	300
		90	3	150
		95	4	150

Worked Examples

Example 1

Determine a suitable embedment material for a DN1200 Saint-Gobain Pipelines' water pipeline installed with a depth of cover 3m under a field. The native soil is relatively poor, coarse grained with >12% fines.

Reference to Fig 4 shows that a DN 1200 pipe at a depth of 3m requires an E^1 = 3000 kN/m^2. Reference to Table 7 shows that suitably excavated material compacted to 85% Sp is required. Reference to Table 8 shows that the degree of compaction is achieved with one pass of a standard vibroplate on layers 300mm thick.

Example 2

Determine a suitable embedment material for a DN300 Saint-Gobain Pipelines' water pipeline installed under a road at depths of cover between 1m and 4.5m. The native soil is relatively poor, fine-grained containing <25% coarse grained particles.

Reference to Fig 5 shows that a DN300 pipe at a depth of cover between 1 and 4.5m requires an E^1 = 0 kN/m^2 i.e. is suitably stiff without any additional soil support. Reference to Table 7 shows that suitably excavated material without compaction will be acceptable. Saint-Gobain Pipelines's water pipes can therefore be laid directly on a trimmed flat bottom trench of any convenient width and backfilled with selected excavated material without compaction (other than that required by the Highway Authority).

Example 3

Conditions as for Example 2 by laid under an embankment.

DN 300 under 1 to 4.5m cover.

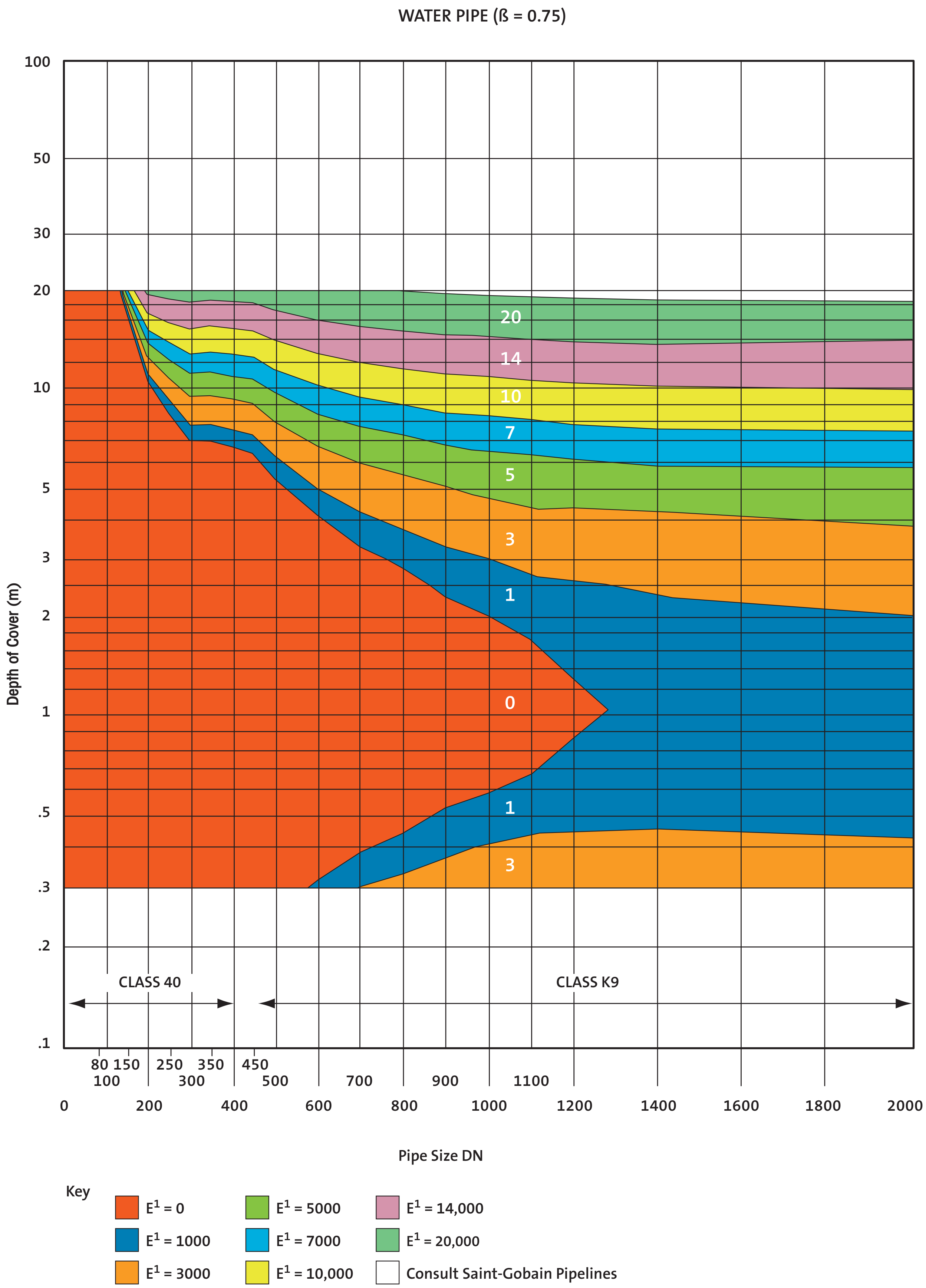
The loading factor from Table 5 for DN300 is 1.6, so the predicted loading for an embankment installation would be equivalent to (1 x 1.6) and (4.5 x 1.6) i.e. 1.6m and 7.2m depth of cover. Using these hypothetical depths in Fig 5 shows that an E^1 = 0 kN/m^2 is required at 1.6m and an E^1 = 1000 kN/m^2 at 7.2m. Reference to Table 8 shows that the latter can be achieved with 3 passes of a standard vibroplate on layers 300mm thick. Note: if the value of E^1 at the actual depth is greater than that of the hypothetical depth then use the larger value.

Example 4

Conditions as for Example 1 except that the pipeline is non-pressure.

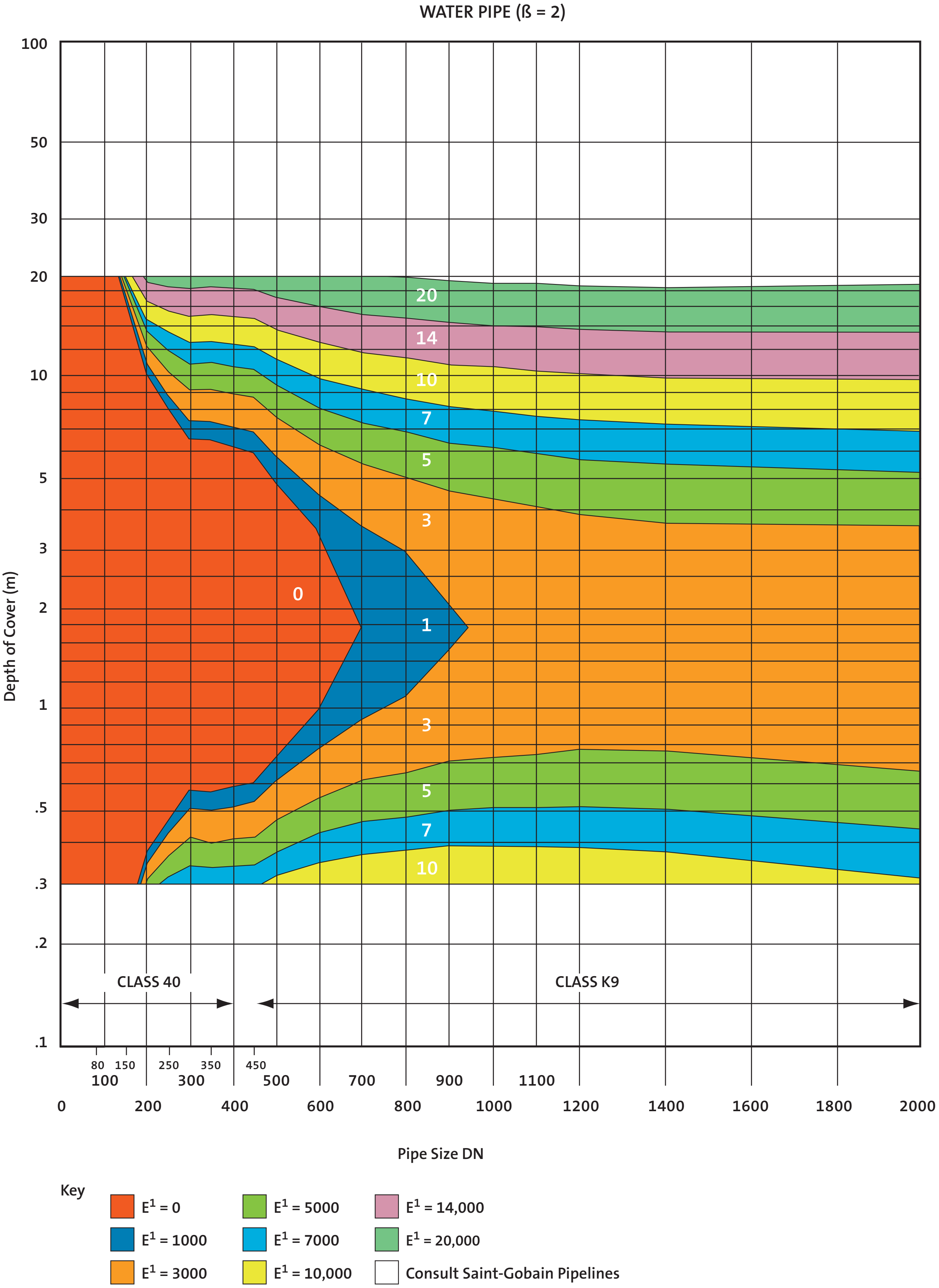
Determine E^1 for pressure pipeline as in Example 1 (E^1 = 3000 kN/m^2). For non-pressure the deflection lag factor is 1.5 and therefore E1 = 1.5 x 3000 kN/m^2 = 4500 kN/m^2. Reference Table 7 shows that suitably excavated material compacted to 90% Sp is required.

Fig 4: Installation in fields and access roads, water pipelines (ß = 0.75)



Soil modules E^1 (kN/m^2)

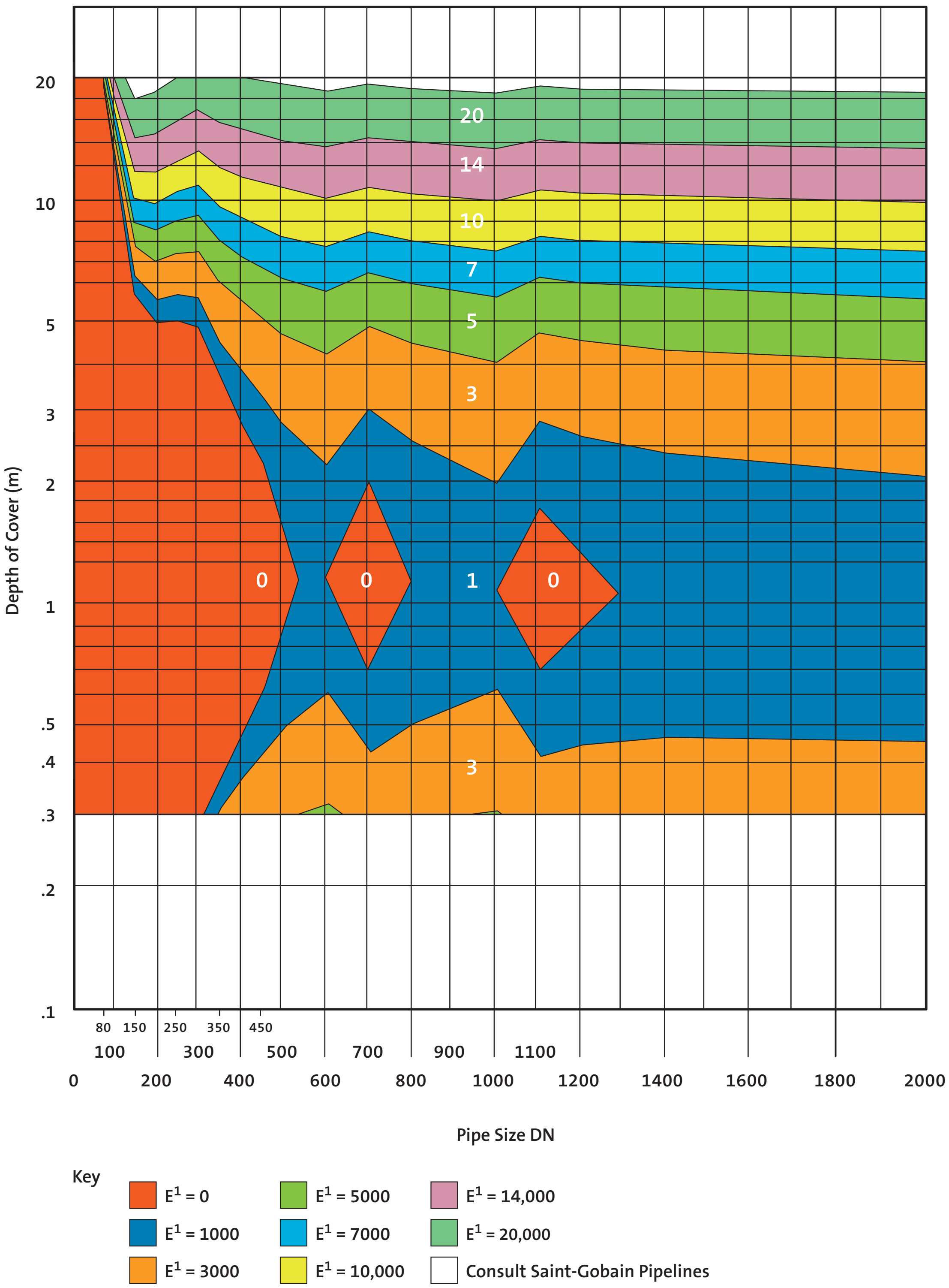
Fig 5: Installation in fields and access roads, water pipelines (ß = 2.0)



Soil modules E^1 (kN/m²)

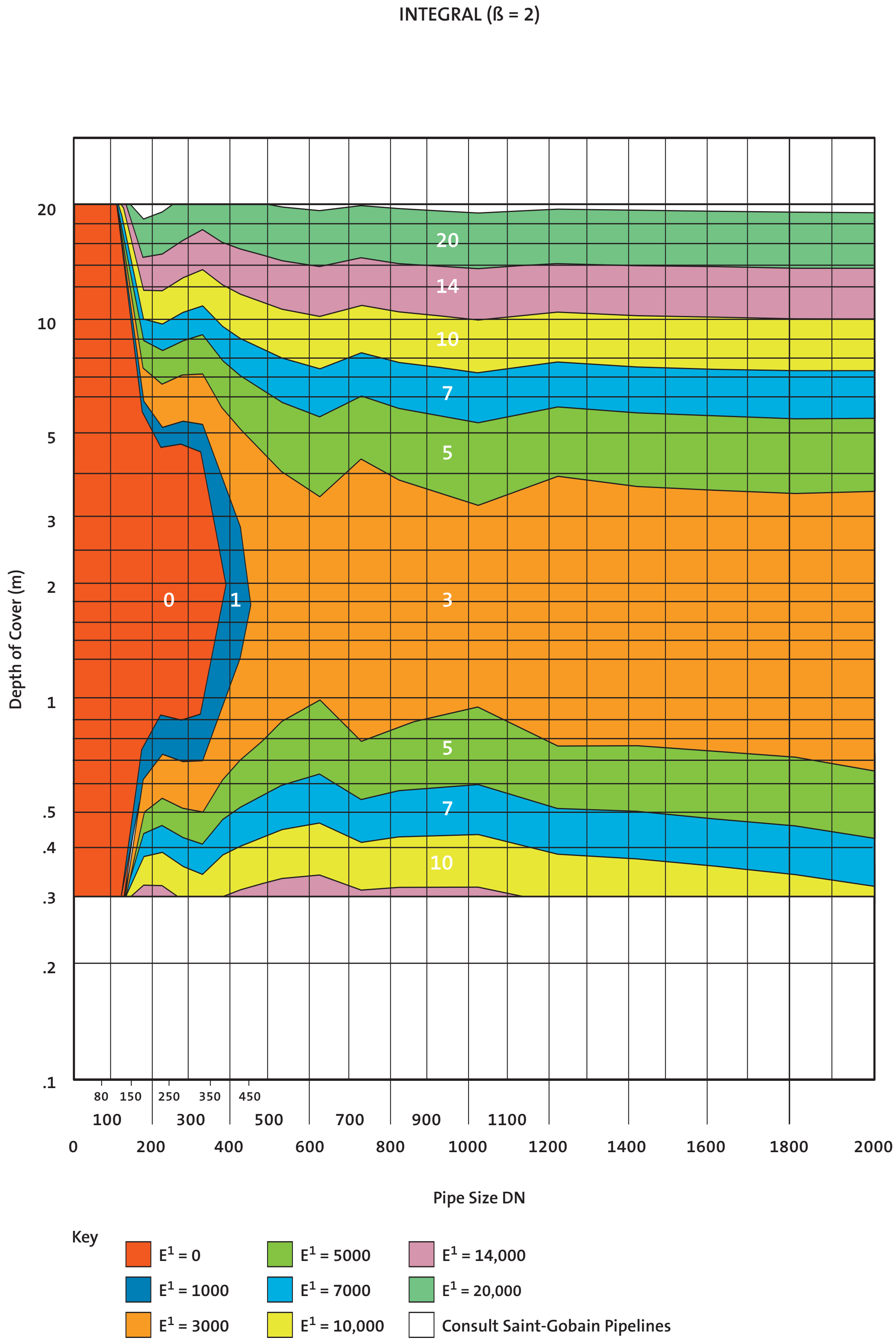
Fig 6: Installation in fields and access roads, sewer pipes (ß = 0.75)

INTEGRAL (ß = 0.75)



Soil modules E^1 (kN/m^2)

Fig 7: Installation under roads and high traffic loads, sewer pipes (ß = 2.0)



Soil modules E^1 (kN/m²)

Anchorage Requirements

Introduction

Pressure pipelines having push-fit flexible joints are subject to forces which tend to separate the joints at changes of direction, blank ends and tapers. At these locations some form of restraint is necessary.

Self-anchored flexible joints are a useful alternative to the traditional concrete anchor block especially in difficult circumstances such as:

- soft ground or ground prone to subsidence
- steep inclines
- where space is limited

Further information on the range of self anchored joints are available in our Water and Sewer Product Guide.

To achieve satisfactory anchorage using self-anchoring joints, it is rarely sufficient to anchor the fitting alone since this will only move the location of possible separation to one of the adjacent joints. However, it is not normally necessary to anchor the entire pipeline if an assessment is made of the reactive soil forces.

The calculation of these forces is a detailed and complex procedure. To assist you, we can undertake this work using a computer program we have developed. Should you wish to take advantage of this service, please contact our Pipeline Technical Sales Department, Tel: 0115 930 0700 with the following information:

- Diameter
- Fitting type (bend, tee etc.) and orientation (horizontal/vertical)
- Test pressure and working pressure
- Depth of cover
- Height of water table above the pipe invert
- Native soil type
- Backfill material
- External protection system

The anchorage program is included in the PipeSpec software.

Thrusts for Anchor Block Design

The magnitude of these thrusts may be calculated as follows:

Blank ends and junctions $= 100 \times A_e \times P$ .....kN

Bends $= 100 \times A_e \times P \times 2 \sin \frac{\theta}{2}$ ..kN

A_e = Cross-sectional area of pipe external diameter De (m^2)

P = Internal pressure (bar)

θ = Bend angle (°)

Static Thrusts

The thrusts act in the direction indicated in Fig 8.

Fig 8

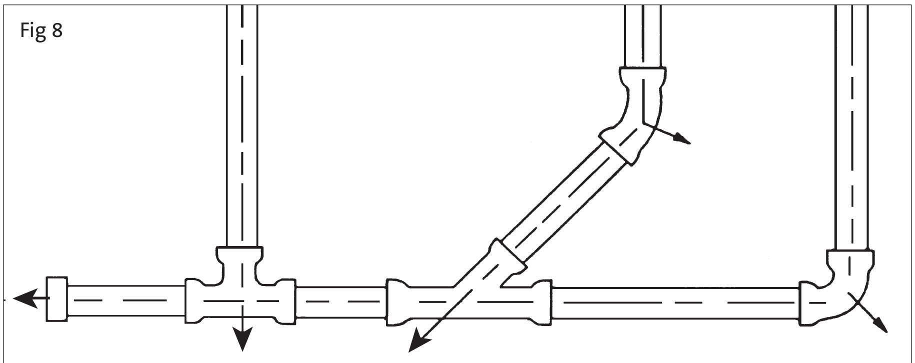


Table 9: Static thrust at fittings

Nominal Size DN	Thrust per 1 bar internal pressure				
	Blank ends and Junctions kN	90° Bends kN	45° Bends kN	22½° Bends kN	22¼° Bends kN
80	0.80	1.10	0.60	0.30	0.20
100	1.09	1.55	0.84	0.43	0.22
150	2.27	3.21	1.74	0.89	0.45
200	3.87	5.47	2.96	1.51	0.76
250	5.90	8.34	4.51	2.30	1.16
300	8.35	11.80	6.39	3.26	1.64
350	11.30	15.95	8.64	4.40	2.21
400	14.45	20.45	11.07	5.64	2.83
450	18.10	25.60	13.85	7.06	3.55
500	22.25	31.45	17.00	8.67	4.36
600	31.65	44.80	24.25	12.36	6.21
700	42.80	60.50	32.75	16.69	8.39
800	55.70	78.75	42.60	21.73	10.92
900	70.15	99.20	53.70	27.37	13.75
1000	86.25	122.00	66.00	33.66	16.91
1100	104.3	147.4	79.8	40.7	20.4
1200	123.70	174.90	94.70	48.27	24.25
1400	167.85	237.40	128.50	65.50	32.90
1600	218.50	309.00	167.20	85.26	42.84
1800	276.10	390.50	211.30	107.70	54.10
2000	340.5	481.5	260.5	132.8	66.7

Fig 9: Horizontal thrust - buried mains

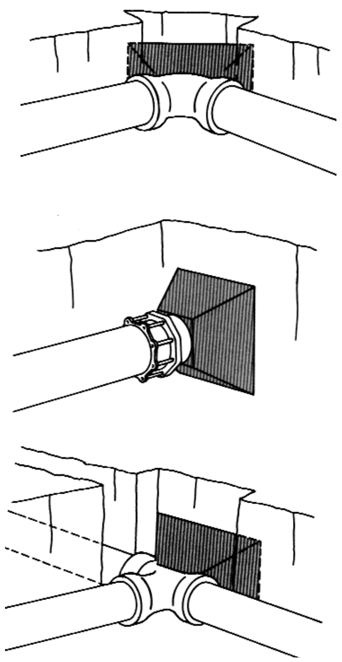


Fig 10: Vertical thrust - buried mains

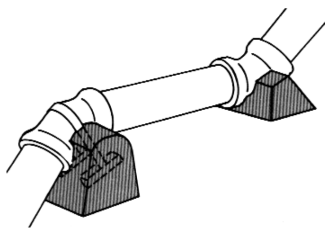
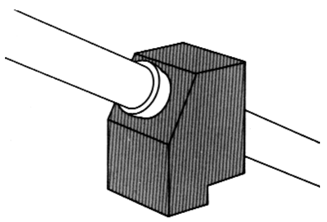


Fig 11: Gradient thrust (1 in 2 or steeper - buried mains. Restraint at each socket.)



Dynamic Thrusts

Dynamic thrusts caused by flowing water act in the same direction as static thrusts. They are insignificant at normal velocities but they can be of sufficient magnitude at high velocities to warrant consideration.

Dynamic thrust at bends may be calculated by the following formula:

$$2 \times 10^{-3} \, W A_i V^2 \, \sin\frac{\theta}{2} \, \text{........kN}$$

Where:

A_i = cross-sectional area of pipe internal diameter (m^2)

W = density of fluid (1000 kg/m^3 for water)

V = velocity of flow (m/s)

θ = bend angle (°)

Where possible, concrete anchor blocks should be of such a shape as to allow sufficient space for the remaking of joints. The following sketches show typical anchorages using concrete anchor blocks, see Figs 9 to 11.

Combined Thrust

For design purposes the combined static and dynamic thrust for water pipelines at bends can be calculated from the formula:

$$(P + 0.01V^2)\,10^2 \quad A_e \, 2 \sin\frac{\theta}{2} \, \text{........kN}$$

Alternatively, Table 4.9 may be used by multiplying the appropriate thrust per bar of internal pressure by

$$P + 0.01V^2$$

Anchorage to resist thrusts must be designed taking full account of the maximum pressure the main is to carry in service or on test, and the safe bearing pressure of the surrounding soil.

Note: Saint-Gobain Pipelines are unable to undertake the design of thrust blocks. This must be carried out by a qualified civil or structural engineer.

DN	Gradient Thrust Spacing of Anchor Blocks* (m) (Fig 11)
80 - 800	5.5
900 - 1000	7
1200 - 2000	8

* When determining the actual position of the support centres it should be noted that pipe lengths may be shorter than nominal length in accordance with tolerances permitted by BS EN 545. Please consult Pipeline Technical Sales Department, Tel: 0115 930 0650/0700.

Supporting Pipes on Piers

Pipelines laid on piers below ground may be subject to extremely high loads imposed by the soil (and in some cases traffic) which are often underestimated.

Saint-Gobain Pipelines has developed a computer program to predict the loads to be carried by the pipe and to recommend suitable saddle supports for such installations.

Please consult the Pipeline Technical Sales Department, Tel: 0115 930 0700 quoting depth of cover and any additional traffic loading etc., where it is necessary to bury pipelines on rigid intermittent supports.

Selection of External Protection

Introduction

Saint-Gobain Pipelines offers a range of external coating systems to suit different ground conditions. As standard, Saint-Gobain Pipelines offer PAM Natural and PAM Integral Plus uti 800mm. For aggresive soil conditions or larger diameters (DN900-2000), additional external protection is available. These include:

- Zinc and bitumen epoxy coating plus Stanguard polythylene sleeving (DN900-2000)
- Tape wrap 25mm overlap
- Tape wrap 55% overlap

Selection of an Appropriate Protection System

Tables 10 and 11 shows the level of protection recommended for various ground conditions.

On request Saint-Gobain Pipelines Technical Sales Department will carry out a detailed soil assessment along the route of a proposed pipeline. The results of the assessment provide a detailed analysis of ground conditions, allowing the most appropriate protection system to be specified.

Saint-Gobain Pipelines' soil assessment procedure has been awarded independent approval by the Water Research Centre.

Special Conditions

For conditions outside the range shown in Table 10 please contact Saint-Gobain Pipelines Services Marketing Department, Tel: 0115 930 0700.

Cathodic Protection

The use of cathodic protection systems for new ductile iron mains is not recommended for the following reasons:

- The jointing methods used in ductile iron pipelines act as electrical insulators, preventing the build up of long-line corrosion currents.
- The range of maintenance-free protection systems available provides suitable protection for iron pipelines.

Table 10: Recommended Protection for various Ground Conditions

Typical Ground Conditions *(for corrosion purposes only. Unless stated it is assumed that selected as dug material is to be used for bed and surround)*	Seasonal or Permanent Waterlogging	
	YES	No
Natural soils with resistivity above 2500 Ω-cm	1 or 2	1 or 2
Natural soils with resistivity above 1500 and 2500 ohmcm	1 or 3	1 or 2
Natural soils with resistivity above 750 and 1500 ohm-cm	1 or 4	1 or 3
Natural soils with resistivity below 750 Ω-cm	4	4
Natural soils containing coal, ironstone, shale or peat	4	3* or 4
Natural soils with pH less than 5	4	3* or 4
Made ground containing clinker, bricks, flints or other materials likely to cause mechanical damage	5	3* or 4
Made ground with light chemical contamination e.g. refuse sites, farmyard waste	4	3* or 4
Made ground with heavy chemical contamination e.g. disused gas plants, industrial sites, mines, chemical plants	5	5
Stray electrical currents e.g. <15m & parallel to CP. pipelines, DC traction systems	3	3
Stray electrical currents e.g. <15m & crossing to CP. pipelines, DC traction systems	4	4
Tidal waters e.g. estuaries, shorelines	5	5

Table 11: Recommended Protection for various Ground Conditions

Reference Number	Description	Protection System
1	Slight to moderately aggresive and aggresive	Tidal waters Zinc-aluminium and epoxy - PAM Natural (available on water pipes uti DN800/PAM Integral Plus (available on sewer pipes DN80-800
2	Slight to moderate aggresive	Zinc and bitumen coating (available on water pipes DN900-2000)
3	Aggresive	Zinc and bitumen coating PE sleeving (available on water pipes DN900-2000)
4	Highly aggresive	Zinc and bitumen/epoxy coating plus tape wrap (25mm overlap)
5	Highly aggresive	Zinc and bitumen/epoxy coating plus tape wrap (55% overlap)
*		Recommended coating plus an imported bed surround

Please Note:

1. Other protection systems may be required/available dependent upon soil conditions. Please contact Technical Sales Department, Tel: 0115 930 0700 for further information.
2. Soil assessment surveys can be arranged through our Technical Sales Department.
3. The cost of an imported bed and surround with a geotextile membrane, and the added expense of disposing of excess soil, may sometimes be prohibitive. A more economical option may, in some cases, be tape wrap, with a 25mm overlap, using the dug material as a fill.

A Brief Description

PAM Natural/PAM Integral Plus pipes have a coating of 400g/m^2 of sprayed metallic zinc-aluminium alloy with a topcoat of 100µm (nominal) epoxy (blue for water/red for sewer). Available on pipes uti DN800.

The coating for larger pipes consists of 200g/m^2 of sprayed metallic zinc, with a topcoat of 70µm (nominal) black bitumen for water pipes DN900-2000 or red epoxy for sewer pipe DN900-2000.

PE sleeving is a loose plastic sleeving with a minimum thickness of 200 microns (See British Standard BS 6076: 1996), which is applied over the zinc and bitumen/epoxy coating.

Tape wrap (e.g. Maflowrap 65/75 MW) comprises a PVC carrier with an approximate thickness of 0.75mm, with a bituminous layer of thickness 0.9mm, which adheres to the pipe surface. This is applied by spirally winding onto the barrel of the pipe over the standard coating with either a 25mm overlap at the edges or, for greater mechanical protection, a 55% overlap giving two layers. A separate hand wrap (e.g. Maflowrap 65/75 T) or plastic muff should be used for covering each pipe joint after installation and before backfilling. A mastic blanket or LD mastic should also be used to create a smooth profile from the spigot to the socket face.

Where an imported bed and surround is to be used, the fill should have the following properties:

- Minimum Cell Resistivity Measurement – R>10,000 ohm-cm.
- Grain size – 0-8mm (preferred) 0-40mm (allowed by WIS 4-08-02, depending upon size)
- Grain shape – rounded and unlikely to puncture the coating.
- Near natural or slightly alkaline pH.
- Absence of organic matter, sulphide residues and carbon bearing materials e.g. coal, ash, clinker.
- Absence of water soluble substances that may be aggressive to ductile iron e.g. sodium chloride from seawater, etc.

If any one of these conditions is not met the bed and surround is rejected.

The imported material should extend at least 200mm from the pipe surface in all directions, and measures should be taken to prevent the migration of the imported material into the surrounding soil and vice versa.

Pipes Built into Structures

Fig 12: Provision of Water Barrier Loose Puddle Flange

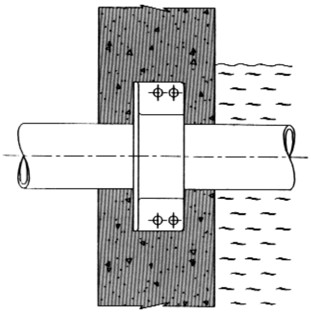
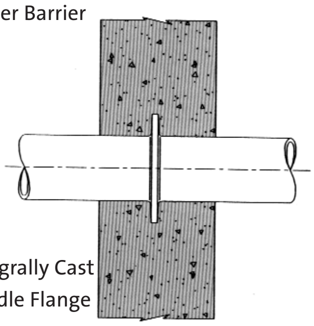
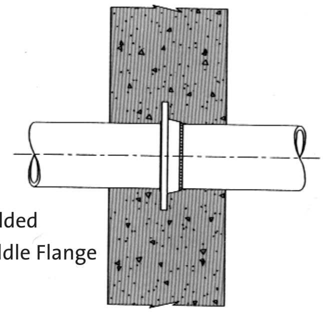


Fig 13: Provision of Anchorage and/or Water Barrier

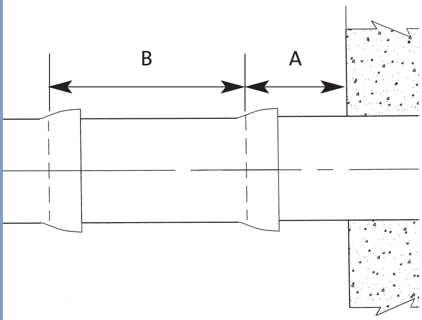


Integrally Cast Puddle Flange



Welded Puddle Flange

Fig 14: Provision of Flexibility



Introduction

There are a number of design considerations to be taken into account where pipes are built into structures

Provision of a Water Barrier

When pipes pass through the concrete walls of tanks holding liquids and the pipe is below the water level, a means of preventing the liquid leaking between the outside of the pipe and the surrounding structure is required. If the type of installation is such that there is no end thrust tending to push the pipe through the structure, a loose (or split) puddle flange (Fig 12) may be used to provide the water barrier.

Split puddle flanges are designed for use on the barrels of pipes produced by the centrifugal casting method, i.e. spigot and socket spun pipes or flanged spun pipes. They are not suitable for use on the barrels of sand cast items (e.g. fittings or riser pieces).

The flange is fitted to the pipe using rubber sheeting, roofing felt or similar material to provide a packing between the flange and the pipe body.

After the flange is bolted around the pipe, the annular space formed on one side of the flange is caulked to effect the watertight seal. The caulked side of the flange should be towards the waterlogged side of the structure (Note: Saint-Gobain Pipelines do not supply the packing and caulking materials referred to above).

Provision of Anchorage

Anchorage may be required where pipes are built into structures to prevent the movement of the pipe through the structure. The magnitude of the forces tending to cause this movement are sufficient to preclude the use of a loose puddle flange. An integrally cast or welded puddle flange is recommended (Fig 13). This will provide anchorage and act as a water barrier. Dimensions of integrally cast welded puddle flanges are as for a standard PN16 flange.

Provision of Flexibility

Where a buried pipeline passes through a rigid structure and differential settlement of the structure and the adjacent ground is possible, two push-fit flexible joints should be introduced immediately adjacent to the face of the structure. This is generally referred to as a 'rocker pipe', shown in Fig 14.

It is recommended that dimension 'A' be as short as possible consistent with making the joint. Dimension 'B' should be equal to the length of a standard rocker pipe or one nominal pipe diameter, whichever is the larger.

Ovality Correction

Where pipes having spigots on which a flexible joint is to be made are built into structures, it is important to ensure that the spigot end is round before the pipe is set into the structure. This may require the use of one of the ovality correction methods shown in the installation section and the equipment must be left in position until the concrete is sufficiently cured.

Geometric Calculations

Introduction

The following information refers to specific situations where ductile iron pipelines can be designed to negotiate long radius curves, offsets and diagonal runs.

Negotiating Long Radius Curves with Push-fit jointed pipes

Long radius curves can be negotiated by deflecting the joints of push-fit pipes, (see Fig 15). The radius of curvature, for given angles of deflection or the angle of deflection required (see Table 12) to produce a given radius may be calculated from the formulae opposite.

$$R = \frac{L}{2 \sin \frac{\theta}{2}} \quad \text{or} \quad \theta = 2\left[\sin^{-1} \frac{L}{2R}\right]$$

Where :

R = radius of curvature

L = laying length of pipe

θ = angle of deflection

Fig 15

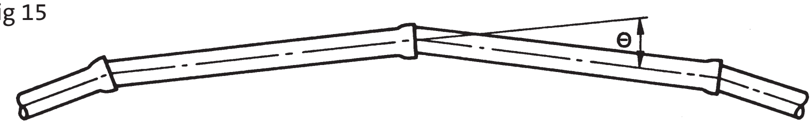


Table 12: Angular Deflection

DN	Max. Angular Deflection	Recommended Max. Angular Deflection for Offsets
80 - 300	5°	3.5°
300 - 1200	4°	2.5°
1400 - 1600	3°	1.5°
1800	2.5°	1°
2000	2°	1°

Offsets Using Standard Double Socket Bends

A deviation in line or level of a pipeline can be readily accommodated using two standard double socket bends and a length of double spigot pipe (see Fig 16). The length of double spigot pipe 'T' necessary to produce a given offset 'A' may be calculated from the formula opposite.

$$T = (A/\sin \theta) - 2(b + c)$$

Where :

c = joint gap (selected)

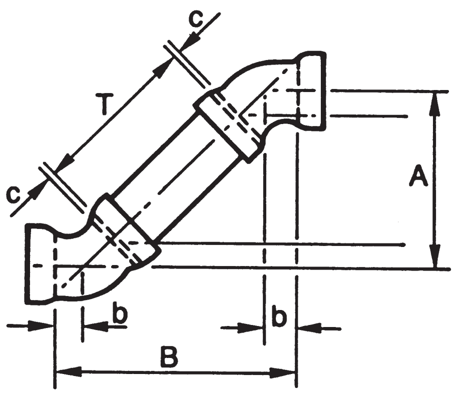
b = leg length of standard bend

θ = angle of bend

The overall length of the assembly 'B' may be calculated from:

$$B = (A/\tan \theta) + 2b$$

Fig 16



Deviation Correction

$D = \sqrt{A^2 + B^2 + C^2}$

$\theta = \text{Tan}^{-1} \left[\frac{1}{C} \sqrt{A^2 + B^2} \right]$

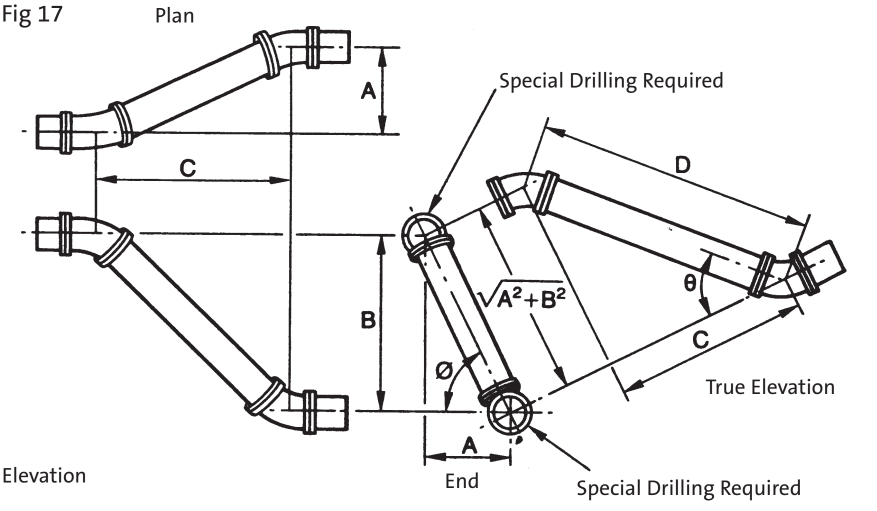
$\emptyset = \text{Tan}^{-1} \frac{B}{A}$

Pipes in Inclined Diagonal Runs with Flanged Pipe

The following formulae may be used for determining the lengths of pipes or the angles of bends where pipes are installed in inclined diagonal runs. Where dimensions A, B, C are known, see Fig 17.

The angle Ø is used to specify the special flange drillings required on the bends at the flanges indicated on the diagram below:

Fig 17



Where the angle of bend and dimensions A and B are known:

$$D = \sqrt{A^2 + B^2} \, / \, \text{Sin}\,\theta$$

$$C = \sqrt{A^2 + B^2} \, / \, \text{Tan}\,\theta$$

Flange Pipework

A fundamental requirement for flanged pipework is its ability to support an external bending moment. The magnitude of these permissible bending moments is related to the weight of the pipe and its contents for a given span. The length of the spans is limited by the need to confine stresses due to the combined effects of internal pressure, bolt tightening and bending moments within safe limits. These same limits are in turn applied to flanged pipework subjected to loads caused by thrusts due to internal pressure, e.g. at changes in direction.

These limits are such that it is recommended that flanged pipe is NOT buried.

The safe working bending moment values for flanged joints are given in Table 13.

The longitudinal bending stress in the barrel of flanged pipes should not exceed $200N/mm^2$

Table 13: Permissible Bending Moments for Flange Joints.

Nominal Size DN	Bending Moment kN m
80	1.8
100	2.3
150	4.0
200	6.0
250	8.6
300	26.0
350	33.8
400	42
450	51
500	63
600	87
700	116
800	146
900	181
1000	222
1100	265
1200	313
1400	423
1600	548
1800	625
2000	770

These figures only apply to welded and integrally cast flanges.

Supporting Pipes

Introduction

The following recommendations assume that no additional bending moments above those due to self weight of the pipe and it's contents are present. Consideration should also be given to the provision of additional support adjacent to valves and other ancillary equipment.

Push-fit Pipe

Single Support per Pipe

It is recommended that above ground installations of spigot and socket pipes be provided with one support per pipe, the supports being positioned behind the socket of each pipe (see Fig 18).

This results in a nominal distance 'A' between supports of:

5.5m for DN80-800

7m for DN900 & DN1000

8m for DN1100-2000

Pipes should be fixed to the supports with steel straps, so that axial movement due to expansion or contraction resulting from temperature fluctuation, is taken up at individual joints in the pipeline. In addition, joints should be assembled with the spigot withdrawn 5 to 10mm from the bottom of the socket to accommodate these thermal movements.

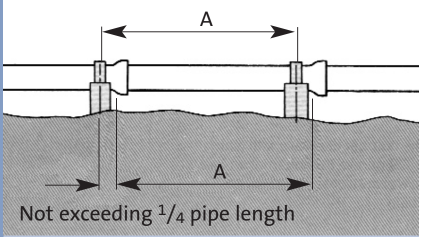
Pipes supported in this way are capable of free deflection and axial movement at the joints which accommodate small movements of the pipe supports.

The optimum saddle angle on the pipe supports will vary depending on the conditions of internal pressure of the pipeline, joint deflection etc. and should conform to the details shown in Table 13.

Purpose designed anchorage must be provided to resist the thrusts developed by internal pressure at bends, tees, etc.

When determining the actual position of the support centres, it should be noted that pipe lengths may be shorter than nominal length in accordance with tolerances permitted by BS EN 545. Please consult Pipelines Technical Sales Department, Tel: 0115 930 0700.

Fig 18



Push-fit - Maximum Span

Where a support cannot be provided at every pipe e.g. at stream crossings etc., spans up to: 11m for DN80-800, 14m for DN900 & DN1000 and 16m for DN1100-2000 can be installed by positioning supports relative to joints as indicated in Fig 19.

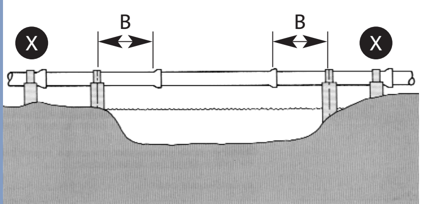
The length of dimension B should not exceed one quarter of the total span.

Cut pipes, fittings, valves, etc. which are adjacent to the span, must be positioned outside the joints marked X and the length between the joints X-X must be equal to 3 full length pipes i.e. 16.5m for DN80-800, 21m for DN900 & 1000 and 24m for DN1100-2000.

The inner saddles carry a double load and in some cases require to have an increased seating angle as shown in Table 13.

To prevent excessive stresses in the pipe, the joints at each end of the centre suspended pipe should not be deflected.

Fig 19



Flanged Pipe

Fig 20

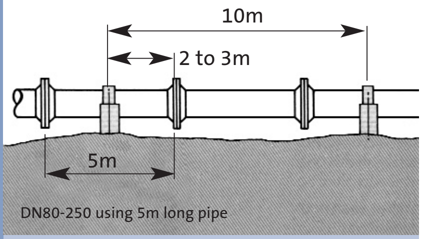


Fig 21

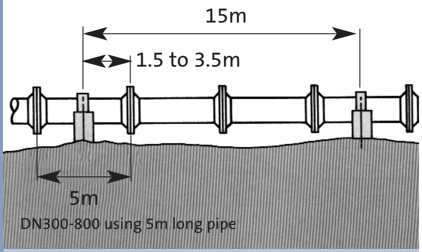
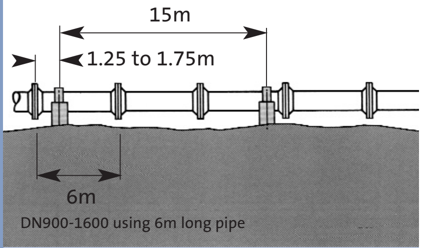


Fig 22



Continuous beam

Flanged pipes are subjected to stresses caused by internal pressure and stresses due to local bending moments created by tightening of the bolts.

Flanged pipes installed as self supporting spans are subjected to additional stresses due to bending moments caused by their own weight and the weight of their contents.

The length of spans of flanged pipe is limited by the need to confine stresses due to the combined effects of internal pressure, bolt tightening and bending moments, within safe limits.

All flanged pipes are designed to operate safely at the maximum site test pressure when subjected to a bending moment caused by self weight and weight of contents equivalent to a simply supported span of 8m for DN80-250 and 12m for DN>300 with a flange joint at the mid span position.

In practice, flanged pipes are usually installed as continuous or fixed end beams and by careful design it is often possible to ensure that the flanged joints are located at zones of lower bending moment.

Figs 20 - 25 show typical installations where spans greater than the nominal 8m or 12m can be obtained.

Beam with fixed ends

Fig 23

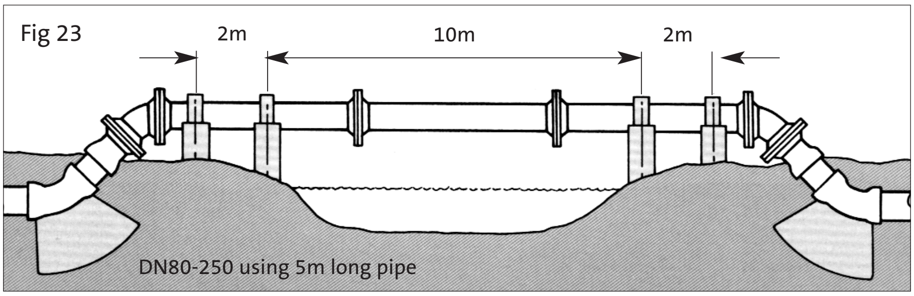


Fig 24

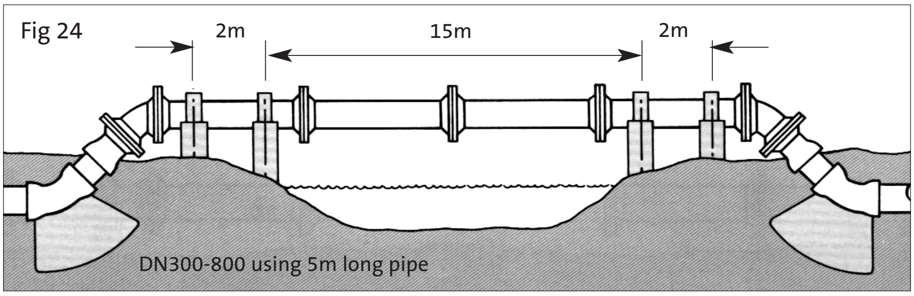
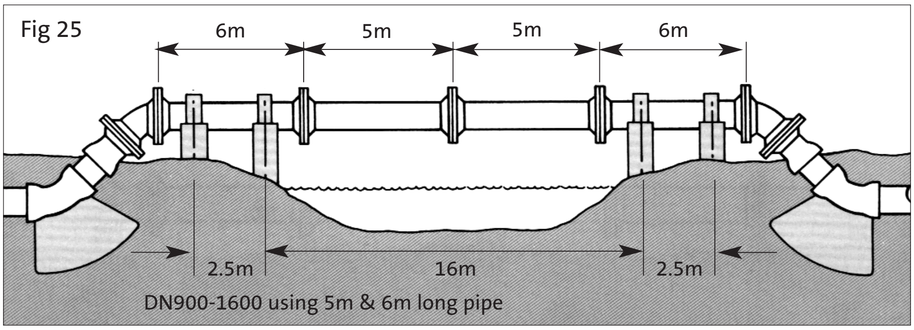


Fig 25



Note: If the actual pressure in the pipeline is lower than the normal maximum rated pressure, higher bending moments may be permissible. Conversely, any additional bending moment over that caused by self weight and weight of contents will reduce the safe spans.

Fig 26

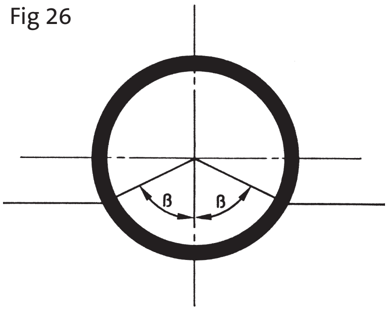


Fig 27

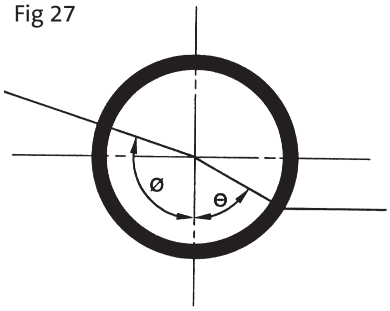


Fig 28

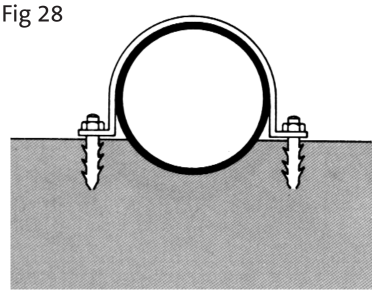


Fig 29: Bolt and Strap Details

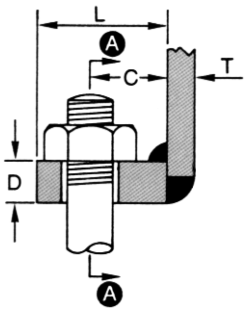
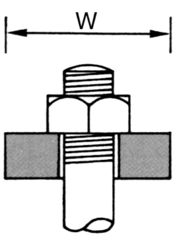


Fig 30: Bolt and Strap Details



Seating Details

Fig 26 shows seating details for pressure or non-pressure pipe straight or deflected downwards and non-pressure deflected sideways.
For pipes deflected upwards the seating details in Fig 26 apply. However, adequate strapping must be designed to cope with any upward thrust.

Fig 27 shows the seating details required for pressure pipes deflected sideways.

Table 14 shows the pipe support details required for the allowable span.

DN	Span	Pressure	Deflection	ß°	Ø	θ
≤800	≤6m	No	Yes	45°	-	-
		Yes	No	45°	-	-
			Yes	90°	130°	45°
	Push-fit >6 & ≤ 11m Flanged DN80-250: >6 ≤ 10m Flanged DN300-800: >6 ≤ 15m	No	No	65°	-	-
		Yes	No	*90°	-	-
900 and 1000	≤ 8m	No	Yes	45°	-	-
		Yes	No	55°	-	-
			Yes	80°	100°	45°
	Push-fit >8 & ≤ 14m	No	No	60°	-	-
	Flanged >8 & ≤ 16m	Yes	No	*90°	-	-
>1000	≤ 9m	No	Yes	45°	-	-
		Yes	No	60°	-	-
			Yes	80°	100°	45°
	> 9 and ≤ 16m	No	No	60°	-	-
		Yes	No	*80°	-	-

* Rubber pad positioned between pipe and concrete saddle.

Strap Details

Fig 28 shows pipe positioned with steel strap. The straps and bolts detailed in Fig 29, 30 and Table 15 are suitable for retaining the pipe in position on the supports. They are not designed to carry the thrusts due to unbalanced loads on bends and other fittings. In these circumstances each case should be considered on its merits and the bolt size and strap design determined accordingly.

Table 15: Strap Details

Nominal Size DN	T mm	W mm	D mm	L mm	C mm	Size of Bolt
80-150	6	40	13	45	25	M12
200-300	6	50	16	50	30	M16
350-600	10	65	19	65	35	M20
700-1000	10	90	25	75	42	M24
1200-2000	10	100	32	85	48	M30

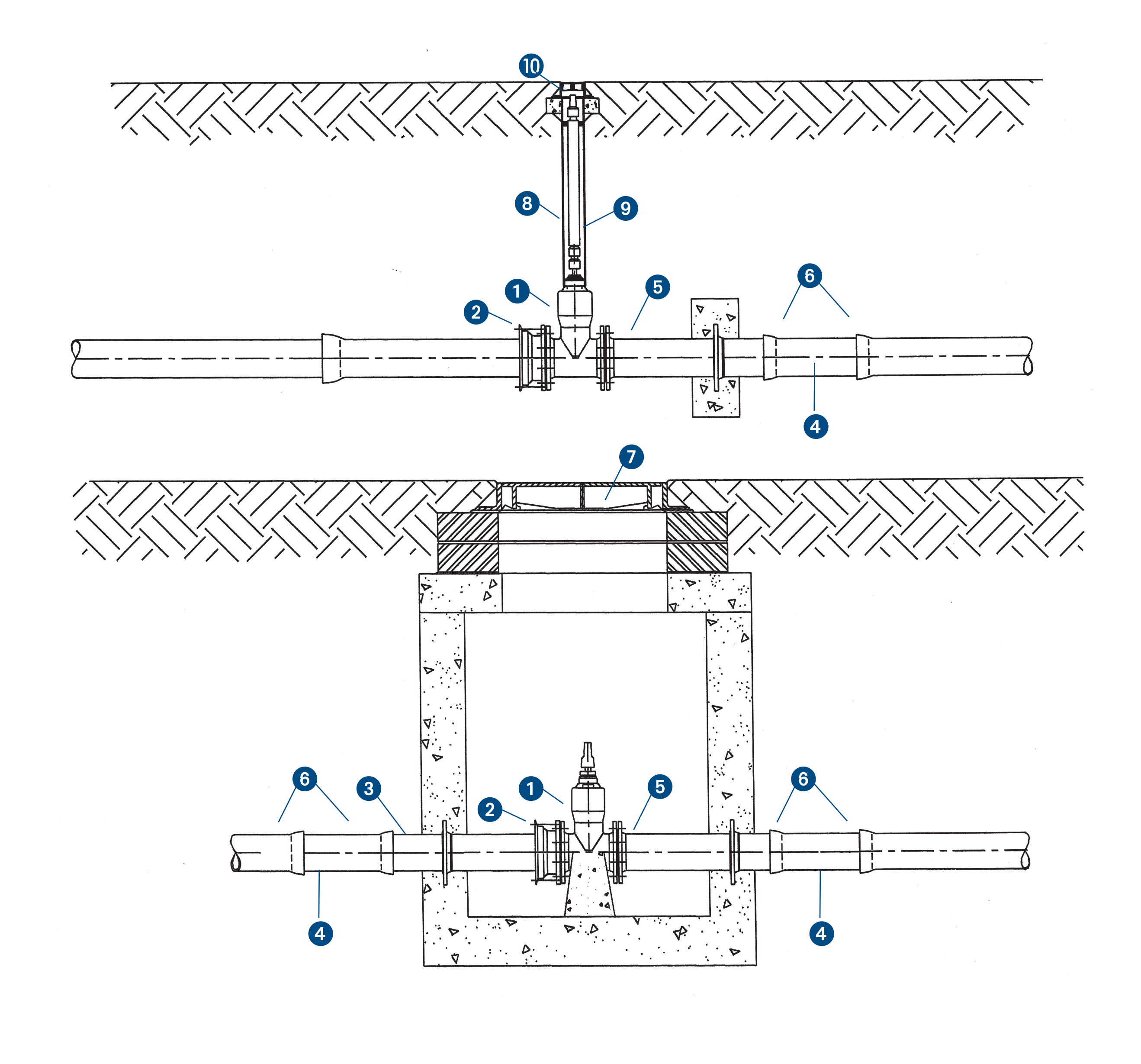
Note: Straps are not available to purchase from Saint-Gobain Pipelines.

Typical Installations

Introduction

The following drawings show examples of typical installations. For specific projects, modification to the layouts shown may be required. Please note that all itemised products are available from Saint-Gobain Pipelines.

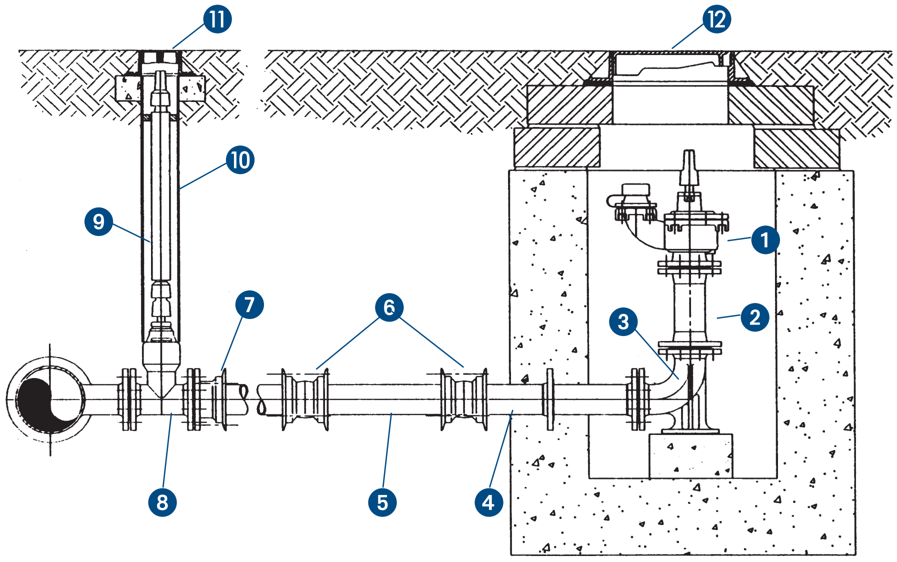
Typical Valve Installation



1 Gate Valve
2 Flange Adaptor
3 Double Spigot Pipe with Puddle Flange
4 Double Spigot Rocker Pipe
5 Flange Spigot Pipe with Puddle Flange
6 Coupling
7 Manhole Cover & Frame
8 Extension Spindle
9 Protection Tube
10 Surface Box

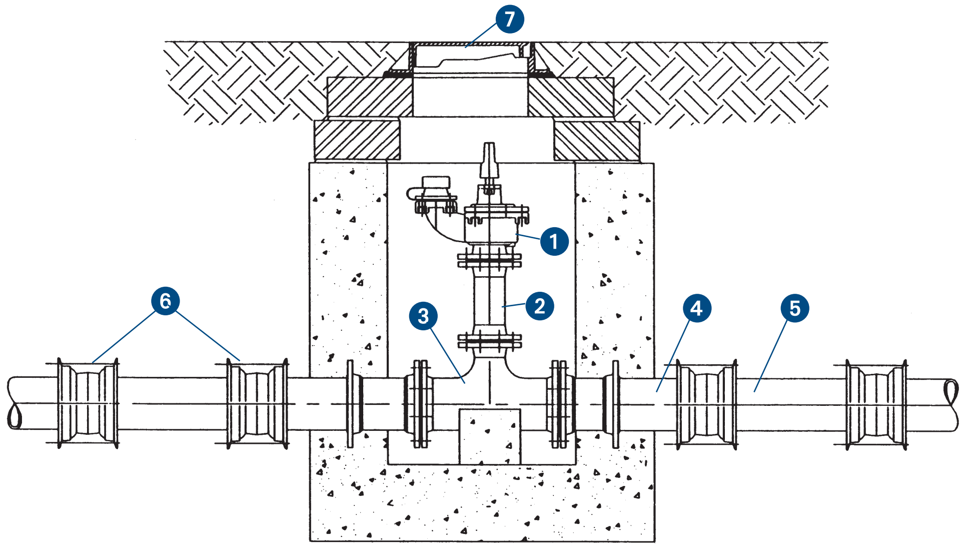
End Of Line

1. Screw Down Fire Hydrant
2. Double Flanged Raising Piece
3. Double Flanged Duckfoot Bend
4. Flange & Spigot Puddle Flange Pipe
5. Double Spigot Rocker Pipe
6. Couplings
7. Flange Adaptor
8. Gate Valve
9. Protection Tube
10. Extension Spindle
11. Surface Box
12. Surface Box



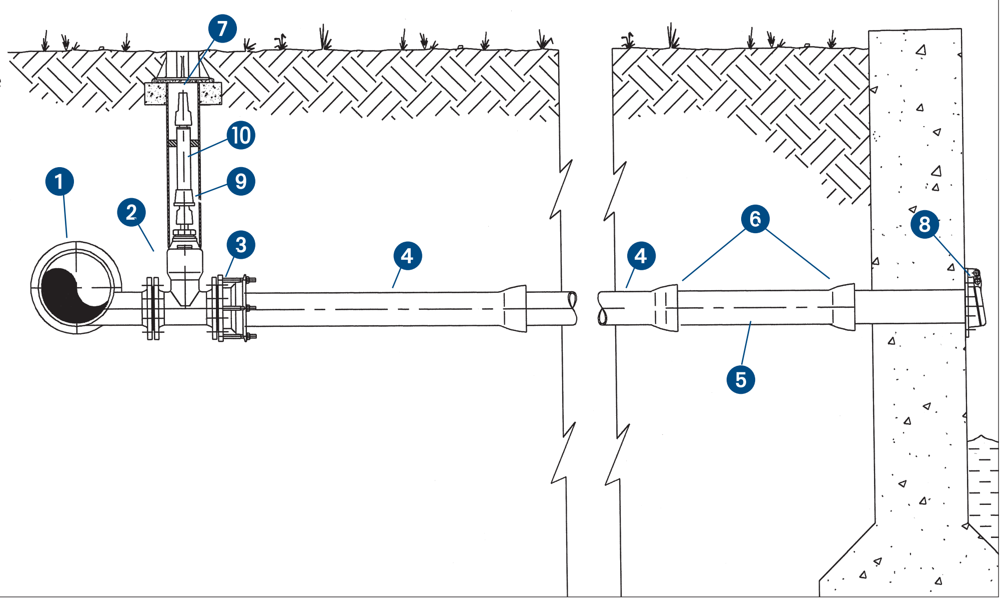
In Line

1. Screw Down Fire Hydrant
2. Double Flanged Raising Piece
3. All Flanged Tee
4. Flange & Spigot Puddle Flange Pipe
5. Double Spigot Rocker Pipe
6. Couplings
7. Surface Box



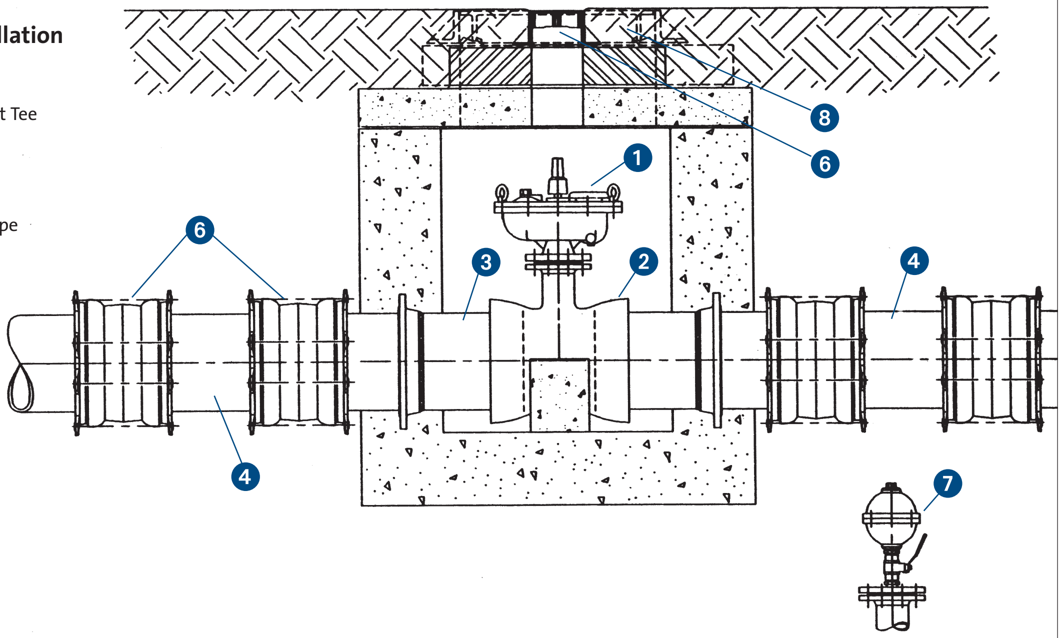
Washout Arrangement

1. Flange on Socket Level Invert Tee
2. Gate Valve
3. Flange Adapter
4. Tyton Pipe
5. Double Spigot Rocker Pipe
6. Couplings
7. Double Spigot Pipe
8. Flap Valve
9. Protection Tube
10. Extension Spindle
11. Ductile Iron Surface Box



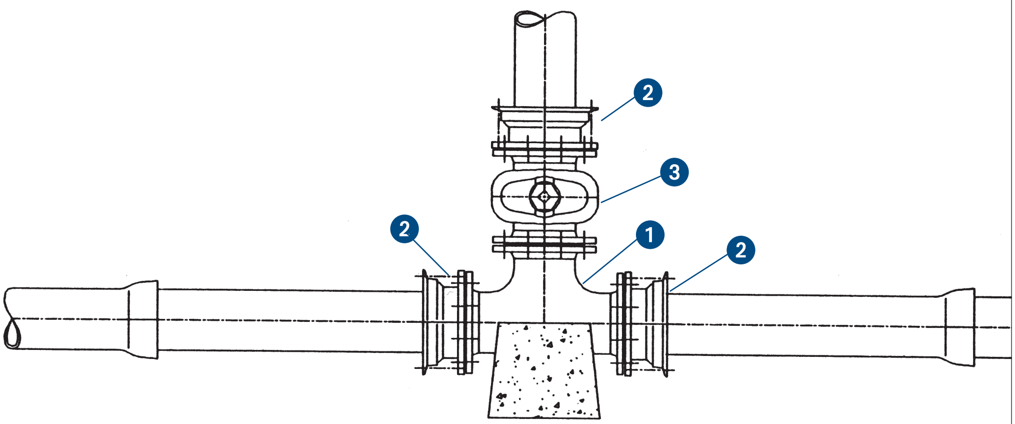
Typical Air Valve Installation

1. Double Orifice Air Valve
2. Flange on Double Socket Tee
3. Double Spigot Puddle Flanged Pipe
4. Double Spigot Rocker Pipe
5. Coupling
6. Surface Box
7. Alternative Single Orifice Air Valve
8. Manhole Cover and Frame



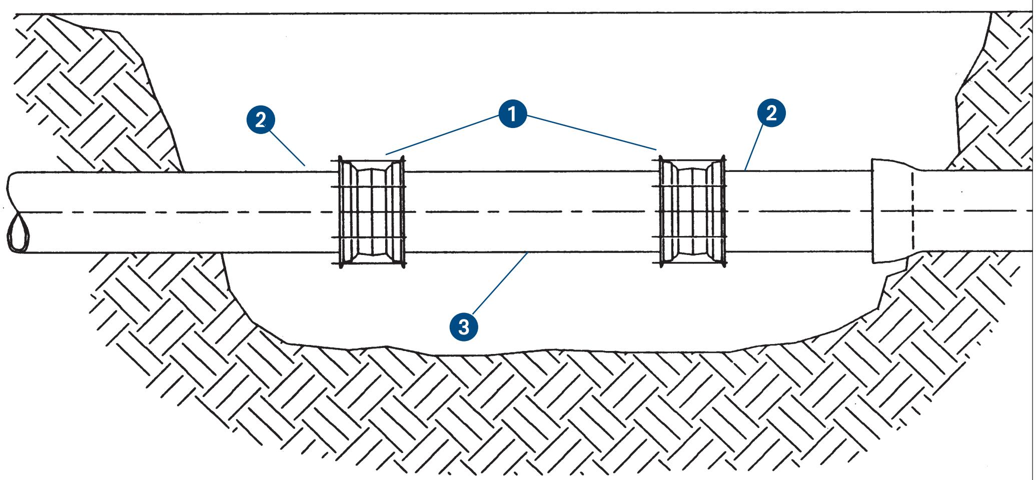
Branch Insertion

1. All Flanged Tee
2. Flange Adapter
3. Gate Valve



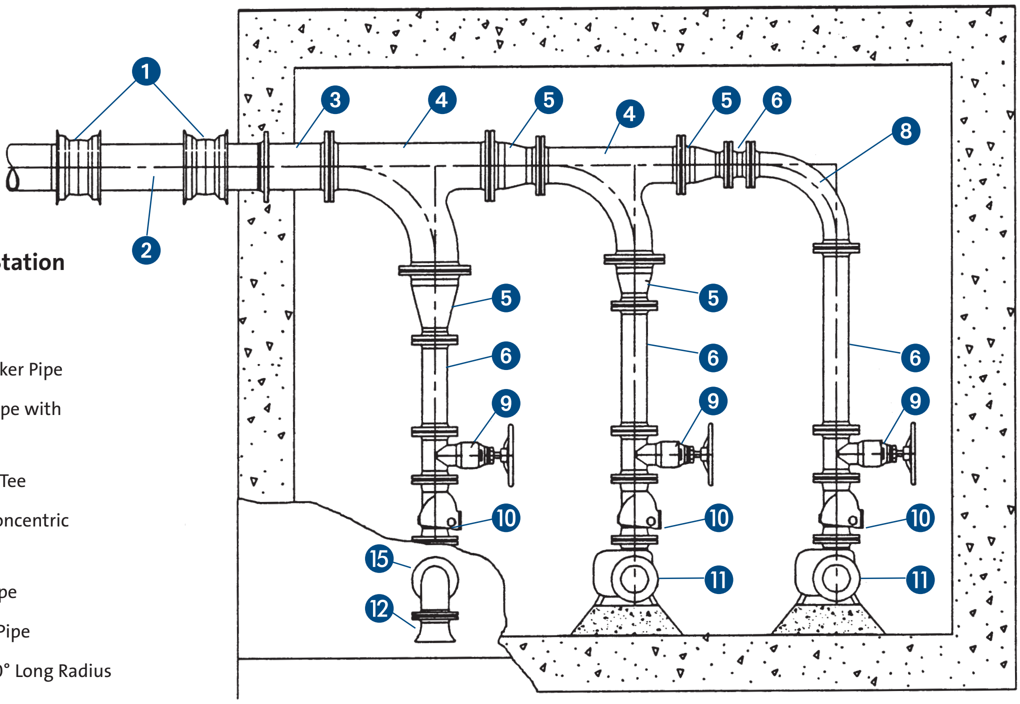
Repair

1. Coupling
2. Existing Main
3. New Pipe

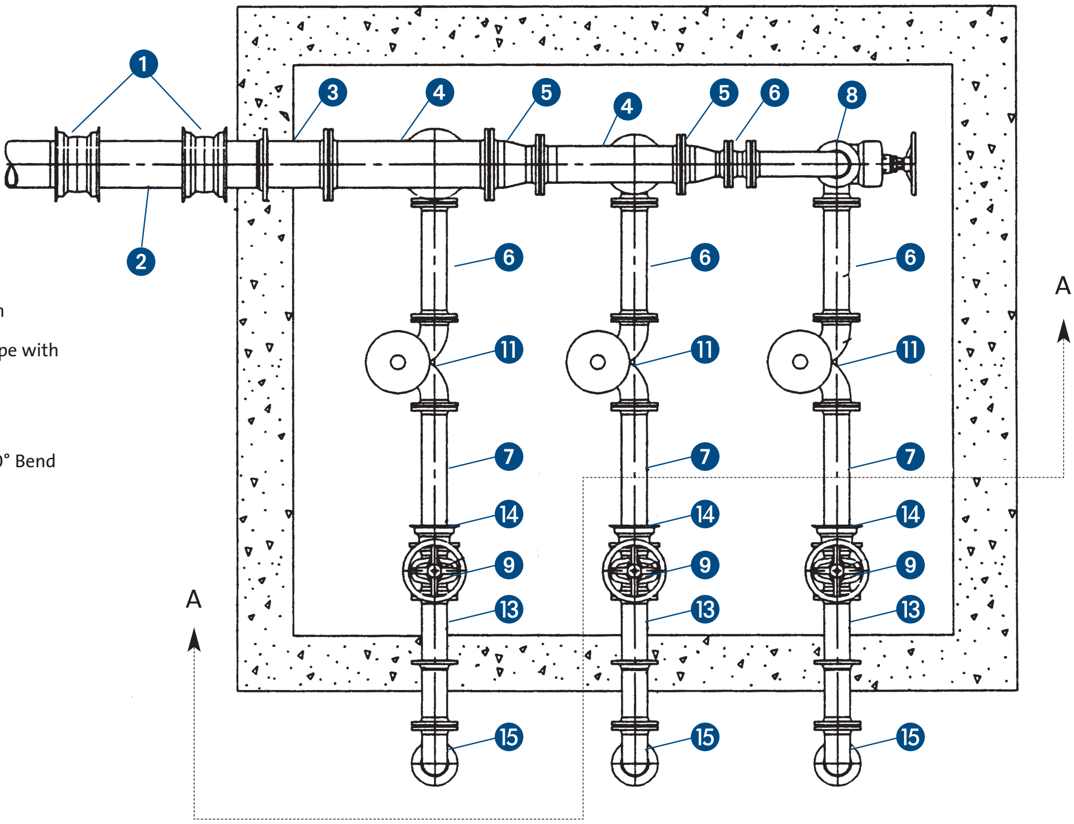


Typical Pumping Station Pipework Layout

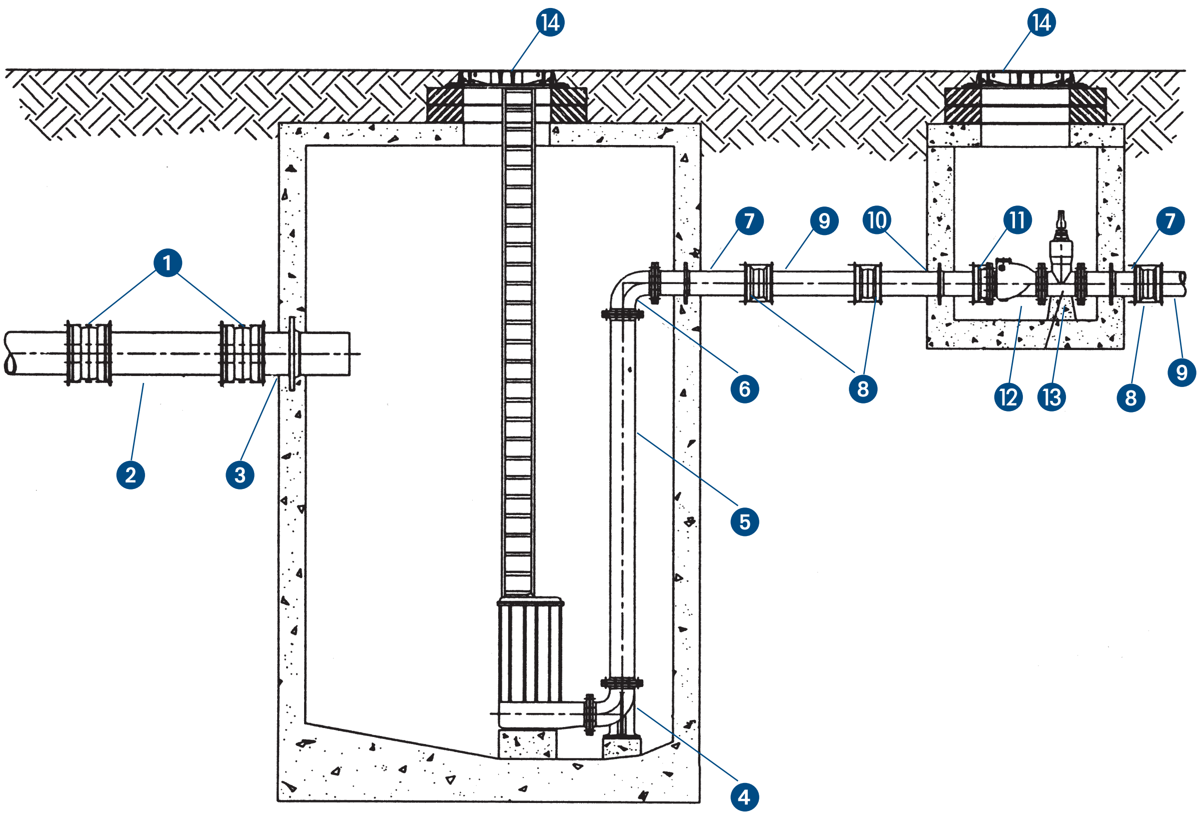
1. Coupling
2. Double Spigot Rocker Pipe
3. Flange & Spigot Pipe with Puddle Flange
4. All Flanged Radial Tee
5. Double Flanged Concentric Taper
6. Double Flanged Pipe
7. Flanged & Spigot Pipe
8. Double Flanged 90° Long Radius bend
9. Gate Valve with Handwheel
10. Non-Return Valve
11. Pump



12. Flanged Bellmouth
13. Double Flanged Pipe with Puddle Flange
14. Flange Adapter
15. Double Flanged 90° Bend

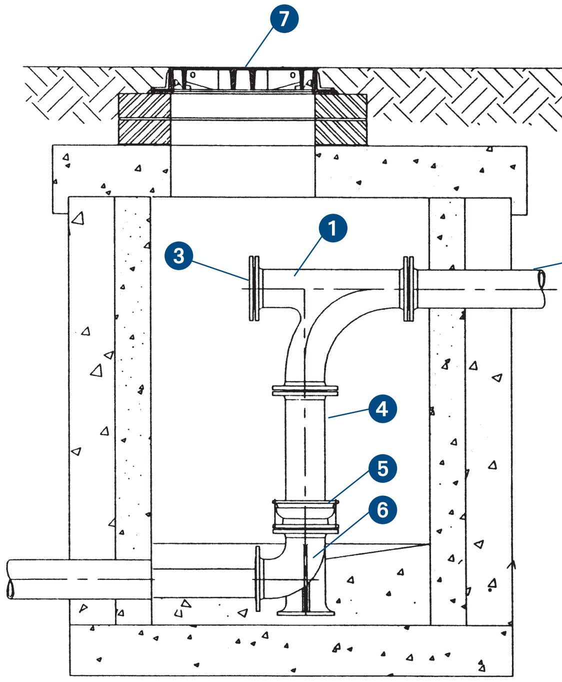


Part sectional Elevation A-A



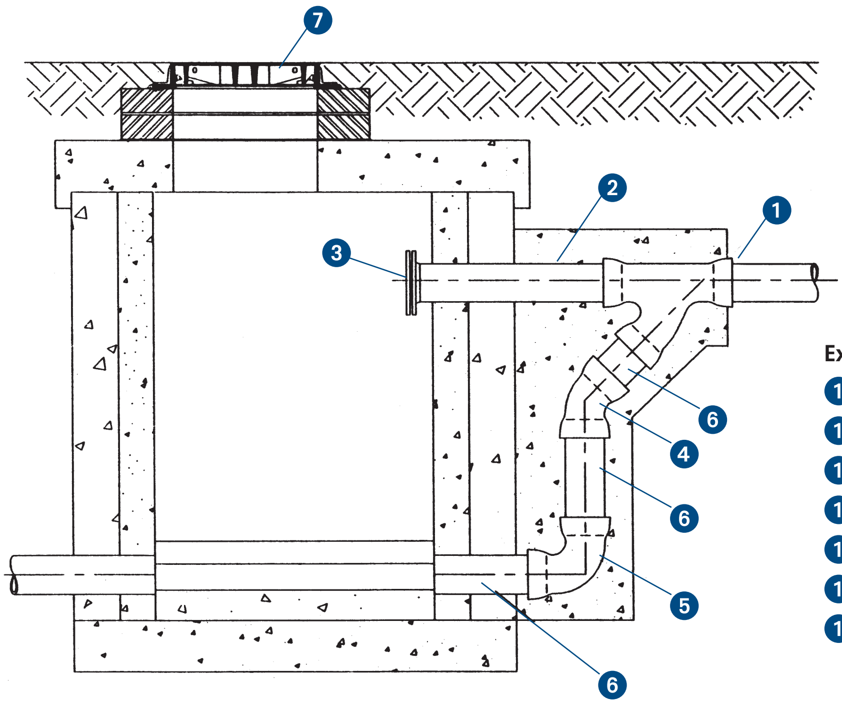
Typical Pumping Station Chamber Layout

1. Coupling
2. Double Spigot Rocker Pipe
3. Double Spigot Pipe with Puddle Flange
4. Double Flanged 90º Duckfoot Bend
5. Double Flanged Pipe
6. Double Flanged 90o Bend
7. Flange and Spigot Pipe with Puddle Flange
8. Coupling
9. Double Spigot Rocker Pipe
10. Double Spigot Pipe with Puddle Flange
11. Flange Adapter
12. Non-return Valve
13. Gate Valve
14. Ductile Iron Manhole Cover and Frame



Typical Backdrop Arrangement
Internal Backdrop

1. All Flanged Radial Tee
2. Flange & Spigot Pipe
3. Blank Flange
4. Flange & Spigot Pipe
5. Flange Adapter
6. Double Flanged 90° Duckfoot Bend
7. Ductile Iron Manhole Cover & Frame



External Backdrop

- 1 All Socket 45° Angle Branch
- 1 Flange & Spigot Pipe
- 1 Blank Flange
- 1 Double Socket 45° Bend
- 1 Double Socket 90° Bend
- 1 Double Spigot Pipe
- 1 Ductile Iron Manhole Cover & Frame

Properties of Ductile Iron

Table 16 shows the principal mechanical and physical properties of ductile iron that may be required for design purposes.

Minimum Ultimate Tensile Strength		$420\ MN/m^2$
Minimum Elongation	Pipes:	10% for DN≤1000
		7% for DN≤1000
	Fittings:	5%
Maximum Design Stresses		
Tension		$170\ MN/m^2$
Compression		$180\ MN/m^2$
Shear		$150\ MN/m^2$
Bending	Circumferential (pipe wall):	$250\ MN/m^2$
	Longitudinal (pipe as beam):	$200\ MN/m^2$
Modulus of Elasticity		$170\ GN/m^2$
Poisson's Ratio		0.28
Density		$7050\ Kg/m^3$
Damping (logarithmic decrement)		$(5 \text{ to } 20) \times 10^{-4}$
Coefficient of Thermal Expansion (20°C - 200°C)		11×10^{-6} per °C
Thermal Conductivity (20°C - 200°C)		36 W/m°C

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Cast iron above ground system BSI Kitemark approved to BS416 part 2, used for soil and waste refurbishment, and external soil stacks for traditional appearance.

Cast iron below ground system BSI Kitemark approved to BS437, favoured for under building drainage, and unstable ground conditions due to its superior strength performance.

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A complete range of sewerage pipeline products available from DN80 to DN1800, fully compliant with the requirements of BS EN 598.

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Large diameter water pipeline products available DN900 to DN1600, fully compliant with the requirements of BS EN 545.

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- Tidal flap valves DN80 to DN600
- Air valves
- Fire hydrants

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