Ductile Iron Pipeline System

A technical guide

JINDAL SAW LTD.
TOTAL PIPE SOLUTIONS

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1.1 The Group

The O. P. Jindal Group was founded in 1952 by Sh. O.P. Jindal, a first generation enterprenuer who began an indigineous single-unit steel plant in Hisar, Haryana.

The group today enjoys global presence with manufacturing facilities across India, USA, Europe, Middle East & Indonesia, mining concessions in Chile, Australia, Indonesia, South Africa & Mozambique with marketing offices around the world. The group is a $15 biillion conglomerate with business interest spanning steel, pipes, mining, power, industrial gases, cement and seaport facilities. The group has further diversified into petroleum, diamond, high value metals and mineral exploration.

Jindal SAW Limited was founded in the year 1984 by Mr. P.R. Jindal.

With an enviable track record of stability, trust, growth and performance for over 30 years, Jindal SAW is now the undisputed leader in the pipe industry with manufacturing facilities in India, UAE, Europe and USA. Jindal SAW manufactures Long Seam SAW Pipes, Helical (spiral) Seam SAW Pipes, Anti-corrosion and Concrete Weight Coatings, Hot Induction Bends, Connector Casings, Ductile Iron Pipes & Fittings, Seamless Tubes & Pipes. Jindal SAW has further diversified into mining & pellets. Our customers include world's leading oil & gas companies, government bodies heading irrigation & water resource and engineering & construction companies which undertake large EPC contracts, transportation, power generation and other industrial applications.

1.2 Ductile Iron (DI) Pipes

Ductile Iron (DI) pipes' good mechanical properties, in adition to high durability and strength, makes them ideal for high-pressure applications. Ductile Iron pipes are used extensively in systems transporting potable water, industrial water, irrigation water and pressure seweage. Metallic pipes, primarily Cast Iron had been used over two centuries for water and wastewater transportation. Ductile Iron pipes which belong to the family of Cast Iron have been developed by treating the molten low-sulphur base iron with magnesium under closely controlled conditions. The startling change in the metal is characterized by the free graphite in Ductile Iron being deposited in the spheroidal or nodular form, leading to maximum continuity of metal matrix thereby forming a stronger and tougher ductile material with high ductility and impact strength.

With protective linings and coatings like cement mortar, Bitumen, Epoxy and Polyurethane, Ductile Iron pipes provide an exceptionally long life to serve the water and sanitation networks.

The flexible and leak tight jointing systems in Ductile Iron pipes, which can be easily push fitted (or mechanically joined) provides ease in transportation of pipes as well as laying works. The pipeline and jointing system can withstand the vagaries of nature, thereby ensuring sustainable and quality piping solutions to the customers.

Jindal SAW had commissioned its first Integrated Greenfield Project for Ductile Iron pipe and Pig Iron unit at Samaghogha, Mundhra, Gujarat, India in the year 2005, close to Mundhra and Kandla ports. This port based facility includes:

- Coke oven battery plant (installed capacity: 380,000 MT per annum)
- Blast furnace (installed capacity: 500,000 MT per annum)
- DI pipe manufacturing facility (installed capacity: 500,000 MT per annum)

In its quest to be a global leader, Jindal SAW has also taken over the assets of Sertubi Spa in Trieste, Italy. The subsidiary by the name Jindal SAW Italia, Spa caters to the requirements of Europe and other Western countries.

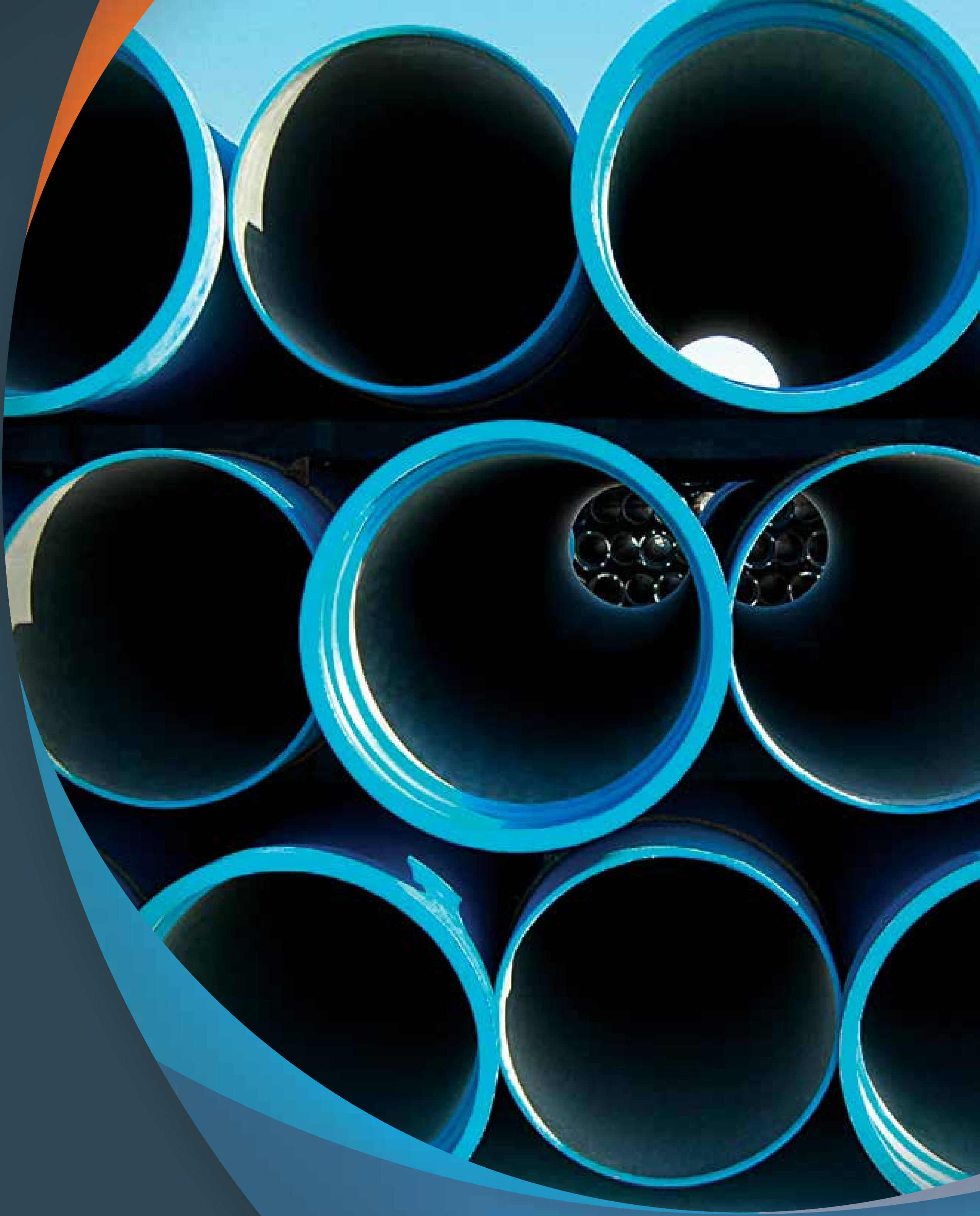
In line with its vision to be a Total Pipeline Solution provider, Jindal SAW has also set up a Ductile Iron fittings plant in Sholapur, Maharashtra, India.

Looking into the tremendous market potential in the Gulf region as well as in the African continent, Jindal SAW has put up a DI pipe manufacturing facility at Abu Dhabi, United Arab Emirates, through its subsidiary 'Jindal SAW Gulf LLC'.The manufacturing capacity of the plant in 3,50,000 MT per annum, producing pipes ranging from 200mm to 2200mm.

Quality is the key mantra at Jindal SAW. Quality checks are carried out at every stage of the manufacturing process to meet the requirements as per international standards.

'Nurture with Nature' is the guiding principle for Jindal SAW. To ensure ecofriendly and sustainable growth, all the plants of Jindal SAW are equipped with advanced pollution control units and ecology conservation systems. Ductile Iron pipes manufactured by the company conform to both Indian and International Standards like IS8329, ISO: 2531, ISO 7186, BSEN 545 and BSEN 598.

GLOBAL REACH



GENERAL TECHNICAL DATA

2.1 Mechanical Properties of Ductile Iron Pipes

2.1.1 Ductile Iron

Ductile Iron is produced by treating the molten low-Sulphur base Iron with Magnesium under closely controlled conditions. The metal characteristics are enhanced by the free graphite in Ductile Iron being deposited in the spheroidal form or nodular form instead of flaky form as in grey Iron. Due to the presence of free graphite in the nodular form, the continuity of metal matrix is at the maximum, leading to the formation of a stronger, tougher ductile material exceeding grey (or cast) Iron in strength, in ductility and in impact strength.

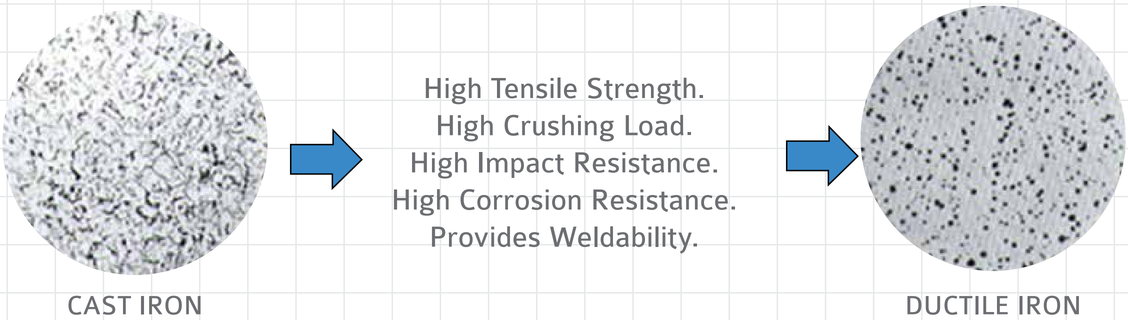


Fig. 2.1.1: Microstructure transformation of Cast Iron to Ductile Iron

Table 2.1.1: Mechanical Properties of Ductile Iron pipes

Mechanical Properties	Values
Tensile Strength	Min. 4,200 Kg/cm^2 or 420 Mpa
Yield Strength	3,000 Kg/cm^2 or 300 Mpa
Minimum Elongation	For Pipe - Min. 10% upto DN 1000 Min. 7% for diameter > DN 1000 For Fittings - 5%
Modulus of Elasticity	1.62 x 10^6 - 1.70 x 10^6 Kg/ cm^2 or 162,000 - 170,000 Mpa
Hardness	Max. 230 BHN
Density	7,050 Kg/m^3
Bending/Beam Strength	More than 500 MPa or 5098 Kg/cm^2
Coefficient of Thermal Expansion	11.5 x 10^{-6} per Degree Celcius (for temperature range 20 -100 °C)
Thermal Conductivity	36 W per Degree Celcius (250 Btu in./ ft^2 h °F) (for temperature range 20 -100 °C)
Specific Heat	461 J/ Kg °K for temperature range 20 -100 °C
Electrical Resistivity	2.24 x 10^{-5} - 3.56 x 10^{-5} Ohm/ cm (for temperature range 20 - 300 °C)
Compressive Strength	550 Mpa (minimum)
Torsional Strength	3,800 Kg/cm^2 or 380 Mpa
Poisson's Ratio	0.275

Hydraulic Design with Ductile Iron Pipeline

- DI Pipes are internally factory cement mortar lined or Epoxy seal coated or Polyurethane lined.
- They offer smooth surface for carrying water.
- Cement mortar lining performs as an active coating, which neutrlizes potential water aggressiveness towards iron by adjusting its pH to a level where stable passivation layer is formed.
- Even after lining, the net flow diameter in Ductle Iron pipe is always more than nominal diameter.

2.2.1 Types of Pipeline Systems

a) Gravity system:

In gravity pipeline system, the source of supply of water is situated at higher elevation than the discharge points.

This system has the following characteristics:

i) Water flows from the higher elevation to lower level by gravity, hence no power is required.

ii) There is economy in capital cost as well as maintenance cost.

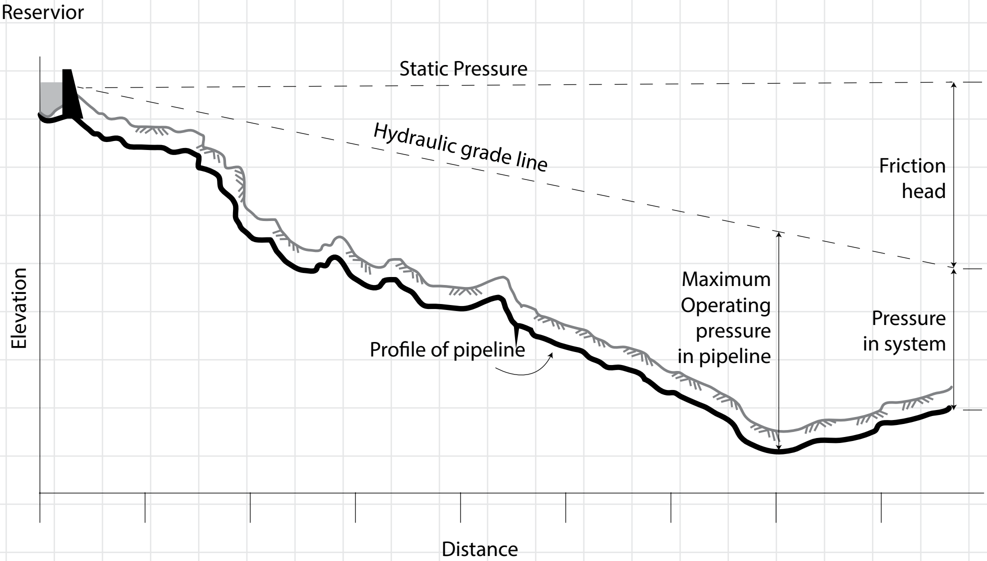


Fig. 2.2.1: Pressure distribution in gravity transmission mains

b) Pumping system:

When the elevation of the intake point is lower than the discharge point in a water supply system, pumping system is deployed.

In this system pumps are installed to achieve the requisite pressure to discharge water at the outlet of the pipe.

The characteristic features of the system is:

i) The pressure of water in the pipeline can be easily controlled.

ii) The piping system is less dependent on the topography of the ground, hence the routing of the pipes can be done as per convenience.

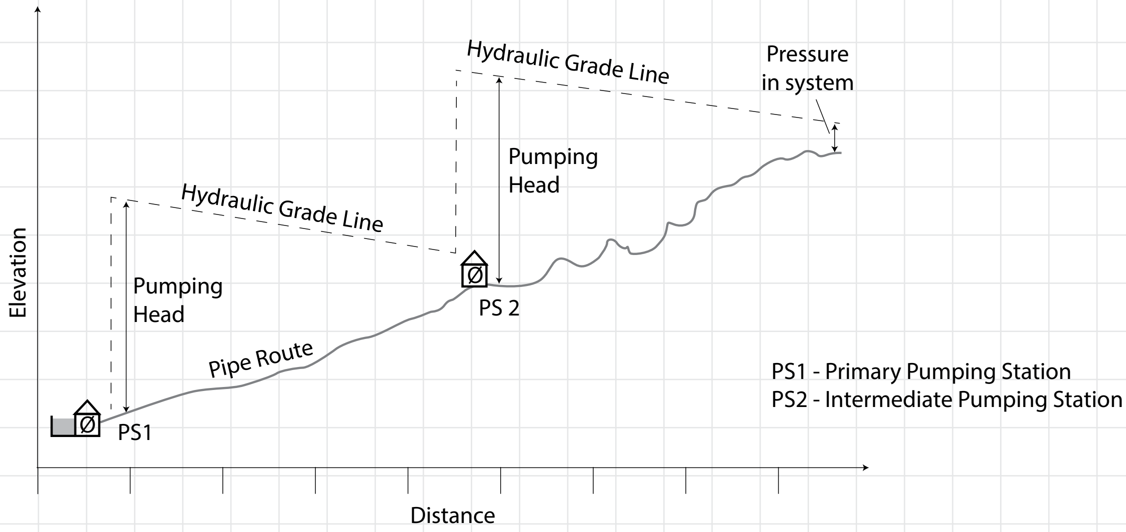


Fig. 2.2.2: Pressure distribution in pumped transmission main

2.2.2 Hydraulic Design of Transmission Main

The hydraulic design illustrated in the following sections has been done assuming 'steady' and 'uniform' flow conditions in pipelines.

In 'steady' flow conditions, the mean velocity in one cross-section of pipe remains constant within a certain period of time.

In 'uniform' flow conditions, the mean velocity between two cross sections is constant at a certain moment of time.

2.2.2.1 Gravity system

Manning's formula is generally used for design of gravity mains.

$$v = \frac{1}{n} R^{2/3} i^{1/2} \qquad \text{Eq - 2.1}$$

For Circular conduits:

$$v = \frac{D^{2/3} i^{1/2}}{2.52\, n} \qquad \text{Eq - 2.2}$$

$$D = \frac{4\, v^{3/2}\, n^{3/2}}{i^{3/4}} \qquad \text{Eq - 2.3}$$

$$Q = \frac{0.312\, D^{8/3}\, i^{1/2}}{n} \qquad \text{Eq - 2.4}$$

Where:

v = Velocity in pipeline (m/s)

Q = Discharge (m^3/s)

n = Roughness co-efficient of pipe material (n = 0.013 for DI pipeline with cement mortar lining)

R = Hydraulic radius of pipe (m) = A/P

A = Area of flow (m^2)

P = Perimeter of pipe in contact with the water (m)

D = Diameter of pipe (m)

i = Slope of energy gradient line (hf/L)

hf = Head loss between two ends of the pipeline

L = Length of pipeline (m)

Design velocity and hydraulic gradient

A velocity range is established for design purpose for two reasons. On the one hand, a certain minimum velocity is required to prevent water stagnation and bacterial growth inside the conduit. On the other hand, maximum velocity will have to be respected in order to control head losses in the system and reduce the effects of water hammer.

The velocity of gravity flow in lined conduits is usually maintained in the range of 0.6 m/s to 1.2 m/s.

Example 1: Pipeline diameter selection for Gravity mains

Given:

(i) Discharge through the pipeline = 40 litres/sec
(ii) Length of the pipeline = 5000 metres
(iii) Elevation head of Reservoir Bed = 15 metres
(iv) Available Head of water at Reservoir = 10 metres
(v) Total Head of water available at Reservoir = 15 + 10 = 25 metres
(vi) Elevation head at discharge point = 3 metres
(vii) Minimum residual head required at the delivery point = 3 metres

To find out:

(i) Diameter of the pipe
(ii) Total head loss in pipeline
(iii) Residual head available at the pipe end

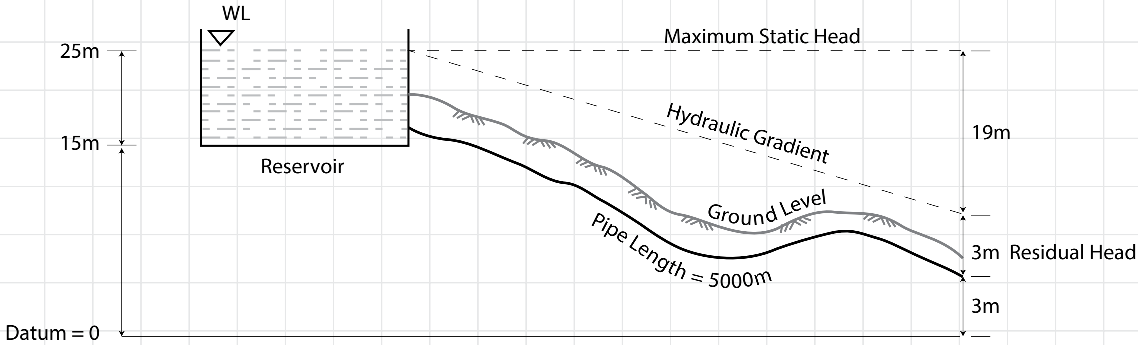


Fig. 2.2.3: Schematic diagram of Gravity main

Solution:

Assume:

(i) Velocity in the pipeline, v = 1.0 m/sec.

(ii) Calculate the flow diameter of the pipeline,

$$D = \left[\frac{4\,Q}{\pi\,v}\right]^{1/2}$$

$$\text{Or,} \quad D = \left[\frac{4 \times 40}{\pi \times 1000}\right]^{1/2}$$

Or, D = 0.225 m = 225 mm.

Select, D = 250 mm

Check,

$$\text{Velocity (v)} = \frac{\text{Discharge (Q)}}{\text{Flow Area of pipe (A)}} = \frac{40 \times 4}{\pi \times 1000 \times (0.25)^2}$$

Velocity (v) = 0.815 m/sec, Hence OK ($\geq$ 0.6 m/sec)

For D = 250mm, Q = 40 lps,

Calculate the hydraulic gradient (i) from Table 2.2.2

We get, i = 2.03m /1000m length of pipe,

Therefore, Frictional Head Loss = Hydraulic gradient x length of pipe.

Or, Frictional Head Loss = 2.03 (m /km length) x 5 (km) = 10.15m

Therefore, Residual Head = Total head at Reservoir - (Frictional Head Loss + Static Head at pipe end).

Or, Residual Head = 25 - (10.15 +3) = 11.85 m (> 3m, Hence Ok)

2.2.2.2 Pumping System

A pumping system is deployed when water has to be transported over large distances or to higher elevation. The pumping head is the total head comprising of the static head (H_s) plus the frictional head loss for the design flow (ΔH) as shown in the figure

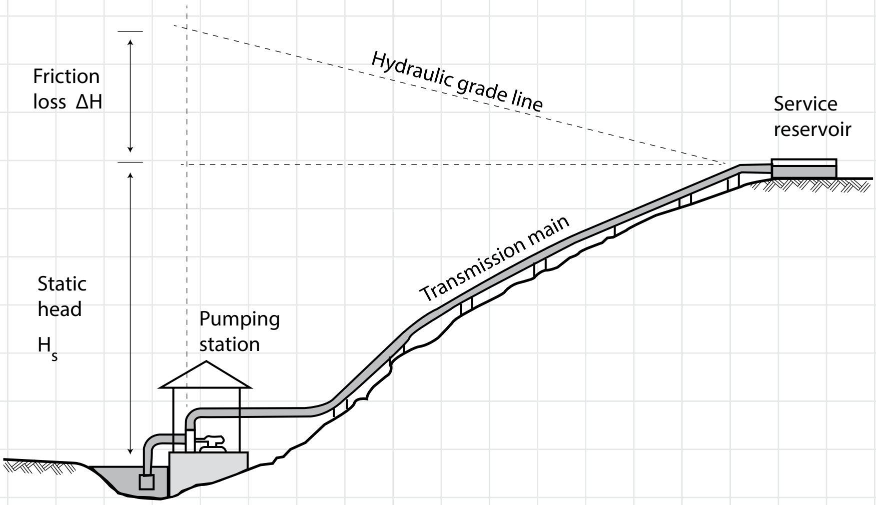


Fig. 2.2.4: Pumping system for water transmission

Following formulae are adopted for sizing of Ductile Iron pipe.

a) Hazen William's (HW) Formula

This formula is applicable for common range of flows and diameters.

$Q = 0.85\ CR^{0.63}\ i^{0.54}\ A$

Where:

Q = Discharge in pipeline (m^3/sec)

C = Roughness coefficient of pipe material

R = Hydraulic radius of pipe = A/P; for full pipe flow R = D/4

D = Flow diameter (m)

A = Flow area (m^2)

P = Perimeter of pipeline in contact with water (m)

i = Slope of energy gradient line (h_f /L)

L = Length of pipeline (m)

Hazen William's C value for pipe linings

S.No.	Type of Lining	C - Value
1.0	CEMENT MORTAR LINING	140
2.0	EPOXY SEAL COAT	145
3.0	POLYURETHANE LINING	150

The accuracy of Hazen William's formula becomes reduced at lower C values (lower than 100) and velocities which are appreciably lower or higher than 1.0 m/s.

b) Darcy Weisbach's (DW) formula

The first dimensionless equation for pipe flow was suggested by Darcy & Weisbach.

$$\frac{h}{L} = \frac{fV^2}{2gD}$$

Where:

i = Slope of energy gradient line (h_f/L)

h_f = Head Loss due to friction over length L in metres

f = Dimensionless friction factor (for Cement mortar lined DI pipe = 0.035)

g = Acceleration due to gravity in m/sec^2

V = Velocity in m/sec

L = Length in metres

D = Diameter in metres

c) Colebrook - White Formula: Recommended Design Equation

The Colebrook - White formula is universally used for determining the head loss coefficient. The formula can be depicted in two forms:

Form 1: For calculating the friction factor:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left\{\frac{2.51}{R_e\sqrt{f}} + \frac{k}{3.7D}\right\}$$

Form 2: For calculating the velocity in the pipeline:

$$V = -2.0\sqrt{(2gDi)}\log_{10}\left\{\frac{2.5v}{D\sqrt{2gDi}} + \frac{k}{3.7D}\right\}$$

$$Q = -1.5714\,D^2\sqrt{(2gDi)}\log_{10}\left\{\frac{2.5v}{D\sqrt{2gDi}} + \frac{k}{3.7D}\right\}$$

We also know that Re = Reynolds number is expressed as,

$$R_e = \frac{VD}{\nu}$$

Where:

Re = Reynolds number

V = Velocity in the pipeline (m/sec)

D = Internal diameter of the pipeline (m)

i = Hydraulic gradient of the pipeline (h/L)

ν = Kinematic viscocity of the fluid at the operating temperature (m^2/sec)

k = The equivalent pipe surface roughness (in m); note that k is not equal to the height of surface imperfection but is a theoretical concept relating to the surface roughness

g = Acceleration due to gravity (m/sec^2)

L = Length of pipeline (m)

From the above equation, if the pipe diameter is known and the value of k (pipe roughness) is known, then the velocity and discharge (discharge = velocity x area) are function of hydraulic gradient (i) and known value of kinematic viscosity of water.

Table 2.2.1 to 2.2.8 gives the value of Velocity (V) and hydraulic gradient (i) for different values of Discharge (Q) for various diameters.

Assumptions taken while computing the table:

a) Absolute roughness for inner pipe wall
   i) k = 0.03mm (for cement lined Ductile Iron pipes)
   ii) k = 0.0013mm (for Epoxy seal coats)
   iii) k = 0.0015mm (for Polyurethane line pipes)

b) Kinematic viscosity of water μ = 1.004 x 10-6 m2/sec at temperature = 20° C

Note: In the given table 2.2.1 to 2.2.8 the following abbreviations have been taken.

Q = Discharge in litres/sec

V = Velocity of flow in m/sec

i = Hydraulic gradient in m/1000m length of pipe

ID = Internal diameter of DI pipe

DN = Nominal diameter of DI pipe

Steps involved in Design of Pumped Transmission Main:

Step 1: Calculate the flow in the pipeline based on the water demand calculated as per national standard Q in litres per second (lps).

Step 2: Calculate the total length (L) of the pipeline in metres.

Step 3: Assuming a velocity of 1.0 m/s, calculate the approximate diameter of the pipe, using the formula $D = \sqrt{(4Q/1000\pi)}$.

Step 4: Decide the nearest possible commercially available nominal diameter of the pipe based on the above calculated value of D. Then calculate the internal diameter of the pipe.

Internal diameter (ID) = External diameter (DE) - 2 x Thickness of the pipe (e pipe) - 2 x Thickness of internal lining of pipe (e lining).

Step 5: Using the selected diameter in Step 4 and given discharge Q, determine the velocity and hydraulic gradient as per Colebrook's formula given in table 2.2.1 to 2.2.8.

Step 6: Calculate the Total frictional loss in the pipeline:

Total frictional loss = Hydraulic Gradient (i) x length of pipeline + Static Head + Losses in fittings, valves, and other appurtenances.

Determination of most economical diameter of pipeline:

Step 7: After deciding the nearest diameter D as per Step 4. Calculate the losses in the diameter range one step above and below the given diameter.

Step 8: Each combination of pumping head (losses calculated for corresponding diameter as in Step 7), should be capable of supplying the required flow rate over the required distance. Smaller pipe diameters will require a higher pumping head to overcome the increase in head losses and vice versa. As a result one pipe diameter will represent the least cost choice, taking into account the capital investment cost, maintenance cost, and the energy cost for pumping.

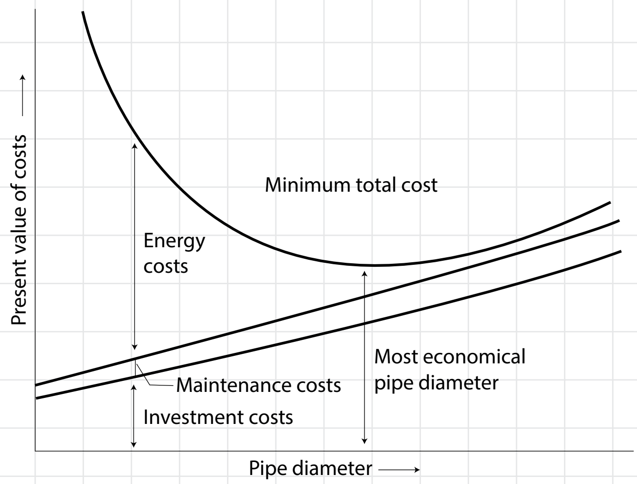


Fig. 2.2.5: Graph Showing Relationship of Investment Cost, Energy Cost and Maintenance Cost

Step 9: As mentioned earlier, the least cost choice of pipe in terms of capital investment cost and running cost will determine the most economical diameter of the pipe.

The stages of Design of pumping system:

The Design life of pumping system is divided into two stages (15 years each).

The pipelines are designed for 30 years. The pumping units are designed for 15 years period.

1st Stage: Capital cost of pipe + Capital cost of pump + Capitalized Energy cost.

2nd Stage: Present worth of replacement cost of pumps + Capitalized Energy cost.

Step 10: Hints:

a) Energy charges of pump (in KW) $= \frac{\gamma \times Q \times H \times 24}{102 \times \eta \times X}$

Where:

Q = Average Discharge for the design period in lps

H = Total head of discharge in metres

γ = Specific weight of water in kg/litre (= 1 kg/litre)

η = Combined efficiency of pump set

X = Hours of pumping for given discharge

b) Pump Cost Capitalized

$Pn = C = P_o (1+ r)^n$

$Po = C/(1+r)^n$

Where:

Po = Initial Capitalized Investment

C = Cost for purchase of pumping set for second stage

r = Rate of compound interest per annum

n = No of years

c) Energy Charges Capitalized

$Cc = Cr \{(1- (1+r)^{-n})/n\}$

Where:

Cc = Capitalized Cost of Energy

Cr = Annual Energy Cost in a given year

Table 2.2.1: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 80 (Class C40)		DN 100 (Class C40)		DN 150 (Class C40)	
	ID (mm) = 81.2		ID (mm) = 101.2		ID (mm) =153	
	V(m/s)	Slope i (m/1000m)	V(m/s)	Slope i (m/1000m)	V(m/s)	Slope i (m/1000m)
3	0.58	4.72				
4	0.77	7.98				
5	0.97	12.01	0.62	4.09		
6	1.16	16.82	0.75	5.71		
7	1.35	22.39	0.87	7.58		
8	1.55	28.71	1.00	9.69		
9	1.74	35.83	1.12	12.04		
10	1.93	43.66	1.24	14.64		
12	2.32	61.57	1.49	20.56	0.65	2.70
14	2.70	82.44	1.74	27.44	0.76	3.58
16	3.09	106.27	1.99	35.26	0.87	4.58
18	3.48	133.06	2.24	44.03	0.98	5.69
20	3.86	162.79	2.49	53.79	1.09	6.92
22	4.25	195.46	2.74	64.45	1.20	8.26
24	4.64	231.08	2.99	76.05	1.31	9.71
26	5.02	269.64	3.23	88.59	1.41	11.27
28	5.41	311.13	3.48	102.06	1.52	12.95
30	5.80	355.56	3.73	116.47	1.63	14.74
35	6.76	479.46	4.35	156.57	1.90	19.69
40			4.98	202.51	2.18	25.33
45			5.60	254.27	2.45	31.65
50			6.22	311.85	2.72	38.66
55					2.99	46.35
60					3.27	54.73
65					3.54	63.78
70					3.81	73.52
75					4.08	83.93
80					4.35	94.97
85					4.63	106.74
90					4.90	119.18
95					5.17	132.30
100					5.44	146.09
110					5.99	175.71
120					6.53	208.03

Table 2.2.2: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 200 (Class C40)		DN 250 (Class C40)		Q (L/s)	DN 300 (Class C40)	
	ID(mm) = 204.60		ID(mm) = 255.00			ID(mm) = 305.6	
	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)		V(m/s)	Slope i (m/1000)
					50	0.68	0.63
					60	0.82	0.88
					70	0.95	1.16
					80	1.09	1.49
20	0.61	1.67			90	1.23	1.85
25	0.76	2.51			100	1.36	2.25
30	0.91	3.51			120	1.64	3.16
35	1.07	4.68	0.69	1.59	140	1.91	4.21
45	1.37	7.47	0.88	2.52	160	2.18	5.42
55	1.67	10.87	1.08	3.66	180	2.46	6.77
65	1.98	14.89	1.27	4.99	200	2.73	8.26
75	2.28	19.52	1.47	6.53	220	3.00	9.89
85	2.59	24.75	1.67	8.26	240	3.27	11.67
105	3.20	37.02	2.06	12.30	260	3.55	13.58
125	3.80	51.69	2.45	17.12	280	3.82	15.65
145	4.41	68.73	2.84	22.71	300	4.09	17.92
165	5.02	88.19	3.23	29.05	320	4.36	20.19
185	5.63	110.03	3.62	36.16	340	4.64	22.68
205	6.24	134.24	4.02	44.05	360	4.91	25.32
225			4.41	52.69	380	5.18	28.09
245			4.80	62.10	400	5.46	31.01
265			5.19	72.27	420	5.73	34.05
285			5.58	83.20	440	6.00	37.24
305			5.98	94.88	460	6.27	40.58
325			6.37	107.31	480	6.55	44.06

Table 2.2.3: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 350 (Class C30)		DN 400 (Class C30)		DN 450 (Class C30)	
	ID(mm) = 355.4		ID(mm) = 406		ID(mm) = 456.2	
	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)
50	0.50	0.61				
60	0.61	0.85				
70	0.71	1.12	0.54	0.59		
80	0.81	1.44	0.62	0.75		
90	0.91	1.79	0.70	0.93		
100	1.01	2.18	0.77	1.13	0.61	0.64
120	1.21	3.06	0.93	1.59	0.73	0.90
140	1.41	4.08	1.08	2.11	0.86	1.19
160	1.61	5.24	1.24	2.71	0.98	1.53
180	1.82	6.54	1.39	3.38	1.10	1.90
200	2.02	7.97	1.55	4.12	1.22	2.32
220	2.22	9.55	1.70	4.93	1.35	2.77
240	2.42	11.27	1.85	5.81	1.47	3.26
260	2.62	13.12	2.01	6.76	1.59	3.79
280	2.82	15.11	2.16	7.77	1.71	4.36
300	3.03	17.23	2.32	8.86	1.84	4.96
320	3.23	19.50	2.47	10.02	1.96	5.60
340	3.43	21.90	2.63	11.24	2.08	6.29
360	3.63	24.43	2.78	12.53	2.20	7.01
380	3.83	27.11	2.94	13.90	2.33	7.77
400	4.03	29.91	3.09	15.33	2.45	8.56
420	4.24	32.86	3.25	16.83	2.57	9.39
440	4.44	35.94	3.40	18.39	2.69	10.26
460	4.64	39.16	3.55	20.03	2.82	11.17
480	4.84	42.51	3.71	21.74	2.94	12.11
500	5.04	46.00	3.86	23.50	3.06	13.10
520	5.24	49.62	4.02	25.35	3.18	14.12
540	5.45	53.38	4.17	27.26	3.31	15.17
560	5.65	57.28	4.33	29.24	3.43	16.27
580	5.85	61.31	4.48	31.28	3.55	17.40
600	6.05	65.48	4.64	33.40	3.67	18.57
620			4.79	35.57	3.79	19.78
640			4.95	37.83	3.92	21.02
660			5.10	40.15	4.04	22.30
680			5.26	42.54	4.16	23.62
700			5.41	44.99	4.28	24.98
720			5.56	47.51	4.41	26.37
740			5.72	50.11	4.53	27.80
760			5.87	52.76	4.65	29.27
780			6.03	55.49	4.77	30.78
800					4.90	32.32
820					5.02	33.90
840					5.14	35.51
860					5.26	37.17
880					5.39	38.85
900					5.51	40.58
920					5.63	42.35
940					5.75	44.16
960					5.88	46.00
980					6.00	47.88

Table 2.2.4: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 500 (Class C30)		DN 600 (Class C30)		DN 700 (Class C25)	
	ID(mm) = 507		ID(mm) = 607.6		ID(mm) = 708.4	
	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)
150	0.74	0.81				
180	0.89	1.13				
210	1.04	1.51	0.72	0.62		
240	1.19	1.94	0.83	0.80		
270	1.34	2.41	0.93	0.99		
300	1.49	2.94	1.04	1.21		
330	1.64	3.52	1.14	1.44	0.84	0.68
360	1.78	4.14	1.24	1.69	0.91	0.80
390	1.93	4.82	1.35	1.97	0.99	0.92
420	2.08	5.55	1.45	2.26	1.07	1.06
450	2.23	6.32	1.55	2.57	1.14	1.21
500	2.48	7.72	1.73	3.14	1.27	1.47
550	2.73	9.26	1.90	3.76	1.40	1.76
600	2.97	10.93	2.07	4.43	1.52	2.07
650	3.22	12.74	2.24	5.16	1.65	2.41
700	3.47	14.69	2.42	5.94	1.78	2.77
750	3.72	16.77	2.59	6.77	1.90	3.16
800	3.96	18.98	2.76	7.66	2.03	3.56
850	4.21	21.34	2.93	8.60	2.16	4.00
900	4.46	23.83	3.11	9.59	2.28	4.46
950	4.71	26.44	3.28	10.64	2.41	4.94
1000	4.96	29.19	3.45	11.74	2.54	5.45
1050	5.20	32.08	3.62	12.89	2.67	5.98
1100	5.45	35.10	3.80	14.10	2.79	6.53
1150	5.70	38.26	3.97	15.35	2.92	7.11
1200	5.95	41.55	4.14	16.67	3.05	7.71
1250	6.19	44.98	4.31	18.03	3.17	8.34
1300			4.49	19.44	3.30	8.99
1350			4.66	20.91	3.43	9.66
1400			4.83	22.44	3.55	10.36
1450			5.00	24.01	3.68	11.09
1500			5.18	25.64	3.81	11.83
1600			5.52	29.05	4.06	13.40
1700			5.87	32.68	4.32	15.06
1800			6.21	36.51	4.57	16.82
1900					4.82	18.67
2000					5.08	20.62
2100					5.33	22.66
2200					5.58	24.79
2300					5.84	27.02
2400					6.09	29.35
2500					6.35	31.77

Table 2.2.5: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 750 (Class C25)		DN 800 (Class C25)		DN 900 (Class C25)	
	ID(mm) = 760.40		ID(mm) = 810.8		ID(mm) = 911.8	
	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)	V(m/s)	Slope i (m/1000)
250	0.55	0.29				
300	0.66	0.40	0.58	0.29		
350	0.77	0.53	0.68	0.39		
400	0.88	0.68	0.78	0.50	0.61	0.28
450	0.99	0.85	0.87	0.62	0.69	0.35
500	1.10	1.04	0.97	0.76	0.77	0.43
550	1.21	1.24	1.07	0.90	0.84	0.51
600	1.32	1.46	1.16	1.06	0.92	0.60
650	1.43	1.69	1.26	1.24	1.00	0.69
700	1.54	1.95	1.36	1.42	1.07	0.80
750	1.65	2.22	1.45	1.62	1.15	0.91
800	1.76	2.51	1.55	1.82	1.23	1.02
850	1.87	2.81	1.65	2.05	1.30	1.15
900	1.98	3.14	1.74	2.28	1.38	1.27
950	2.09	3.47	1.84	2.52	1.46	1.41
1000	2.20	3.83	1.94	2.78	1.53	1.55
1100	2.42	4.59	2.13	3.33	1.69	1.86
1200	2.64	5.41	2.33	3.93	1.84	2.19
1300	2.86	6.31	2.52	4.58	1.99	2.55
1400	3.08	7.27	2.71	5.27	2.15	2.94
1500	3.30	8.29	2.91	6.02	2.30	3.35
1600	3.53	9.39	3.10	6.81	2.45	3.79
1700	3.75	10.55	3.29	7.65	2.60	4.25
1800	3.97	11.77	3.49	8.53	2.76	4.74
1900	4.19	13.06	3.68	9.46	2.91	5.26
2000	4.41	14.42	3.88	10.44	3.06	5.80
2100	4.63	15.85	4.07	11.47	3.22	6.37
2200	4.85	17.34	4.26	12.55	3.37	6.96
2300	5.07	18.89	4.46	13.67	3.52	7.58
2400	5.29	20.52	4.65	14.84	3.68	8.22
2500	5.51	22.21	4.84	16.07	3.83	8.90
2600	5.73	23.96	5.04	17.33	3.98	9.59
2700	5.95	25.78	5.23	18.64	4.14	10.32
2800	6.17	27.67	5.43	20.00	4.29	11.07
2900			5.62	21.41	4.44	11.84
3000			5.81	22.87	4.60	12.64
3250			6.30	26.71	4.98	14.76
3500					5.36	17.04
3750					5.75	19.47
4000					6.13	22.07

Table 2.2.6: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 1000 (Class C25)		DN 1100 (Class C25)		DN 1200 (Class C25)	
	ID(mm) = 1012.8		ID(mm) = 1114.8		ID(mm) = 1215.8	
	V(m/s)	Slope i (m/1000)	V in (m/s)	Slope i (in m/1000m)	V in (m/s)	Slope i (in m/1000m)
500	0.62	0.25				
750	0.93	0.54	0.77	0.34	0.65	0.22
1000	1.24	0.93	1.03	0.58	0.86	0.38
1250	1.55	1.41	1.28	0.88	1.08	0.57
1500	1.86	1.99	1.54	1.23	1.29	0.80
1750	2.17	2.66	1.79	1.65	1.51	1.08
2000	2.48	3.43	2.05	2.13	1.72	1.38
2250	2.79	4.30	2.31	2.66	1.94	1.73
2500	3.10	5.25	2.56	3.25	2.15	2.11
2750	3.42	6.31	2.82	3.90	2.37	2.53
3000	3.73	7.45	3.08	4.61	2.59	2.99
3250	4.04	8.70	3.33	5.37	2.80	3.48
3500	4.35	10.03	3.59	6.20	3.02	4.01
3750	4.66	11.46	3.84	7.08	3.23	4.58
4000	4.97	12.99	4.10	8.01	3.45	5.18
4250	5.28	14.60	4.36	9.01	3.66	5.83
4500	5.59	16.31	4.61	10.06	3.88	6.50
4750	5.90	18.12	4.87	11.16	4.09	7.22
5000	6.21	20.02	5.13	12.33	4.31	7.97
5250	6.52	22.00	5.38	13.55	4.52	8.75
5500			5.64	14.83	4.74	9.58
5750			5.89	16.17	4.96	10.44
6000			6.15	17.56	5.17	11.33
6250			6.41	19.01	5.39	12.27
6500					5.60	13.23
6750					5.82	14.24
7000					6.03	15.28
7250					6.25	16.37
7500					6.46	17.48
7750					6.68	18.63
8000					6.89	19.81

Table 2.2.7: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 1400 (Class C25)		DN 1600 (Class C25)		DN 1800 (Class C25)	
	ID(mm) = 1412.6		ID(mm) = 1614.6		ID(mm) = 1817.6	
	V in (m/s)	Slope i (in m/1000m)	V(m/s)	Slope i (in m/1000m)	V(m/s)	Slope i (in m/1000m)
1000	0.64	0.18				
1250	0.80	0.27	0.61	0.142		
1500	0.96	0.38	0.73	0.200	0.58	0.112
1750	1.12	0.51	0.86	0.266	0.67	0.149
2000	1.28	0.66	0.98	0.341	0.77	0.191
2250	1.44	0.82	1.10	0.426	0.87	0.238
2500	1.60	1.00	1.22	0.519	0.96	0.290
2750	1.76	1.20	1.34	0.621	1.06	0.346
3000	1.92	1.42	1.47	0.731	1.16	0.408
3250	2.07	1.65	1.59	0.850	1.25	0.474
3500	2.23	1.90	1.71	0.978	1.35	0.545
3750	2.39	2.17	1.83	1.115	1.45	0.620
4000	2.55	2.45	1.95	1.260	1.54	0.701
4250	2.71	2.75	2.08	1.414	1.64	0.786
4500	2.87	3.07	2.20	1.576	1.74	0.876
4750	3.03	3.40	2.32	1.747	1.83	0.970
5000	3.19	3.75	2.44	1.926	1.93	1.069
5250	3.35	4.12	2.57	2.114	2.02	1.173
5500	3.51	4.51	2.69	2.310	2.12	1.281
5750	3.67	4.91	2.81	2.515	2.22	1.394
6000	3.83	5.33	2.93	2.729	2.31	1.512
6250	3.99	5.76	3.05	2.951	2.41	1.634
6500	4.15	6.21	3.18	3.181	2.51	1.761
6750	4.31	6.68	3.30	3.420	2.60	1.893
7000	4.47	7.17	3.42	3.667	2.70	2.029
7250	4.63	7.68	3.54	3.923	2.80	2.170
7500	4.79	8.20	3.66	4.185	2.89	2.315
7750	4.95	8.73	3.79	4.460	2.99	2.466
8000	5.11	9.28	3.91	4.741	3.08	2.620
8250	5.27	9.85	4.03	5.030	3.18	2.779
8500	5.43	10.44	4.15	5.331	3.28	2.944
8750	5.59	11.05	4.28	5.635	3.37	3.112
9000	5.75	11.67	4.40	5.953	3.47	3.284
9250	5.91	12.31	4.52	6.274	3.57	3.462
9500	6.06	12.96	4.64	6.605	3.66	3.644
9750	6.22	13.63	4.76	6.945	3.76	3.830
10000			4.89	7.294	3.86	4.021
10250			5.01	7.654	3.95	4.216
10500			5.13	8.017	4.05	4.419
10750			5.25	8.391	4.15	4.624
11000			5.38	8.773	4.24	4.834
11250			5.50	9.163	4.34	5.047
11500			5.62	9.561	4.43	5.267
11750			5.74	9.971	4.53	5.491
12000			5.86	10.387	4.63	5.718
12250			5.99	10.811	4.72	5.951
12500			6.11	11.244	4.82	6.189

Continued...

...continued

Q (L/s)	DN 1400 (Class C25)		DN 1600 (Class C25)		DN 1800 (Class C25)	
	ID(mm) = 1412.6		ID(mm) = 1614.6		ID(mm) = 1817.6	
	V in (m/s)	Slope i (in m/1000m)	V(m/s)	Slope i (in m/1000m)	V(m/s)	Slope i (in m/1000m)
13250					5.11	6.927
13500					5.21	7.183
13750					5.30	7.443
14000					5.40	7.707
14250					5.49	7.976
14500					5.59	8.250
14750					5.69	8.528
15000					5.78	8.811
15250					5.88	9.098
15500					5.98	9.389
15750					6.07	9.685
16000					6.17	9.988

Table 2.2.8: Relationship of Velocity (V) and Hydraulic Gradient (i) using Colebrook's formula

Q (L/s)	DN 2000 (Class C25)		DN 2200 (Class C25)	
	ID(mm) = 2020.4		ID(mm) = 2216.4	
	V(m/s)	Slope i (in m/1000m)	V(m/s)	Slope i (in m/1000m)
1750	0.55	0.089	0.45	0.063
2000	0.62	0.114	0.52	0.081
2250	0.70	0.142	0.58	0.100
2500	0.78	0.172	0.65	0.122
2750	0.86	0.206	0.71	0.146
3000	0.94	0.242	0.78	0.171
3250	1.01	0.281	0.84	0.199
3500	1.09	0.323	0.91	0.229
3750	1.17	0.368	0.97	0.260
4000	1.25	0.416	1.04	0.294
4250	1.33	0.466	1.10	0.329
4500	1.40	0.519	1.17	0.366
4750	1.48	0.575	1.23	0.405
5000	1.56	0.633	1.30	0.446
5250	1.64	0.694	1.36	0.489
5500	1.72	0.758	1.43	0.534
5750	1.79	0.825	1.49	0.580
6000	1.87	0.894	1.56	0.629
6250	1.95	0.966	1.62	0.679
6500	2.03	1.041	1.69	0.732
6750	2.11	1.118	1.75	0.786
7000	2.18	1.198	1.82	0.842
7250	2.26	1.282	1.88	0.900
7500	2.34	1.366	1.94	0.961
7750	2.42	1.454	2.01	1.023
8000	2.50	1.545	2.07	1.085
8250	2.57	1.638	2.14	1.152
8500	2.65	1.734	2.20	1.219
8750	2.73	1.834	2.27	1.289
9000	2.81	1.935	2.33	1.359
9250	2.89	2.040	2.40	1.432
9500	2.96	2.147	2.46	1.506
9750	3.04	2.256	2.53	1.583
10000	3.12	2.368	2.59	1.661
10250	3.20	2.484	2.66	1.741
10500	3.28	2.601	2.72	1.824
10750	3.35	2.721	2.79	1.908
11000	3.43	2.843	2.85	1.994
11250	3.51	2.970	2.92	2.081
11500	3.59	3.098	2.98	2.171
12250	3.82	3.498	3.18	2.450
12500	3.90	3.637	3.24	2.548
12750	3.98	3.778	3.31	2.646
13000	4.06	3.922	3.37	2.746
13250	4.13	4.068	3.44	2.848
13500	4.21	4.217	3.50	2.954
13750	4.29	4.371	3.57	3.061
14000	4.37	4.525	3.63	3.168
14250	4.45	4.683	3.70	3.277

Continued...

...continued

Q (L/s)	DN 2000 (Class C25)		DN 2200 (Class C25)	
	ID(mm) = 2020.4		ID(mm) = 2216.4	
	V(m/s)	Slope i (in m/1000m)	V(m/s)	Slope i (in m/1000m)
15250	4.76	5.340	3.95	3.734
15500	4.84	5.510	4.02	3.852
15750	4.92	5.683	4.08	3.973
16000	4.99	5.859	4.15	4.095
16250	5.07	6.039	4.21	4.219
16500	5.15	6.219	4.28	4.347
16750	5.23	6.403	4.34	4.475
17000	5.31	6.589	4.41	4.605
17250	5.38	6.778	4.47	4.736
17500	5.46	6.970	4.54	4.870
17750	5.54	7.165	4.60	5.005
18000	5.62	7.362	4.67	5.142
18250	5.70	7.562	4.73	5.281
18500	5.77	7.764	4.80	5.423
18750	5.85	7.969	4.86	5.565
19000	5.93	8.176	4.93	5.710
19250	6.01	8.387	4.99	5.856
19500	6.09	8.599	5.06	6.006
19750	6.16	8.815	5.12	6.155
20000			5.19	6.306
20250			5.25	6.460
20500			5.32	6.615
20750			5.38	6.772
21000			5.45	6.931
21250			5.51	7.092
21500			5.58	7.256
21750			5.64	7.420
22000			5.71	7.588
22250			5.77	7.755

2.3

Design of Ductile Iron Pipes for Internal Pressure and External Loads

2.3.1 Design Considerations

The design of Ductile Iron pipes used for conveying water or any other fluid is carried out considering the following:
a. With or without internal pressure
b. With or without earth and traffic loading

2.3.2 Design for Internal Pressure

Based on the design of the pumping main or distribution network, calculate the operating pressure of the pipeline, designated as Allowable Operating Pressure (PFA). Based on the PFA, select the appropriate class of pipes from International Standards BSEN 545 or ISO 2531 i.e. C20, C25, C30, C40, C50, C64 or C100.

Note: For more details on the internal pressure design, refer to ISO 10803.

2.3.3 Design for External Pressure

2.3.3.1 General considerations

Buried pipes are designed to support external superimposed load, including the weight of the soil above and any live load, such as wheel load due to vehicle or equipment.

Ductile Iron pipes fall in the category of Semi Rigid pipes.

Semi-rigid (Ductile Iron) pipes distribute the external load to the surrounding soil and bedding material. Semi-rigid Pipes are stiff enough to withstand buckling. They are designed on the basis of permissible deflection.

2.3.3.2 Step 1: Calculation of vertical pressure on the pipe crown due to earth load and traffic loads

Vertical pressure (q) due to external load

$q = q_1 + q_2$

Where:

q_1 = Pressure due to earth loads (Mpa)
q_2 = Pressure due to traffic loads (Mpa)

Pressure due to earth loads: q_1

The following formula is applied

$q_1 = 0.001\gamma H$

Where:

γ = Unit weight of backfill in KN/m3
H = Height of earth cover (distance from pipe crown to ground surface), in metres

Pressure due to traffic loads: q_2

The following simplified formula covers a wide range of traffic load

$$q_2 = 0.04 \times \frac{\beta}{H} (1-2\times10^{-4} DN)$$

Where:

β = Traffic load factor
H = Height of cover (m)
DN = Nominal size of pipe (mm)

Note: This formula is not applicable when H < 0.3m.

Three types of traffic loading are to be considered:
Main Roads: β = 1.50 This is the general case, except access roads
Access Roads: β = 0.75 Roads where lorry / truck traffic is prohibited
Rural Areas: β = 0.50 All other cases

Note: In certain countries, national regulations require the use of higher values for β.

All pipelines should be designed for at least β = 0.5 and pipelines laid adjacent to roads should be designed to withstand the full road loading.

For heavy traffice loading ,'β' can be calculated using the following formula:

$$\beta = \frac{P}{100}$$

Where:
P = Wheel load in KN.

Note1: Pipelines laid under heavy traffic like railroads, airports, highways, special β values will apply.

Note2: For cases, where ational standard exists for Axial Load for different types of vehicles, the pressure due to trafice loading (i.e. q2) should be determined as per equaltion given below:

$$P_p = \frac{3P_s}{2\pi h^2 \left[1+\left(\frac{d}{h}\right)^2\right]^{2.5}}$$

Where:

Pp = Uniformly transmitted load on the pipe, lb/in2

Ps = Concentrated load at suface, above pipe, lb

D = Offset distance from pipe to line of application of surface load, in

H = Height of cover, in

Step 2: Calculation for Deflection of Ductile Iron pipe

The popular formula for calculation of pipe ring deflection is that developed by M.G. Spangler and later modified by Watkins and Spangler at the Iowa State University.

Design Equation
The Spangler-Watkins formula is given below:

$$\Delta = 100 \times \frac{K_x q}{8S + 0.061E'}$$

Where:
Δ = Pipe diametral deflection, in percentage of external diameter D
e = The average of the minimum pipe wall thickness and nominal pipe wall thickness in mm
K_x = Deflection coefficient depending on the bedding reaction angle
q = Total vertical pressure at pipe crown due to all external loads (Mpa)
E = Modulus of elasticity of the pipe wall material (Mpa)
S = $\frac{EI}{(D-e)^3}$ is the pipe diameter stiffness (Mpa)
I = $e^3/12$ is the second moment of area of the pipe per unit length (mm3)
D = Pipe external diameter (mm)
E' = Modulus of soil reaction (Mpa)

The modulus of soil reaction E' of the sidefill depends upon the trench type and type of soil (refer table 2.3.1)

Table 2.3.1: Modulus of Soil Reaction E'

Trench Type	1	2	3	4	5
Placement of Emedment	Dumped	Very Light Compaciton	Light Compaction	Medium Compaction	High Compaction
Standard Procotor Density of Sidefill %	a	>75	>80	>85	>90
Bedding Reaction Angle (2α)	30°	45°	60°	90°	150°
K_x	0.108	0.105	0.102	0.096	0.085
E' (Mpa)					
Soil Group A	4	4	5	7	10
Soil Group B	2.5	2.5	3.5	5	7
Soil Group C	1	1.5	2	3	5
Soil Group D	0.5	1	1.5	2.5	3.5
Soil Group E	b	b	b	b	b
Soil Group F	b	b	b	b	b
a) Depending on the type of soil and its mositure content a Standard Proctor Density of 70% to 80% should normally be achieved by simply dumping the soil in the trench.					
b) Use an E' value of 0 unless it can be ensured that a higher value will be achieved consistently.					

Table 2.3.2: Soil Classification

Soil Group	Description
A	Angular graded stone (6 to 40mm), also including a number of fill materials that have regional significance such as crushed stone, crushed gravel, pea gravel and crushed shells
B	Coarse - grained soils with little or no fines. No particles larger than 40mm
C	Coarse grained soils with fines and fine-grained soils with medium to no plasticity, with greater than 25% coarse particles, liquid limit (LL) less than 50%
D	Fine grained soils with medium to no plasticity, with less than 25% coarse particles, liquid limit (LL) less than 50%
E	Fine- grained soils with medium to high plasticity, liquid limit (LL) greater than 50%
F	Organic soils

Step 3: Allowable Pipe Diametral Deflection

The allowable pipe diametral deflection, (Δ_{max}) normally provides sufficient safety against yield bending strength of the pipe wall, lining deformation, joint leak tightness, and hydraulic capacity of the pipe. The allowable deflection for Ductile Iron pipes (with Cement Mortar Lining) = 4%. The allowable deflection for all classes of Ductile Iron pipe is given in Table D1 to D7 of ISO 2531.

Step 4: Compare the Deflection calculated in Step 2 with that of Allowable Deflection of pipe given in Step 3

Also from the formula given below, the maximum depth of cover (H) can be calculated.

$$q_1+q_2 = \frac{(\Delta(8S+0.061E'))}{K_x x100}$$

As Δ,S,E', K_x are known, the above equation will take the form of a quadratic equation, as q_1 and q_2 are functions of H (refer step 1) Therefore, the value of H can be obtained by solving quadratic equation. After we get the allowable depth of cover, we can check whether the same is sufficient at site as per the ground conditions. If depth of cover available at site is lower than the value of H calculated above, select the higher class of pipe and then re-calculate the allowable depth of cover, till it is safe.

Example 1: Design of Ductile Iron pipe for external load

Pipe Data:

Pipe Material	Characteristics	Symbol	Data	Reference
Ductile Iron, Class - C40, DN 700	External Diameter	D	738mm	ISO 2531 Table D.4
	Wall Thickness	t	12.4mm	- do -
	Allowable Deflection	$(\Delta/D)_A$	3.55 %	- do -
	Stiffness	$S=(EI/D^3)$	0.055 Mpa	- do -

Embedment Data (Given):

The selection of the appropriate embedment is one of the prime objectives of the design process, and the embedment characteristics can be varied by the designer in order to obtain a satisfactory and economic solution.

Characteristics	Symbol	Data	Reference
Type of Bed and Surround Material(s) - Soil Group		B	Ref: Table 1, ISO10803
Degree of Compaction		Medium	- do -
Modulus of Soil Reaction for Native Soil	E'	5 Mpa	- do -
Deflection Co-efficient (depending on Bedding Reaction Angle) - Medium Compacted Soil	K_x	0.096	- do -
Trench Width	B	1300mm	Given

External Loading Data (Given):

Parameter	Symbol	Data	Reference
Depth of Cover	H	1.3 M	Given
Unit Weight of Backfill	γ	20 KN/m^3	Given
Traffic Load Factor (β) for Main Road	β	1.5	Cl 6.2.2 ISO 10803

Step 1:

a) Calculation of vertical pressure on the pipe crown due to earth load.

$q_1 = 0.001\ \gamma\ H$

$= 0.001 \times 20 \times 1.3 = 0.026$ Mpa

b) Calculation of vertical pressure on the pipe crown due to traffic load.

$q_2 = 0.04\ \beta/H\ (1 - 2x\ 10^{-4}\ DN)$

or $q_2 = 0.04 \times (1.5 / 1.3) x\ (1 - 2 \times 10^{-4} \times 700)$

$= 0.040$ Mpa

Therefore, q = Vertical pressure on the pipe crown due to earth load and traffic load $(q_1 + q_2) = 0.026 + 0.040 = 0.066$ Mpa

Step 2:

Based on the value of q = 0.066 Mpa, calculate the, deflection on the pipe.

$$\Delta = \frac{q \times K_x \times 100}{(8S + 0.061\ E')}$$

$$= \frac{0.066 \times 0.096 \times 100}{(8 \times 0.055 + 0.061 x\ 5)}$$

= 0.85 % of Pipe external diameter < Allowable deflection (3.55%)

Hence the design is safe for DI DN 700 Class C40.

Example 2

Pipe Data:

Pipe Material	Characteristics	Symbol	Data	Reference
Ductile Iron, Class - C20, DN 700	External Diameter	D	738mm	ISO 2531 Table D.1
	Wall Thickness	t	7.3mm	- do -
	Allowable Deflection	$(\Delta/D)A$	3.8 %	- do -
	Stiffness	$S=(EI/D^3)$	0.009 Mpa	- do -

Embedment Data (Given):

The selection of the appropriate embedment is one of the prime objectives of the design process, and the embedment characteristics can be varied by the designer in order to obtain a satisfactory and economic solution.

Characteristics	Symbol	Data	Reference
Type of Bed and Surround Material(s) - Soil Group		B	Ref: Table 2.3.2
Degree of Compaction		Medium	Ref: Table 2.3.1
Modulus of Soil Reaction for Native Soil	E'	5 Mpa	- do -
Deflection Coefficient (depending on bedding reaction angle) - Medium Compacted Soil	K_x	0.096	- do -
Trench Width	B	1300mm	Given

External Loading Data (Given):

Parameter	Symbol	Data	Reference
Depth of cover	H	7.0m	Given
Unit Weight of Backfill	γ	20 KN/m^3	Given
Traffic Load Factor (β) for Main Road	β	2.0	Cl 6.2.2 ISO 10803

Step 1:

a) Calculation of vertical pressure on the pipe crown due to earth load.

$q_1 = 0.001\ \gamma\ H$

$= 0.001 \times 20 \times 7.0 = 0.14$ Mpa.

b) Calculation of vertical pressure on the pipe crown due to traffic load.

$q_2 = 0.04\ \beta/H\ (1 - 2x\ 10^{-4}\ DN)$
or, $q_2 = 0.04 \times (2 / 7.0) x\ (1 - 2 \times 10^{-4} \times 700)$
$= 0.010$ Mpa

Therefore, q = Vertical pressure on the pipe crown due to earth load and traffic load $(q_1 + q_2) = 0.14 + 0.010 = 0.15$ Mpa

Step 2:

Based on the value of q = 0.15 Mpa, calculate the, deflection on the pipe.

$$\Delta = \frac{q\ K_x\ 100}{(8S + 0.061\ E')}$$

$$= \frac{0.069 \times 0.096 \times 100}{(8 \times 0.009 + 0.061 x\ 5)}$$

= 3.82 % of Pipe external diameter ≥ Allowable deflection (3.8%)

Hence the design is unsafe for DN 700 Class C 20.
Choose higher class of pipe for safe design.

2.4 Technical Specifications of Ductile Iron Pipes

Product Name	Ductile Iron pipe suitable for Push-on-Joint, Flanged Joint, Restrained Joint as per ISO 2531; BSEN 545; BSEN 598; ISO 7186; IS 8329, ISO 10804
Class of Pipe	C20, C25, C30, C40, C50, C64, C100, Class K7, Class K9 and PP Class
Size Range	DN 80mm to DN 2200mm
Standard Length	5.5m /6.0m
Internal Linings	• Cement* Mortar Lining as per ISO 4179 • Cement Mortar Lining with Bituminous Seal Coat as per ISO 16132 • Cement Mortar Lining with Epoxy Seal Coat as per ISO 16132 • Polyurethane Lining as per BSEN 15655 *Cement Type: Ordinary Portland Cement/ Sulphate Resistant Cement/ Blast Furnace Slag Cement/ High Alumina Cement
Outside Coatings	• Zinc Coating (130 gm/m² or 200 gm/m² or 400 gm/m²) with finishing layer of Bitumen/ Blue Epoxy/ Red Epoxy/ Aluminum pigmented Bitumen as per ISO 8179 • Alloy of Zinc and Aluminium with or without metals having a minimum mass of 400 gm/m² with finishing layer of Bitumen/Blue Epoxy/ Red Epoxy as per ISO 8179 • Polyurethane Coating as per BSEN 15189
Outside On-site Protection	• Polyethylene Sleeving as per ISO 8180
Coating of Joint Area	• Bitumen as per BS 3416 • Epoxy - Blue/ Red as per BSEN 14901 • Polyurethane as per BSEN 15189

2.5 Pipe Dimensions

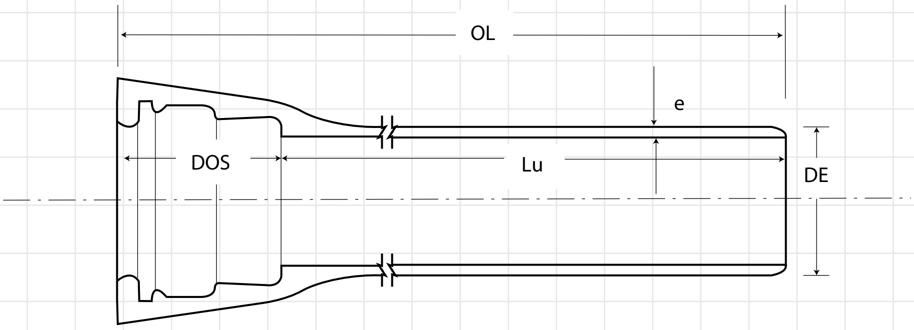


Fig. 2.5.1: Dimension of Socket and Spigot pipe

Key

OL = Overall length in meters

DOS = Depth of socket in meters

Lu = OL - DOS; standardized length in meters

e = Nominal wall thickness in mm

DE = Nominal external diameter of spigot in mm

Table 2.5.1: Dimension Details of JSAW Pipes

DN (mm)	Extenal Diameter, DE (mm)		Nominal Pipe Wall Thickness, e (mm) Various Classes of Pipes									
	Nominal	Limit Deviations	C20	C25	C30	C40	C50	C64	C100	As per BSEN 598 (Pressure Pipe)	K7	K9
80	98	+1 / -2.7				4.4	4.4	4.4	4.8	4.8	5.0	6.0
100	118	+1 / -2.8				4.4	4.4	4.4	5.5	4.8	5.0	6.0
125	144	+1 / -2.8				4.5	4.5	4.8	6.5	4.8	5.0	6.0
150	170	+1 / -2.9				4.5	4.5	5.3	7.4	4.8	5.0	6.0
200	222	+1 / -3.0				4.7	5.4	6.5	9.2	4.9	5.0	6.3
250	274	+1 / -3.1				5.5	6.4	7.8	11.1	5.3	5.3	6.8
300	326	+1 / -3.3			5.1	6.2	7.4	8.9	12.9	5.6	5.6	7.2
350	378	+1 / -3.4		5.1	6.3	7.1	8.4	10.2	14.8	6.0	6.0	7.7
400	429	+1 / -3.5		5.5	6.5	7.8	9.3	11.3	16.5	6.3	6.3	8.1
450	480	+1 / -3.6		6.1	6.9	8.6	10.3	12.6	18.4	6.7	6.6	8.6
500	532	+1 / -3.8		6.5	7.5	9.3	11.2	13.7	20.2	7.0	7.0	9.0
600	635	+1 / -4.0		7.6	8.7	10.9	13.1	16.1	23.8	7.7	7.7	9.9
700	738	+1 / -4.3	7.3	8.8	9.9	12.4	15.0	18.5	27.5	9.6	9.0	10.8
750	790	+1/ -4.3									9.7	11.3
800	842	+1 / -4.5	8.1	9.6	11.1	14.0	16.9	21.0		10.4	10.4	11.7
900	945	+1 / -4.8	8.9	10.6	12.3	15.5	18.8	23.4		11.2	11.2	12.6
1000	1048	+1 / -5.0	9.8	11.6	13.4	17.1	20.7			12.0	12.0	13.5
1100	1152	+1 / -6.0	10.6	12.6	14.7	18.7	22.7			14.4	14.4	14.4
1200	1255	+1 / -5.8	11.4	13.6	15.8	20.2				15.3	15.3	15.3
1400	1462	+1 / -6.6	13.1	15.7	18.2					17.1		17.1
1500	1565	+1 / -7.0	13.9	16.7	19.4					17.9		18.0
1600	1668	+1 / -7.4	14.8	17.7	20.6					18.9		18.9
1800	1875	+1 / -8.2	16.4	19.7	23.0					20.7		20.7
2000	2082	+1 / -9.0	18.1	21.8	25.4					22.5		22.5
2200	2288	+1 / -9.8	19.8	23.8								24.3

NOTE: The K-7 pipes of higher thickness as per the respective national standard may be supplied.
The tolerance on pipe wall thickness is - (1.3+0.001 DN).
- for centrifugally cast pipes, minimum wall thickness shall not be less than 3.0mm

Table 2.5.2: Thickness of Socketed Fittings

Nominal Size	Pressure Class	Wall Thickness, e (mm)	
DN	C	Nominal	Tolerances
80	64	7.0	-2.30
100	64	7.2	-2.40
150	64	7.8	-2.45
200	64	8.4	-2.50
250	50	9.0	-2.55
300	50	9.6	-2.60
350	50	10.2	-2.65
400	40	10.8	-2.70
450	40	11.4	-2.75
500	40	12.0	-2.80
600	40	13.2	-2.90
700	30	14.4	-3.00
750	30	15.0	-3.05
800	30	15.6	-3.10
900	30	16.8	-3.20
1000	30	18.0	-3.30
1100	30	19.2	-3.40
1200	30	20.4	-3.50
1400	30	22.8	-3.70
1600	25	25.2	-3.90
1800	25	27.6	-4.10
2000	25	30.0	-4.30
2200	25	32.4	-4.50

2.6 Allowable Pressure

2.6.1 Classification of Ductile Iron pipes from Thickness (K) Class to Pressure (C) Class

Prior to revision of International Standards in the year 1998, Ductile Iron pipes were classified based on the thickness, i.e K7, K8, K9 etc (also known as Thickness Class). The allowable pressures were calculated based on the nominal wall thickness of the pipe. As per ISO 2531:1998, the minimum thickness in the standards was K9. In event of lower operating pressure in the system users had no choice than to select the K9 class of pipe with higher value of allowable operating pressures. On the other hand, other pipe materials such as for Steel pipes, the pipes' wall thickness were designed on the basis of operating pressure in the system with the assumption of certain safety factors. In view of the above so as to bring parity in classification of Ductile Iron pipes, amendment to ISO 2531:1998 were done to introduce 'C' class pipes in the revised edition of ISO 2531:2009.

EN 545:2002 edition introduced class C 40 pipes along with K9 class pipes. Finally in the subsequent revision of EN 545:2010 the pressure class was introduced completely abolishing the Thickness based classification.

In line with the introduction of 'C' class pipes, the Design Standard for Ductile Iron pipes,i.e. ISO 10803:2011 was revised accordingly.

PFA: Allowable Operating Pressure: Maximum hydrostatic pressure that a component is capable of withstanding continuously in service. For 'C' class pipes, the number followed by letter 'C' indicates the PFA. For example C 20 means the pipe has maximum allowable pressure of 20 bar or 20 Kg./cm^2. For 'C' class, the values are given in Table 2.6.1.

PMA: Allowable Maximum Operating Pressure: Maximum pressure occurring from time to time, including surge, that a component is capable of withstanding in service.

PMA = 1.2x PFA; the values are given in Table 2.6.1.

PEA: Allowable Test Pressure: Maximum hydrostatic pressure that a newly installed pipe/component is capable of withstanding for a relatively short duration, in order to ensure the integrity and tightness of the pipeline.

PEA =1.2x PFA + 5 bar; the values are given in Table 2.6.1.

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Table 2.6.1: 'C' Class Pipe - As per ISO 2531 & BSEN 545

Pressure Class	Allowable Operating Pressure, PFA	Maximum Allowable Operating Pressure, PMA	Allowable Site Test Pressure, PEA
C	Bar	Bar	Bar
20	20	24	29
25	25	30	35
30	30	36	41
40	40	48	53
50	50	60	65
64	64	76.8	81.8
100	100	120	125

Table 2.6.2: Allowable Pressures of Components with Flanged Joints

Pressure Class	Allowable Operating Pressure, PFA	Maximum Allowable Operating Pressure, PMA	Allowable Site Test Pressure, PEA
PN	Bar	bar	Bar
10	10	12	17
16	16	20	25
25	25	30	35
40	40	48	53

Table 2.6.3: Allowable Pressures of Components with Socketed Fittings

Nominal Size	Allowable Operating Pressure, PFA	Maximum Allowable Operating Pressure, PMA	Allowable Site Test Pressure, PEA
	Bar	bar	Bar
100 - 200	64	77	82
250 - 350	50	60	65
400 - 600	40	48	53
700 - 1400	30	36	41
1500 - 2200	25	30	35

(1 bar = 0.1 Mpa =1.0197 Kg/cm^2 =10.199 meter of water head)

Table 2.6.4: Allowable Pressures of Components with Flexible Joints

Pipe Size (mm)	Allowable Operating Pressure (PFA)in Bar		Allowable Maximum Operating Pressure (PMA) in Bar		Allowable Site Pressure (PFA) in Bar	
DN	K9	K9	K9	K9	K9	K9
	ISO10803	BSEN 545	ISO10803	BSEN 545	ISO10803	BSEN 545
80	64	85	77	102	96	107
100	64	85	77	102	96	107
125	64	85	77	102	96	107
150	64	79	77	95	96	100
200	62	62	77	74	79	79
250	54	54	73	65	70	70
300	49	49	67	59	64	64
350	45	45	61	54	59	59
400	42	42	58	51	56	56
450	40	40	54	48	53	53
500	38	38	53	46	51	51
600	36	36	49	43	48	48
700	34	34	46	41	46	46
800	32	32	43	38	43	43
900	31	31	42	37	42	42
1000	30	30	41	36	41	41
1100	29	29	38	35	40	40
1200	28	28	38	34	39	39
1400	28	28	37	33	38	38
1600	27	27	36	32	37	37
1800	26	26	36	31	36	36
2000	26	26	35	31	36	36

2.7 Works Hydrostatic Test Pressure

Hydrostatic Work Test Pressure for Pipes and Fittings

Hydrostatic tests are done at works to check the leak-tightness of pipes. The tests are carried out before application of external coating and internal lining.

a) 'K'class Ductile Iron Pipes

Table 2.7.1: Hydrostatic Test Pressure at Works for 'K' Class Ductile Iron pipes

Nominal Diameter	Minimum Hydrostatic Test Pressure at Works, Mpa					
	Centrifugally Cast Pipes with Flexible Joints		Pipes with Welded-on Flange			
	K7	K9	PN 10	PN16	PN 25	PN 40
DN 80 - DN 300	3.2	5.0	1.6	2.5	3.2	4.0
DN 350 - DN 600	2.5	4.0	1.6	2.5	3.2	4.0
DN 700 - DN 1000	1.8	3.2	1.6	2.5	3.2	4.0
DN 1100 - DN 2000	1.2	2.5	1.6	2.5	3.2	-

b) 'C'class Ductile Pipes

The internal hydrostatic test pressure should be raised until it reaches the works hydrostatic test pressure, equal to the pressure class and limited to the pressure of preferred class. Higher pressures are permissible. The total duration of the pressure cycle shall not be less than 15 seconds including 10 second at test pressure.

c) Ductile Iron Fittings

Table 2.7.2: Hydrostatic Test Pressure at Works for Ductile Iron fittings

Nominal Diameter (DN)	Pipes not Centrifugally Cast, Fittings and Accessories (Bar)
80 - 300	25
350 - 600	16
700 - 2200	10

2.8 Standard Lining

2.8.1 Internal Lining of Cement Mortar

The internal cement mortar lining of Ductile Iron pipes constitute a dense, homogeneous layer covering the total internal surface of the pipe barrel. The cement mortar mix shall comprise cement, sand and water. The cement should be one of those listed below:

- Ordinary Portland cement
- Blast Furnace Slag cement
- Sulphate Resistant cement and
- High Alumina cement

The water used in the mortar mix complies with standard set for drinking water.

Fig. 2.8.1: Internal Cement Mortar Lining

2.8.2 Strength of Lining

When measured, the compressive strength of the cement mortar after 28 days of curing shall not be less than 50 Mpa. The compressive strength of the lining is directly related to other functional properties such as high density, good bond and low porosity.

2.8.3 Thickness and Surface Condition

The surface of the cement mortar lining should be uniform and smooth. Trowel marks, protrusion of sand grains and surface texture inherent to the method of manufacture are acceptable. However, there should be no recesses or local defects which reduce the thickness to below the minimum value. The nominal thickness of the cement mortar lining and its tolerance should be as given in table below:

Table 2.8.1: Thickness of Cement Mortar Lining

DN	Thickness,mm	
	Nominal Value	Limit Deviation
40 - 300	4	-1.5
350 - 600	5	-2.0
700 - 1200	6	- 2.5
1400 - 2000	9	-3.0
2200	12	-5.0

Note: Higher thickness can also be provided as per customer requirement.

2.9 Standard Coating

All pipes are supplied with an external coating of metallic Zinc or Zinc-Aluminium Alloy (Zn-Al Alloy) with a finishing layer of Bitumen/Epoxy Resin. Aluminium Pigmented Bitumen.

2.9.1 External Coating of Zinc with Finishing Layer of Bitumen

The external coating of Ductile Iron pipes comprise of a layer of metallic Zinc, followed by a finishing layer of a Bituminous/Epoxy resin. The Zinc is normally applied on oxide-free surface pipes after heat treatment or it may also be applied on blast-cleaned pipes. Prior to application of the Zinc, the pipe surface should be dry and free from rust or non-adhering particles or foreign matter such as oil or grease.

2.9.2 Coating Characteristics

The metallic Zinc coating covers the external surface of the pipe and provides a dense, continuous, uniform layer. The purity of the Zinc used should be at least 99.99%. The Ductile Iron pipes are manufactured by Jindal SAW with the following option on the basis of Zinc mass applied to the pipe surface:

1. The mean mass of Zinc per unit area is 130g/m^2 (for pipes and fittings)
2. The mean mass of Zinc per unit area is 150g/m^2 (for pipes)
3. The mean mass of Zinc per unit area is 200g/m^2 (for pipes)
4. The mean mass of Zinc per unit area is 400g/m^2 (for pipes)
5. The mean mass of Zinc Aluminium per unit area is 400g/m^2 (for pipes)

The uniformity of the finishing layer is checked and when measured, the mean thickness of the finishing layer should not be less than 70 µm and the local minimum thickness not less than 50 µm.

The criteria for selection of lining and coating for Ductile Iron pipes has been given in Table 2.13.4 and 2.13.5.

2.10 Joints, Allowable Deflection, Type Test

Ductile Iron pipes can be joined by four types of joints -

1. Push-on Joint 2. Mechanical Joint 3. Flange Joint 4. Restrained Joint

2.10.1 Push-on Joint

This joint is commonly and widely used. Ductile Iron pipes comprise of socket and spigot ends. The inside surface of the socket has grooves to hold the rubber gasket. The gasket has a hard part called the 'heel' which gets engaged in the groove of the socket to firmly hold the gasket. The other part of the gasket is the bulb portion which is comparatively softer than the heel portion of the gasket. Both softer bulb and the harder heel portions of the gaskets are vulcanized to form a circular single part. The spigot of the next pipe has a taper portion to facilitate smooth insertion of the spigot end in to the socket of the pipes. The spigot is inserted into the socket holding the rubber gasket. The spigot exerts uniform circumferential pressure over the soft portion of the rubber gasket and the pipe is pushed in to the socket until one line of the insertion mark gets into the socket and the other insertion mark is visible. This is to ensure that a small gap is left between the two pipes in order to ensure the deflection in the pipeline and also to accommodate the linear expansion due to thermal effect on the pipeline laid above ground. In this fashion the pipeline is made continuously.

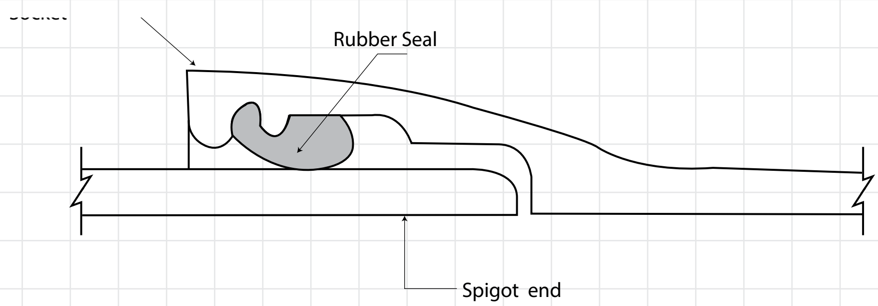


Fig. 2.10.1: Push-on Joint

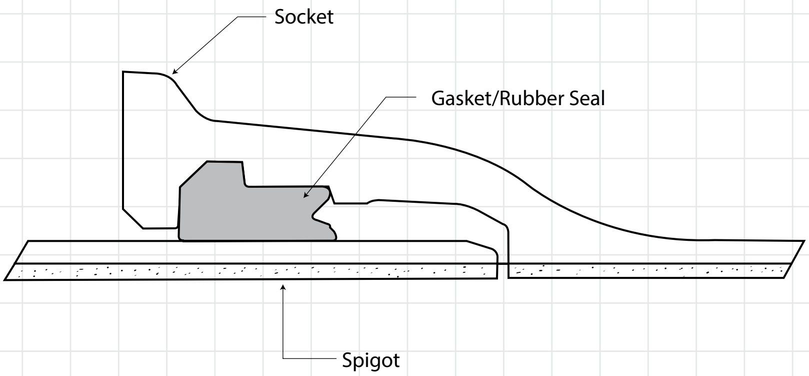


fig. 2.10.2 AJ joint Profile

2.10.2 Mechanical Joint

This joint is used where it is difficult to effect Push-on joint. This joint can also be used to make good a leaking pipe in a pipeline. This joint is also a type of Push-on joint but unlike in Push-on joint the rubber gasket is tightened to exert circumferential pressure on spigot of the pipe to provide a positive seal. This joint comprises a gland, a trapezium shaped gasket and set of bolts, nuts and washers. The socket of the pipe in this joint has a circumferential collar to facilitate gripping of the hooks bolts used in this joint. In order to complete this joint the metal gland is inserted over the spigot end of one pipe. The gland has sufficient number of bolt holes. The gland is of 'L' shaped. The socket of the next pipe to be joined will not have any groves inside but the internal diameter will be sufficient enough to accommodate a trapezium shaped rubber gasket. This trapezium shaped gasket is inserted over the spigot of the pipe where the gland is already inserted. The spigot of pipe with the gland and rubber gasket is inserted in to the socket of the next pipe and bolts are inserted into the gland in such a manner that the hook heads are towards the socket of the pipe to be joined. The gland along with rubber gasket brought closer the socket of the next pipe and the bolts are tightened from gland side so that proper gripping of the hook bolts over the circumferential collar of the the socket is ensure. The gland pushes the rubber gasket and presses it so that the circumferential seal is effected after jointing.

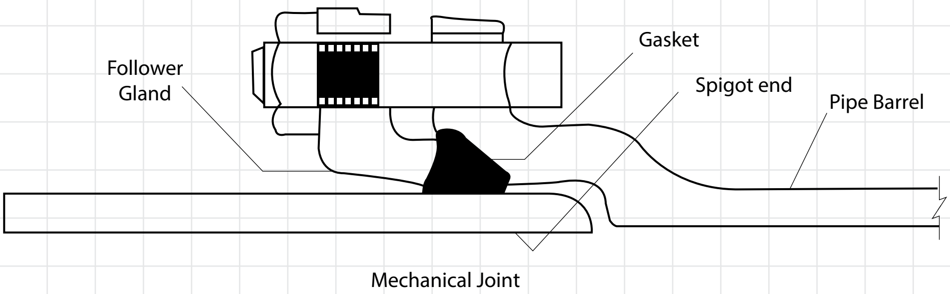


Fig. 2.10.3: Mechanical Joint

2.10.3 Flange Joint

Flange joints are rigid joints. Flanges are fixed on either ends of barrel pipe piece. This type of joint can be made in Ductile Iron pipes in three different manufacturing processes. They are:

1. **Integrally Cast flanged pipes:**
   In Intregally cast flanged pipes the Ductile Iron pipes with flanges are cast in foundries with integrally cast flanges on them. These flange pipes are normally of very small length say 1 to 1.5 m. They are heavier to handle and one may have to use many pipes for vertical lift and as much extra bolts, nuts etc. This type flange pipes are used for very small lengths.
2. **Welded-on flanged pipes:**
   In Welded-on flanged pipes the flanges are welded on to the ends of the pipe barrels.
3. **Screwed-on flanged pipes:**
   In screwed-on flanged pipes both flanges and barrels of DI pipe are provided with female and male threads respectively. The flanges are threaded over the DI pipe barrel.

The jointing of the two flanged end pipes is done by placing gaskets in between the flanges and tightening the flanges with bolts, nuts and washers.

Table 2.10.1: Classification of Flanged Pipes

Size Range (mm)	Pressure Class (N/mm2)
80 - 2200mm	PN 10
	PN 16
	PN 25
	PN 40

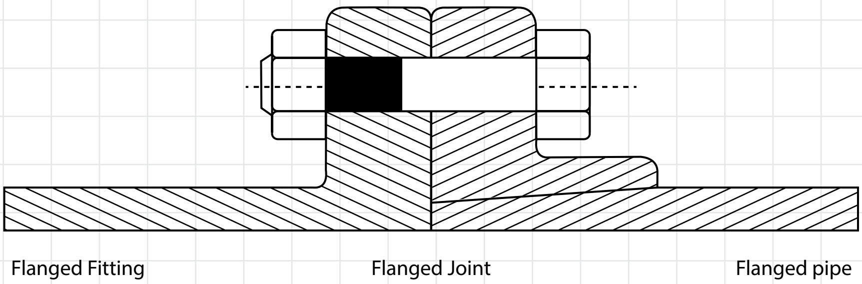
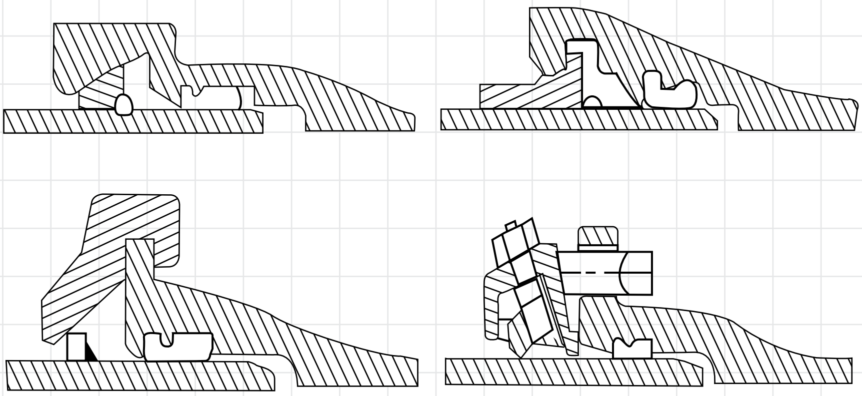


Fig. 2.10.4: Flanged Joint

2.10.4 Restrained Joint Pipes

The Ductile Iron pipes are supplied to suit and facilitate restrained jointing in which the axial movement of the pipe is arrested by mechanical means. The DI pipes with these joints are ideally suitable for the pipe line to be laid over loose soil or marshy land where one cannot provide anchor blocks at Tee points, or bends etc. Restrained Jointed DI pipes are used for high pressure water transmission. It is also used where the pipeline traverses a hilly terrain. This joint comprises an assembly of socket and spigot pipes with glands, split ring and a set of hook bolts, nuts and washers. The spigot end of the pipe is provided with a weld bead. The socket of the pipe to be joined have a circumferential projected collar. The procedure for jointing two pipes is as under:

- The gland made of SG iron have an internal diameter slightly above the dimension of the weld bead outer diameter. The gland is slid over the spigot end of the pipe and rested.
- The split ring or arrester ring or retainer ring has an internal diameter exactly as that of external diameter of the pipe barrel. The split ring is opened slightly and slid over the weld bead and rested within the gland in such manner that the taper of the spit ring and the inside taper of the gland match exactly.
- Insert the rubber gasket into the socket of the next pipe to be joined.
- Make the jointing of the two pipes by inserting the spigot end of one pipe into another.
- Move the gland along with split ring towards the socket of the next pipe till the weld bead on to spigot of the pipe.
- Insert the hook bolts from the socket side into the gland and start tightening using bolts, nuts and washers.
- Complete tightening to esure restrained jointing.



Restrained Joints

Fig. 2.10.5: Different Types Restrained Joints

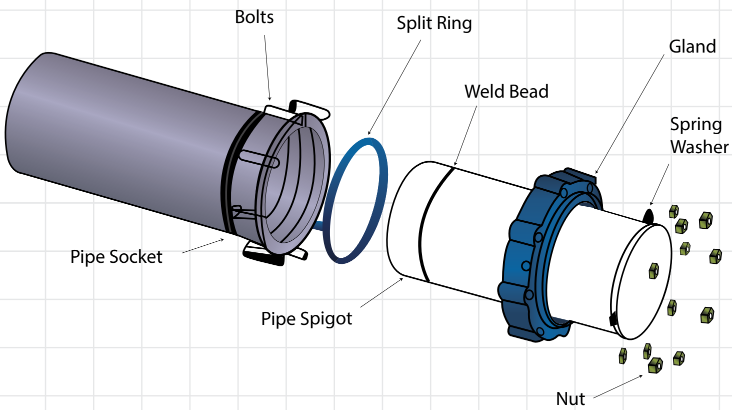


Fig. 2.10.6: Restrained Joint Component

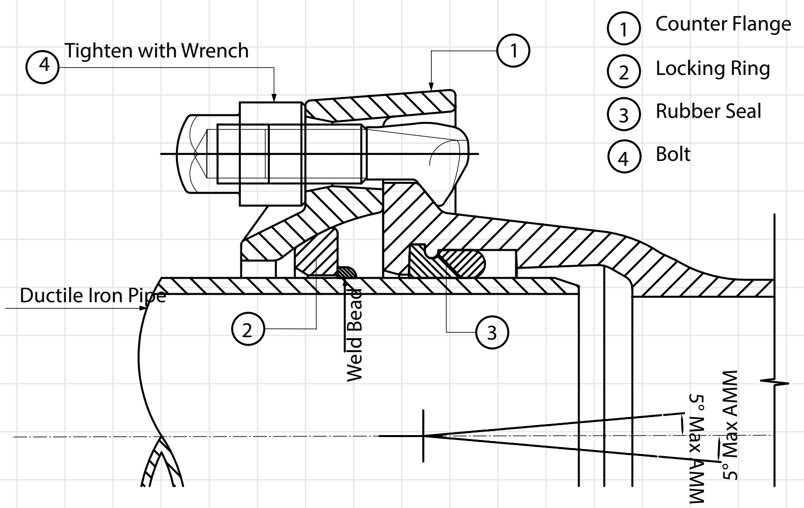


Fig. 2.10.7: JSAW Restrained Joint (JSAW MRJ)

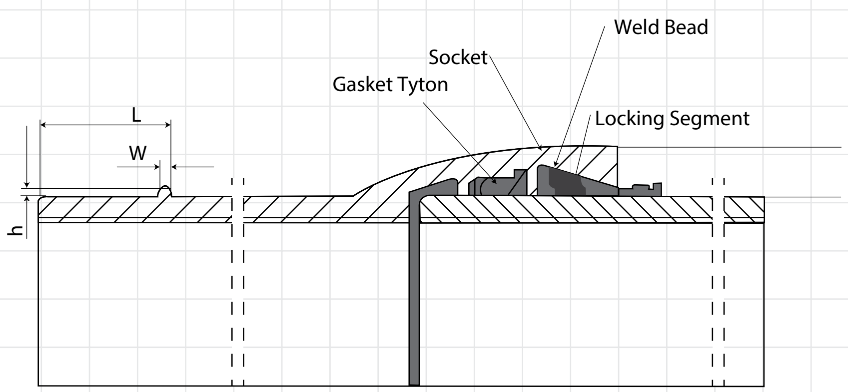


fig. 2.10.8 : JSAW Double Chamber Restrained Joint (JSAW LOCK)

2.10.5 Calculation of Length of Pipeline to be Restrained

Restrained Joint System functions in a manner similar to thrust blocks. The thrust force is balanced with the reactive forces generated by the restrained unit of the piping with the soil.

The design of the thrust resistant system will determine the length of the pipe that must be restrained on each side of the focus of the thrust force. The length of restraint of the pipe will be a function of pipe size, the internal pressure, depth of cover, the characteristic of the soil surrounding the pipe and the type of encasement of pipe.

The calculation of length that must be restrained is independent of the system of anchoring used.

The source of restraining force is two fold:

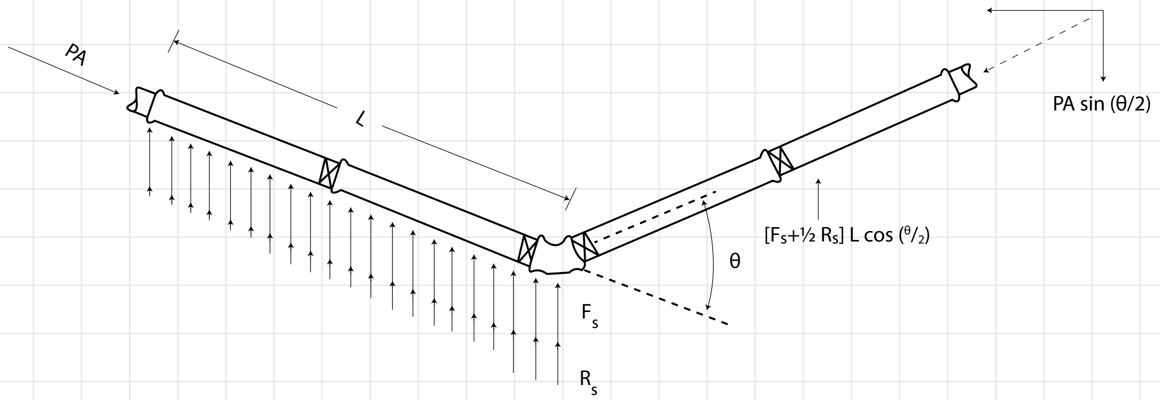
i) The static friction between the pipe unit and the soil.

ii) The restraint provided by the pipe as it bears against the side fill soil along each leg of the bend.

Reference to AWWA - M-41, the following equations are used to calculate the restrained joint length:

i) For Horizontal Bend

The free body diagram of a restrained pipe unit is shown below:



The restrained length L is given by the formula:

$$L = \frac{S_f \, PA \tan(\theta/2)}{F_f + \frac{1}{2}R_s}$$

Where:

L = Restrained length of pipe in m on each side of bend

F_f = Unit frictional force (KN/m)

$F_f = F_s$: For standard asphaltic coated pipe

$F_f = 0.7\ F_s$: For Polyethylene encased pipe

S_f = Factor of Safety (usually 1.5)

P = Thrust force by internal pressure in KN/m^2

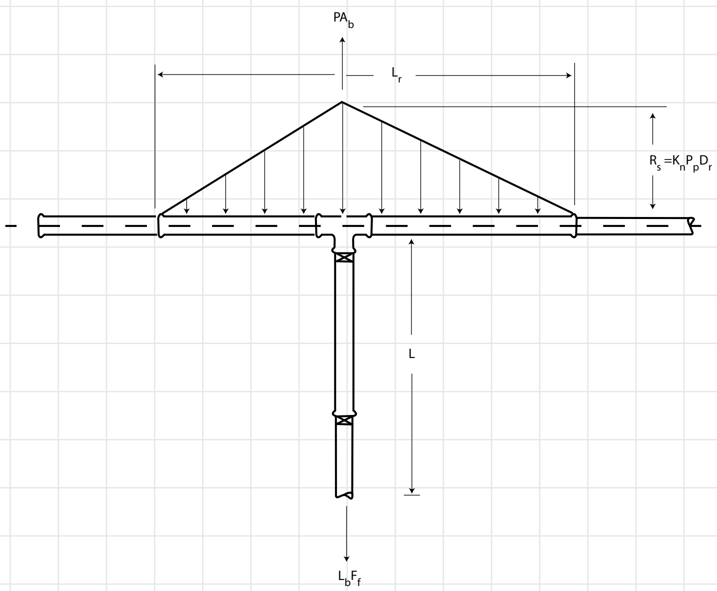
A = Cross sectional Area of pipe in m^2

θ = Angle of bend (in degrees)

R_s = Maximum unit lateral resistance on pipe

F_s = Unit Frictional Force

ii) For Tee



$$L = \frac{S_f\ PA_b - \frac{1}{2} R_s L_r}{F_f}$$

Where:

L = Length of the restrained pipe on the branch (m)

F_f = Unit frictional force (KN/m)

$F_f = F_s$: For standard asphaltic coated pipe

$F_f = 0.7\ F_s$: For Polyethylene encased pipe

S_f = Factor of Safety (usually 1.5)

P = Thrust force by internal pressure in KN/m^2

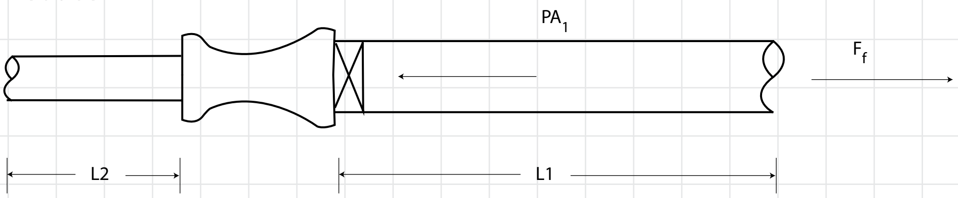
A_b = Cross sectional Area of large pipe (in m^2)

R_s = Maximum unit lateral resistance on pipe

L_r = Total length between the first joints on either side of the tee (m)

F_s = Unit Frictional Force

iii) **Reducer**



$$L = \frac{S_f\ P(A_1 - A_2)}{F_f} \qquad L_1 = \frac{S_f\ P(A_1 - A_2)}{F_{f1}} \qquad L_2 = \frac{S_f\ P(A_1 - A_2)}{F_{f2}}$$

Where:

L = Length of restrained pipe on the large side of reducer (m)

F_f = Unit frictional force (KN/m)

$F_f = F_s$: For standard asphaltic coated pipe

$F_f = 0.7\ F_s$: For Polyethylene encased pipe

S_f = Factor of Safety (usually 1.5)

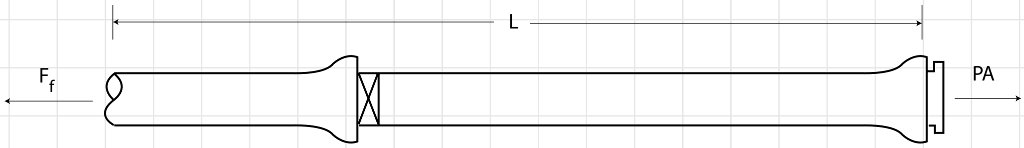
P = Thrust force by internal pressure in KN/m2

A_1 = Cross sectional Area of large pipe (in m2)

A_2 = Cross sectional Area of small pipe (in m2)

F_s = Unit Frictional Force

iv) **For Dead End:**



$$L = \frac{S_f\ PA}{F_f}$$

Where:

L = Restrained Length (m)

F_f = Unit Frictional force (KN/m)

S_f = Factor of Safety (usually 1.5)

P = Thrust force by internal pressure in KN/m2

A = Cross sectional Area of pipe (in m2)

Unit Frictional Force is given by the formula:

$F_s = A_p C + W \tan \delta$

Where:

C = fc Cs From soil Parameter table (KN/m2)

Ap = Surface area of pipe bearing on the soil (in m2/m)

δ = fφ Φ from soil classification tables (in degrees)

Ap = ½ π D for bends. Assume half the pipe circumference bears against the soil.

Ap = π D for Tees, Dead Ends and Reducers. Assume the full pipe circumference bears against the soil

And

W = 2We + Wp+ Ww Unit normal force γ(KN/m)

Where:

2We = Vertical load on top and bottom surfaces of the pipe taken as the prism load (KN/m)

Wp = Weight of the pipe (KN/m)

Ww = Weight of the water (KN/m)

We = H γ D

H = Depth of bury to the top of the pipe (m)

γ = Backfill Soil Density (KN/m^3)

D = Pipe Diameter (m)

Unit Bearing Resistance is given by the formula:

$R_S = K_n P_P D$

Where:

Kn = Trench Compaction factor

D = Pipe Diameter (m)

And

$P_P = \gamma H_C N_\varnothing + 2C_S N_\varnothing^{0.5}$ or $P_P = \gamma H_C N_\varnothing + 2C_S\sqrt{N_\varnothing}$

Where:

P_P = Passive soil pressure (KN/m^2)

γ = Backfill soil density (KN/m^3)

H_C = Mean depth from surface to centre line of pipe (m)

C_S = Soil cohesion (KN/m^2)

$N_\varnothing$ = $\tan^2(45° + ½Ø)$

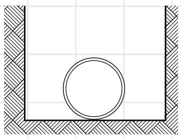
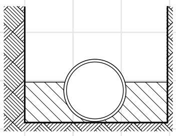
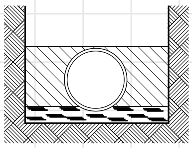
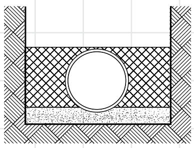
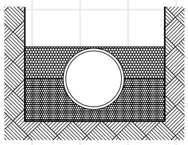
Ø = Inernal friction of the soil

Table 2.10.2 Soil Parameters

							Kn (as per Laying conditions - Trench type)			
Soil Designation	Soil Description	φ	f_{ϕ}	C_s	f_c	γ	2	3	4	5
		deg		KN/m²		KN/m²				
Clay 1	Clay of medium to Low Plasicity, LL* < 50, <25% coarse particles (CL & CL-ML)	0	0	14.37	0.8	14.14	0.20	0.40	0.60	0.85
Silt 1	Silts of medium to Low Plasticity LL < 50, <25% coarse particles (ML & ML-CL)	29	0.75	0	0	14.14	0.20	0.40	0.60	0.85
Clay 2	Clay of medium to Low Plasicity with sand or gravel, LL < 50, 25-50% coarse particles (CL)	0	0	14.37	0.8	14.14	0.40	0.60	0.85	1.00
Silt 2	Silt of Medium to Low Plasticity with sand or gravel, LL < 50, 25-50% coarse particles.(ML)	29	0.75	0	0	14.14	0.40	0.60	0.85	1.00
Coh- gran	Cohesive granular soils, > 50% coarse particles.(GC & SC)	20	0.65	9.58	0.4	14.14	0.40	0.60	0.85	1.00
Sand Silt	Sand or gravel with silt ,> 50% coarse particles.(GM & SM)	30	0.75	0	0	14.14	0.40	0.60	0.85	1.00
Clean Sand or Clean Gravel	Clean sand or Clean gravel, > 95% coarse particles.(SW, SP & GW)	36	0.8	0	0	15.71	0.40	0.60	0.85	1.00

*Note : * LL = Liquid Limit*

Laying Conditions (Trench Type):

Trench Type	Trench Description	
Type 1		Pipe bedded in 4"(100mm)minimum loose soil. Backfill slightly consolidated to top of pipe
Type 2		Pipe bedded in sand, gravel or crushed stone to depth of 1/8 pipe diameter, 4" (100mm) minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99)
Type 3		Pipe bedded in 4" (100mm) minimum loose soil. Backfill slightly consolidated to top of pipe
Type 4		Pipe bedded in sand, gravel or crushed stone to depth of 1/8 pipe diameter, 4" (100mm) minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99)
Type 5		Pipe bedded to its centerline in compacted granular material, 4" minimum under pipe. Compacted granular or select material to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99)

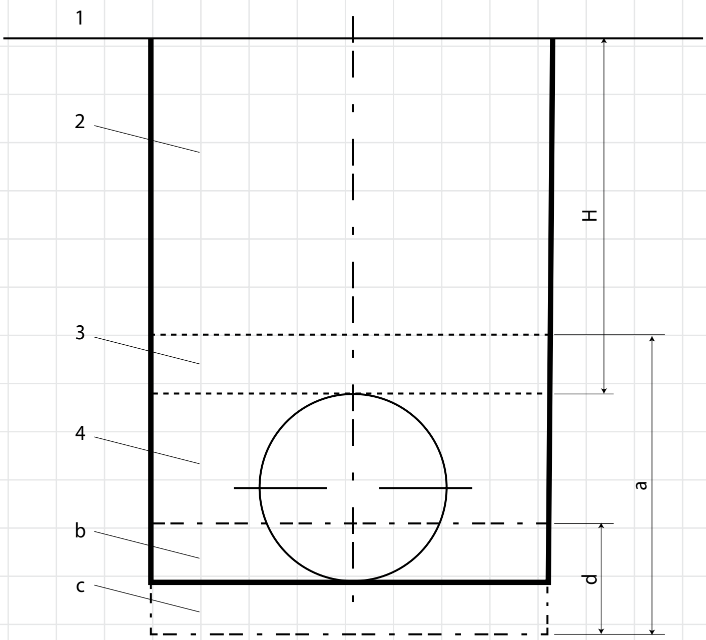
Soil type: Sandy Silt		Ratio of pipe friction angle to soil friction angle:	0.75	Soil cohesion:	0 KN/m2
Internal friction angle of soil:	30o	Ratio of pipe cohesion to soil cohension:	0	Trench condition modifier:	0.85

Table 2.10.3 - Length of pipe in metres to be ancnhored on either side of bend (for pressure test = 1 bar)

DN	Bend 90°			Bend 45°			Bend 22½°			Bend 11¼°			Blank Flange		
	Depths of Cover														
	1.0 m.	1.5 m.	2.0 m.	1.0 m.	1.5 m.	2.0 m.	1.0 m.	1.5 m.	2.0 m.	1.0 m.	1.5 m.	2.0 m.	1.0 m.	1.5 m.	2.0 m.
80	0.367	0.249	0.189	0.152	0.103	0.078	0.073	0.050	0.038	0.036	0.025	0.019	0.921	0.628	0.476
100	0.439	0.299	0.226	0.182	0.124	0.094	0.087	0.059	0.045	0.043	0.029	0.022	1.102	0.753	0.572
150	0.619	0.424	0.323	0.257	0.176	0.134	0.123	0.084	0.064	0.061	0.042	0.032	1.567	1.074	0.818
200	0.793	0.547	0.417	0.328	0.226	0.173	0.158	0.109	0.083	0.078	0.054	0.041	2.016	1.389	1.059
250	0.959	0.665	0.509	0.397	0.276	0.211	0.191	0.132	0.101	0.094	0.066	0.050	2.449	1.696	1.297
300	1.119	0.781	0.600	0.463	0.323	0.248	0.223	0.155	0.119	0.110	0.077	0.059	2.871	1.997	1.531
350	1.270	0.892	0.687	0.526	0.370	0.285	0.253	0.177	0.137	0.125	0.088	0.068	3.265	2.284	1.757
400	1.415	0.999	0.772	0.586	0.414	0.320	0.282	0.199	0.154	0.139	0.098	0.076	3.652	2.566	1.978
450	1.554	1.103	0.855	0.644	0.457	0.354	0.309	0.220	0.170	0.153	0.109	0.084	4.027	2.842	2.196
500	1.691	1.207	0.938	0.701	0.500	0.389	0.337	0.240	0.187	0.167	0.119	0.092	4.399	3.117	2.414
600	1.949	1.405	1.098	0.807	0.582	0.455	0.388	0.279	0.219	0.192	0.138	0.108	5.104	3.647	2.837
700	2.187	1.592	1.251	0.906	0.660	0.518	0.435	0.317	0.249	0.215	0.157	0.123	5.763	4.152	3.244
750	2.302	1.683	1.327	0.954	0.697	0.550	0.458	0.335	0.264	0.227	0.166	0.131	6.086	4.401	3.446
800	2.414	1.773	1.401	1.000	0.734	0.580	0.480	0.353	0.279	0.238	0.175	0.138	6.404	4.647	3.647
900	2.624	1.943	1.543	1.087	0.805	0.639	0.522	0.387	0.307	0.259	0.191	0.152	7.002	5.117	4.032
1000	2.821	2.106	1.680	1.169	0.873	0.696	0.561	0.419	0.334	0.278	0.207	0.166	7.571	5.570	4.406
1100	3.009	2.263	1.814	1.247	0.938	0.751	0.599	0.450	0.361	0.296	0.223	0.179	8.119	6.013	4.774
1200	3.183	2.412	1.941	1.319	0.999	0.804	0.633	0.480	0.386	0.314	0.238	0.191	8.634	6.434	5.127
1400	3.502	2.689	2.183	1.451	1.114	0.904	0.697	0.535	0.434	0.345	0.265	0.215	9.568	7.220	5.797
1600	3.789	2.945	2.409	1.570	1.220	0.998	0.754	0.586	0.479	0.373	0.290	0.237	10.441	7.963	6.436
1800	4.050	3.183	2.621	1.678	1.319	1.086	0.806	0.633	0.522	0.399	0.314	0.258	11.249	8.665	7.046
2000	4.286	3.403	2.821	1.776	1.410	1.169	0.853	0.677	0.561	0.422	0.335	0.278	11.990	9.322	7.625
2200	4.526	3.622	3.019	1.875	1.501	1.251	0.900	0.721	0.601	0.446	0.357	0.297	12.873	10.060	8.255

Note : Length to be anchored should be calculated for different pressures by multiplying the above length with the pressure (in bar)
For example = Length to be anchored for 30 bar pressure for DN 150 -90 deg Bend at 1.5 m depth = 0.424 x 30 = 12.72 m

Laying Condition (Trench type)



Key
1 surface
2 main backfill
3 initial backfill
4 side fill
H depth of cover
a Embedment.
b Upper beddding.
c Lower bedding.
d Bedding.

Fig. 2.10.9: Trench Types

The trench types are the following:

a) Trench type 1: Embedment dumped
b) Trenchtype 2: Embedment with very light compaction, greater than 75% standard Proctor density
c) Trenchtype 3: Embedment with light compaction, greater than 80% standard Proctor density
d) Trenchtype 4: Embedment with medium compaction, greater than 85% standard Proctor density
e) Trenchtype 5: Embedment with high compaction, greater than 90% standard Proctor density

2.10.6 Allowable Deflection

Push-on joints can be deflected up to 3°30' depending upon pipe diameter. Long radius curves can be negotiated without fittings. The details are as mentioned in the following table:-

Table 2.10.4: Allowable Deflection on Push-on Ductile Iron pipes (as per Standard)

DN	Deflection	Length of Pipe	Radius	Displacement
mm	degree	m	m	cm
80 - 300	3^0 30'	5.5	90	34
		6	98	37
350 - 600	2^0 30'	5.5	126	24
		6	137	26
700 - 800	1^0 30'	5.5	210	14
		6	229	16
900 - 2000		5.5	210	14
		6	229	16
2200		6	229	16

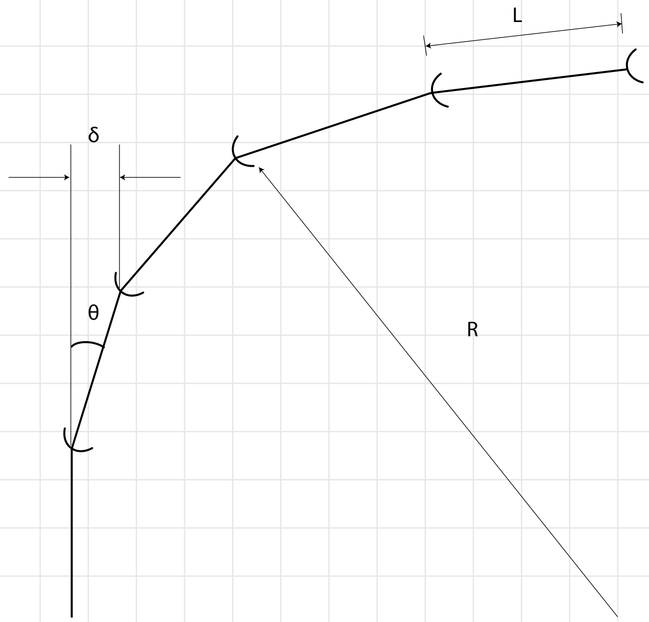


Fig. 2.10.10: Allowable Deflection of Push-on Joints

Where:

θ = Angle of Deflection

δ = Displacement in meters = L x Sin θ

R = Radius in meters = L / (2 x tan θ/2)

L = Length of each pipe in meters

2.10.7 Type Test

Type tests are carried out in order to ensure adequate joint performance up to the highest pressure. All flexible joints for Ductile Iron pipes and components are designed in compliance with the highest pressure requirement. Joint designs are Type Tested to demonstrate leak tightness to both internal and external pressure under the most unfavorable conditions of casting tolerance and joint movement.

There is a Type test for at least one DN for each of the grouping given below:

DN Grouping	80 - 250	300 - 600	700 - 1000	1100 - 2000
Preferred DN in Each Grouping	200	400	800	1600

One DN is representative of a group when the performances are based on the same design parameters throughout the size range.

The type test is carried out in the configuration of maximum design radial gap between the components to be joined (smallest spigot together with largest socket).

The type tests to ensure the adequacy of leak tightness of joints constitutes of the following pressure testing:

A. Positive Internal Hydrostatic pressure
B. Negative Internal pressure
C. Positive External Hydrostatic pressure
D. Cyclic Internal Hydraulic pressure

Table 2.10.5: Requirements for Type Test of Ductile Iron pipe

<table>
<tr><th>Test</th><th>Test Requirement</th><th>Test Conditions</th><th>Test Method</th></tr>
<tr><td rowspan="3">Positive Internal Hydrostatic Pressure</td><td>Test pressure: 1.5 PFA +5 bar</td><td rowspan="2">Joint of maximum annulus, aligned and withdrawn, with shear load</td><td rowspan="3">In accordance with clause no. 7.2.2 of BSEN 545</td></tr>
<tr><td>Test Duration: 2 hours</td></tr>
<tr><td>No visible leakage</td><td>Joint of maximum annulus, deflected</td></tr>
<tr><td rowspan="3">Negative Internal Pressure</td><td>Test pressure: 0.9 bar</td><td rowspan="2">Joint of maximum annulus, aligned and withdrawn, with shear load</td><td rowspan="3">In accordance with clause no. 7.2.3 of BSEN 545</td></tr>
<tr><td>Test duration: 2 hours</td></tr>
<tr><td>Maximum pressure change during test period: 0.09 bar</td><td>Joint of maximum annulus, deflected</td></tr>
<tr><td rowspan="3">Positive External Hydrostatic Pressure</td><td>Test pressure: 2 bar</td><td rowspan="3">Joint of maximum annulus, aligned with shear load</td><td rowspan="3">In accordance with clause no. 7.2.4 of BSEN 545</td></tr>
<tr><td>Test Duration: 2 hours</td></tr>
<tr><td>No visible leakage</td></tr>
<tr><td rowspan="3">Cyclic Internal Hydraulic Pressure</td><td>24000 cycles</td><td rowspan="3">Joint of maximum annulus, aligned and withdrawn, with shear load</td><td rowspan="3">In accordance with clause no. 7.2.5 of BSEN 545</td></tr>
<tr><td>Test pressure: Between PMA and (PMA-5) bar</td></tr>
<tr><td>No visible leakage</td></tr>
</table>

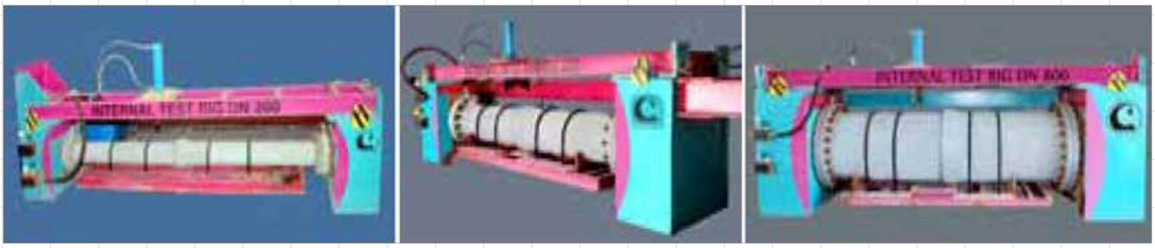


Fig. 2.10.11: Type Test Facility in JSAW Plant

2.10.8 Rubber Gaskets for Flexible Jointing System

Rubber Gasket provides leak tight flexible jointing system in Ductile Iron pipelines. Earlier natural rubber was used, but with the advancement in technology SBR (Styrene Butadiene Rubber) gaskets and lately EPDM (Ethylene Propylene Diene Monomer Rubber) gaskets are being successfully used for the jointing system. For special service conditions, Nitrile Butadiene Rubber (NBR) and Fluoro-Carbon gasket are also used.

The Rubber gaskets provide satisfactory sealing of upto 100% compression set. Extrapolated test results like 'Compression Set' & 'Stress Relaxation' on Rubber gaskets have indicated the life of Rubber gasket to be more than 100 years. Moreover, the rubber gasket in a pipe joint is cut off from sunlight, Oxygen contact, Ozone contact and UV radiation, and temperature variance, which enhances the durability of the gasket.

Fig. 2.10.12: Rubber Gasket

Fig. 2.10.13a Sectional details of Tyton Sit Gasket

Fig. 2.10.13b Sectional details of Tyton Sit Plus Gasket

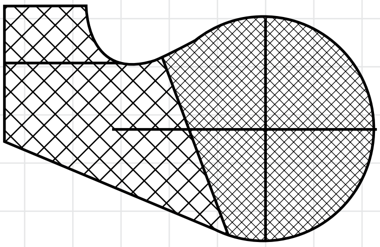


Fig. 2.10.13c Sectional details of TJ Gasket

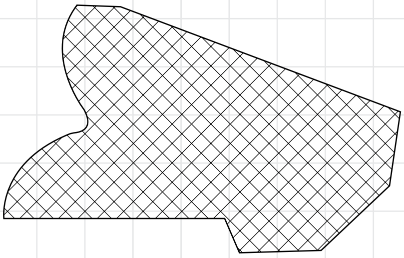


Fig. 2.10.13d Sectional details of AJ Gasket

A rubber gasket consists of two parts, the harder part called 'Heel' and a softer part called 'Bulb' as shown in the figure.

The Heel is the anchorage part of the gasket, which rests in the groove and anchors the gasket from turning over during jointing. This zone has a hardness range of 75 - 85 in the Shore A hardness scale. The bulb is the softer section, which plays the main role in sealing the gap between the socket internal and spigot external. This has a hardness range of 55 - 65 in the Shore A hardness scale.

2.10.9 Gasket for Flanged Joints

Gasket for Flanged joints are placed in between the flanges to provide a leak proof joint.

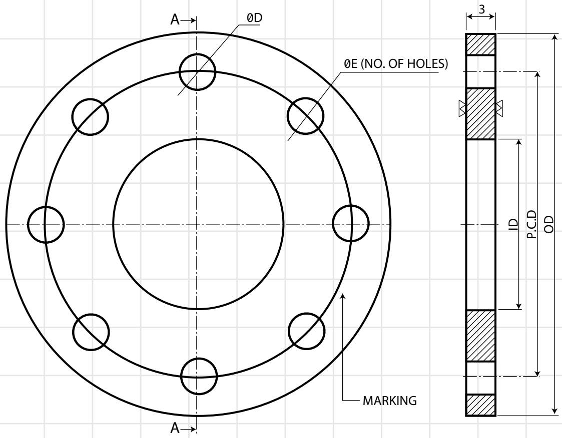


Table 2.10.6a Dimension Details of Full Face Rubber Gasket for Flange Joint

DN	ID		PN 10				PN 16			
		b	OD	No. of Holes	Hole Dia	Bolt Circle Dia	OD	No. of Holes	Hole Dia	Bolt Circle Dia
80	89	3	200	8	18	160	200	8	18	160
100	115	3	220	8	18	180	220	8	18	180
125	141	3	250	8	18	210	250	8	18	210
150	169	3	285	8	22	240	285	8	22	240
200	220	3	340	8	22	295	340	12	22	295
250	273	3	395	12	22	350	405	12	26	355
300	324	3	445	12	22	400	460	12	26	410
350	356	3	505	16	22	460	520	16	26	470
400	407	3	565	16	26	515	580	16	30	525
450	458	3	615	20	26	565	640	20	30	585
500	508	3	670	20	26	620	715	20	33	650
600	610	3	780	20	30	725	840	20	36	770
700	712	5	895	24	30	840	910	24	36	840
800	813	5	1015	24	33	950	1025	24	39	950
900	915	5	1115	28	33	1050	1125	28	39	1050
1000	1016	5	1230	28	36	1160	1255	28	42	1170
1200	1220	5	1455	32	39	1380	1485	32	48	1390
1400	1420	5	1675	36	42	1590	1685	36	48	1590
1600	1620	5	1915	40	48	1820	1930	40	55	1820
1800	1820	5	2115	44	48	2020	2130	44	55	2020
2000	2020	5	2325	48	48	2230	2345	48	60	2230

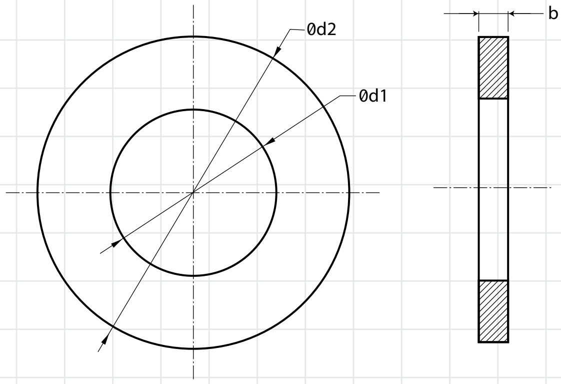


Table 2.10.6b: Dimension Details of Rubber Gasket for Flange joints for Raised Face Only

			PN-10	PN-16	PN-25	PN-40
DN	d1	b	d2	d2	d2	d2
80	84	3	132	132	132	132
100	104	3	156	156	156	156
125	129	3	184	184	184	184
150	154	3	211	211	211	211
200	205	3	266	266	274	284
250	256	3	319	319	330	345
300	307	3	370	370	389	409
350	358	3	429	429	448	465
400	407	3	480	480	503	535
450	457	3	530	548	548	560
500	508	3	582	609	609	615
600	608	3	682	720	720	735
700	709	5	794	794	820	-
750	760	5	857	857	883	-
800	811	5	901	901	928	-
900	911	5	1001	1001	1028	-
1000	1012	5	1112	1112	1140	-
1100	1114	5	1218	1218	1240	-
1200	1214	5	1328	1328	1350	-

2.10.10 Gaskets for Thrust Resistance:

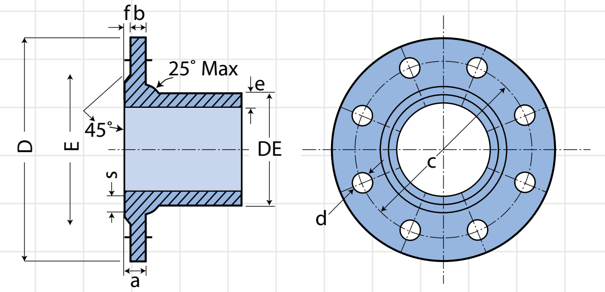
Specially designed customized Restrained Joint gaskets, also called Steel Inserted gaskets, are used to counteract thrust force. These gaskets are provided with steel inserts, which have better anchorage and grip with the pipe. The size and numbers of steel inserts is designed to resist the thrust force that the pipe line is subjected to.

Fig. 2.10.14: Modified Gaskets with Steel Inserts

2.11.1 Standard Dimensions of Flanges

Flanged joints are rigid joints and are generally used for above ground installations. The pressure rating of the fittings are done according to the rating of the flange used (PN10, PN16, PN25, PN40 etc).

Table 2.11.1: Dimensions of Standard Flange Drilling for Flange Fittings PN 10

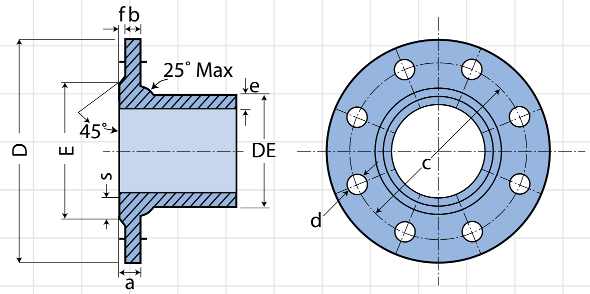


DE -	Pipe outer diameter.
D -	Outer diameter of flange.
E -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe outer diameter.
d -	Bolt hole diameter.

Nominal Diameter	Dimensions									No. of Holes	Hole Dia (Φd)	Bolt Size
DN	DE	D	e	E	C	b	f	a	s			In Metric
80	98	200	7	132	160	16	3	19	15	4	19	M16
100	118	220	7.2	156	180	16	3	19	15	8	19	M16
150	170	285	7.8	211	240	16	3	19	15	8	23	M20
200	222	340	8.4	266	295	17	3	20	15	8	23	M20
250	274	395	9	319	350	19	3	22	16	12	23	M20
300	326	445	9.6	370	400	20.5	4	24.5	17.5	12	23	M20
350	378	505	10.2	429	460	20.5	4	24.5	19.5	16	23	M20
400	429	565	10.8	480	515	20.5	4	24.5	19.5	16	28	M24
450	480	615	11.4	530	565	21	4	25.5	20	20	28	M24
500	532	670	12	582	620	22.5	4	26.5	21	20	28	M24
600	635	780	13.2	682	725	25	5	30	24	20	31	M27
700	738	895	14.4	794	840	27.5	5	32.5	24	24	31	M27
800	842	1015	15.6	901	950	30	5	35	24.5	24	34	M30
900	945	1115	16.8	1001	1050	32.5	5	37.5	26.5	28	34	M30
1000	1048	1230	18	1112	1160	35	5	40	28	28	37	M33
1100	1152	1340	19.2	1231	1270	38	5	43	30	28	37	M33
1200	1255	1455	20.4	1328	1380	40	5	45	31.5	32	40	M36
1400	1462	1675	22.8	1530	1590	41	5	46	32	36	43	M39
1600	1668	1915	25.2	1750	1820	44	5	49	34.5	40	49	M45
1800	1875	2115	27.6	1950	2020	47	5	52	36.5	44	49	M45
2000	2082	2325	30	2150	2230	50	5	55	38.5	48	49	M45
2200	2288	2550	32.4	2370	2440	53	6	59	41.5	52	56	M52

All dimensions are in millimetres.

Table 2.11.2: Dimensions of Standard Flange Drilling for Flange Fittings PN 16

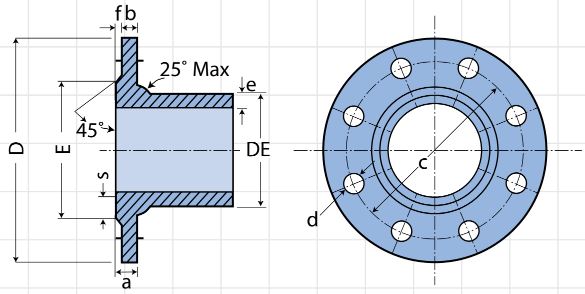


DE -	Pipe outer diameter.
D -	Outer diameter of flange.
E -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe outer diameter.
d -	Bolt hole diameter.

Nominal Diameter	Dimensions									No. of Holes	Hole Dia (Φd)	Bolt Size
DN	DE	D	e	E	C	b	f	a	s			In Metric
80	98	200	7	132	160	16	3	19	15	8	19	M16
100	118	220	7.2	156	180	16	3	19	15	8	19	M16
150	170	285	7.8	211	240	16	3	19	15	8	23	M20
200	222	340	8.4	266	295	17	3	20	16	12	23	M20
250	274	400	9	319	355	19	3	22	17.5	12	28	M24
300	326	455	9.6	370	410	20.5	4	24.5	19.5	12	28	M24
350	378	520	10.2	429	470	22.5	4	26.5	21	16	28	M24
400	429	580	10.8	480	525	24	4	28	22.5	16	31	M27
450	480	640	11.4	548	585	26	4	30	24	20	31	M27
500	532	715	12	609	650	27.5	4	31.5	25	20	34	M30
600	635	840	13.2	720	770	31	5	36	27	20	37	M33
700	738	910	14.4	794	840	34.5	5	39.5	27.5	24	37	M33
800	842	1025	15.6	901	950	38	5	43	30	24	41	M36
900	945	1125	16.8	1001	1050	41	5	46	32.5	28	41	M36
1000	1048	1255	18	1112	1170	45	5	50	35	28	44	M39
1100	1152	1355	19.2	1218	1270	48.5	5	53.5	37.5	32	44	M39
1200	1255	1485	20.4	1328	1390	52	5	57	40	32	50	M45
1400	1462	1685	22.8	1530	1590	55	5	60	42	36	50	M45
1600	1668	1930	25.2	1750	1820	60	5	65	45.5	40	57	M52
1800	1875	2130	27.6	1950	2020	65	5	70	49	44	57	M52
2000	2082	2345	30	2150	2230	70	5	75	52.5	48	62	M56
2200	2288	2555	32.4	2370	2440	75	6	81	56.5	52	62	M56

All dimensions are in millimetres.

Table 2.11.3: Dimensions of Standard Flange Drilling for Flange Fittings PN 25

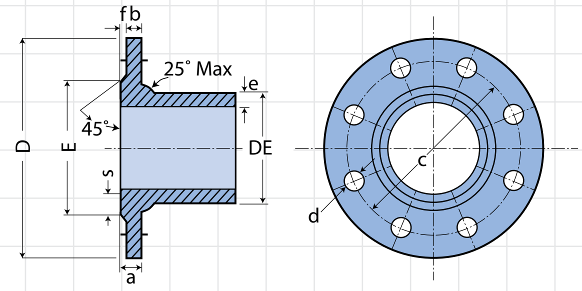


DE -	Pipe outer diameter.
D -	Outer diameter of flange.
E -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe outer diameter.
d -	Bolt hole diameter.

Nominal Diameter	Dimensions									No. of Holes	Hole Dia (Φd)	Bolt Size
DN	DE	D	e	E	C	b	f	a	s			In Metric
80	98	200	7	132	160	16	3	19	15	8	19	M16
100	118	235	7.2	156	190	16	3	19	15	8	23	M20
150	170	300	7.8	211	250	17	3	20	16	8	28	M24
200	222	360	8.4	274	310	19	3	22	17.5	12	28	M24
250	274	425	9	330	370	21.5	3	24.5	19.5	12	31	M27
300	326	485	9.6	389	430	23.5	4	27.5	22	16	31	M27
350	378	555	10.2	448	490	26	4	30	24	16	34	M30
400	429	620	10.8	503	550	28	4	32	25.5	16	37	M33
450	480	670	11.4	548	600	30.5	4	34.5	27.5	20	37	M33
500	532	730	12	609	660	32.5	4	36.5	29	20	37	M33
600	635	845	13.2	720	770	37	5	42	33.5	20	41	M36
700	738	960	14.4	820	875	41.5	5	46.5	33.5	24	44	M39
800	842	1085	15.6	928	990	46	5	51	35.5	24	50	M45
900	945	1185	16.8	1028	1090	50.5	5	55.5	39	28	50	M45
1000	1048	1320	18	1140	1210	55	5	60	42	28	57	M52
1100	1152	1420	19.2	1240	1310	60.5	5	65.5	45	32	57	M52
1200	1255	1530	20.4	1350	1420	64	5	69	48.5	32	57	M52
1400	1462	1755	22.8	1560	1640	69	5	74	52	36	62	M56
1600	1668	1975	25.2	1780	1860	76	5	81	56.5	40	62	M56
1800	1875	2195	27.6	1980	2070	83	5	88	61.5	44	70	M64
2000	2082	2425	30	2210	2300	90	5	95	66.5	48	70	M64

All dimensions are in millimetres.

Table 2.11.4: Dimensions of Standard Flange Drilling for Flange Fittings PN 40



DE -	Pipe outer diameter.
D -	Outer diameter of flange.
E -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe outer diameter.
d -	Bolt hole diameter.

Nominal Diameter	Dimensions									No. of Holes	Hole Dia (Φd)	Bolt Size
DN	DE	D	e	E	C	b	f	a	s			In Metric
80	98	200	7	132	160	16	3	19	15	8	19	M16
100	118	235	7.2	166	190	16	3	19	15	8	23	M20
150	170	300	7.8	211	250	23	3	26	18	8	28	M24
200	222	375	8.4	284	320	27	3	30	21	12	31	M27
250	274	450	9	345	385	31.5	3	34.5	24	12	34	M30
300	326	515	9.6	409	450	35.5	4	39.5	27.5	16	34	M30
350	378	580	10.2	465	510	40	4	44	31	16	37	M33
400	429	660	10.8	535	585	44	4	48	33.5	16	41	M36
450	480	685	11.4	560	610	46	4	50	35	20	41	M36
500	532	755	12	615	670	48	4	52	36.5	20	44	M39
600	635	890	13.2	735	795	53	5	58	40.5	20	50	M45

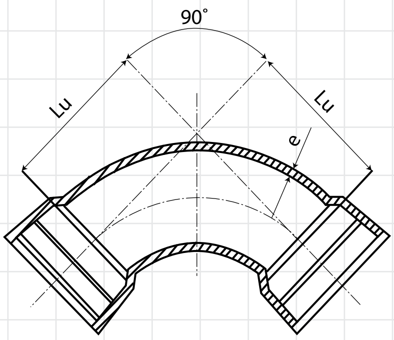
Note:

1. All dimensions are in millimetres.

2. JSAW also manufactures PN 40 flanges in size range DN 700 - DN 1200 (details available on request).

2.11.2 Standard Dimensions of Socketed Fittings for Push-on Joints

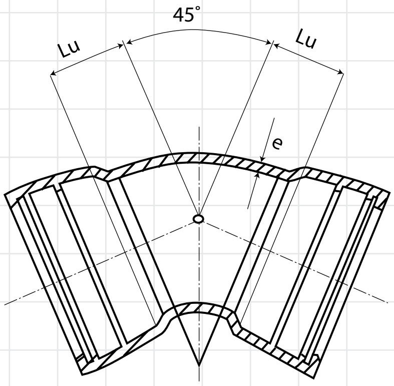
Double Socket 90° Bends



(DN)	e	90°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	100	100
100	7.20	120	100
125	7.50	145	64
150	7.80	170	64
200	8.40	220	64
250	9.00	270	50
300	9.60	320	50
350	10.20	370	50
400	10.80	420	40
450	11.40	470	40
500	12.00	520	40
600	13.20	620	40
700	14.40	720	30
750	15.00	770	30
800	15.60	820	30
900	16.80	920	30
1000	18.00	1020	30
1100	19.20	1130	30
1200	20.40	1230	30
1400	22.80	1430	30
1500	24.00	1530	25
1600	25.20	1630	25
1800	27.60	1320	25

All dimensions are in millimetres.

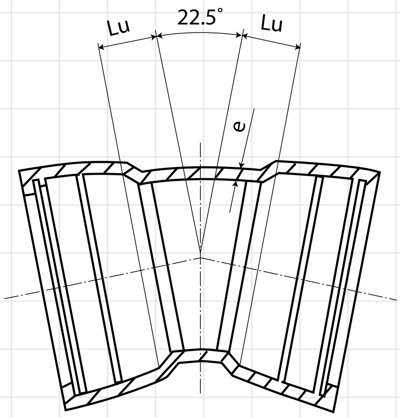
Double Socket 45° Bend



(DN)	e	45°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	55	100
100	7.20	65	100
125	7.50	75	64
150	7.80	85	64
200	8.40	110	64
250	9.00	130	50
300	9.60	150	50
350	10.20	175	50
400	10.80	195	40
450	11.40	220	40
500	12.00	240	40
600	13.20	285	40
700	14.40	330	30
750	15.00	350	30
800	15.60	370	30
900	16.80	415	30
1000	18.00	460	30
1100	19.20	505	30
1200	20.40	550	30
1400	22.80	515	30
1500	24.00	540	25
1600	25.20	565	25
1800	27.60	610	25
2000	30.00	660	25
2200	32.40	710	25

All dimensions are in millimetres.

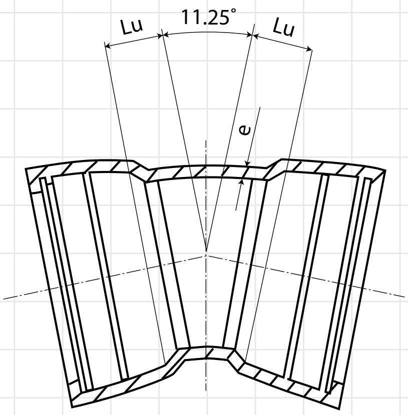
Double Socket 22.5° Bend



(DN)	e	22.5°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	40	100
100	7.20	40	100
125	7.50	50	64
150	7.80	55	64
200	8.40	65	64
250	9.00	75	50
300	9.60	85	50
350	10.20	95	50
400	10.80	110	40
450	11.40	120	40
500	12.00	130	40
600	13.20	150	40
700	14.40	175	30
750	15.00	185	30
800	15.60	195	30
900	16.80	220	30
1000	18.00	240	30
1100	19.20	260	30
1200	20.40	285	30
1400	22.80	260	30
1500	24.00	270	25
1600	25.20	280	25
1800	27.60	305	25
2000	30.00	330	25
2200	32.40	355	25

All dimensions are in millimetres.

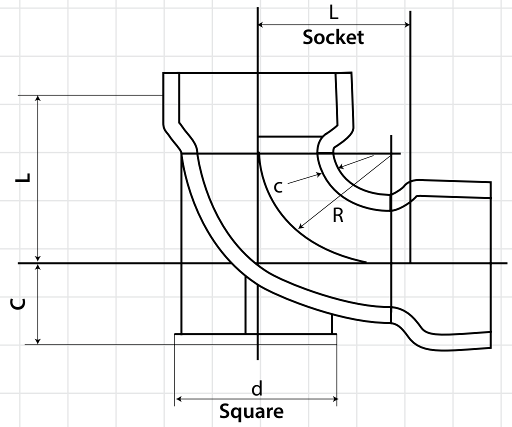
Double Socket 11.25° Bend



(DN)	e	11.25°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	30	100
100	7.20	30	100
125	7.50	35	64
150	7.80	35	64
200	8.40	40	64
250	9.00	50	50
300	9.60	55	50
350	10.20	60	50
400	10.80	65	40
450	11.40	70	40
500	12.00	75	40
600	13.20	85	40
700	14.40	95	30
750	15.00	100	30
800	15.60	110	30
900	16.80	120	30
1000	18.00	130	30
1100	19.20	140	30
1200	20.40	150	30
1400	22.80	130	30
1500	24.00	140	25
1600	25.20	140	25
1800	27.60	155	25
2000	30.00	165	25
2200	32.40	190	25

All dimensions are in millimetres.

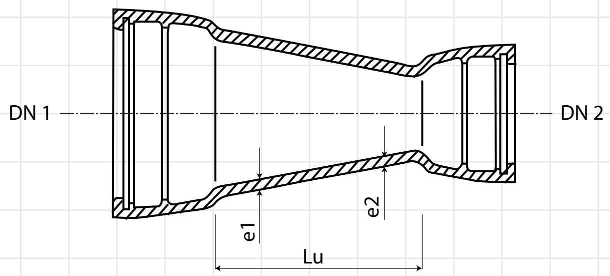
Duckfoot Double Socket 90° Bend



DN	e	L	c	d	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
80	7.00	100	110	180	100
100	7.20	120	125	200	100
150	7.80	170	160	250	64
200	8.40	220	190	300	64
250	9.00	270	225	350	50
300	9.60	320	255	400	50
350	10.20	370	290	450	50
400	10.80	420	320	500	40
450	11.40	470	355	550	40
500	12.00	520	385	600	40
600	13.20	620	450	700	40
700	14.40	720	515	800	30
800	15.60	820	580	900	30
900	16.80	920	645	1000	30
1000	18.00	1020	710	1100	30
1100	19.20	1130	775	1200	30
1200	20.40	1230	840	1300	30
1400	22.80	1430	970	1500	30
1600	25.20	1630	1100	1700	25
1800	27.60	1830	1230	1900	25

All dimensions are in millimetres.

Double Socket Concentric Tapers



DN 1	DN 2	e1	e2	Lu	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
100	80	7.20	7.00	90	100
125	80	7.50	7.00	140	64
125	100	7.50	7.20	100	64
150	80	7.80	7.00	190	64
150	100	7.80	7.20	150	64
150	125	7.80	7.50	100	64
200	80	8.40	7.00	290	64
200	100	8.40	7.20	250	64
200	125	8.40	7.50	200	64
200	150	8.40	7.80	150	64
250	80	9.00	7.00	390	50
250	100	9.00	7.20	351	50
250	125	9.00	7.50	300	50
250	150	9.00	7.80	250	50
250	200	9.00	8.40	150	50
300	80	9.60	7.00	490	50
300	100	9.60	7.20	450	50
300	150	9.60	7.80	350	50
300	200	9.60	8.40	250	50
300	250	9.60	9.00	150	50
350	80	10.20	7.00	589	50
350	100	10.20	7.20	549	50
350	125	10.20	7.50	499	50
350	150	10.20	7.80	448.5	50
350	200	10.20	8.40	360	50
350	250	10.20	9.00	260	50
350	300	10.20	9.60	160	50
400	80	10.80	7.00	686	40
400	100	10.80	7.20	564	40
400	150	10.80	7.80	546	40
400	200	10.80	8.40	448	40
400	250	10.80	9.00	360	40
400	300	10.80	9.60	260	40
400	350	10.80	10.20	160	40
450	80	11.40	7.00	784	40

Continued...

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DN 1	DN 2	e1	e2	Lu	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
450	100	11.40	7.20	745	40
450	150	11.40	7.80	644	40
450	200	11.40	8.40	546	40
450	250	11.40	9.00	450	40
450	300	11.40	9.60	352	40
450	350	11.40	10.20	260	40
450	400	11.40	10.80	160	40
500	100	12.00	7.20	844	40
500	150	12.00	7.80	744	40
500	200	12.00	8.40	646	40
500	250	12.00	9.00	550	40
500	300	12.00	9.60	452	40
500	350	12.00	10.20	360	40
500	400	12.00	10.80	260	40
500	450	12.00	11.40	168	40
600	100	13.20	7.20	1042	40
600	150	13.20	7.80	941	40
600	200	13.20	8.40	843.5	40
600	250	13.20	9.00	747	40
600	300	13.20	9.60	650	40
600	350	13.20	10.20	553	40
600	400	13.20	10.80	460	40
600	450	13.20	11.40	365	40
600	500	13.20	12.00	260	40
700	150	14.40	7.80	1136	30
700	200	14.40	8.40	1038	30
700	250	14.40	9.00	942	30
700	300	14.40	9.60	844	30
700	350	14.40	10.20	747	30
700	400	14.40	10.80	654	30
700	450	14.40	11.40	560	30
700	500	14.40	12.00	480	30
700	600	14.40	13.20	280	30
800	300	15.60	9.60	1042	30
800	350	15.60	10.20	946	30
800	400	15.60	10.80	851.8	30
800	450	15.60	11.40	758	30
800	500	15.60	12.00	662	30
800	600	15.60	13.20	480	30
800	700	15.60	14.40	280	30
900	350	16.80	10.20	1141	30
900	500	16.80	12.00	858	30
900	600	16.80	13.20	668	30
900	700	16.80	14.40	480	30

Continued...

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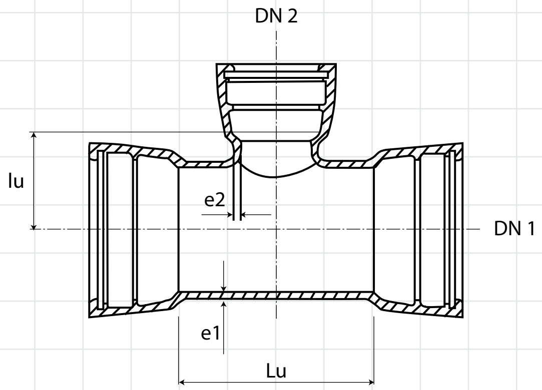
DN 1	DN 2	e1	e2	Lu	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
900	800	16.80	15.60	280	30
1000	400	18.00	10.80	1243	30
1000	500	18.00	12.00	1054	30
1000	600	18.00	13.20	864	30
1000	700	18.00	14.40	670	30
1000	800	18.00	15.60	480	30
1000	900	18.00	16.80	280	30
1100	700	19.20	14.40	480	30
1100	800	19.20	15.60	480	30
1100	900	19.20	16.80	495	30
1100	1000	19.20	18.00	280	30
1200	700	20.40	14.40	1080	30
1200	800	20.40	15.60	890	30
1200	900	20.40	16.80	480	30
1200	1000	20.40	18.00	480	30
1200	1100	20.40	19.20	324	30
1400	800	22.80	15.60	360	30
1400	900	22.80	16.80	360	30
1400	1000	22.80	18.00	360	30
1400	1100	22.80	19.20	360	30
1400	1200	22.80	20.40	360	30
1500	900	24.00	16.80	360	25
1500	1000	24.00	18.00	360	25
1500	1100	24.00	19.20	360	25
1500	1200	24.00	20.40	260	25
1500	1400	24.00	22.80	260	25
1600	1000	25.20	18.00	360	25
1600	1100	25.20	19.20	360	25
1600	1200	25.20	20.40	560	25
1600	1400	25.20	22.80	360	25
1600	1500	25.20	24.00	260	25
1800	1100	27.60	19.20	480	25
1800	1200	27.60	20.40	480	25
1800	1400	27.60	22.80	360	25
1800	1500	27.60	24.00	360	25
1800	1600	27.60	25.20	360	25
2000	1800	30.00	27.60	360	25
2200	2000	32.40	30.00	360	25

All dimensions are in millimetres.

All Socket Tee



DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
80	80	7.00	7.00	170	85	100
100	80	7.20	7.00	170	95	100
100	100	7.20	7.20	190	95	64
125	100	7.50	7.20	195	110	64
125	125	7.50	7.50	225	110	64
150	80	7.80	7.00	170	120	64
150	100	7.80	7.20	195	120	64
150	125	7.80	7.50	255	125	64
150	150	7.80	7.80	255	125	64
200	80	8.40	7.00	175	145	64
200	100	8.40	7.20	200	145	64
200	125	8.40	7.50	255	150	64
200	150	8.40	7.80	255	150	64
200	200	8.40	8.40	315	155	64
250	80	9.00	7.00	180	170	50
250	100	9.00	7.20	200	170	50
250	125	9.00	7.50	260	175	50
250	150	9.00	7.80	260	175	50
250	200	9.00	8.40	315	180	50
250	250	9.00	9.00	375	190	50
300	80	9.60	7.00	210	210	50
300	100	9.60	7.20	205	195	50
300	150	9.60	7.80	260	200	50
300	200	9.60	8.40	320	205	50
300	250	9.60	9.00	375	210	50
300	300	9.60	9.60	435	220	50
350	80	10.20	7.00	205	260	50
350	100	10.20	7.20	205	260	50
350	150	10.20	7.80	325	270	50
350	200	10.20	8.40	325	270	50
350	250	10.20	9.00	495	290	50
350	300	10.20	9.60	495	285	50

...continued

DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
350	350	10.20	10.20	495	290	50
400	80	10.80	7.00	185	285	40
400	100	10.80	7.20	210	285	40
400	150	10.80	7.80	270	295	40
400	200	10.80	8.40	325	295	40
400	250	10.80	9.00	440	310	40
400	300	10.80	9.60	440	310	40
400	350	10.80	10.20	560	320	40
400	400	10.80	10.80	560	320	40
450	80	11.40	7.00	215	310	40
450	100	11.40	7.20	215	310	40
450	150	11.40	7.80	270	315	40
450	200	11.40	8.40	330	320	40
450	250	11.40	9.00	390	330	40
450	300	11.40	9.60	445	335	40
450	350	11.40	10.20	560	345	40
450	400	11.40	10.80	560	345	40
450	450	11.40	11.40	620	350	40
500	80	12.00	7.00	195	335	40
500	100	12.00	7.20	215	335	40
500	150	12.00	7.80	330	344	40
500	200	12.00	8.40	330	345	40
500	250	12.00	9.00	565	370	40
500	300	12.00	9.60	565	370	40
500	350	12.00	10.20	565	370	40
500	400	12.00	10.80	565	370	40
500	450	12.00	11.40	680	380	40
500	500	12.00	12.00	680	380	40
600	80	13.20	7.00	340	395	40
600	100	13.20	7.20	340	395	40
600	150	13.20	7.80	340	395	40
600	200	13.20	8.40	340	395	40
600	250	13.20	9.00	570	416	40
600	300	13.20	9.60	570	420	40
600	350	13.20	10.20	570	420	40
600	400	13.20	10.80	570	420	40
600	450	13.20	11.40	800	440	40
600	500	13.20	12.00	800	436	40
600	600	13.20	13.20	800	440	40
700	100	14.40	7.20	230	435	30
700	150	14.40	7.80	285	440	30
700	200	14.40	8.40	345	445	30
700	250	14.40	9.00	460	460	30

...continued

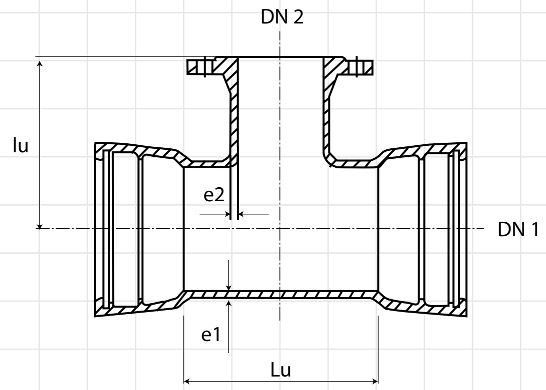
DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
700	300	14.40	9.60	460	460	30
700	350	14.40	10.20	575	470	30
700	400	14.40	10.80	575	470	30
700	450	14.40	11.40	925	470	30
700	500	14.40	12.00	925	480	30
700	600	14.40	13.20	925	490	30
700	700	14.40	14.00	925	500	30
800	100	15.60	7.20	235	485	30
800	150	15.60	7.80	290	490	30
800	200	15.60	8.40	350	495	30
800	250	15.60	9.00	465	510	30
800	300	15.60	9.60	465	510	30
800	350	15.60	10.20	815	520	30
800	400	15.60	10.80	815	540	30
800	450	15.60	11.40	815	540	30
800	500	15.60	12.00	815	530	30
800	600	15.60	13.20	815	540	30
800	700	15.60	14.40	1045	550	30
800	800	15.60	15.60	1045	565	30
900	100	16.80	7.20	300	540	30
900	150	16.80	7.80	300	540	30
900	200	16.80	8.40	355	545	30
900	250	16.80	9.00	820	570	30
900	300	16.80	9.60	820	570	30
900	350	16.80	10.20	820	570	30
900	400	16.80	10.80	820	570	30
900	450	16.80	11.40	820	590	30
900	500	16.80	12.00	820	590	30
900	600	16.80	13.20	820	590	30
900	800	16.80	15.60	1170	615	30
900	900	16.80	16.80	1170	625	30
1000	100	18.00	7.20	305	590	30
1000	150	18.00	7.80	305	590	30
1000	200	18.00	8.40	360	595	30
1000	250	18.00	9.00	595	620	30
1000	300	18.00	9.60	595	620	30
1000	350	18.00	10.20	595	620	30
1000	400	18.00	10.80	595	620	30
1000	500	18.00	12.00	1290	640	30
1000	600	18.00	13.20	1290	640	30
1000	700	18.00	14.40	1290	665	30
1000	800	18.00	15.60	1290	665	30

...continued

DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
1000	1000	18.00	18.00	1290	685	30
1100	150	19.20	7.80	386	645	30
1100	200	19.20	8.40	370	645	30
1100	400	19.20	10.80	600	670	30
1100	600	19.20	13.20	830	825	30
1100	800	19.20	15.60	1065	715	30
1100	1000	19.20	18.00	1295	735	30
1100	1100	19.20	19.20	1410	745	30
1200	200	20.40	8.40	375	695	30
1200	300	20.40	9.60	537	700	30
1200	400	20.40	10.80	605	720	30
1200	600	20.40	13.20	840	740	30
1200	800	20.40	15.60	1070	765	30
1200	900	20.40	16.80	1170	767	30
1200	1000	20.40	18.00	1300	785	30
1200	1200	20.40	20.40	1567	821	30
1400	400	22.80	10.80	800	820	30
1400	600	22.80	13.20	1030	840	30
1400	800	22.80	15.60	1260	1010	30
1400	1000	22.80	18.00	1495	1040	30
1400	1200	22.80	20.40	1725	905	30
1400	1400	22.80	22.80	1960	930	30
1500	400	24.00	10.80	810	920	25
1500	600	24.00	13.20	1040	940	25
1500	800	24.00	15.60	1275	965	25
1500	1000	24.00	18.00	1505	985	25
1500	1200	24.00	20.40	1730	955	25
1500	1400	24.00	22.80	1965	980	25
1500	1500	24.00	24.00	2080	990	25
1600	400	25.20	10.80	810	920	25
1600	600	25.20	13.20	1040	940	25
1600	800	25.20	15.60	1275	1120	25
1600	1000	25.20	18.00	1505	970	25
1600	1200	25.20	20.40	1740	994.7	25
1600	1400	25.20	22.80	1970	1030	25
1600	1600	25.20	25.20	2200	1050	25
1800	600	27.60	13.20	1055	1040	25
1800	800	27.60	15.60	1285	1065	25
1800	1000	27.60	18.00	1520	1085	25
1800	1200	27.60	20.40	1740	994.5	25
1800	1400	27.60	22.80	1980	1130	25
1800	1600	27.60	25.20	2215	1150	25
1800	1800	27.60	27.60	2445	1175	25

All dimensions are in millimetres.

Flange on Double Socket Tees



DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
80	40	7.00	7.00	170	165	10	16
80	50	7.00	7.00	170	165	10	16
80	80	7.00	7.00	170	165	10	16
100	40	7.20	7.00	170	175	10	16
100	50	7.20	7.00	190	175	10	16
100	65	7.20	7.00	170	175	10	16
100	80	7.20	7.00	170	175	10	16
100	100	7.20	7.20	190	180	10	16
125	50	7.50	7.00	225	200	10	16
125	65	7.50	7.00	225	200	10	16
125	80	7.50	7.00	170	190	10	16
125	100	7.50	7.20	195	195	10	16
125	125	7.50	7.50	225	200	10	16
150	40	7.80	7.00	160	205	10	16
150	65	7.80	7.00	170	205	10	16
150	50	7.80	7.00	160	205	10	16
150	80	7.80	7.00	170	205	10	16
150	100	7.80	7.20	195	210	10	16
150	150	7.80	7.80	255	220	10	16
200	80	8.40	7.00	175	235	10	16
200	40	8.40	7.00	175	225	10	16
200	50	8.40	7.00	175	225	10	16
200	60	8.40	7.00	175	235	10	16
200	65	8.40	7.00	175	235	10	16
200	100	8.40	7.20	200	240	10	16
200	125	8.40	7.50	255	250	10	16
200	150	8.40	7.80	255	250	10	16
200	200	8.40	8.40	315	260	10	16
250	50	9.00	7.00	180	265	10	16
250	60	9.00	7.00	180	265	10	16
250	65	9.00	7.00	180	265	10	16
250	80	9.00	7.00	180	265	10	16

Continued...

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DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
250	100	9.00	7.20	200	270	10	16
250	150	9.00	7.80	260	280	10	16
250	200	9.00	8.40	315	290	10	16
250	250	9.00	9.00	375	300	10	16
300	40	9.60	7.00	210	295	10	16
300	50	9.60	7.00	210	295	10	16
300	60	9.60	7.00	210	295	10	16
300	80	9.60	7.00	180	295	10	16
300	100	9.60	7.20	205	300	10	16
300	125	9.60	7.50	260	310	10	16
300	150	9.60	7.80	260	310	10	16
300	200	9.60	8.40	320	320	10	16
300	250	9.60	9.00	380	330	10	16
300	300	9.60	9.60	435	340	10	16
350	50	10.20	7.00	205	330	10	16
350	65	10.20	7.00	205	330	10	16
350	80	10.20	7.00	205	330	10	16
350	100	10.20	7.20	205	330	10	16
350	125	10.20	7.50	325	340	10	16
350	150	10.20	7.80	325	340	10	16
350	200	10.20	8.40	325	350	10	16
350	250	10.20	9.00	495	360	10	16
350	300	10.20	9.60	495	370	10	16
350	350	10.20	10.20	495	380	10	16
400	50	10.80	7.00	185	355	10	16
400	80	10.80	7.00	185	355	10	16
400	100	10.80	7.20	210	360	10	16
400	150	10.80	7.80	270	370	10	16
400	200	10.80	8.40	325	380	10	16
400	250	10.80	9.00	440	390	10	16
400	300	10.80	9.60	440	400	10	16
400	350	10.80	10.20	560	420	10	16
400	400	10.80	10.80	560	420	10	16
450	50	11.40	7.00	215	390	10	16
450	80	11.40	7.00	215	390	10	16
450	100	11.40	7.20	215	390	10	16
450	125	11.40	7.50	270	400	10	16
450	150	11.40	7.80	270	400	10	16
450	200	11.40	8.40	330	410	10	16
450	250	11.40	9.00	390	420	10	16
450	300	11.40	9.60	445	430	10	16
450	350	11.40	10.20	560	450	10	16

Continued...

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DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
450	400	11.40	10.80	560	450	10	16
450	450	11.40	11.40	620	460	10	16
500	50	12.00	7.00	215	420	10	16
500	80	12.00	7.00	215	420	10	16
500	100	12.00	7.20	215	420	10	16
500	150	12.00	7.80	275	430	10	16
500	200	12.00	8.40	330	440	10	16
500	250	12.00	9.00	565	450	10	16
500	300	12.00	9.60	565	460	10	16
500	350	12.00	10.20	565	480	10	16
500	400	12.00	10.80	565	480	10	16
500	450	12.00	11.40	680	500	10	16
500	500	12.00	12.00	680	500	10	16
600	80	13.20	7.00	340	475	10	16
600	100	13.20	7.20	340	500	10	16
600	150	13.20	7.80	340	500	10	16
600	200	13.20	8.40	340	500	10	16
600	250	13.20	9.00	570	540	10	16
600	300	13.20	9.60	570	520	10	16
600	350	13.20	10.20	570	540	10	16
600	400	13.20	10.80	570	540	10	16
600	450	13.20	11.40	800	560	10	16
600	500	13.20	12.00	800	560	10	16
600	600	13.20	13.20	800	580	10	16
700	80	14.40	7.00	230	520	10	16
700	100	14.40	7.20	230	520	10	16
700	150	14.40	7.80	285	520	10	16
700	200	14.40	8.40	345	525	10	16
700	250	14.40	9.00	576	539	10	16
700	300	14.40	9.60	460	540	10	16
700	350	14.40	10.20	575	555	10	16
700	400	14.40	10.80	575	555	10	16
700	500	14.40	12.00	925	600	10	16
700	450	14.40	11.40	925	600	10	16
700	600	14.40	13.20	925	585	10	16
700	700	14.40	14.40	925	600	10	16
800	80	15.60	7.00	235	570	10	16
800	100	15.60	7.20	235	570	10	16
800	150	15.60	7.80	290	580	10	16
800	200	15.60	8.40	350	585	10	16
800	250	15.60	9.00	465	600	10	16
800	300	15.60	9.60	465	600	10	16
800	400	15.60	10.80	580	615	10	16

Continued...

...continued

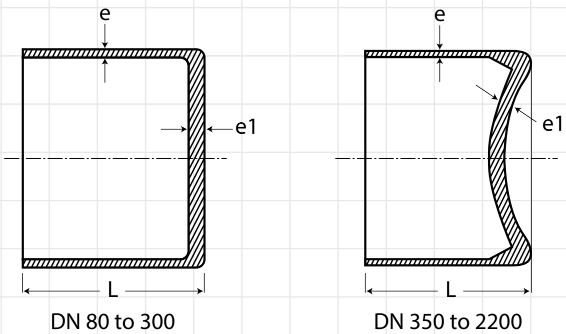
DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
800	450	15.60	11.40	815	630	10	16
800	500	15.60	12.00	815	630	10	16
800	600	15.60	13.20	1045	645	10	16
800	700	15.60	14.40	1045	660	10	16
800	800	15.60	15.60	1045	675	10	16
900	100	16.80	7.20	300	640	10	16
900	150	16.80	7.80	300	640	10	16
900	200	16.80	8.40	355	645	10	16
900	250	16.80	9.00	820	650	10	16
900	300	16.80	9.60	820	650	10	16
900	350	16.80	10.20	820	650	10	16
900	400	16.80	10.80	590	675	10	16
900	450	16.80	11.40	820	715	10	16
900	500	16.80	12.00	820	715	10	16
900	600	16.80	13.20	1170	705	10	16
900	800	16.80	15.60	1170	750	10	16
900	900	16.80	16.80	1170	750	10	16
1000	150	18.00	7.80	305	700	10	16
1000	200	18.00	8.40	360	705	10	16
1000	250	18.00	9.00	595	735	10	16
1000	300	18.00	9.60	595	735	10	16
1000	350	18.00	10.20	595	735	10	16
1000	400	18.00	10.80	595	735	10	16
1000	450	18.00	11.40	1290	765	10	16
1000	500	18.00	12.00	1290	765	10	16
1000	600	18.00	13.20	1290	765	10	16
1000	700	18.00	14.40	1290	765	10	16
1000	800	18.00	15.60	1290	795	10	16
1000	1000	18.00	18.00	1290	825	10	16
1100	150	19.20	7.80	386	765	10	16
1100	200	19.20	8.40	386	765	10	16
1100	250	19.20	9.00	600	795	10	16
1100	300	19.20	9.60	600	795	10	16
1100	400	19.20	10.80	600	795	10	16
1100	500	19.20	12.00	700	795	10	16
1100	600	19.20	13.20	830	825	10	16
1100	800	19.20	15.60	1065	855	10	16
1100	1000	19.20	18.00	1295	885	10	16
1100	1100	19.20	19.20	1410	900	10	16
1200	150	20.40	7.80	407	825	10	16
1200	200	20.40	8.40	407	825	10	16
1200	300	20.40	9.60	537	830	10	16
1200	400	20.40	10.80	637	855	10	16

Continued...

DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
1200	600	20.40	13.20	840	885	10	16
1200	800	20.40	15.60	1070	915	10	16
1200	900	20.40	16.80	1170	915	10	16
1200	1000	20.40	18.00	1300	945	10	16
1200	1200	20.40	20.40	1567	975	10	16
1400	250	22.80	9.00	560	897.5	10	16
1400	400	22.80	10.80	1030	980	10	16
1400	600	22.80	13.20	1030	980	10	16
1400	800	22.80	15.60	1260	1010	10	16
1400	1000	22.80	18.00	1495	1040	10	16
1400	1200	22.80	20.40	1725	1070	10	16
1400	1400	22.80	22.80	1960	1100	10	16
1500	400	24.00	10.80	805	1005	10	16
1500	600	24.00	13.20	1035	1035	10	16
1500	800	24.00	15.60	1270	1065	10	16
1500	1000	24.00	18.00	1500	1095	10	16
1500	1200	24.00	20.40	1730	1125	10	16
1500	1400	24.00	22.80	1965	1155	10	16
1500	1500	24.00	24.00	2080	1170	10	16
1600	250	25.20	9.00	1040	1050	10	16
1600	300	25.20	9.60	1040	1050	10	16
1600	400	25.20	10.80	1040	1060	10	16
1600	600	25.20	13.20	1040	1090	10	16
1600	800	25.20	15.60	1275	1120	10	16
1600	1000	25.20	18.00	1505	1150	10	16
1600	1200	25.20	20.40	1740	1180	10	16
1600	1400	25.20	22.80	1970	1210	10	16
1600	1600	25.20	25.20	2200	1240	10	16
1800	250	27.60	9.00	410	1120	10	16
1800	600	27.60	13.20	1055	1200	10	16
1800	800	27.60	15.60	1285	1230	10	16
1800	900	27.60	16.80	1520	1260	10	16
1800	1000	27.60	18.00	1520	1260	10	16
1800	1200	27.60	20.40	1750	1290	10	16
1800	1400	27.60	22.80	1980	1320	10	16
1800	1600	27.60	25.20	2215	1350	10	16
1800	1800	27.60	27.60	2445	1380	10	16
2000	250	30.00	9.00	720	1265	10	16
2000	600	30.00	13.20	1065	1310	10	16
2000	1000	30.00	18.00	1530	1370	10	16
2000	1400	30.00	22.80	1995	1430	10	16
2200	600	32.40	13.20	1080	1420	10	16
2200	1200	32.40	20.40	1775	1510	10	16
2200	1800	32.40	27.60	2470	1600	10	16

All dimensions are in millimetres.

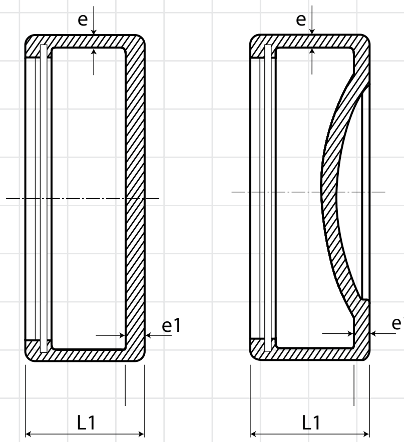
Plugs



DN	e1	e	L
80	7.00	7.00	200
100	7.20	7.20	200
150	7.80	7.80	225
200	8.40	8.40	250
250	9.00	9.00	250
300	9.60	9.60	275
350	12.20	10.20	275
400	13.00	10.80	275
450	13.70	11.40	275
500	14.40	12.00	275
600	15.80	13.20	300
700	17.30	14.40	300
800	18.70	15.60	300
900	20.10	16.80	325
1000	21.60	18.00	350
1100	32.00	19.20	375
1200	34.00	20.40	400
1400	22.80	22.80	1477
1600	25.20	25.20	1683
1800	27.60	27.60	1889
2000	30.00	30.00	2095
2200	32.40	32.40	2301

All dimensions are in millimetres.

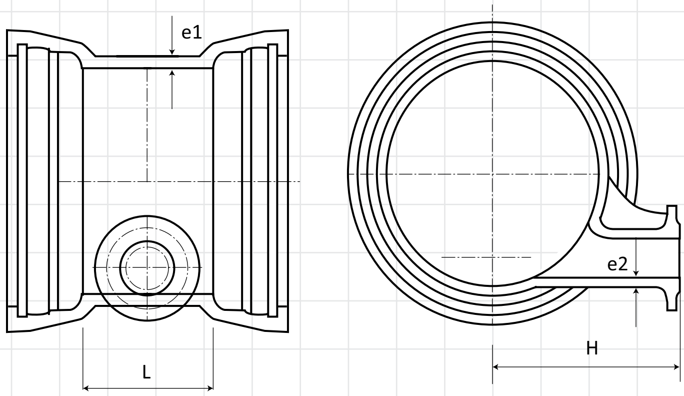
Caps



DN	e	e1	L1
80	7.00	7.00	108
100	7.20	7.20	111
125	7.50	7.50	113
150	7.80	7.80	119
200	8.40	8.40	126
250	9.00	9.00	133
300	9.60	9.60	139
350	10.20	10.20	140
400	10.80	10.80	142
450	11.40	11.40	154
500	12.00	12.00	156
600	13.20	13.20	160
700	14.40	14.40	191
800	15.60	15.60	204
900	16.80	16.80	221
1000	18.00	18.00	233
1100	19.20	19.20	260
1200	20.40	20.40	285

All dimensions are in millimetres.

Double Socket Level Invert Tee with Flanged Branch



DN	dn	e1	L	e2	H	Pressure (Bar)	
mm	mm	mm	mm	mm	mm	PN 10	PN 16
100	50	7.20	170	7.00	175	10	16
100	80	7.20	190	7.00	175	10	16
150	50	7.80	170	7.00	205	10	16
150	80	7.80	195	7.00	205	10	16
150	100	7.80	195	7.20	210	10	16
200	50	8.40	175	7.00	235	10	16
200	80	8.40	175	7.00	235	10	16
200	100	8.40	200	7.20	240	10	16
200	150	8.40	315	7.80	250	10	16
250	50	9.00	180	7.00	265	10	16
250	65	9.00	260	7.00	265	10	16
250	80	9.00	180	7.00	265	10	16
250	100	9.00	200	7.20	270	10	16
250	150	9.00	320	7.80	280	10	16
300	50	9.60	210	7.00	295	10	16
300	80	9.60	210	7.00	295	10	16
300	100	9.60	205	7.20	300	10	16
300	150	9.60	435	7.80	310	10	16
300	200	9.60	320	8.40	320	10	16
350	65	10.20	270	7.00	330	10	16
350	80	10.20	205	7.00	330	10	16
350	100	10.20	205	7.20	330	10	16
350	150	10.20	325	7.80	360	10	16
350	200	10.20	345	8.40	350	10	16
400	80	10.80	274	7.00	391	10	16
400	100	10.80	210	7.20	360	10	16
400	150	10.80	270	7.80	370	10	16
400	200	10.80	345	8.40	380	10	16
400	250	10.80	464	9.00	390	10	16
450	80	11.40	298	7.00	390	10	16
450	100	11.40	318	7.20	390	10	16

Continued...

...continued

DN	dn	e1	L	e2	H	Pressure (Bar)	
mm	mm	mm	mm	mm	mm	PN 10	PN 16
450	150	11.40	305	7.80	400	10	16
450	200	11.40	430	8.40	410	10	16
450	250	11.40	475	9.00	420	10	16
450	300	11.40	526	9.60	430	10	16
500	80	12.00	215	7.00	420	10	16
500	100	12.00	255	7.20	420	10	16
500	125	12.00	348	7.50	400	10	16
500	150	12.00	330	7.80	440	10	16
500	200	12.00	350	8.40	440	10	16
500	250	12.00	565	9.00	450	10	16
500	300	12.00	565	9.60	480	10	16
500	350	12.00	582	10.20	480	10	16
600	100	13.20	280	7.20	403	10	16
600	150	13.20	340	7.80	500	10	16
600	200	13.20	340	8.40	500	10	16
600	250	13.20	295	9.00	450	10	16
600	300	13.20	570	9.60	520	10	16
600	350	13.20	570	10.20	540	10	16
700	150	14.40	356	7.80	520	10	16
700	200	14.40	365	8.40	525	10	16
700	250	14.40	575	9.00	539	10	16
700	300	14.40	490	9.60	540	10	16
700	350	14.40	592	10.20	555	10	16
700	400	14.40	575	10.80	555	10	16
750	150	15.00	360	7.80	500	10	16
800	100	15.60	295	7.20	570	10	16
800	150	15.60	340	7.80	580	10	16
800	200	15.60	350	8.40	585	10	16
800	250	15.60	815	9.00	600	10	16
800	300	15.60	815	9.60	600	10	16
800	450	15.60	815	11.40	630	10	16
900	150	16.80	300	7.80	640	10	16
900	200	16.80	440	8.40	645	10	16
900	500	16.80	820	12.00	715	10	16
1000	200	18.00	450	8.40	705	10	16
1000	250	18.00	595	9.00	705	10	16
1000	300	18.00	595	9.60	705	10	16
1000	350	18.00	595	10.20	735	10	16
1100	200	19.20	386	8.40	765	10	16
1100	300	19.20	525	9.60	765	10	16
1100	400	19.20	660	10.80	795	10	16
1200	200	20.40	445	8.40	825	10	16
1200	250	10.40	566	9.00	825	10	16

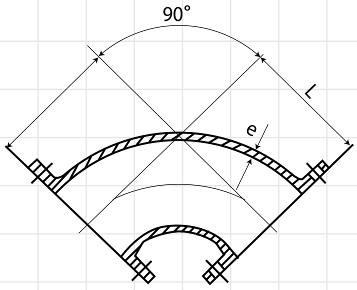
Continued...

...continued

DN	dn	e1	L	e2	H	Pressure (Bar)	
mm	mm	mm	mm	mm	mm	PN 10	PN 16
1200	300	20.40	566	9.60	825	10	16
1200	400	20.40	700	10.80	855	10	16
1400	200	22.80	460	8.40	850	10	16
1400	250	22.80	560	9.00	897.5	10	16
1500	200	24.00	465	8.40	900	10	16
1600	250	25.20	1040	9.00	1060	10	16
1600	400	25.20	1040	10.80	1060	10	16
1600	800	25.20	1275	15.60	1120	10	16
1800	250	27.60	680	9.00	1200	10	16
1800	400	27.60	835	10.80	1200	10	16
2000	600	30.00	1065	13.20	1310	10	16

All dimensions are in millimetres.

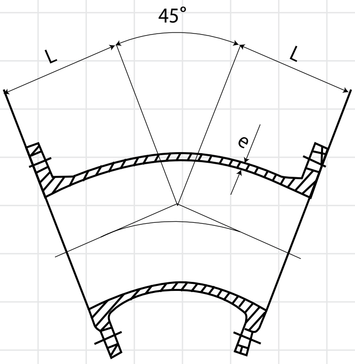
Double Flange 90° Bends



DN	e	90°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	165	10	16
100	7.20	180	10	16
125	7.50	200	10	16
150	7.80	220	10	16
200	8.40	260	10	16
250	9.00	350	10	16
300	9.60	400	10	16
350	10.20	450	10	16
400	10.80	500	10	16
450	11.40	550	10	16
500	12.00	600	10	16
600	13.20	700	10	16
700	14.40	800	10	16
750	15.00	850	10	16
800	15.60	900	10	16
900	16.80	1000	10	16
1000	18.00	1100	10	16
1100	19.20	1235	10	16
1200	20.40	1340	10	16
1400	22.80	1550	10	16
1500	24.00	1660	10	16
1600	25.20	1765	10	16

All dimensions are in millimetres.

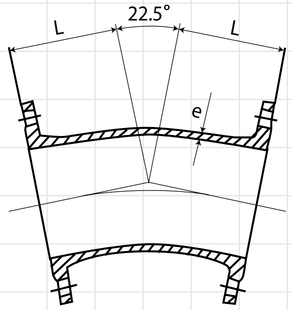
Double Flange 45° Bends



DN	e	45°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	130	10	16
100	7.20	140	10	16
150	7.80	160	10	16
200	8.40	180	10	16
250	9.00	350	10	16
300	9.60	400	10	16
350	10.20	298	10	16
400	10.80	324	10	16
450	11.40	350	10	16
500	12.00	375	10	16
600	13.20	426	10	16
700	14.40	478	10	16
750	15.00	504	10	16
800	15.60	529	10	16
900	16.80	581	10	16
1000	18.00	632	10	16
1100	19.20	694	10	16
1200	20.40	750	10	16
1400	22.80	775	10	16
1600	25.20	845	10	16
1800	27.60	910	10	16
2000	30.00	980	10	16
2200	32.40	880	10	16

All dimensions are in millimetres.

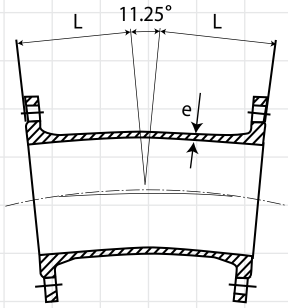
Double Flange 22.5° Bends



DN	e	22.50°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	105	10	16
100	7.20	110	10	16
150	7.80	109	10	16
200	8.40	131	10	16
250	9.00	190	10	16
300	9.60	210	10	16
350	10.20	210	10	16
400	10.80	239	10	16
450	11.40	350	10	16
500	12.00	375	10	16
600	13.20	426	10	16
700	14.40	300	10	16
750	15.00	317	10	16
800	15.60	335	10	16
900	16.80	375	10	16
1000	18.00	410	10	16
1100	19.20	442	10	16
1200	20.40	750	10	16
1400	22.80	524	10	16
1600	25.20	940	10	16

All dimensions are in millimetres.

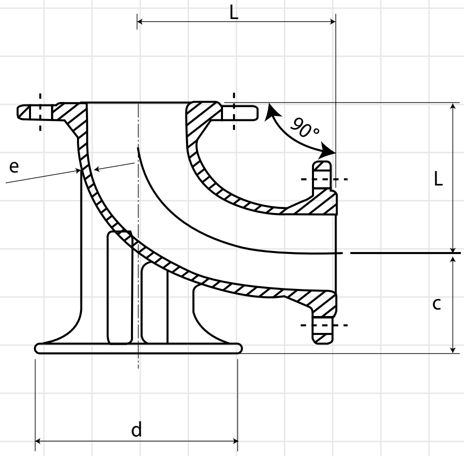
Double Flange 11.25° Bends



DN	e	11.25°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	113	10	16
100	7.20	115	10	16
150	7.80	113	10	16
200	8.40	132	10	16
250	9.00	165	10	16
300	9.60	175	10	16
350	10.20	191	10	16
400	10.80	205	10	16
450	11.40	349	10	16
500	12.00	375	10	16
600	13.20	426	10	16
700	14.40	230	10	16
750	15.00	242	10	16
800	15.60	255	10	16
900	16.80	280	10	16
1000	18.00	310	10	16
1100	19.20	321.5	10	16
1200	20.40	346	10	16
1400	22.80	403	10	16
1600	25.20	885	10	16

All dimensions are in millimetres.

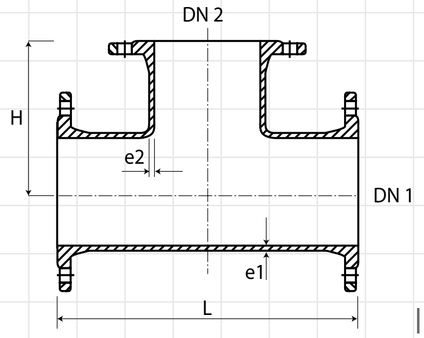
Double Flange DuckFoot 90° Bends



DN	e	L	c	d	PFA (Bar)	
mm	mm	mm	mm	mm	PN 10	PN 16
80	7.00	165	110	180	10	16
100	7.20	180	125	200	10	16
125	7.50	200	140	225	10	16
150	7.80	220	160	250	10	16
200	8.40	260	190	300	10	16
250	9.00	350	225	350	10	16
300	9.60	400	255	400	10	16
350	10.20	450	290	450	10	16
400	10.80	500	320	500	10	16
450	11.40	550	355	550	10	16
500	12.00	600	385	600	10	16
600	13.20	700	450	700	10	16
700	14.40	800	515	800	10	16
800	15.60	900	580	900	10	16
900	16.80	1000	645	1000	10	16
1000	18.00	1100	710	1100	10	16
1100	19.20	1235	775	1200	10	16
1200	20.40	1340	840	1300	10	16
1400	22.80	1550	970	1500	10	16
1500	24.00	1660	1035	1600	10	16
1600	25.20	1765	1100	1700	10	16
1800	27.60	1970	1240	1900	10	16

All dimensions are in millimetres.

All Flanged Tees



Nominal Diameter		e1	e2	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
60	50	7.00	7.00	330	165	10	16
65	65	7.00	7.00	330	165	10	16
80	40	7.00	7.00	330	145	10	16
80	50	7.00	7.00	330	165	10	16
80	65	7.00	7.00	330	145	10	16
80	80	7.00	7.00	330	165	10	16
100	40	7.20	7.00	360	155	10	16
100	50	7.20	7.00	360	180	10	16
100	60	7.20	7.00	360	155	10	16
100	80	7.20	7.00	360	175	10	16
100	100	7.20	7.20	360	180	10	16
125	40	7.50	7.00	400	170	10	16
125	50	7.50	7.00	400	170	10	16
125	65	7.50	7.00	400	170	10	16
125	80	7.50	7.00	400	190	10	16
125	100	7.50	7.20	400	195	10	16
125	125	7.50	7.50	400	200	10	16
150	40	7.80	7.00	440	185	10	16
150	50	7.80	7.00	440	205	10	16
150	65	7.80	7.00	440	185	10	16
150	80	7.80	7.00	440	205	10	16
150	100	7.80	7.20	440	210	10	16
150	125	7.80	7.50	440	215	10	16
150	150	7.80	7.80	440	220	10	16
200	50	8.40	7.00	520	235	10	16
200	65	8.40	7.00	520	215	10	16
200	80	8.40	7.00	520	235	10	16
200	100	8.40	7.20	520	240	10	16
200	125	8.40	7.50	520	245	10	16
200	150	8.40	7.80	520	250	10	16
200	200	8.40	8.40	520	260	10	16
250	40	9.00	7.00	405	265	10	16
250	50	9.00	7.00	405	250	10	16

Continued...

...continued							
Nominal Diameter		e1	e2	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
250	60	9.00	7.00	405	265	10	16
250	80	9.00	7.00	405	250	10	16
250	100	9.00	7.20	700	275	10	16
250	125	9.00	7.50	485	280	10	16
250	150	9.00	7.80	485	268	10	16
250	200	9.00	8.40	700	325	10	16
250	250	9.00	9.00	700	350	10	16
300	50	9.60	7.00	450	290	10	16
300	80	9.60	7.00	450	290	10	16
300	100	9.60	7.20	800	300	10	16
300	150	9.60	7.80	505	310	10	16
300	200	9.60	8.40	800	350	10	16
300	250	9.60	9.00	620	323	10	16
300	300	9.60	9.60	800	400	10	16
350	80	10.20	7.00	850	295	10	16
350	100	10.20	7.20	850	325	10	16
350	150	10.20	7.80	850	325	10	16
350	200	10.20	8.40	850	325	10	16
350	250	10.20	9.00	850	325	10	16
350	300	10.20	9.60	850	425	10	16
350	350	10.20	10.20	850	425	10	16
400	50	10.80	7.00	900	325	10	16
400	80	10.80	7.00	900	325	10	16
400	100	10.80	7.20	900	350	10	16
400	150	10.80	7.80	900	350	10	16
400	200	10.80	8.40	900	350	10	16
400	250	10.80	9.00	900	350	10	16
400	300	10.80	9.60	900	450	10	16
400	350	10.80	10.20	900	450	10	16
400	400	10.80	10.80	900	450	10	16
450	80	11.40	7.00	950	355	10	16
450	100	11.40	7.20	950	375	10	16
450	150	11.40	7.80	950	375	10	16
450	200	11.40	8.40	950	375	10	16
450	250	11.40	9.00	950	375	10	16
450	300	11.40	9.60	950	475	10	16
450	350	11.40	10.20	950	475	10	16
450	400	11.40	10.80	950	475	10	16
450	450	11.40	11.40	950	475	10	16
500	80	12.00	7.00	1000	400	10	16
500	100	12.00	7.20	1000	400	10	16
500	150	12.00	7.80	1000	400	10	16
500	200	12.00	8.40	1000	400	10	16
500	250	12.00	9.00	1000	400	10	16
							Continued...

...continued

Nominal Diameter		e1	e2	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
500	300	12.00	9.60	1000	500	10	16
500	350	12.00	10.20	1000	500	10	16
500	400	12.00	10.80	1000	500	10	16
500	500	12.00	12.00	1000	500	10	16
600	80	13.20	7.00	1100	450	10	16
600	100	13.20	7.20	1100	450	10	16
600	150	13.20	7.80	1100	450	10	16
600	200	13.20	8.40	1100	450	10	16
600	250	13.20	9.00	1100	550	10	16
600	300	13.20	9.60	1100	550	10	16
600	350	13.20	10.20	1100	550	10	16
600	400	13.20	10.80	1100	550	10	16
600	450	13.20	11.40	1100	550	10	16
600	500	13.20	12.00	1100	550	10	16
600	600	13.20	13.20	1100	550	10	16
700	100	14.40	7.20	540	510	10	16
700	150	14.40	7.80	600	520	10	16
700	200	14.40	8.40	650	525	10	16
700	250	14.40	9.00	760	540	10	16
700	300	14.40	9.60	760	540	10	16
700	350	14.40	10.20	870	555	10	16
700	400	14.40	10.80	870	555	10	16
700	450	14.40	11.40	1200	600	10	16
700	500	14.40	12.00	1000	570	10	16
700	600	14.40	13.20	1200	600	10	16
700	700	14.40	14.40	1200	600	10	16
800	100	15.60	7.20	560	570	10	16
800	150	15.60	7.80	620	580	10	16
800	200	15.60	8.40	690	585	10	16
800	250	15.60	9.00	800	600	10	16
800	300	15.60	9.60	800	600	10	16
800	400	15.60	10.80	910	615	10	16
800	450	15.60	11.40	1030	630	10	16
800	500	15.60	12.00	1030	630	10	16
800	600	15.60	13.20	1350	645	10	16
800	700	15.60	14.40	1350	660	10	16
800	800	15.60	15.60	1350	675	10	16
900	150	16.80	7.80	650	640	10	16
900	200	16.80	8.40	730	645	10	16
900	250	16.80	9.00	840	660	10	16
900	400	16.80	10.80	950	675	10	16
900	450	16.80	11.40	1500	705	10	16
900	500	16.80	12.00	1500	705	10	16

Continued...

Nominal Diameter		e1	e2	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
900	600	16.80	13.20	1500	705	10	16
900	700	16.80	14.40	1500	705	10	16
900	800	16.80	15.60	1500	735	10	16
900	900	16.80	16.80	1500	750	10	16
1000	100	18.00	7.20	720	700	10	16
1000	150	18.00	7.80	720	700	10	16
1000	200	18.00	8.40	770	705	10	16
1000	300	18.00	9.60	990	735	10	16
1000	400	18.00	10.80	990	735	10	16
1000	450	18.00	11.40	1080	745	10	16
1000	500	18.00	12.00	1650	740	10	16
1000	600	18.00	13.20	1650	765	10	16
1000	700	18.00	14.40	1650	795	10	16
1000	800	18.00	15.60	1650	795	10	16
1000	1000	18.00	18.00	1650	825	10	16
1100	150	19.20	7.80	760	765	10	16
1100	200	19.20	8.40	760	765	10	16
1100	400	19.20	10.80	980	795	10	16
1100	600	19.20	13.20	1210	825	10	16
1100	800	19.20	15.60	1470	855	10	16
1100	1000	19.20	18.00	1690	885	10	16
1100	1100	19.20	19.20	1800	900	10	16
1200	150	20.40	7.80	780	825	10	16
1200	200	20.40	8.40	780	825	10	16
1200	300	20.40	9.60	940	825	10	16
1200	400	20.40	10.80	1070	855	10	16
1200	600	20.40	13.20	1240	885	10	16
1200	800	20.40	15.60	1470	915	10	16
1200	900	20.40	16.80	1445	896	10	16
1200	1000	20.40	18.00	1700	945	10	16
1200	1200	20.40	20.40	1950	975	10	16
1400	150	22.80	7.80	1120	950	10	16
1400	200	22.80	8.40	1120	950	10	16
1400	400	22.80	10.80	1050	950	10	16
1400	600	22.80	13.20	1550	980	10	16
1400	800	22.80	15.60	1760	1010	10	16
1400	1000	22.80	18.00	2015	1040	10	16
1400	1200	22.80	20.40	2245	1070	10	16
1400	1400	22.80	22.80	2200	1100	10	16
1500	400	24.00	10.80	1070	1005	10	16
1500	600	24.00	13.20	1575	1035	10	16
1500	800	24.00	15.60	1570	1065	10	16
1500	1000	24.00	18.00	2040	1095	10	16
1500	1200	24.00	20.40	2010	1125	10	16
1500	1400	24.00	22.80	2230	1155	10	16

...continued

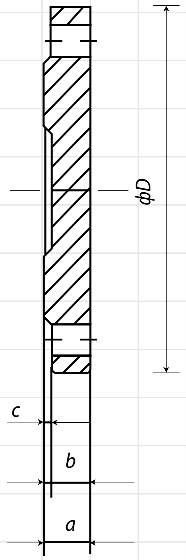
Continued...

...continued

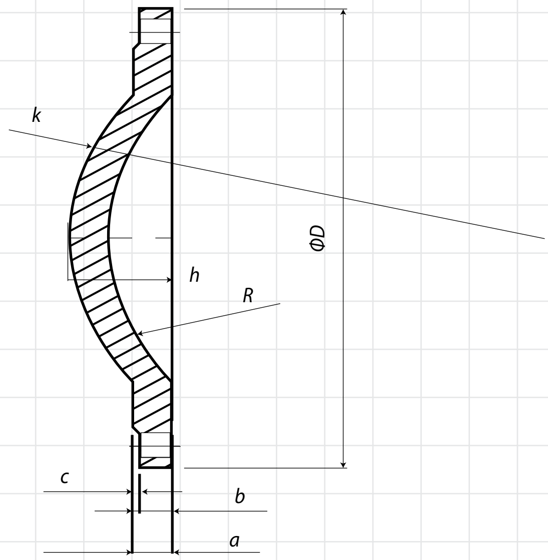
Nominal Diameter		e1	e2	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
1500	1500	24.00	24.00	2340	1170	10	16
1600	200	25.20	8.40	1600	1050	10	16
1600	300	25.20	9.60	1600	1050	10	16
1600	400	25.20	10.80	1600	1050	10	16
1600	600	25.20	13.20	1600	1090	10	16
1600	800	25.20	15.60	1835	1120	10	16
1600	1000	25.20	18.00	2065	1150	10	16
1600	1100	25.20	19.20	2300	1180	10	16
1600	1200	25.20	20.40	2300	1180	10	16
1600	1400	25.20	22.80	2300	1210	10	16
1600	1600	25.20	25.20	2480	1240	10	16
1800	600	27.60	13.20	1655	1200	10	16
1800	800	27.60	15.60	1885	1230	10	16
1800	1000	27.60	18.00	2120	1260	10	16
1800	1200	27.60	20.40	2350	1290	10	16
1800	1400	27.60	22.80	2320	1320	10	16
1800	1600	27.60	25.20	2540	1350	10	16
1800	1800	27.60	27.60	2760	1380	10	16
2000	600	30.00	13.20	1705	1310	10	16
2000	1000	30.00	18.00	2170	1370	10	16
2000	1400	30.00	22.80	2635	1430	10	16
2200	600	32.40	13.20	1560	1420	10	16
2200	1200	32.40	20.40	1220	1510	10	16
2200	1800	32.40	27.60	2880	1600	10	16

All dimensions are in millimetres.

Blank Flanges - PN 10 & PN 16



For DN 80 To DN 300

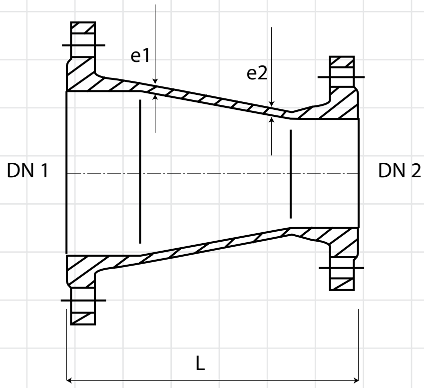


For DN 350 To DN 1600

DN	PN 10						PN 16					
	Ø D	a	b	c	K & R	h	Ø D	a	b	c	K & R	h
80	200	19.0	16.0	3.0	.---	.---	200	19.0	16.0	3.0	.---	.---
100	220	19.0	16.0	3.0	.---	.---	220	19.0	16.0	3.0	.---	.---
125	250	19.0	16.0	3.0	.---	.---	250	19.0	16.0	3.0	.---	.---
150	285	19.0	16.0	3.0	.---	.---	285	19.0	16.0	3.0	.---	.---
200	340	20.0	17.0	3.0	.---	.---	340	20.0	17.0	3.0	.---	.---
250	395	22.0	19.0	3.0	.---	.---	400	22.0	19.0	3.0	.---	.---
300	455	24.5	20.5	4.0	.---	.---	455	24.5	20.5	4.0	.---	.---
350	505	24.5	20.5	4.0	325	71	520	26.5	22.5	4.0	325	71
400	565	24.5	20.5	4.0	375	80	580	28.0	24.0	4.0	375	80
450	615	25.5	21.0	4.0	425	88	640	30.0	26.0	4.0	425	88
500	670	26.5	22.5	4.0	475	97	715	31.5	27.5	4.0	475	97
600	780	30.0	25.0	5.0	575	114	840	36.0	31.0	5.0	575	114
700	895	32.5	27.5	5.0	675	131	910	39.5	34.5	5.0	675	131
800	1015	35.0	30.0	5.0	775	148	1025	43.0	38.0	5.0	775	148
900	1115	37.5	32.5	5.0	875	165	1125	46.5	41.5	5.0	875	165
1000	1230	40.0	35.0	5.0	975	182	1255	50.0	45.0	5.0	975	182
1100	1340	43.0	38.0	5.0	1075	199	1355	53.5	48.5	5.0	1075	199
1200	1455	45.0	40.0	5.0	1175	216	1485	57.0	52.0	5.0	1175	216
1400	1675	46.0	41.0	5.0	1375	244	1685	60.0	55.0	5.0	1375	244
1600	1915	49.0	44.0	5.0	1575	276	1930	65.0	60.0	5.0	1575	276
1800	2115	52.0	47.0	5.0	1775	312	2130	70.0	65.0	5.0	1775	312

All dimensions are in millimetres.

Double Flanged Concentric Tapers



DN	DN 2	e1	e2	L	Concentric	
					PFA	
					PN 10	PN 16
mm	mm		mm		Bar	
80	50	7.00	7.00	200	10	16
80	65	7.00	7.00	200	10	16
100	50	7.20	7.00	200	10	16
100	65	7.20	7.00	200	10	16
100	80	7.20	7.00	200	10	16
125	80	7.50	7.00	200	10	16
125	100	7.50	7.20	200	10	16
150	50	7.80	7.00	200	10	16
150	80	7.80	7.00	200	10	16
150	100	7.8	7.20	200	10	16
150	125	7.80	7.50	200	10	16
200	50	8.40	7.00	300	10	16
200	80	8.4	7.0	300	10	16
200	100	8.4	7.2	300	10	16
200	125	8.40	7.50	300	10	16
200	150	8.40	7.80	300	10	16
250	50	9.0	7.0	300	10	16
250	80	9.0	7.0	300	10	16
250	100	9.0	7.2	300	10	16
250	125	9.00	7.50	300	10	16
250	150	9.0	7.8	300		
250	200	9.0	8.40	300	10	16
300	80	9.6	7.0	300	10	16
300	100	9.6	7.2	300	10	16
300	150	9.6	7.8	300	10	16
300	200	9.6	8.4	300	10	16
300	250	9.60	9.00	300	10	16
350	100	10.2	7.2	300	10	16
350	150	10.2	7.8	300	10	16
350	200	10.2	8.4	300	10	16
350	250	10.20	9.00	300	10	16
350	300	10.20	9.60	300	10	16
400	80	10.8	7.0	250	10	16
400	150	10.8	7.8	300	10	16
400	200	10.8	8.4	300	10	16
400	250	10.80	9.00	300	10	16

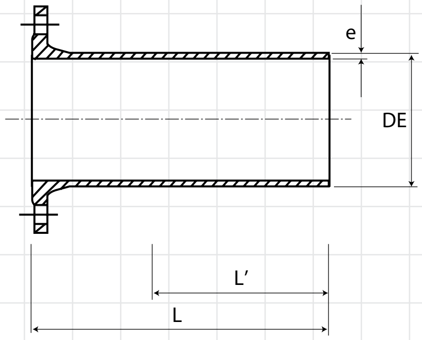
Continued...

...continued

DN	DN 2	e1	e2	L	Concentric PFA PN 10	Concentric PFA PN 16
mm	mm	mm			Bar	
400	300	10.80	9.60	300	10	16
400	350	10.80	10.20	300	10	16
450	200	11.4	8.4	750	10	16
450	250	11.4	9.0	300	10	16
450	300	11.4	9.6	300	10	16
450	350	11.4	10.2	300	10	16
450	400	11.4	10.8	300	10	16
500	100	12.00	7.20	600	10	16
500	200	12.00	8.40	630	10	16
500	250	12.0	9.0	600	10	16
500	300	12.0	9.6	315	10	16
500	350	12.0	10.2	600	10	16
500	400	12.0	10.8	600	10	16
500	450	12.0	11.4	600	10	16
600	200	13.20	8.40	600	10	16
600	300	13.2	9.6	600	10	16
600	350	13.2	10.2	600	10	16
600	400	13.20	10.8	600	10	16
600	450	13.2	11.4	600	10	16
600	500	13.20	12.00	600	10	16
700	200	14.4	8.4	1050	10	16
700	400	14.40	10.80	800	10	16
700	500	14.4	12.0	700	10	16
700	600	14.40	13.20	600	10	16
800	200	15.60	8.40	980	10	16
800	400	15.6	10.8	950	10	16
800	500	15.6	12.0	800	10	16
800	600	15.60	13.20	600	10	16
800	700	15.60	14.4	600	10	16
900	600	16.80	13.20	600	10	16
900	700	16.80	14.40	600	10	16
900	800	16.80	15.6	600	10	16
1000	600	18.0	13.2	1000	10	16
1000	700	18.0	14.4	800	10	16
1000	800	18.00	15.60	600	10	16
1000	900	18.00	16.80	600	10	16
1100	700	19.20	14.40	905	10	16
1100	900	19.20	16.80	700	10	16
1100	1000	19.20	18.00	600	10	16
1200	600	20.40	13.20	950	10	16
1200	800	20.40	15.60	950	10	16
1200	1000	20.40	18.00	790	10	16
1200	1100	20.40	18.00	790	10	16
1400	1200	22.80	20.40	850	10	16
1600	1100	25.20	19.20	1465	10	16
1600	1200	25.20	20.40	1085	10	16
1600	1400	25.2	22.80	910	10	16
1800	1600	27.6	25.20	970	10	16
2000	1600	30.00	25.20	1400	10	16
2000	1800	30	27.60	1030	10	16
2200	2000	32.4	30.00	1090	10	16

All dimensions are in millimetres.

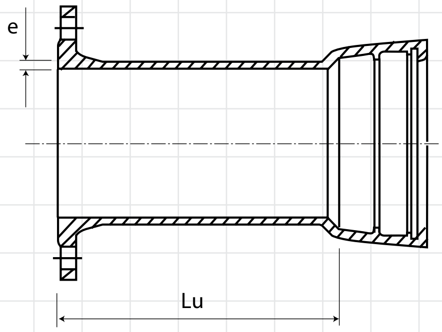
Flange Spigot



DN	DE	e	L	L'	PFA (Bar)	
					PN10	PN16
80	98	7.00	350	215	10	16
100	118	7.20	360	215	10	16
125	144	7.50	370	220	10	16
150	170	7.80	380	225	10	16
200	222	8.40	400	230	10	16
250	274	9.00	420	240	10	16
300	326	9.60	440	250	10	16
350	378	10.20	460	260	10	16
400	429	10.80	480	270	10	16
450	480	11.40	500	280	10	16
500	532	12.00	520	290	10	16
600	635	13.20	560	310	10	16
700	738	14.40	600	330	10	16
750	790	15.00	600	330	10	16
800	842	15.60	600	330	10	16
900	945	16.80	600	330	10	16
1000	1048	18.00	600	330	10	16
1100	1152	19.20	600	330	10	16
1200	1255	20.40	600	330	10	16
1400	1462	22.80	710	390	10	16
1600	1668	25.20	780	430	10	16
1800	1875	27.60	850	470	10	16
2000	2082	30.00	920	500	10	16
2200	2282	32.40	990	540	10	16

All dimensions are in millimetres.

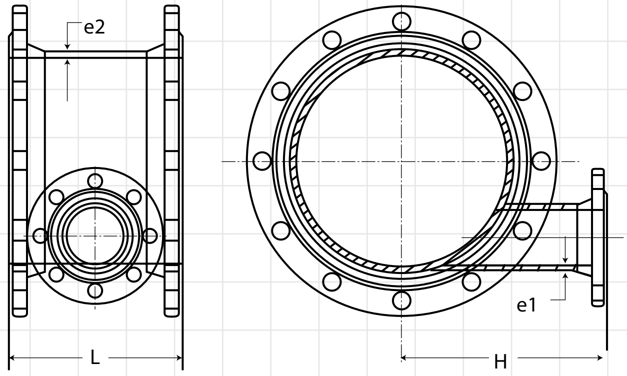
Flange Socket



DN	e	Lu	PFA (Bar)	
			PN10	PN16
80	7.00	130	10	16
100	7.20	130	10	16
125	7.50	135	10	16
150	7.80	135	10	16
200	8.40	140	10	16
250	9.00	145	10	16
300	9.60	150	10	16
350	10.20	155	10	16
400	10.80	160	10	16
450	11.40	165	10	16
500	12.00	170	10	16
600	13.20	180	10	16
700	14.40	190	10	16
800	15.60	200	10	16
900	16.80	210	10	16
1000	18.00	220	10	16
1100	19.20	230	10	16
1200	20.40	240	10	16
1400	22.80	310	10	16
1500	24.00	330	10	16
1600	25.20	330	10	16
1800	27.60	350	10	16
2000	30.00	370	10	16
2200	32.40	390	10	16

All dimensions are in millimetres.

All Flanged Scour Tee



DN	dn	e2	e1	L	h
100	80	7.20	7.00	360	175
150	80	7.80	7.00	440	205
200	80	8.40	7.00	520	235
200	100	8.40	7.20	520	240
200	150	8.40	7.80	520	250
250	80	9.00	7.00	250	275
250	100	8.40	7.20	700	275
300	80	9.60	7.00	255	300
300	100	9.60	7.20	450	300
300	150	9.60	7.80	505	310
350	100	10.20	7.20	545	330
400	80	10.80	7.00	414	391
400	100	10.80	7.20	332	360
400	150	10.80	7.80	900	350
400	200	10.80	8.40	900	350
400	300	10.80	9.60	900	450
450	100	11.40	7.20	285	375
500	80	12.00	7.00	430	420
500	100	12.00	7.20	290	400
500	150	12.00	7.80	1000	400
500	200	12.00	8.40	1000	400
500	300	12.00	9.60	810	480
600	80	13.20	7.00	530	441
600	100	13.20	7.20	295	450
600	150	13.20	7.80	582	500
600	200	13.20	8.40	1100	450
700	150	14.40	7.80	600	520
700	200	14.40	8.40	650	525
800	150	15.60	7.80	620	580
800	200	15.60	8.40	690	585
900	150	16.80	7.80	370	600
900	200	16.80	8.40	730	645

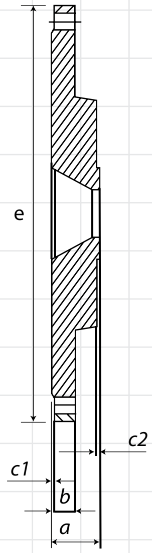
Continued...

...continued

DN	dn	e2	e1	L	h
1000	200	18.00	8.40	770	705
1000	300	18.00	9.60	770	705
1100	200	19.20	8.40	760	765
1100	300	18.00	9.60	770	705
1200	200	20.40	8.40	780	825
1200	300	20.40	9.60	870	825
1400	200	22.80	8.40	1120	890
1600	200	25.20	10.80	1135	1030
1600	300	25.20	9.60	1600	1090
1800	250	27.60	8.40	1150	1200

All dimensions are in millimetres.

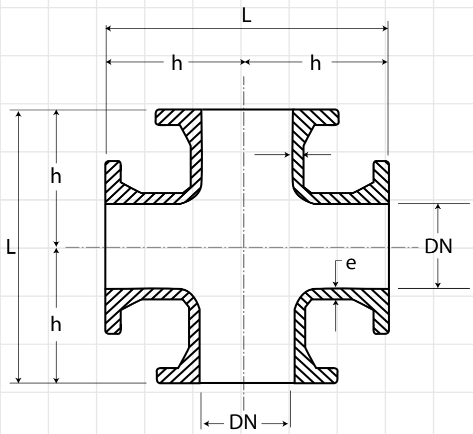
Reducing Flange - PN 10 & PN 16



		PN 10					PN 16				
DN	dn	D	a	b	c1	c2	D	a	b	c1	c2
150	80	285	45.0	16.0	3	3	285	45.0	23.0	3	3
150	100	385	40.0	17.0	3	3	285	40.0	17.0	3	3
200	80	340	40.0	17.0	3	3	340	40.0	17.0	3	3
200	100	340	40.0	17.0	3	3	340	40.0	17.0	3	3
200	125	340	40.0	17.0	3	3	340	40.0	17.0	3	3
300	150	445	90.0	20.5	4	3	455	90.0	20.5	4	3
350	250	505	48.0	20.5	4	3	520	54.0	22.5	4	3
400	200	565	87.0	20.5	4	3	580	87.0	24.0	4	3
400	250	565	48.0	20.5	4	3	580	54.0	24.0	4	3
400	300	565	49.0	20.5	4	4	580	55.0	24.0	4	4
600	200	780	193.0	25.0	5	3	840	193.0	31.0	5	3
700	500	895	56.0	27.5	5	4	910	67.0	34.5	5	4
900	700	1115	63.0	32.5	5	5	1125	73.0	41.5	5	5
1000	700	1230	63.0	35.0	5	5	1255	73.0	45.0	5	5
1000	800	1230	68.0	35.0	5	5	1255	77.0	45.0	5	5

All dimensions are in millimetres.

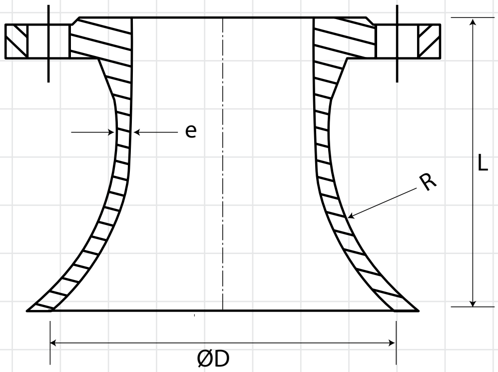
All Flanged Crosses



DN	e	L	h	PFA (Bar)	
				PN10	PN16
80	7.00	330	165	10	16
100	7.20	360	180	10	16
150	7.80	440	220	10	16
200	8.40	520	260	10	16
250	9.00	700	350	10	16
300	9.60	800	400	10	16
350	10.20	850	425	10	16
400	10.80	900	450	10	16
450	11.40	950	475	10	16
500	12.00	1000	500	10	16
600	13.20	1100	550	10	16

All dimensions are in millimetres.

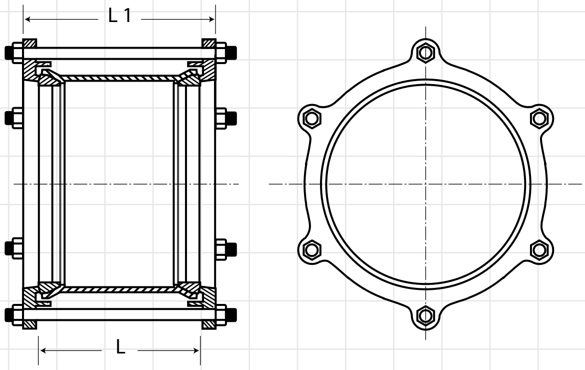
Flanged Bell Mouth



DN	Φ D	e	R	L	PFA (Bar)	
					PN10	PN16
80	160	7.00	100.00	135	10	16
100	185	7.20	106.00	140	10	16
125	215	7.50	114.60	150	10	16
150	245	7.50	119.00	155	10	16
200	310	8.40	137.00	170	10	16
250	370	9.00	150.00	190	10	16
300	435	9.60	169.00	210	10	16
350	495	10.20	181.00	225	10	16
400	560	10.80	200.00	245	10	16
450	620	11.40	212.00	260	10	16
500	685	12.00	231.00	280	10	16
600	810	13.20	262.00	300	10	16
700	945	14.40	281.00	340	10	16
800	980	15.60	423.16	380	10	16
900	1095	16.80	496.10	415	10	16
1000	1210	18.00	548.70	450	10	16

All dimensions are in millimetres.

Mechanical Joint (MJ) Collar



DN	Wall Thickness	Body Length	Assembly Length	Setting Gap	
	e	L	L1	Min.	Max.
80	7.00	230	298	25	100
100	7.20	230	298	25	100
125	7.50	235	300	25	105
150	7.80	241	309	25	105
200	8.40	246	316	25	110
250	9.00	251	325	25	115
300	9.60	256	333	25	120
350	10.20	271	362	25	125
400	10.80	276	370	25	125
450	11.40	281	379	25	135
500	12.00	296	397	25	135
600	13.20	306	414	25	135
700	14.40	316	431	25	156
800	15.60	316	438	25	166
900	16.80	326	464	25	170
1000	18.00	336	482	25	180
1100	19.20	364	533	25	190
1200	20.40	374	550	25	170
1400	22.80	478	648	25	145
1600	25.20	473	664	25	145
1800	27.60	502	704	25	150
2000	30.00	522	734	25	155

All dimensions are in millimetres.

Note:

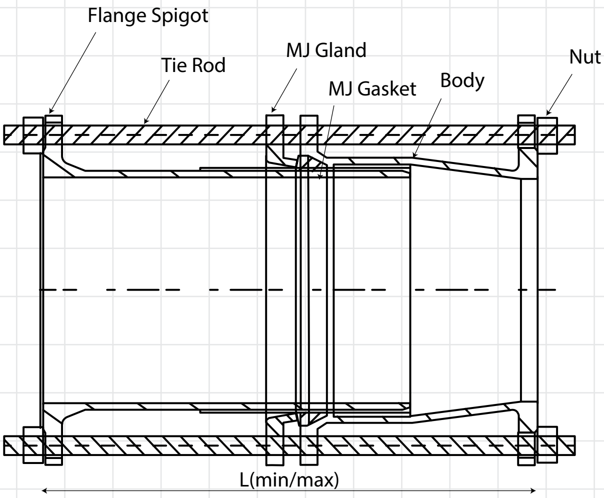
1) *Length of the items are subject to change to meet the requirement of customer as per mutual agreement.*
2) *All the manufacturers are mandated to have their own design for the collars. Some manufactures have the design of collars with the Push-on Joint on both ends (called as Double Socket Collars where as some manufacturers have the design with Mechanical Joint on both ends (called as MJ Collar).*

Advantage of MJ Collar:

The MJ Collars have the following advantage over Double Socket Collar:

1. For operational convenience point Mechanical Joint Collars are preferred over Double Socket Collars.
2. Since the Collars are mainly used for joining spigot ends of two pipes. The bevel ends of pipes are prepared at site. In such cases, if the bevel ends are not prepared smoothly, the Tyton gasket, used for sealing purpose, are susceptible for damage during installation of Double Socket Collars. By use of MJ collars, probability of gasket damage is nil as the gasket positioning is done after exact positioning of Spigot ends.
3. MJ Collar design provides better gasket sealing and chances of leakage are less as the gasket sealing is done by tightening of bolts from both ends using tie rod.
4. The MJ Collar are light weight as compared to Double Socket Collars, hence the handling/installation is simple and convenient.
5. The Assembly and dis-assembling of MJ Collar is easy as compared to Double Socket Collar.

Dismantling Joint

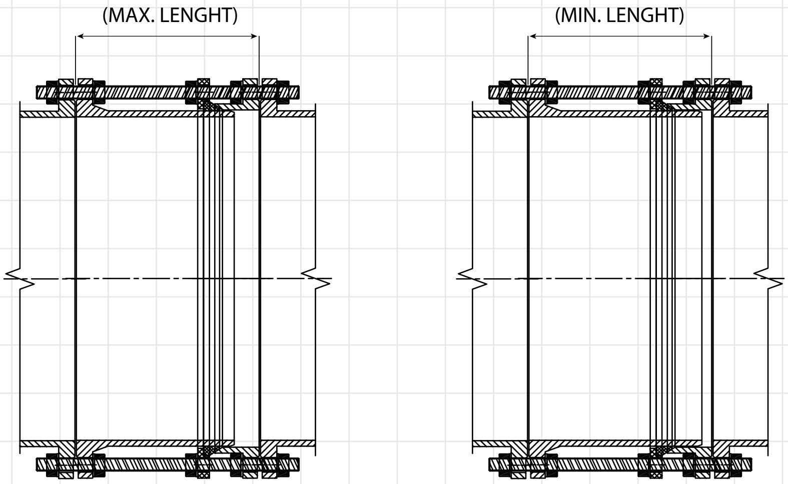


TYPE A

DN	e	Type A (Long Length) L		Allowable Operating Pressure (PFA), Bar
		Min.	Max.	PN16
80	7.00	480	530	16
100	7.20	490	540	16
125	7.50	505	600	16
150	7.80	515	567	16
200	8.40	540	595	16
250	9.00	565	622	16
300	9.60	590	650	16
350	10.20	615	677	16
400	10.80	640	705	16
450	11.40	665	732	16
500	12.00	690	760	16
600	13.20	740	812	16
700	14.40	790	867	16
800	15.60	800	882	16
900	16.80	810	894	16
1000	18.00	820	904	16
1100	19.20	830	924	16
1200	20.40	840	924	16

Note:
1. All dimensions are in millimetres.
2. Length of the items are subject to change to meet the requirement of customer as per mutual agreement.

Dismantling Joint

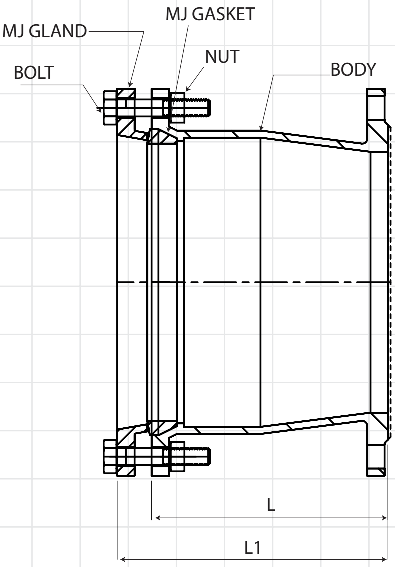


TYPE B

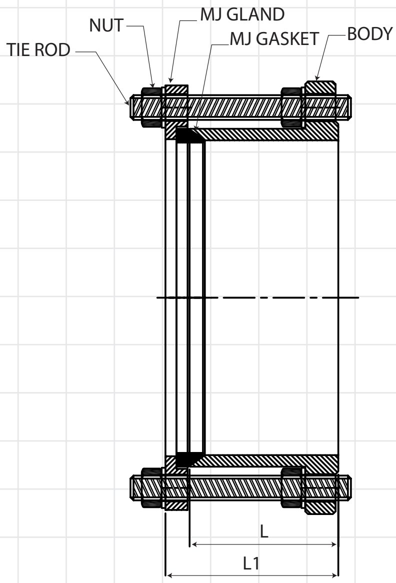
DN Size	Minimum allowable length Min.		Maximum allowable length Max.	
	PN10	PN16	PN10	PN16
125	175	175	225	225
500	285	285	335	335
600	295	295	345	345
700	320	320	370	370
800	330	330	380	380
900	315	315	365	365
1000	340	340	390	390
1100	385	385	435	435
1200	351	351	411	411
1400	366	366	416	416
1600	375	400	425	425
1800	465	465	515	515
2000	465	465	515	515

Note:
1. All dimensions are in millimeters.
2. Length of the items are subject to change to meet the requirement of customer as per mutual agreement.

Flanged Adapter



TYPE A

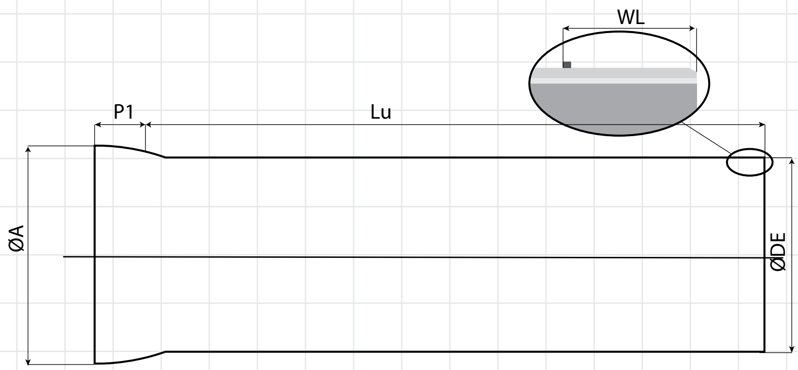


TYPE B

DN	e	Type A		Type B		Allowable Operating Pressure (PFA), Bar
		Body Length	Assembly Length	Body Length	Assembly Length	
		L	L1	L	L1	PN16
80	7.00	281	245	73	97	16
100	7.20	281	245	76	100	16
125	7.50	285	245	76	100	16
150	7.80	291.5	255.5	76	100	16
200	8.40	300	263	76	102	16
250	9.00	309.5	270.5	90	119	16
300	9.60	318.5	278	90	121	16
350	10.20	338	290.5	110	144	16
400	10.80	347	298	110	146	16
450	11.40	356.5	305.5	110	149	16
500	12.00	370.5	318	132.6	158,5	16
600	13.20	389	333	130	167.5	16
700	14.40	407.5	348	115	167	16
800	15.60	426	358	122	170.3	16
900	16.80	444	373	125	173	16
1000	18.00	458	383	126	167	16
1100	19.20	498.5	412	130	203	16
1200	20.40	517	427	164	204	16
1400	22.80	-	-	170	213	16
1500	24.00	-	-	170	257	16
1600	25.20	-	-	175	225.4	16
1800	27.60	-	-	190	288	16
2000	30.00	-	-	180	245.4	16

Note:
1. All dimensions are in millimetres.
2. Length of the items are subject to change to meet the requirement of customer as per mutual agreement.
3. JFL also manufacture Flange Adapter in higher sizes i.e. DN 1400 to DN 2000 (details available on request).

JSAW-Lock Double Chamber Restrained Joint Details



Normal Pressure Applications								
Size	PFA (Bar) *	Deflection (Degree)	Tractive Force (KN)	No. of Locks	External Diameter (DE)	Socket OD (A)	Socket Depth (P1)	Weld Distance (WL)
100	40	5	60	5	118	170	123	85
150	40	5	120	5	170	246	130	85
200	40	4	190	8	222	290	142	95
250	40	4	290	8	274	354	163	100
300	40	4	420	8	326	410	174	105
350	30	3	430	8	378	460	171	110
400	30	3	560	8	429	524	183	117
500	30	3	850	9	532	654	200	117
600	35	2	1400	10	635	766	216	122
700	27	2	1390	10	738	836	198	125
800	25	1.5	1690	10	842	950	198	125
900	25	1.5	2130	12	945	1069	206	128
1000	25	1.5	2620	12	1048	1180	229	142
1200	25	1.2	**	29***	1255	1390	324	220
1400	22	1	**	29***	1462	1624	322	230
1500	20	1	**	29***	1565	1725	326	235
1600	20	1	**	29***	1668	1840	352	245
1800	16	1	**	29***	1875	2065	348	253

*Note : *-For higher or any other special PFA requirements, please contact us.*
***- For tractive forces please consult JSAW.*
****- Locks include complete kit including rubber spacer*

High Pressure Applications								
Size	PFA (Bar) *	Deflection (Degree)	Tractive Force (KN)	No. of Locks	External Diameter (DE)	Socket OD	Socket Depth (P1)	Weld Distance (WL)
100	100	5	140	5	118	170	123	85
150	100	5	290	5	170	246	130	85
200	64	4	300	8	222	316	142	95
250	64	4	460	8	274	390	163	100
300	45	4	470	8	326	410	174	105
350	38	3	621	8	378	460	171	110
400	35	3	640	8	429	540	183	117
500	35	3	980	9	532	670	200	117

*Note : *-For higher or any other special PFA requirements, please contact us.*

2.12 Corrosion Resistance

2.12.1 Corrosion Resistance of Cement Mortar Linings

Cement mortars are porous materials. The intricate pores entrap water due to capillary action. The water held in the structure, also called Pore solution, is always in equilibrium at a high pH (11 -13) due to the presence of Calcium, Potassium and Sodium ions brought by the cement.

Iron (base metal for Ductile Iron pipes), when coming in contact with water, forms different compounds (oxides, hydrated oxides etc) depending on the electrochemical potential and pH condition. A passivation zone is established when the pH remains between 9 and 13.5 in the system. A cement mortar lining thus performs as an active coating, which neutralizes potential water aggressiveness towards Iron by adjusting its pH to a level where a stable passivating layer is formed.

2.12.2 Chemical Resistance to Effluents

Corrosion in sewer piplines occurs due to septic transformations leading to formation of Hydrogen Sulphide gas.

BSEN 598 has recommended tests to be carried out for pipelines and components intended to be used for transportation of effluents.

Pipelines, fittings and joints should be demonstrated by six-month exposure tests to an acid solution and to an alkaline solution according to established procedure in the code.

After six months of testing, the following conditions are met:

- Thickness of cement mortar lining within 0.2mm of the original thickness;
- No visible cracking, blistering or disbanding of the Epoxy or Polyurethane based coatings.
- No visible cracking on the rubber gasket; its hardness, tensile strength and elongation remains in conformity with the specified values.

Table 2.12.1: Chemical Resistance of Cement Mortar Linings

Aggressive Factors (mg/litre)	Ordinary Portland Cement	Blast Furnace Slag Cement (more than 60% slag)	High Alumina Cement
Ammonium, NH_4+	< 30	< 30	NL
Magnesium, Mg ++	<100	<500	NL
Sulphates, $S0_4$--	< 400	< 3000	NL
Aggressive CO_2	<7	<15	NL
pH	>6	> 5.5	4 < pH<12

NL: No Limitations

Table 2.12.1 above gives concentration limits of different ions in fluids in contact with cement mortar linings composed with three types of cement. These limits ensure safe long term performance.

In addition to the indications given in Table 2.12.1 tests and experience have shown that high Alumina cement mortars resist to a variety of chemicals like glycols, glycerine, phenols, Calcium Bisulphate, Sodium Thiosulphate, Butyric acid, Acetic acid etc.

In few cases where cement mortar linings are exposed to sulphate attack, ordinary Portland cement is replaced by 'Sulphur Resisting' Portland cement.

For sea water applications, Ductile Iron pipes with internal cement mortar linings of high Alumina cement or Blast furnace slag cement are used.

2.12.3 Abrasion Resistance

Cement mortar lining's resistance to abrasion is of importance especially in drainage and sewage pipelines where the effluents can carry a fair amount of solid particles.

Abrasion resistance tests are conducted in Ductile Iron pipes as per BSEN 598. When tested according to the provisions of the said standard, the pipes cannot have an abrasion depth greater than 0.6mm after 100,000 movements (50,000 cycles) for every type of cement lining, or 0.2mm for Epoxy or Polyurethane linings.

2.13.1 Seal Coat for Cement Mortar Lining

Epoxy seal coat for Cement mortar lining is provided if the customer specifies it. Unless otherwise specified by the purchaser, the minimum Dry Film Thickness (DFT) provided is average 70 micron with minimum at one point of 50 micron.The coating is uniform, free of thin spots and other imperfections.

Pipe Preparation
The pipe internally lined with cement mortar is shot blasted or buffed using a mechanical device and the cement laitance layer is thoroughly removed. The pipe is then thoroughly cleaned of all loose foreign matter with the help of clean, dry, oil free compressed air in a manner that does not adversely affect the cleaned surface. Alternatively, vacuum cleaning or other methods may be used in place of compressed air, without affecting the pipe surface.

Application of Seal Coat System
The seal coat is applied using an airless spray gun mounted on a moving boom. If more than one coat is applied, the subsequent coat is applied within the time limits, surface conditions and temperature recommended by the manufacturer.

Visual Appearance
The seal coat is uniform and when visually examined, it is free from any coating irregularities likely to be detrimental to the performance of the seal coat.

Seal Coat Repair
For minor damage to the seal coat at the ends of pipe, no repair of the seal coat is necessary.

2.13.2 Polyurethane Lining

Polyurethane lining material consists of two component solvent free Epoxy resin. Mineral fillers, pigments and additives are selected in order that the final product complies with the performance requirements given in BSEN 15655.

Application Method: Airless Hot Spray Method

Surface Preparation

Prior to the application of the Polyurethane lining, the surface of the pipes or fittings to be lined, should be clean, free of rust, loose constituent materials, dirt, oil, grease and moisture.

In cold weather, or any time when the moisture tends to condense on the surface of the pipe or fitting, it should be uniformly warmed for sufficient time prior to cleaning. The surface temperature should be maintained at least 5°C above the dew point.

The Polyurethane lining should be of:
- Uniform colour, except the spigot end and the internal socket profile which may be of a different colour and different coating material.
- Uniform appearance and smoothness except for admissible repairs.
- Free from visible defects (pinholes, bubbles, blisters, wrinkles, cracks or voids).

Slight superficial variations of colour or brilliance due to repairs or prolonged exposure to sunlight of contact with other pipes are permissible.

Minimum Lining Thickness

Table 2.13.1: Polyurethane Lining Thickness

Lining Thickness of Pipes and Fittings for Drinking Water Transportation		
DN	Mean value x, µm	(x-26), µm
80 - 200	≥1300	≥ 800
>200	≥1500	≥ 800
Lining Thickness of Pipes and Fittings for Wastewater Transportation		
80 - 200	≥ 1300	≥800
250 - 700	≥ 1500	≥ 800
750 - 1000	≥ 1800	≥1000
> 1000	≥ 2000	≥1000

Note: Higher thickness can also be provided as per customer requirement.

2.13.3 Epoxy (Synthetic) Coating

Epoxy coating is provided if the customer specifies it. Unless otherwise specified by the purchaser, the minimum dry film thickness (DFT) of Epoxy coating should be average 70 micron with minimum at one point of 50 micron. After curing but prior to laying of pipes, the coating should be a continuous film, free of thin spots and other imperfections.

Coating Application
The pipe coating should be applied in accordance with the manufacture's recommendations. Application of Epoxy coating is carried out by airless spray equipment.

Pipe Preparation
The pipe exterior should be thoroughly cleaned of all loose foreign matter with the help of clean, dry, oil free compressed air in a manner that does not adversely affect the cleaned surface. Alternatively, vacuum cleaning or other methods can be used in place of compressed air. Shot blasting can also be used.

Application of Epoxy Coating System
If more than one coat is applied, the subsequent coat should be applied within the time limits, surface conditions and temperature recommended by the manufacturer. If the period between coats is exceeded, then a repair procedure should be obtained from the coating manufacturer and its recommendations followed.

Coating Repair
Accessible areas of pipe requiring coating repairs should be cleaned to remove debris and damaged coating using grinders or other means acceptable to the purchaser. The adjacent coating should be feathered by sanding, grinding or other methods approved by the purchaser. Accumulated debris should be removed by vacuum blowing or wiping with clean rags.

2.13.4 Polyurethane Coating

Polyurethane consists of high build, two components, resin. The coating is capable of airless spray application to provide an average 2mm of Dry Film Thickness (DFT) in a continuous application.

The mechanical properties of the coating should meet the requirements of DIN 30671/BS EN 15189

Table 2.13.2: General Specification of Polyurethane Coating

Materials	
Polyurethane Minimum Thickness	700 microns
Non-porosity Test Voltage	4.2/6KV
Impact Test (using wire mesh/conductive rubber electrode)	10 J
Adhesion Test	8MPa
Hardness	70 Shore D

Surface Preparation

Prior to the application of the Polyurethane coating, the surface of the pipes or fittings to be coated should be clean, free of rust, loose constituent materials, dirt, oil, grease and moisture.

In cold weather, or any time when the moisture tends to condense on the surface of the pipe or fitting, it should be uniformly warmed for sufficient time prior to cleaning. The surface temperature should be maintained at least 5°C above the dew point.

The surface should be prepared by grinding (only for pipes) and sand (grit) blasting.

Finished Polyurethane Coating

The Polyurethane coating should be of:

- Uniform colour, except the spigot end and the socket which may be of a different colour for permitted marking.
- Uniform appearance and smoothness except for admissible repairs.
- Free from visible defects (pinholes, bubbles, blisters, wrinkles, cracks or voids).

Slight superficial variations of colour or brilliance due to repairs or prolonged exposure to sunlight of contact with other pipes are permissible.

Minimum Coating Thickness - 700 micron

2.13.5 Polyethylene Sleeve

Protective Polyethylene sleeves are used to cover DI pipes and fittings installed in buried conditions and accordance to ISO 8180.

The Polyethylene sleeve is black in colour and resistant to the effect of ultra violet light.

The material is made from a polymer with a melt flow index as measured according to BS 2782, of 10 or less and a density in the range of 0.910 to 0.935 g/ml. The sleeve is free from pinholes, gels, undispersed raw materials and particles of foreign matter. The film shall not contain more than 5% by weight of material other than Polyethylene.

The material used for making the film is Polyethylene or a mixture of Polyethylene and or Ethylene and Olefin co-polymers. Its density should be between 910 and 930 kg/m^3. Polyethylene sleeves are stored in a cool dry store, away from direct sunlight or excessive heat.

Table 2.13.3: Lay Flat Width of Tubular Polyethylene Sleeve

Nominal Internal Diameter of Pipe (mm)	Lay Flat Width (mm)
80	350
100	350
150	450
200	550
250	650
300	700
350	800
400	1100
450	1100
500	1350
600	1350
700	1750
800	1750
900	2000
1000	2000
1100	2500
1200	2500
1400	2750
1500	2750
1600	3100
1800	3600
2000	4000
2200	4350

Note: Actual lay flat width of the tubular film shall not differ from the nominal by more than ± 2.5%

Thickness

The nominal thickness of the sleeving should not be less than 200 µm and not more than 250 µm unless otherwise agreed. The negative tolerance on the nominal thickness shall not exceed 10%. If necessary, it is permitted to use thicker sleeving or double sleeving.

Mechanical Properties

Tensile strength of the film in the longitudinal and transverse direction should not be less than 8.3 Mpa.

The elongation at the fracture of the film in the longitudinal and transverse directions should not be less than 300%.

The dielectric strength of the film should be 31.5 V/µm minimum.

Corrosion Protection Recommendations

Table 2.13.4: Recommended Protection System

Soil Corrosivity	Typical Ground Conditions	Protection System	Reference Standard
Non Aggressive > 3000 ohm.cm	Natural soil with resistivity > 3000 ohm.cm without water table	Zinc coating 130 gm/m sq with Finishing layer of 70 micron of Bitumen	ISO: 8179 Part 1 & 2
Moderately Aggressive >1000 < 3000 Ohm.com	Natural peaty soils Natural soil containing coal, iron stone or shale without water table pH range between 5 and 6 without water table	Zinc coating 200 gm/m sq with Finishing layer of 100 micron Epoxy/Polyurethane	ISO: 8179 Part 1 & 2
Aggressive >500 < 1000 ohm.cm	Natural soil with seasonal water table resistivity between 1500 to 2500 ohm.cm Natural soil with permanent water table resistivity between 500 to 1000 ohm.cm	Zinc coating 400 gm/m sq with Finishing layer of 70 micron of Bitumen/Epoxy	ISO: 8179 Part 1 & 2
Highly Aggressive < 500 ohm.cm	Natural soil with resistivity below 500 ohm.cm permanent water table. Natural soil with pH less than 5 and permanent water table Stray electrical current or near Cathodically protected pipeline.	Polyurethane coating of 700 micron	EN 15189
Extremely aggressive	Soil made up of Clinker, brick which may cause mechanical damage with seasonal/permanent water table Ground with chemical contamination/ high salinity tidal saline water /Sea shoreline	Zinc coating 200 gm/m sq with additional protection Optional a) Extruded Polyethylene b) Adhesive tape wrapping c) Fibre reinforced cement mortar coating of at least 5 mm.	a) EN 14628 b) EN 15189

Precautions of Handling, Storing and Installation of DI Pipes

This section recommends practices for handling, storing and installing external coating systems for external corrosion control on piping systems.

• Pipes with coating system should be so handled that there is no damage to the system during handling, storage and installation

Table 2.13.5: Criteria for Selection of Special Lining and Coatings for Ductile Iron pipes

Parameters				Corrosivity			Protection Systems		Ref. Specification
Soil Resistivity	P^H	Moisture Content	Water Table	Chlorides	Cinders/ Landfills		For Class C20 and Above	Low Thickness Pipe	
(ohm-cm)		(%)	Low/ Medium/ High	(ppm)	Existence/ Non-Existence				
> 4000	6.5-7.5	<15%	Low	< 50	Non - existence	Very Low	Zinc Rich Paint with Finishing Layer of Bitumen	Metallic Zinc Coating (130 g/m²) with finishing layer of Bitumen	ISO:8179/ Part 1 /2
3000-4000	6.5-7.5	<15%	Low	< 50	Non - existence	Low	Metallic Zinc Coating (130 9/m²) with finishing layer of Bitumen	Thicker Metallic Zinc with finishing layer of Bitumen	ISO:8179/ Part 1/2
1500-3000	5.0-6.0	15-30%	Medium	>50	Existence	Medium	Zinc Rich Paint with finishing layer of Bitumen + Polyethylene sleeving	Metallic Zinc Coating (200 g/ m²) with finishing layer of Bitumen + Polyethylene sleeving	ISO:8179/ Part V1 + ISO:8180
1500-3000	5.0-6.0	> 30%	Medium/ High	> 50	Existence	Aggressive	Metallic Zinc Coating (200 g/m²) with finishing layer of Bitumen + Polyethylene sleeving	Thicker Metallic Zinc with finishing layer of Bitumen + Polyethylene Sleeving	IS0:8179 + ISO:818O
< 1500	< 5.0	> 30%	High	> 50	Existence	Highly Aggressive	Thicker Metallic Zinc with finishing layer of Bitumen + Polyethylene Tape Wrapping (30 % overlap)	Thicker Metallic Zinc with finishing layer of Bitumen + Polyethylene Tape Wrapping (30% overlap)	
< 1000	< 5.0	< 30%	High	50	Existence	Highly Aggressive	Thicker Metallic Zinc with finishing layer of Bitumen + Polyethylene Tape Wrapping (50% overlap) + Cathodic Protection Epoxy Coating	Thicker Metallic Zinc with finishing layer of Bitumen + Polyethylene Tape Wrapping (50% overlap) + Cathodic Protection Epoxy Coating	ISO:15589/ Part 1:2003
Pipes exposed to atmosphere instead structures or above ground						-	Expoxy Coating	Expoxy Coating	
Pipes to be used under aggressive sewage and microbial induced corrosion conditions						-	Polyurethane Coating	Polyurethane Coating	
In case of stray currents, the necessary protection may be decided based on discussion with necessary protection									

Note: The above table is for guideline only

2.14 Welding of Ductile Iron Pipe

Unlike cast iron, ductile iron can be welded to facilitate accommodation of fixtures, field repairing and attaching accessories. The lower surface-to-volume ratio of the nodular graphite in Ductile Iron results in less Carbon dissolution and the formation of fewer types of carbide and less carbon martensite. Further, Ductile Iron pipe is having a predominant ferritic matrix, is capable of local plastic deformation to accommodate welding stresses.

The filler material used for welding for Ductile Iron is of Nickel-Iron alloys (with 50-55% of nickel), or Ni-iron Manganese alloys. Manual arc welding with feasible nickel iron alloy electrode is not recommended.

Material for Welding

Table 2.14.1: Composition of Fe-Ni Alloy Electrode

Type of Electrode		Dimension
Ni-Fe	Ni-Fe-Mn	
Ni - 50 to 55%	Ni - 43.5%	Length - 350 mm
Fe - 40 to 45°/o	Fe -44%	Diameter mm -2.4, 3.2, 4.0 & 4.8
C - 1.5%	C - 1.5%	
	Mn - 11%	

Table 2.14.2: Amperage Range for Different Size of Electrode

Electrode size (mm)	Amperage - AC supply (Amp)	Amperage - DC supply (Amp)
2.4	56-65	50-65
3.2	80-100	80-100
4.0	100-125	100-125
4.3	125-150	120-150

Type of Welding Process

1. Shielded Metal-Arc Welding: It is the most common welding process used on Ductile Iron pipe in the field.
2. Metal Inert Gas (MIG) Welding: MIG arc welding using Argon or Argon-Helium shielding gas with short circuiting transfer is suitable for joining Ductile Iron with Mild steel. Because of the relatively low heat input with this process, the hard portion of the heat affected zone is usually confined to a thin layer next to welded metal. As a result the strength and ductility of the welded joint are about the same as those of the base material.

2.15 Design of Thrust Block

Piping systems are subjected to unbalanced thrust forces resulting from static and dynamic fluid forces acting on the pipe. These forces must be balanced to maintain integrity of the piping system. Unbalanced thrust forces occur at change in direction of flow such as bends, tees, reducers, valves and dead ends. Reactive forces can be provided in the form of thrust blocks, or transmitting forces in the pipe wall by restrained, harnessed, flanged or welded joints (forces from the pipe shell is transferred to the soil).

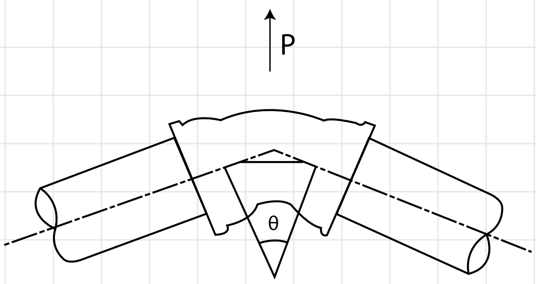
2.15.1 Principles for Design of Thrust Block

The fundamental principles of fluid mechanics are used for determining the resultant/reactive forces in the piping system. They are as follows:

a. Conservation of Matter (mass)
b. Conservation of Energy
c. Conservation of Momentum

The thrust forces developed at different flow transition points are given below:

a) At Bend

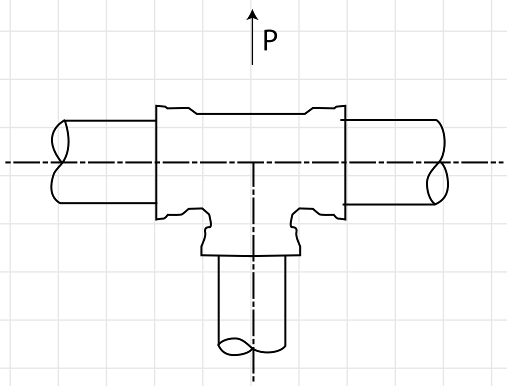


$$P = 2pA \sin \frac{\theta}{2}$$

Where,

P = Thrust force
p = Internal pressure
A = Sectional area of pipe
θ = Angle of blend

b) At Tee

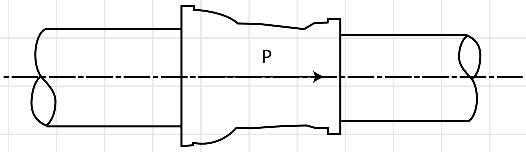


$$P = pA$$

Where,

P = Thrust force.
p = Internal pressure
A = Cross Sectional are of branch pipe

c) At Reducer



P = p (A-a)

Where,

P = Thrust force
p = Internal pressure
(A-a) = Difference in Cross Sectional area
A = c/s Area of bigger pipe
a = c/s Area of smaller pipe

d) At Pipeline End

P = pA

Where,

P = Thrust force
p = Internal pressure
A = Cross Sectional are of pipe

Table 2.15.1: Thrust force (in KN) on Pipe Bends (Considering 1 bar Internal Pressure)

DN	90° Bend	45° Bend	22-½° Bend	11-¼° Bend	Pipe End
80	0.711	0.385	0.196	0.098	0.502
100	1.110	0.601	0.306	0.154	0.785
150	2.498	1.352	0.689	0.346	1.766
200	4.441	2.403	1.225	0.616	3.140
250	6.938	3.755	1.914	0.962	4.906
300	9.991	5.407	2.757	1.385	7.065
350	13.599	7.360	3.752	1.885	9.616
400	17.763	9.613	4.901	2.462	12.560
450	22.481	12.166	6.202	3.116	15.896
500	27.754	15.020	7.657	3.847	19.625
600	39.966	21.629	11.027	5.540	28.260
700	54.398	29.440	15.008	7.540	38.465
750	62.446	33.796	17.229	8.656	44.156
800	71.050	38.452	19.603	9.849	50.240
900	89.923	48.666	24.810	12.465	63.585
1000	111.016	60.081	30.629	15.389	78.500
1100	134.329	72.698	37.061	18.620	94.985
1200	159.863	86.517	44.106	22.160	113.040
1400	217.591	117.759	60.033	30.162	153.860
1500	249.785	135.183	68.916	34.625	176.625
1600	284.200	153.808	78.411	39.395	200.960
1800	359.691	194.663	99.239	49.859	254.340
2000	444.063	240.325	122.517	61.555	314.000
2200	537.316	290.793	148.245	74.481	379.940

Eg.: To calculate the thrust force on DN 200 90˚ bend at an internal pressure of 20 bar Multiply 4.441 x 20 = 88.82 KN

2.15.2 Calculation of Thrust Block in Ductile Iron Pipes

Concrete Thrust Block

The principle used for designing of the Thrust block is that the thrust force is resisted by an adequate bearing area of the concrete block supported by the adjacent soil.

The Steps involved are:
Calculate the Bearing area of the soil

$$\text{Bearing area required} = \frac{\text{Thrust Force}}{\text{Safe horizontal bearing capacity of soil}}$$

$$A = \frac{F_u}{P_{bearing}}$$

Where:

F_u = total thrust force (kN)
A = bearing area of thrust block (m^2)
$P_{bearing}$ = bearing capacity of soil (kN/m^2)

Note: The Factor of Safety = 1.5 or 2 should be multiplied with the bearing area calculated.

Determine the bearing capacity of the surrounding soil.

Table 2.15.2: Bearing Capacities for Different Type of Soil

Soil Type	Bearing Capacity (KN/ sqm)
Rock	
Hard Sound Rock: Broken with some difficulty and rig when struck	10000
Medium Hard Rock: Cannot be scraped or peeled with a knife. Hand held specimen breaks with firm blow of the pick	5000
Soft Rock: Can just be scraped with a knife: Indentation of 2 to 4mm with firm blow of the pick point	2000
Very Soft Rock: Can be peeled with a knife: Material crumbles under firm blows with sharp end of a geological pick	1000
Non Cohesive Soils	
Dense Well-graded Sand, Gravel and Sand-gravel mixture	
Dry	400
Submerged	200
Loose Well-graded Sand, Gravel, Sand-gravel mixtures or Dense Uniform Sand	
Dry	200
Submerged	100
Loose Uniform Sand	
Dry	100
Submerged	40

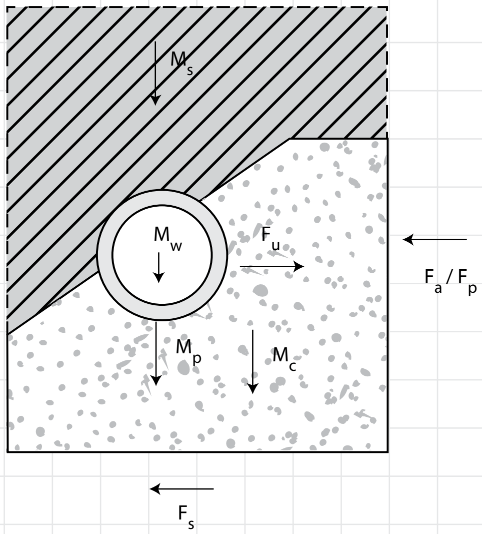


Fig. 2.15.1: Schematic diagram of Thrust Forces acting on pipe and surrounding soil

Calculate the Frictional Resistance.

The Total Frictional Resistance (Fs) between the thrust block and soil is given by,

$$F_s = \mu (M_c + M_w + M_s + M_p) g$$

Where:

M_c = Mass of concrete thrust block (in kg)
M_w = Mass of water in pipe resting on the thrust block (in kg)
M_s = Mass of soil on top of thrust block (in kg)
M_p = Mass of pipe resting on thrust block (in kg)
μ = Frictional coefficient between soil and thrust block
g = Acceleration due to gravity (m/s2)

Table 2.15.3: Friction between thrust block and different type of soil

Soil	Friction Coefficient (µ)
Clean Hard Rock	0.7
Clean Gravel to Coarse Sand	0.55 to 0.6
Clean Fine to Medium Sand, Medium to Coarse Sand With Silt, Gravel with Silt or Clay	0.45 to 0.55
Clean Fine Sand: Fine to Medium Sand with Silt or Clay	0.35 to 0.45
Fine Sand with Silt, Non-Plastic Silt	0.3 to 0.35
Very Firm and Hard Clay	0.4 to 0.50
Medium to Hard Clay and Clay with Silt	0.3 to 0.35

N.B: The Friction coefficient (µ) is affected by the degree of compaction and moisture content in soil.

Design of Concrete Block for Horizontal Bend

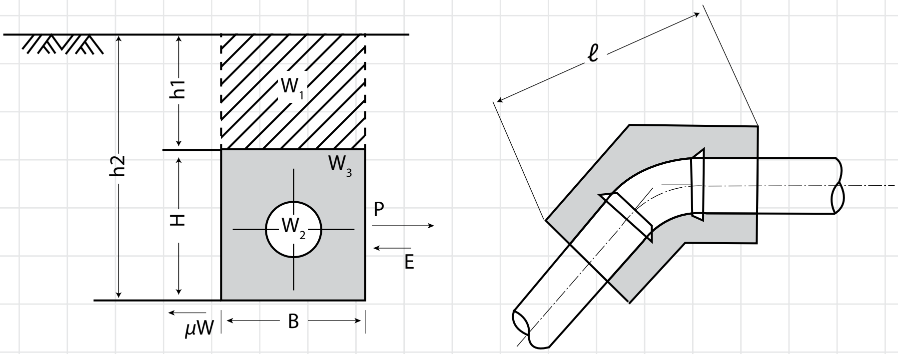


Fig. 2.15.2: Schematic Diagram of Thrust Forces Horizontal Bend

Where:

P = Thrust force

W = Total weight of the block bottom (= $W_1 + W_2 + W_3$)

W_1 = Weight of soil on the block

W_2 = Weight of water and pipe in the block

W_3 = Weight of block

μW = Friction force

μ = Friction coefficient between concrete block and soil

E = Passive earth pressure at the backside of the block

$$E = \frac{1}{2} C_e \gamma (h_2^2 - h_1^2) \ell$$

Ce: Coefficient of passive earth pressure

$$C_e = \tan^2 (45° + \frac{\Phi}{2})$$

Φ: Internal friction angle of soil

γ: Unit weight of soil

ℓ: Projection length of block

For the horizontal bend, the concrete block should satisfy:

$P < \mu W + E$

Note: When concrete block is constructed under the water table, buoyancy should be taken into consideration for the design.

Design of Concrete Block for Upward Vertical Bend

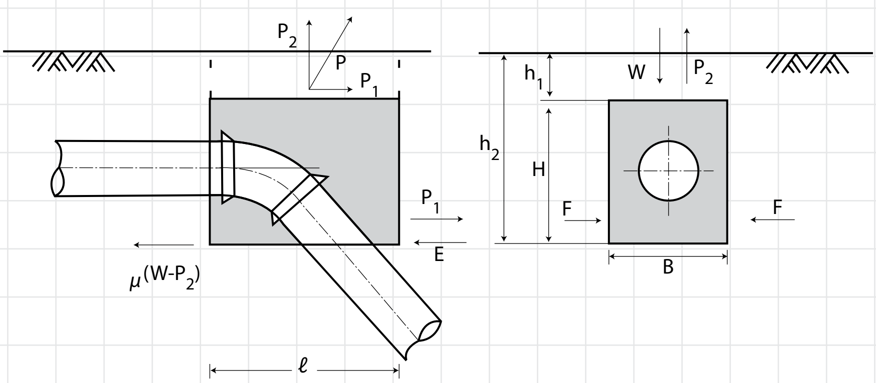


Fig. 2.15.3: Schematic Diagram of Thrust Forces Acting on Upward Vertical Bend

Where:

P	=	Thrust force
P_1	=	Horizontal component of the thrust force
P_2	=	Vertical component of the thrust force
$\mu(W-P_2)$	=	Friction force
E	=	Passive earth pressure at the backside of the block
F	=	Active earth pressure at the both sides of the block

Concrete block should be designed to satisfy the following conditions:

a) Against the horizontal component of the thrust force

$$P_1 = P\sin\frac{\theta}{2} < \mu(W-P_2)+E$$

b) Against the vertical component of the thrust force

$$P_2 = P\cos\frac{\theta}{2} < W+F$$

$$F = 2F^1 = \frac{1}{2}C_e^1 \gamma_s (h_2^2 - h_1^2) 2 (B+\ell)\mu$$

Where:

B	=	Width of the block
ℓ	=	Length of the block
C_e	=	Coefficient of active earth pressure
$C_e^{\,1}$	=	$\tan^2(45°-\phi/2$

Note: When concrete block is constructed under the water table, buoyancy should be taken into consideration for the design.

Design of Concrete Block for Downward Vertical Bend

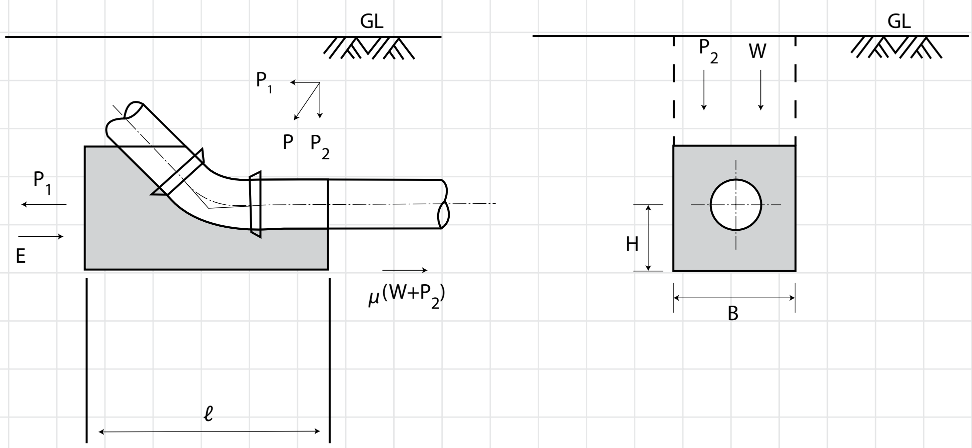


Fig. 2.15.4: Schematic Diagram of Thrust Forces Acting on Downward Vertical Bend

Concrete block should be designed to satisfy the following conditions:

a) Against the horizontal component of the thrust force

$$P_1 = P\sin\frac{\theta}{2} < \mu(W+P_2)+E$$

b) Against the vertical component of the thrust force

$$P_2 = P\cos\frac{\theta}{2}$$

$$\sigma = \frac{W+P_2}{B\ell} < \sigma_a$$

Where:

σ = Required bearing capacity of the ground

σ_a = Allowable bearing capacity of the ground

When the allowable bearing capacity of the ground is not sufficient, a number of piles or other counter measures are required.

Note: When concrete block is constructed under the water table, buoyancy should be taken into consideration for the design.

2.15.3 Design of Concrete Block (Joint Exposed)

There are locations in a pipeline where the bends and tees are kept exposed for accessibility to the joints during or after the hydrostatic pressure test at site. Concrete blocks are used to resist the thrust forces on such exposed joints.

Reference to 'American Water Works Association (AWWA M41)' the design procedure of concrete block on horizontal bend is given as below:

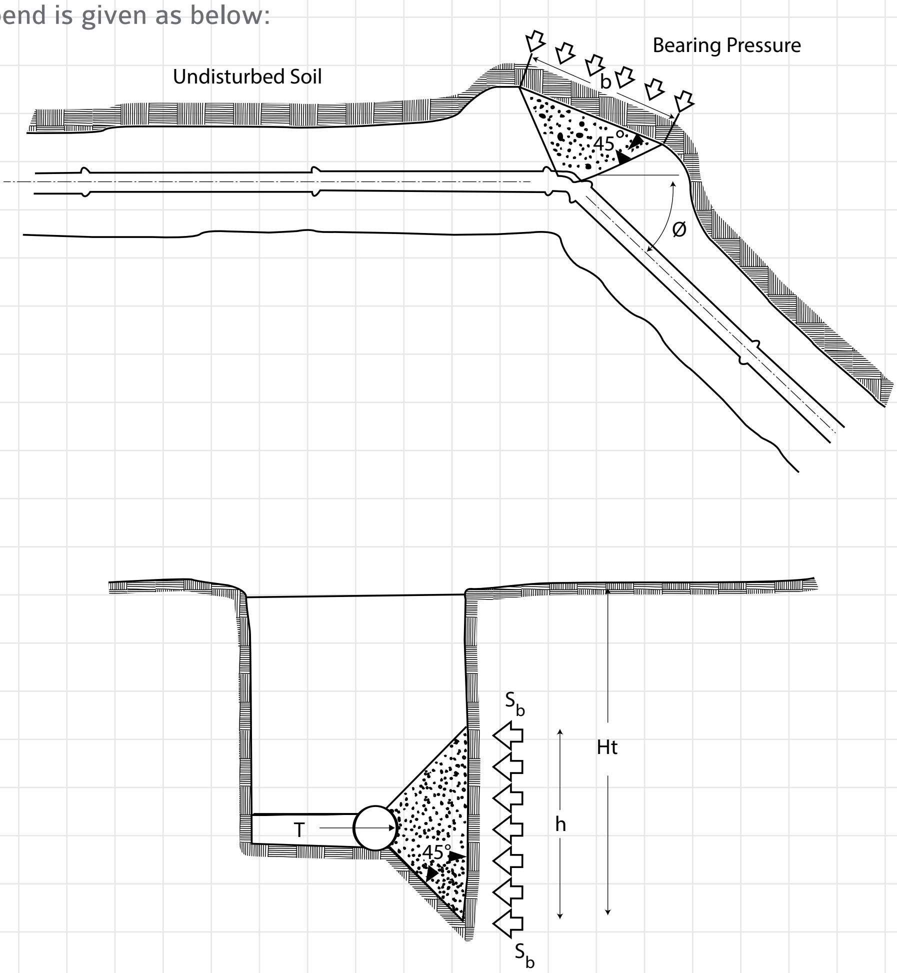


Fig. 2.15.5: Concrete Block with Joint Exposed

The thrust force is transferred to the soil through a larger bearing area of the thrust block, such that the resultant pressure on the soil does not exceeds its bearing strength.

Design of thrust blocks consists of determining the appropriate bearing area of the block for a particular set of soil conditions. The general criteria for design of thrust blocks are as follows:

- Bearing surface should, where possible, be placed against undisturbed soil. Otherwise, for filled up soil, a compaction not less than 90 percent Standard Proctor density should be achieved.
- Block height 'h' should be equal to or less than one half the total depth to the bottom of the block 'Ht', but not less than the pipe outside diameter 'DE'.
- Block height 'h', should be chosen such that the calculated block width 'b' varies between one and two times of height.

The required block area A_b is given as:

$$A_b = hb = S_f P / S_b$$

Then for Horizontal bend,

$$b = \frac{2S_f PA \sin(\theta/2)}{h S_b}$$

Where:

P = Thrust Force

S_f = Factor of Safety (usually 1.5)

S_b = Horizontal Bearing Strength of Soil

A = Cross-sectional area of Pipe

b = Thrust Block Width

h = Thrust Block Height

Table 2.15.4: Friction Coefficient between Pipe or Concrete and Soil

Type of Soil	Friction Co-efficient
Gravel	0.6
Clay	0.2 - 0.5
Dry Sand	0.5
Wet Sand	0.33

Table 2.15.5: Unit Weight and Internal Friction Angle of Soil

Type of Soil	Conditions	Unit Weight (KN/m3)	Internal Friction Angle (Degree)
Normal Soil	Dry	14	35 - 40
	Wet	16	45
	Saturated	18	25 - 30
Sand	Dry	16	30 - 35
	Wet	18	40
	Saturated	20	25
Sand Mixed with Clay	Dry	15	40 - 45
	Wet	19	20 -25
Clay	Dry	16	40 - 45
	Wet	20	20 - 25
Gravel	Dry	18	35 - 40
	Wet	19	27 - 40
Silt	-	17	10 - 20

MANUFACTURING PROCESS

Manufacturing Process of Ductile Iron Pipes

Molten Iron Preparation

Molten metal is produced in the blast furnace. The super heating and chemical correction of the molten metal is done in the induction furnace by adding required quantity of Mild Steel scrap. The molten metal from the Induction Furnace is further taken into converter and Magnesium is added to convert the graphite into spheroidal shape.

The molten metal treated with magnesium is transferred to the casting platform.

Centrifugal Casting

The molten metal is poured into the water-cooled jacketed metallic centrifugal casting machine, spinning at high speed. The mould is cooled by the water flowing in the jacket which helps in solidifying the molten metal in the form of a pipe. The casted pipe is extracted by an extractor and transferred to annealing furnace.

Annealing

Annealing is a heat treatment wherein a material composition is altered, causing changes in its properties such as strength and hardness. Annealing is used to induce ductility, soften material, relieve internal stresses, refine the structure by making it homogeneous and improve cold working properties. Annealing furnace is a horizontal chain style furnace made up of heating section, heat holding section, slow cooling section and fast cooling section. The Ductile Iron pipe, after entering the furnace, is pushed rolling forward by claws on chains driven by a speed regulating motor.

Zinc Coating

After heat treatment the DI pipe is transferred to Zinc Coating section where the Zinc wire is melted using electric arc and applied to the external surface of the pipe by spraying evenly.

Hydrostatic Testing

After Annealing, bell and spigot end, internal and external surface of the DI pipes are finished to remove fins and so on, and then checked for their dimensions. After cleaning and finishing, Ductile Iron pipes are hydro tested one by one as per the standard specification and requirements.

Cement Lining

A mixture of cement, sand and water as per specified proportion is pumped through a lance into the pipe spinning at low speed. The pipe is then rotated at high speed where excessive water from the cement slurry is discharged leaving behing dense cement mortar lining the internal surface of the pipeline. Cement lining is then passed to the curing chamber where the desired humidity is maintained.

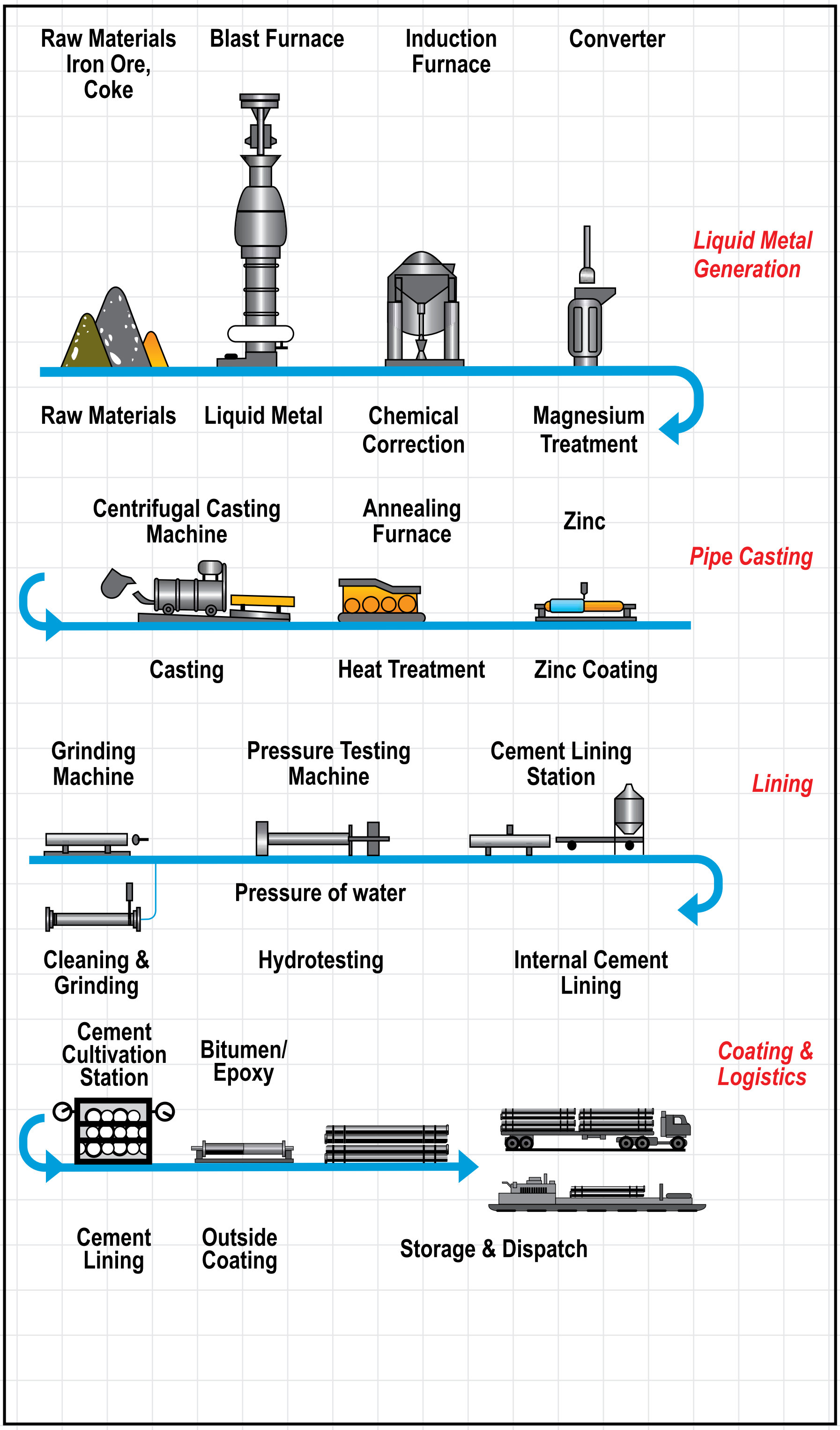
Bitumen Coating

After curing the DI pipes are transferred to Bitumen/Epoxy coating stations. The anti-corrosive Bitumen/ Epoxy layer is applied to external surface of pipes and internal surface of socket. The Bitumen/Epoxy layer applied must be even, without any trace of dripping or flowing. The pipes after coating, are transferred to drying chambers.

Marking, Packing and Shipping

The pipes coming out of drying chambers are marked with installation mark at spigot end and various marking as per specification including the trade mark, if any, are painted on the external surface of pipes. After marking, the pipes are transferred to yard for final inspection and despatches to respective clients.

Flow Chart of Manufacturing Process of Ductile Iron Pipes



QUALITY ASSURANCE PLAN

4.1 Quality Control

Quality Control (QC) is a collection of methods and techniques for ensuring that a product is conforming to standards and is produced & delivered according to given requirements.

Quality is measured by the degree of conformance to pre-determined specifications and standards, and deviations from these standards can lead to poor quality and low reliability. Efforts for quality improvement are aimed for elimination defects, reduction of rejection and hence overall reductions in production costs. Quality checks done on Ductile Iron pipes include the following parameters:

1. **Thorough Check of All Raw Materials for Compliance with Respective National and International Standard Specifications**
2. **Chemical Analysis**
   - Composition of molten metal
   - Chemical analysis
3. **Mechanical Test**
   - Tensile strength
   - Elongation
   - Hardness
   - Microstructure
4. **Dimensions**
   - Sample checking for socket dimensions
   - Checking on external diameter
   - Checking internal diameter
   - Pipe thickness
   - Length of pipes
   - Ovality
   - Straightness of pipes, champhering of spigot end
5. **Surface Defect Checks**
   - Pin holes
   - Pitting
   - Cut marks
   - Surface netting/imperfection
   - Excess mould powdering/undissolved mould powder
6. **Casting Defects Checks**
   - Cold shots
   - Lapping of metal surface
7. **External Coating - Online Quality Checks**
   - Measurement of Zinc/Zinc Aluminiun mass deposit on pipe surface
   - Measurement of finishing layer (Bitumen/resin) thickness on pipe surface
8. **Internal Lining - Online Quality Checks**
   - Checking of type of cement being used
   - Checking of water cement and sand ratio
   - Checking of cement-sand ratio
   - Checking of wet CML thickness
   - Checking for uniform holiday free seal coating over cement mortar lining (if seal coat provided)

4.2 Stages of Manufacturing and Quality Checks

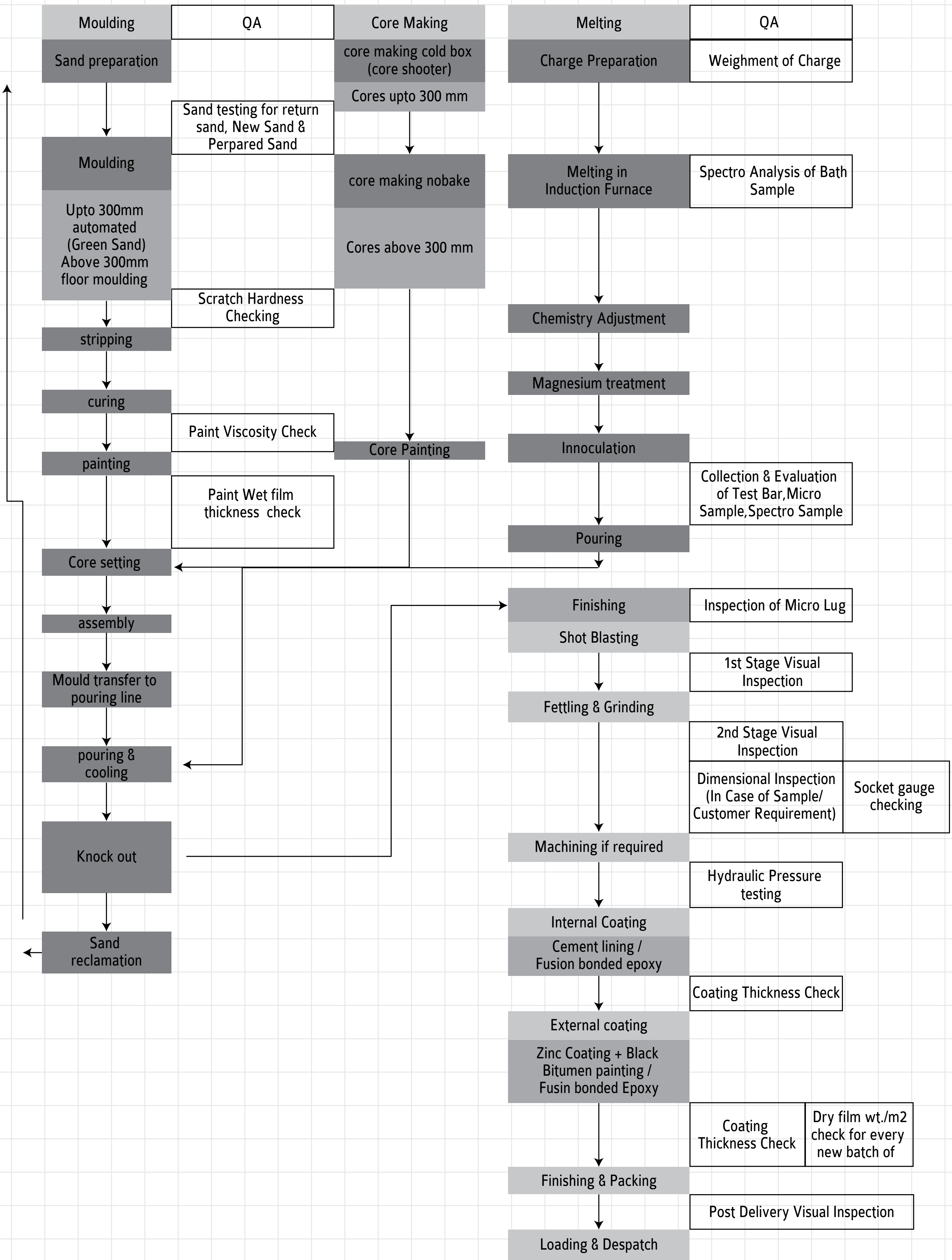
4.2.1 Ductile Iron Pipes

All the tests mentioned earlier are carried out at different stages of production as shown in the following flow chart:

Stages of Manufacturing	Quality Checks
Raw Material Reciept/ Storage	Analysis of Raw Material According to Specification for Every Consignment
Mini Blast Furnace Operation	Operational Parameters, Chemical Analysis, Temperature
Liquid Metal Furnace	Chemical Analysis
Chemistry Adjustment and Super Heating In Induction Furnace	Temperature and Chemical Analysis, Addition of MS Scrap if Required
Magnesium Treatment in Converter	Magnesium Addition by Weight/Length of Wire
Pipe Casting	Spinning Parameter; Temperature, Core for Socket, Mould for Pipe, Inoculation Powder/ Mould Powder
Heat Treatment (Annealing)	Physical Test, Microstructure
Zinc Coating	Zinc Mass Deposit and Continuity
Finishing	Socket Grove; Visual; Gauging; Spigot Ends for Champhering
Hydrostatic Pressure Testing	Pressure Rating, Body Leak and Sweat
Cement Mortar Lining	Cement/ Sand/Water Ratio, Thickness. Bore Checking and Uniformity
Steam Curing	Temperature; Humidity; Visual and Gauging
Bitumen Coating	Thickness and Continuity
Marking	As Per Specification and Client Requirement
Stacking & Bundling (if required)	Type of Stacking, Recommended Height and Strength of Bundle
Party/ Third Party Inspection	
Dispatch	To Ensure Correct Ordered Material Supplied

4.2.2 Ductile Iron Fittings

Flow Chart of Manufacturing Process of Ductile Iron Fittings



4.3 Sample Size

To carry out inspection it is practically not possible to check each and every pipe. Hence the sample pipes are segregated from the LOT. The sample size should be as follows:

Table 4.3.1: Sample Size for Different Lots of Pipe Diameter

S. No.	Lot Size	Sample Size	Acceptance
	(Numbers)	(Numbers)	(Numbers)
1	Up to 50	8	0
2	51 to 100	13	1
3	101 to 150	20	1
4	151 to 300	32	2
5	301 and above	50	3

Note: From the above sampled size randomly selected pipes are sent for mechanical properties test and chemical composition test.

INSTALLATION GUIDE

5.1 Packing

Bundled Pipe

Bundling of DI pipe is done mostly for break-bulk shipment. Bundling is sometimes also done for facilitating the loading of small size pipes (DN 80 to DN 150), in container shipment as well. The pattern of bundling may change on case to case basis depending on mode of shipment.

Each bundle has two wooden battens placed parallel to each other at the bottom. Separator wooden battens are also provided between two rows/layers of pipes to provide stability to the bundle. The pipes are bundled such that the successive pipes have sockets in opposite direction, viewed vertically or horizontally. The pipes are strapped with adequate number of steel straps to ensure that the straps do not snap even during multiple handling.

Shipping marks are provided on each bundle with the help of metal tags or self adhesive stickers.

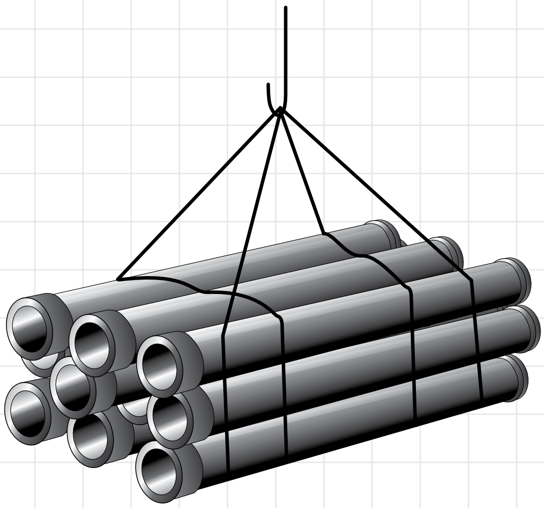


Fig. 5.1.1: Building of Pipes for Break-bulk Shipment

Loose Pipes

In both types of shipments i.e. break-bulk or container shipment, the pipes of sizes DN 200 and above are shipped in loose condition. These pipes require careful handling to avoid damages. Shipping marks are provided by stenciling or pasting adhesive stickers on the pipes.

Packing of Accessories

Rubber Gasket

Rubber gaskets are packed in corrugated card board boxes properly sealed in dark PE bags (so that they are not exposed to air and light) when shipped in containers and in wooden cases and when shipped by conventional vessels.

Lubricants

Lubricants are packed in plastic jars which are further packed in corrugated card board boxes or wooden cases, as the case may be.

Lifting of Pipe

Single pipes should be handled using chains, hooks, slings or fork lift. When chains and hooks are used for lifting pipe, it should be lifted one by one. The hooks and chains used should be of correct sizes and hooks should always be padded. For lifting multiple pipes at a time, spreader bar should be used. When fork lift trucks are used for unloading pipes, it should be ensured that the fork blades do not damage the pipe or external coating.

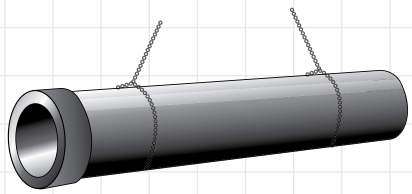


Fig. 5.2.1: Lifting of Pipes with Sling

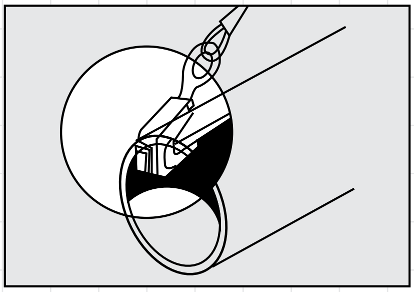


Fig. 5.2.2: Lifting of Pipes with Hooks

Loading and Transportation

All pipes should be secured to the lorry or railway wagon using rope/strips during transit. The pipes may be loaded on the vehicle in bundles, pyramid or straight formation. Small pipes are supplied in bundles or single pipes as per the customer choice. The higher diameter pipes are despatched as single pipes.

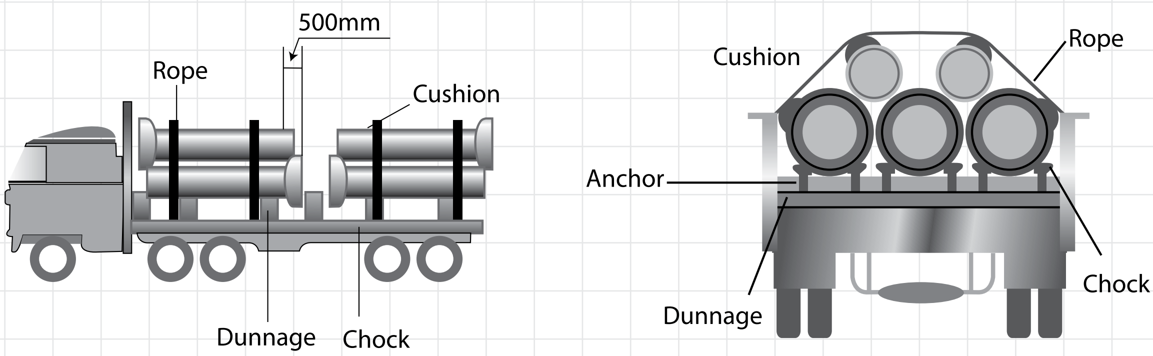


Fig. 5.2.3: Arrangement of Pipes for Transportation on Road

Unloading

When cranes are used for off-loading individual pipes, slings of lifting beams with the purpose designed padded hooks should always be used. In no circumstances wire ropes, chains, unpadded metal hooks or lifting hooks should be used, directly in contact with pipe. Smaller sizes, up to DN 400 may be lifted with wide fabric slings.

When cranes are not available and the mass permits (up to DN 250), individual pipes should be off-loaded by rolling them down a ramp formed of timber skids extending from the vehicle side to ground. Suitably steadying ropes should be used to prevent the pipes from rolling down at excessive speed and striking other pipes or objects on the ground. In no circumstance the pipe should be allowed to fall on floor, tires or sand.

The storage area should be leveled, horizontal with a hard surface. Bundled pipe can be off-loaded directly onto the storage area. Bundles can be stacked on top of each other to a height not to exceed the recommended stacking height (as given in table 5.2.1). Loose pipes should be stacked on a bottom base of wooden bearing having thikness of at least 100mm.

Table 5.2.1 Stacking Height Limitations of Ductile Iron Pipe

DN Size in mm	Maximum Layer of Pipes
100	16
150	14
200	12
250	10
300	8
350	7
400	7
450	6
500	6
600	4
700	3
800	2
900	2
1000	2
1100	2
1200	2
1400	1
1500	1
1600	1
1800	1
2000	1
2200	1

Unloading of Ductile Iron pipes

Ductile Iron pipes should be unloaded from the truck with cranes with proper slings and padded hooks. Fork lifts with specially padded booms are also used for unloading pipes from the truck. In no circumstances wire ropes, chains, unpadded metal hooks or lifting hooks should be used, which are in direct contact with the pipe.

Following precautions should be taken while unloading the pipes:

- Trucks should be parked at level ground during unloading.
- Proper caution messages should be displayed while unloading the truck.
- Chock blocks should be properly secured before the straps are released, to prevent pipe rolling out of control.
- Steel bands should be cut with long handle steel cutter.
- Pipe should not be rolled off or dropped on old tires or cushion.
- Personnel should remain away from the truck while unloading the pipes.

Fig. 5.2.4: Fork Lift with Padded Booms Used for Unloading of Pipes from Trucks

5.3 Stacking

5.3.1 Square Stacking

Pipes should be stacked socket to spigot. The pipes' axis should be parallel to the ground. The ground should be perfectly flat and hard. Each alternate layer of pipe should be positioned with their axes at right angles to those of the layer below. The pipes rest directly on the layer below. When forming a stack it is important to ensure that pipes are lowered in such a manner that damage does not occur to the protective outside coating/s.

Fig. 5.3.1: Square Stacking of DI Pipes

5.3.2 Parallel Stacking

Pipes should be stacked socket to socket on each layer. When the first layer is complete, wooden bearers of adequate thickness should be provided to ensure sockets of one layer do not touch barrels of lower layer. Wooden bearers should be placed approximately 600mm from each end of the pipe. The sockets of each successive layer should be reversed.

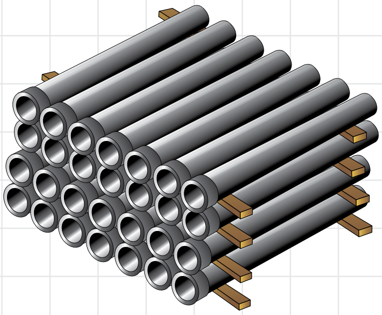


Fig. 5.3.2: Parallel Square Stacking of DI Pipes

5.3.3 Pyramid Stacking

In Pyramid Stacking, each pipe nestles between the two pipes immediately below it. In one layer the sockets of each pipe should be in the same direction. In successive layers, the pipe should be reversed. It is absolutely essential that pipes at the ends of the bottom layer should be securely chocked along their length. There is no restriction in the number of pipes along the bottom layer.

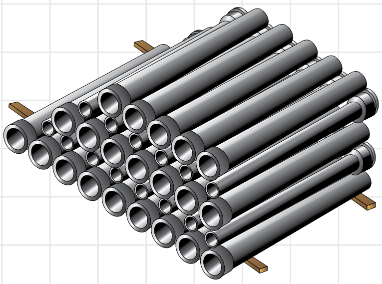


Fig. 5.3.3: Pyramid Stacking of DI Pipes

5.4 Lowering

5.4.1 Trench Width and Trench Types

Excavation may be done by hand or by machine. The trench should be so dug that pipe is laid to the required gradient and at the required depth. The width of the trench at bottom should provide not less than 200mm clearance on both sides of the pipe. Additional width should be provided at positions of sockets and flanges for jointing. Trench should be of sufficient width so that placing of timber supports, strutting and planking and handling of specials, if required can be carried out conveniently. The type of trench and bedding in different soil strata is shown below:

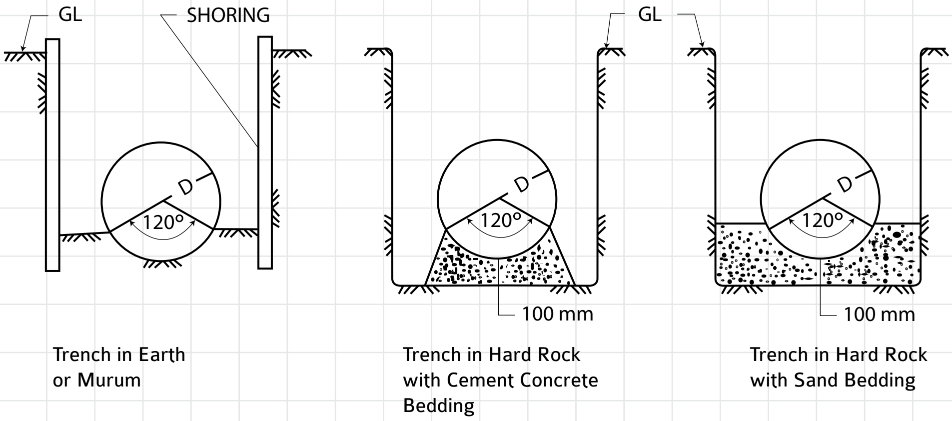


Fig. 5.4.1: Position of DI Pipes in Different Bedding Conditions

Whenever, mechanical compaction is not required, the suggested widths of the trench as guideline are given below:

Table 5.4.1: Suggested Trench Width

Nominal Size (DN)	Trench Width (mm)
80	700
100 – 125	750
150	770
200	810
250	870
300	915
350	970
400	1020
450	1070
500	1120
600	1220
700	1340
800	1430
900	1525
1000	1680
1200	1830
1400	2030
1600	2285
1800	2480
2000	2700
2200	2890
2400	3095
2600	3300

5.4.2 Pipe Laying

- Pipes should at all times be handled with care. Pipes should be lowered into the trench with tackle suitable for the pipes.
- A mobile crane or a well designed set of shear legs should be used and the position of the sling checked, when the pipe is just clear off the ground, to ensure a proper balance.
- Where lifting equipment is not available, small diameter pipes should be lowered mannually.
- All persons should vacate the section of the trench into which the pipe is being lowered.
- All construction debris should be cleared from the inside of the pipe either before or just after a joint is made. This can be done by passing a pull-through along the pipe, or by hand, depending on a diameter of the pipe.
- When laying is not in progress, a temporary end closure should be fitted securely to the open end of the pipeline. In the event of the trench becoming flooded, in which case the pipes should be held down either by partial re-filling of the trench or by temporary strutting.

5.5 Jointing

Jointing procedures will vary according to the type of joint being used. Basic conditions which should be ensured for all types of joints are:

- Cleanliness of all parts
- Correct location of components
- Centralization of spigot within socket
- Strict compliance with jointing instructions

5.5.1 Jointing Methods

- Centre the spigot in the socket and keep it in this position.
- Push the spigot into the socket, checking alignment and level.
- Deflect, if required, within the permissible limits.
- Push in the spigot until the mark is in line with the socket face. Do not go beyond this position.
- The assembly of DI push-on joint pipes and connections is easily performed using some standard equipment such as crowbars, TIRFOR type winches or the bucket of a machanical excavator.

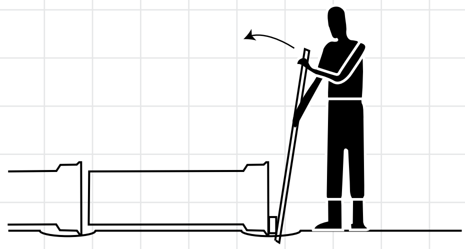
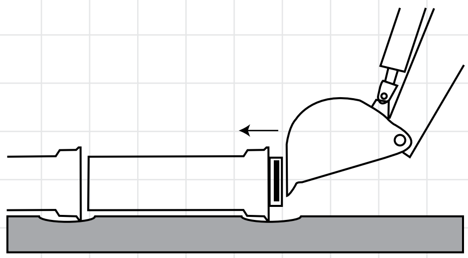
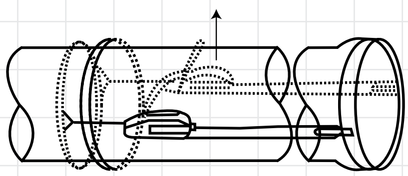
CROWBAR METHOD (for DN 80 to 150) The crowbar levers against the ground. The pipe socket face must be protected with a piece of hard wood. The jointing done by the leverage of the crowbar.	
EXCAVATOR BUCKET (for all Diameter) The hydraulic force of the arm of a mechanical excavator can be effectively used to assemble pipes and straight fittings. However the following precautions are to be taken: • Between the socket and excavator bucket, place a wooden batten as a cushion • Exert a slow and steady force observing the rules for joint assembly	
TIRFOR type mechanical winches or chain pulley: • DN 150 to 300: TIRFOR type winch, capacity 1.6 Tons, steel cable and rubber protected hooks • DN 350 to 600: TIRFOR type winch, capacity 3.5 Tons, steel cable and rubber protected hooks • DN 700 to DN 1200: Two TIRFOR type winches, capacity 3.5 Tons, placed diametrically opposite, Two steel cables and two rubber protected hooks • DN 1400 to DN 2200: Three TIRFOR type winches, capacity 5.0 Tons, placed diametrically @ 120° to each other, three steel cables and three rubber protected hooks	
#Any of the above methods as found suitable can be used.	

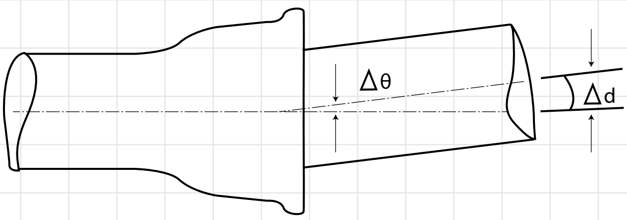
Fig. 5.5.1: Push-on Jointing Method for DI Pipes

5.5.2 End Preparation for Jointing

Where Push-on joints are to be used, the cut ends should be chamfered by filing or grinding similar to the original spigot ends.

For DN 300 and above sizes, where the pipes are to be checked and ascertained as being suitable for cutting i.e. the pipe OD should be within the ovality tolerances as specified in the relevant standard.

5.5.3 Permissible Deflection after Laying



Δθ = Deflection, Δd = Deviation, for Push-on Joint and Mechanical Joint

Allowable Deflection has been given in Table 2.10.4

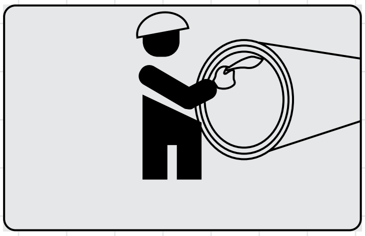
5.5.4 Lubrication

A layer of lubrication should be applied on the exposed surface of the gasket, and the spigot end. The lubricating paste to be brush applied. No petroleum base lubricant should be used.

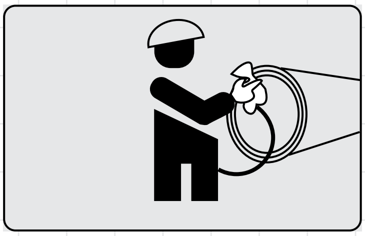
5.5.5 Jointing of Push-on Joint

a) Procedure for Insertion of Rubber Gasket for Push-on Joint

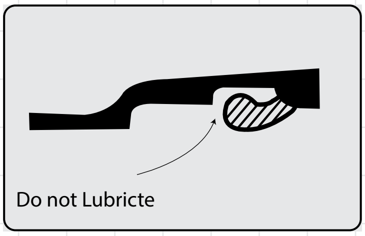
- Clean the inside of socket groove where gasket heel is to be inserted using a wire brush and a rag.



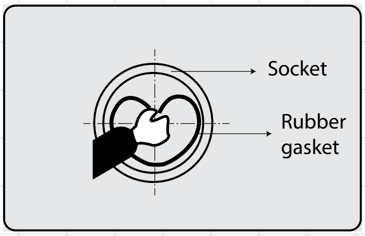
- Clean gasket and insert to socket with the squre section gasket heel in the retaing groove.



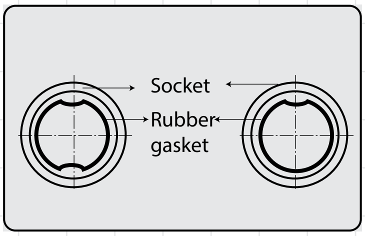
- Coat with lubrication paste on the spigot end of the pipe and the exposed surface of the gasket.



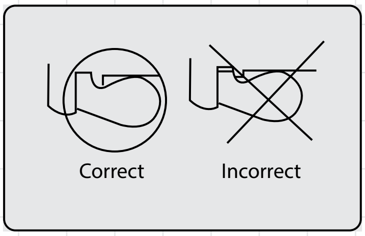
- The insertion of DN 80 to DN 150 gaskets is facilitated by turning the gasket inside out, gripping one end and folding the free end down (to make Heart shape) as shown below:



- The insertion of DN 200 and larger gaskets is facilitaed by folding the gasket as shown by looping it into a heart shape with the gasket bulb towards the back of the socket. For DN 800 - DN 1600 it is preferable to loop the gasket into shape of a cross for insertion.



- After insertion of the gasket, confirm that the Heel position is properly seated in socket groove.



b) Insertion Depth of Socket

- The insertion depth of the spigot is indicated by two parallel lines at the outside of spigot end as shown in figure 5.5.2. The pipe spigot should be inserted in the socket in aligned condition as shown in fig below. The deflection in the pipe should be provided (within the allowable limit) after the insertion.

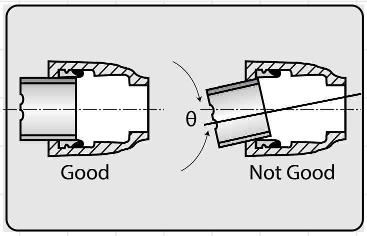


Table 5.5.1: Insertion Depth for Socketed Joints

DN	Insertion Depth for TJ pipe		Insertion Depth for AJ pipe	
	Minimum	Maximum	Minimum	Maximum
80	65	73	72	80
100	68	76	74	82
125	70	78	77	85
150	74	82	80	88
200	80	88	86	94
250	85	93	86	94
300	90	98	87	95
350	90	98	90	98
400	90	103	92	100
450	93	108	88	103
500	93	108	90	105
600	93	108	95	110
700	123	138	120	135
750	123	138	-	-
800	133	148	120	135
900	148	163	120	135
1000	158	173	135	150
1100	178	188	-	-
1200	193	203	-	-
1400	213	238	-	-
1500	218	243	-	-
1600	233	258	-	-
1800	255	285	-	-
2000	285	315	-	-

c) Joint Correction

- Ensure that gasket is located correctly around its whole circuference with its groove on the retaining bead in the socket and retaining heel firmly bedded in its seat. At time of insertion of the spigot end check alignment of the pipes and fittings.
- Esure that the gasket is correctly in position by inserting the end of a metal urler (130mm to 200mm lenght) through the annular spigot and socket gap until it touches the gasket. The ruler must penetrate to the same depth around the whole circumference. If a difference is found, the gasket may have been displaced and the joing should be dismatled and attemped again.

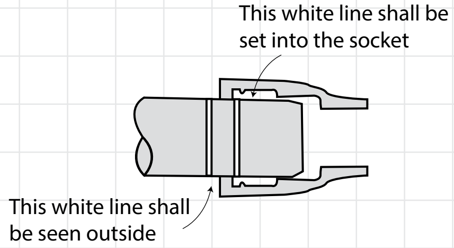


Fig. 5.5.2: Figures Showing Push-on Jointing Porcedures for DI pipes

d) Joint Dismantling

- Socketed joints can usually be separated by using lifting equipment approprate to the size of the pipe. Secure a webbing sling, of suitable size and strength, around the pipe near the end farthest from the joint to be dismatled. Then attach to the lifting equipment and raise and lower the pipe, within the specified deflection limitations, whilst at the same time exerting slight pulling force, so that the spigot is 'walked' out of the socket.

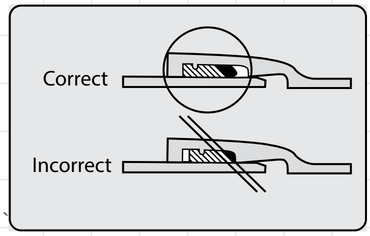
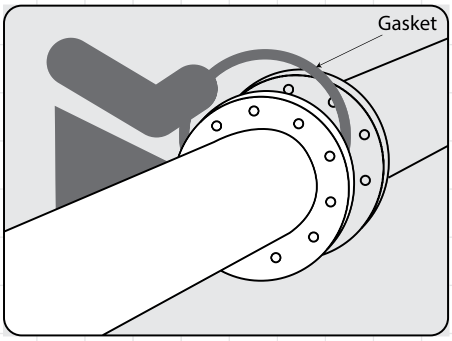


Fig. 5.5.3: Correct Position of Rubber Gasket in Push-on Joint

5.5.6 Procedure for Jointing of Flanged Fittings

Flanged joints are both rigid and self anchoring, and are primarily used in above ground installations. To ensure a proper jointing, it is imperative to align the faces of the flanged ends in a straight line.



Manual Bolt Tightening Procedure

a) Ensure that the flanges are parallel and axially aligned.
b) Lubricate the nut and bolt threads, and the contact face of the nut on the flange.
c) Locate the gasket and lightly nip the bolts.
d) Tighten evenly to approximately one third of the final torque following the sequence shown in Bolt Tightening Sequence below.
e) Repeat the tightening sequence in at least three more steps to the full torque. If required by the procedure, use a torque wrench.
f) Finally re-tighten adjacent bolts, start and finish at the same bolt, e.g. 1, 3, 2, 4 and 1. Use a torque wrench if required.

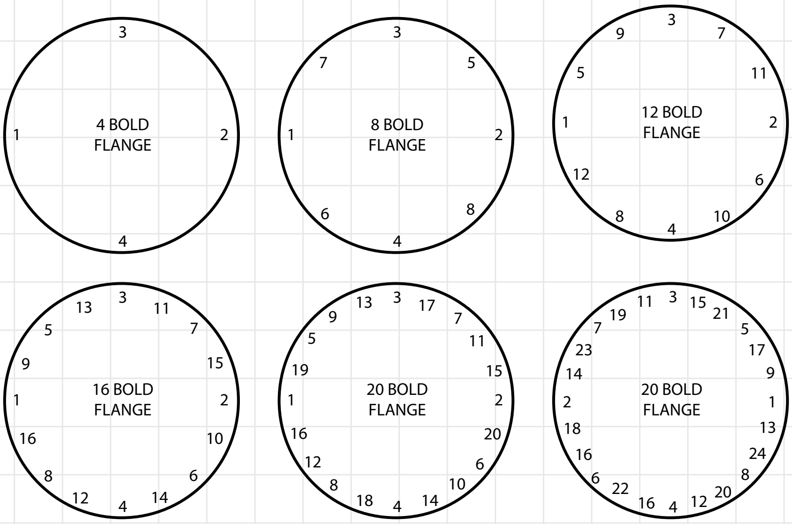


Fig. 5.5.4: Figures Showing Manual Bolt Tightening Procedure

Table 5.5.2: Bolting Torques Required for Tightening of Flanged Joints

Class	PN -10 Flanged Joints - Approx. Bolting Torque (Nm)			PN -16 Flanged Joints - Approx. Bolting Torque (Nm)			PN -25 -Flanged Joints - Approx. Bolting Torque (Nm)			PN -40 Flanged Joints - Approx. Bolting Torque (Nm)		
DN	Bolt Size	No. of Bolts	Tightening Torque (Nm)	Bolt Size	No. of Bolts	Tightening Torque (Nm)	Bolt Size	No. of Bolts	Tightening Torque (Nm)	Bolt Size	No. of Bolts	Tightening Torque (Nm)
80	M16	4	70	M16	8	70	M16	8	85	M16	8	141
100	M16	8	75	M16	8	80	M20	8	125	M20	8	249
150	M20	8	115	M20	8	120	M24	8	185	M24	8	321
200	M20	8	130	M20	12	115	M24	12	200	M27	12	575
250	M20	12	120	M24	12	165	M27	12	250	M30	12	808
300	M20	12	130	M24	12	180	M27	16	285	M30	16	808
350	M20	16	125	M24	16	175	M30	16	330	M30	16	843
400	M24	16	170	M27	16	220	M33	16	435	M36	16	1113
450	M24	20	165	M27	20	250	M33	20	450	M36	20	1113
500	M24	20	180	M30	20	270	M33	20	485	M39	20	759
600	M27	20	225	M33	20	365	M36	20	700	M45	20	1086
700	M27	24	230	M33	24	465	M39	24	795			
800	M30	24	300	M36	24	630	M45	24	1150			
900	M30	28	300	M36	28	645	M45	28	1185			
1000	M33	28	390	M39	28	835	M52	28	1620			
1100	M33	28	395	M39	32	850	M52	32	1655			
1200	M36	32	495	M45	32	1140	M52	32	1940			
1400	M39	36	590	M45	36	1300	M56	36	2395			
1600	M45	40	765	M52	40	1690	M56	40	2745			
1800	M45	44	1086	M52	44	2389	M64	44	3311			
2000	M45	48	1348	M56	48	2389	M64	48	3311			

5.5.8 Procedure for Assembly of JSAW Mechanical Restrained Joint System Ductile Iron Pipe.

1. Before assembling, make sure that the coupling faces of the ring and the gland are clean, then position the gland and the locking ring on the spigot end of the pipe.
2. Keep sufficient space beneath the socket in order to tighten the bolts with the torque wrench during the installation of MR joint accessories.
3. The locking ring should be fitted on the spigot end of the pipe to be jointed and passed over the weld bead. The ring has to adhere solidly to the pipe and its flat side should be adjacent to the weld bead.
4. During installation make sure that the components to be assembled are aligned.
5. When the joint has been assembled, check again to ensure the correct position of the ring and its adherence to the pipe near the weld bead, then fix the gland to the socket using the locking bolts.
6. Make sure the gland and pipe are coaxial, using centring spacers if necessary, and make sure that the moment between the pipe and gland is constant when the pipes are aligned.
7. Once the MRJ gland has been positioned correctly, fit and tighten the bolts in crossed sequence, using a torque wrench to tighten to the correct torque.
8. After hydraulic testing, it is highly recommended that the tightness of the bolts are checked with the torque wrench, and further tightened if necessary.

5.5.9 Procedure for Assembly of JSAW-Lock Restrained Joint System Ductile Iron Pipe.

1. Keep the lock insertion grooves/opening on the top side to facilitate the easy insertion of locks.
2. Before assembling, make sure that all the chambers of the Double chamber sockets are thoroughly clean.
3. Install the gasket in the innermost chamber of the socket as per the procedure explained earlier in the catalogue for push-on joint.
4. Clean the spigot end of pipe with weld bead using a soft brush thoroughly removing all the dust, foreign particles, excess paints etc.
5. Apply a thin layer of lubricant on the spigot end of pipe particularly near the bevel end of the pipe.
6. The spigot end with weld bead is pushed in the socket using suitable tools depending upon the pipe size. Care should be taken to keep the pipe at perfect aligned condition without having any angular deflection.
7. The lock segments should be inserted one by one through the window provided in the socket face and distributed along the pipe circumference of the pipe working alternatively left and right.
8. After inserting the last lock, all the locks should be clamped using a strap. The clamping strap should be tightened until the locking segments are bearing firmly against the pipe surface all around.

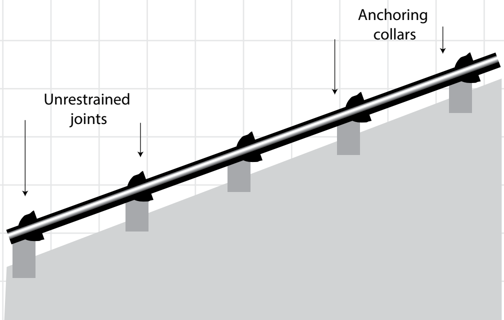
Pipe Laying on Hilly Terrain

The Push-on joints make DI pipe conducive for laying in hilly area. These are:

- Flexibility of the joints, which is capable of withstanding angular deflection upto 150mm due to vertical ground movements.
- Restrained push-on joints are also flexible and can withstand axial forces generated due to inclined alignment of pipe.
- Easy and fast assembly with unskilled labour and no power supply requirement.
- Pipes can be laid in all weather conditions.

Laying of Ductile Iron pipes on steep inclines can be performed by anchoring of pipes as given below:

a) By the installation of concrete thrust blocks on every pipe,



b) By the installation of a concrete thrust block at the head of a self-anchored pipe section.

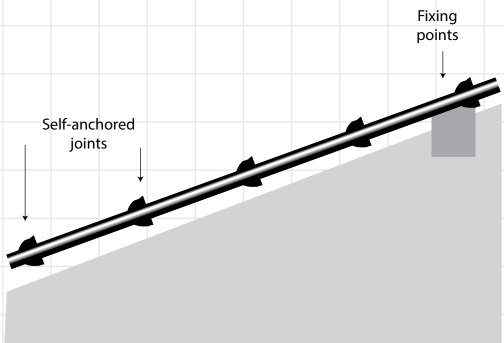


Fig. 5.6.1: Laying of DI pipes on Steep Inclines

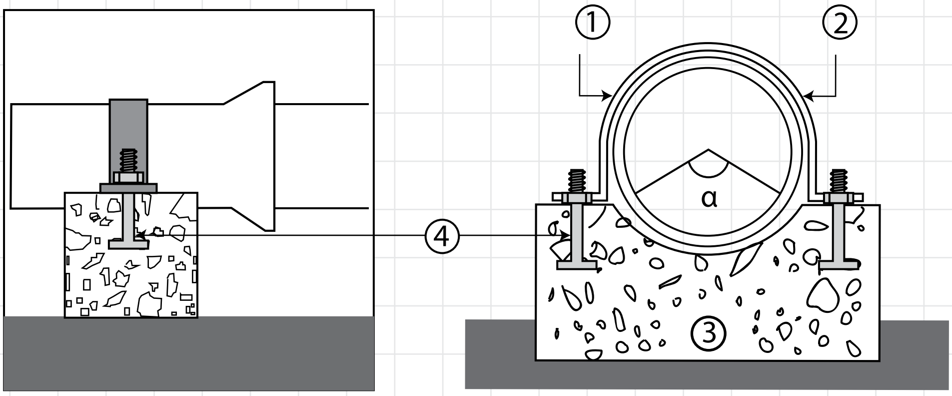
Basic precaution during pipe bed preparation

- The width of trench should be as narrow as possible.
- The width of the trench should be typically pipe Outer diameter + 300mm.
- In rocky ground which is common in hilly areas, all stones/hard rock with sharp edges should be removed from the trench bed. Avoid the use of angular granular material 20mm or greater in size for bedding or sidefill.

Basic precautions during laying of pipe

1. In Push-on joint, the direction of the flow has nothing to do with the direction of the socket. However, in hilly terrain, it is a general practice to keep the socket face uphill while pipeline is laid on a slope (both in case of over ground and underground installation).

2. Anchoring of pipes for overground installation is done with steel straps as shown below:



(1) Seel strap of suitable dimension (2) Ductile Iron pipe
(3) Concrete base, α = 120 deg. (4) Holding Down Bolt

Fig. 5.6.2: Anchoring of Pipes with Steel Straps

3. For laying pipe in a vertical curvature as in a hill top, the direction of the socket is changed as given below.

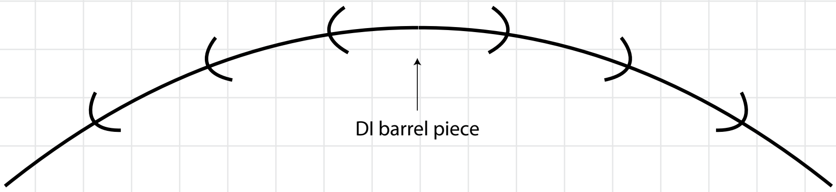


Fig. 5.6.3: Socket Position of Pipes - Vertical Curvature

4. All Fittings should be suitably anchored against displacement.
5. Ensure adequate engagement of spigot in the socket. All spigots should be marked with depth of socket before laying and care should be taken to see that all joints are completely assembled upto the required mark.
6. The joint deflection should not be more than the recommended deflection.
7. Air Valves (AV) play an important role towards purging out air entrapped in the pipeline and thereby prevent building up of surge pressures. Air valves are placed at all the crest of the alignment. Scour Valves (SV) should be located at the trough portion of the alignment to facilitate dewatering of pipe sections for maintenance.

Installation of Pipeline Components

Installation of valves

Valves are necessary for the isolating segments of the pipeline, for draining the liquids and venting of air pockets.

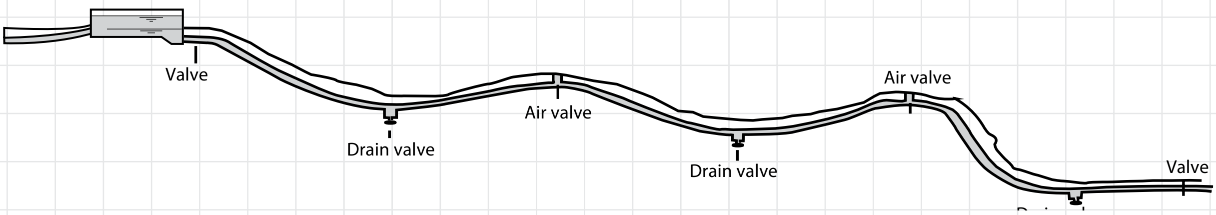


Figure 5.6.4 : Placement of Valves Along the Pipeline Alignment

Various types of valves should be provided as per the guidelines below:

Air Valves

An air valve is required to facilitate the release of air at high flow rates, when the pipeline is being filled and to permit the entry of air at higher flow rates during draining. Air valves should be provided at every peak point in case of undulating terrain and at every 1km on a flat terrain. The size and type of air valve should be determined for pipe sizes above 400 mm, double orifice air relief valves should be installed. For pipe sizes above 800mm, use of tees with DN 600mm flanged branch and flanged cover incorporated with an air relief valve is preferred from the point of view of maintenance. If the pipe size is exceptionally large, special devices should be considered.

Scour Valves or Drain Valves

Scour valves or drain valves should be provided at every low point for draining and flushing.

The size of the valve will depend upon the volume of water to be drained, the time available and the capacity of the receiving water course or area.

The design should ensure that the kinetic energy of the discharge is safely dissipated; a washout manhole may be provided for this purpose. Washouts should be designed to avoid any unacceptable deterioration of water quality by appropriate physical arrangements.

Isolation Valves

The location of isolating valves should be planned to facilitate shut-off in an emergency. Consideration should be given to the number of properties likely to be affected in relation to the required level of service. Local circumstances involving housing density and the location of hospitals, schools, apartment buildings and industrial premises should be taken into account.

Isolation valves should be installed on all branches as close as possible to the through main. Valve location and metering installation should facilitate leak detection procedures. Between two line valves it may be useful to install facilities for releasing pressure, for venting and draining. For principal and local mains, hydrants can fulfil this purpose.

The distance and location of shut off valves should be fixed according to the local conditions. In general, the intervals between shut-off valves should not exceed:

- In trunk mains: 5 km
- In principal mains: 2 km
- In local mains (rural): 1 km
- In local mains (urban): 0.5 km

Prior to installation, the valves should be inspected for direction of opening, number of turns to open, freedom of operation, tightness of test plugs, cleanliness of valve ports and seating surfaces, handling damage and cracks. Defective valves should be corrected or stored separately for further inspection.

Hydrants

Hydrants are required for fire-fighting. They can also be used for operational purposes, e.g. filling, draining, venting and flushing of the main. Wherever, hydrants are installed on trunk mains or principal mains, it is recommended that an isolating valve be provided. Consideration should be given to avoiding stagnation at hydrants.

All valves should be provided with necessary support. Valves installed above ground or in plant piping systems should be supported to prevent bending of the valve and connections as a result of the pipe loading.

Valves must be placed in concrete or masonry chambers to allow the access and the operation. Access manholes should be large enough to allow removal of valve for future replacement.

Thrust resulting from the valve closure should be carefully considered in the design of the piping system and valve chambers.

Ductile Iron piping over a bridge requires special care and precautions to accommodate the complex stresses and forces developed in bridge members.

5.7.1 Pipe Support Structure on Bridge

Typical installations of Ductile Iron pipe on bridges involve a basic 'pipe-on-supports' approach. The deciding factors are:
- Pipe size (weight of water filled pipe)
- Type of the bridge/support systems construction
- Local practice and regulatory requirements of the bridge structure
- Available space for placement of the pipe on the bridge
- Hydraulic thrusts and the required anchorage of components

Support Width

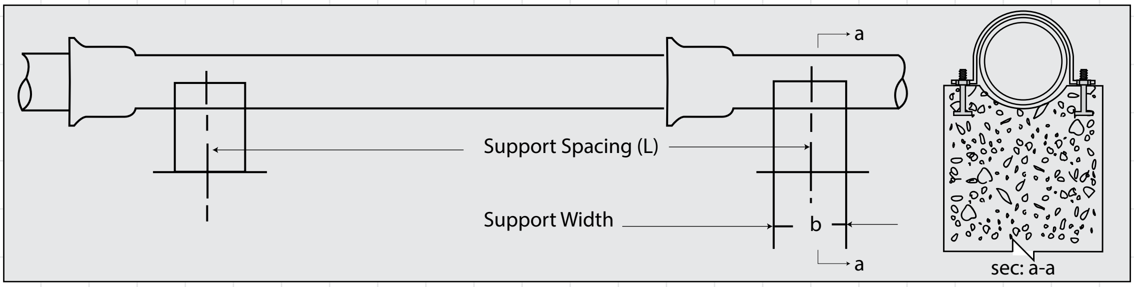


Fig. 5.7.1: Position of Pipe Support

The most accepted formula for saddle supports, the minimum width (b) is determined by the equation given below:

$b = \sqrt{2Dt}$

Where:
b = Minimum (axial) saddle width (mm)
D = Actual outside diameter of pipe (mm)
t = Nominal pipe wall thickness (mm)

The location of the pipeline on the bridge will, in many cases, dictate the type of support to be used. DI pipe placement on common type of bridge crossing is shown in figures 5.7.2, 5.7.3 and 5.7.4.

Pipe Support:

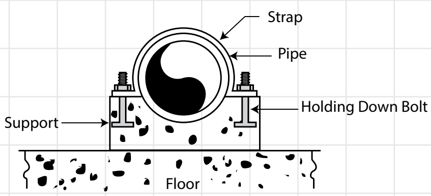


Fig. 5.7.2: DI Pipe Support with strap

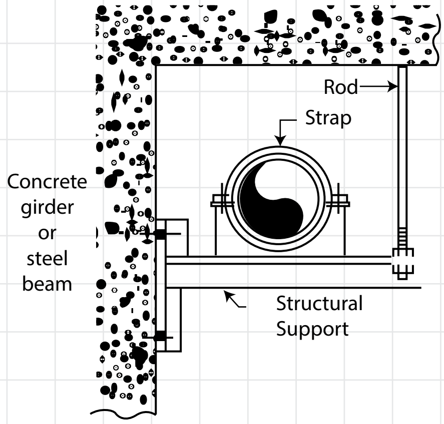


Fig. 5.7.3: DI Pipe Support under Concrete Cantelever

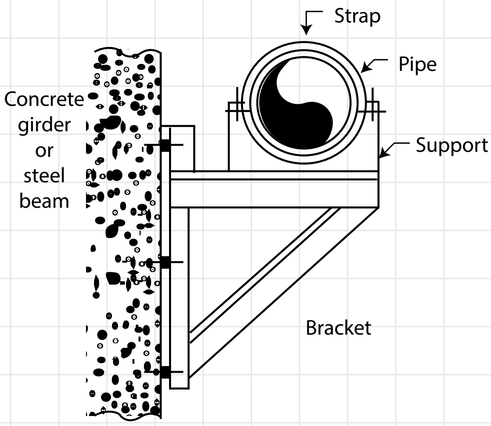


Fig. 5.7.4: DI Pipe Support on Steel Bracket

5.7.2 Thrust Restraining on the Bridge

When a flexibly joined Ductile Iron pipeline is pressurized, some thrust forces develop at the bends and even at slightly deflected joints. If not adequately stabilized, these forces can cause the joints to deflect to their maximum, creating a 'snaking' of the pipeline and possibly even separation of unrestrained joints. Thrust restrained joint are also used on bridges.

5.7.3 Expansion/Contraction Couplings

Contraction and expansion of the bridge structures is a common phenomenon which may have an effect on the piping system laid over it. To accommodate the longitudinal forces, expansion/contraction couplings may be used. The number and location of expansion/contraction couplings should be determined by the length and design of the bridge in consideration.

A typical bridge crossing with Ductile Iron pipe Push-on joint is given below:

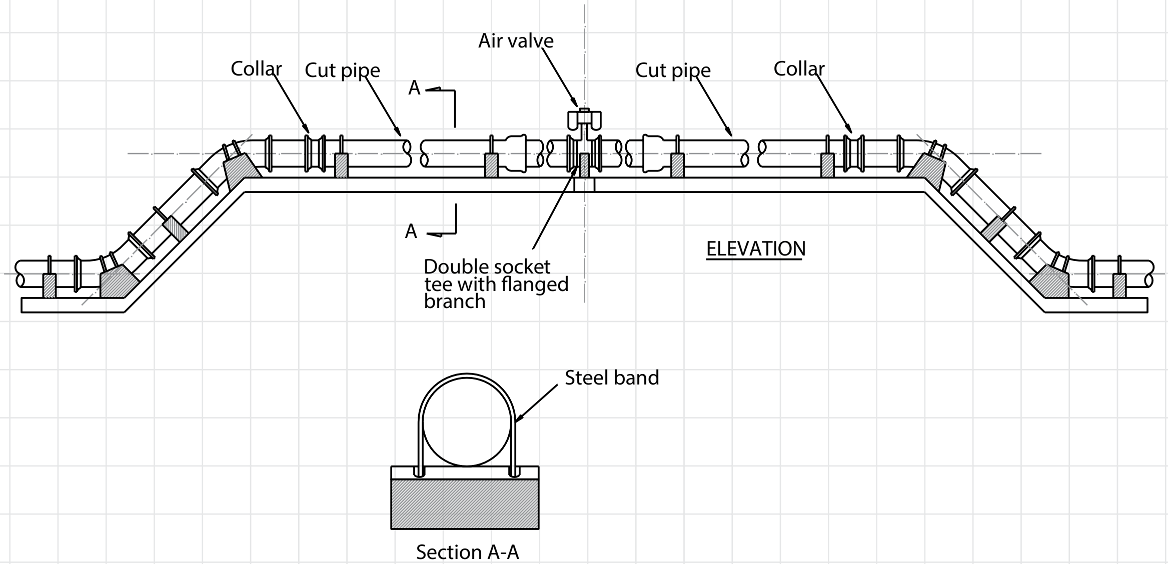


Fig. 5.7.5: Overground Pipe Support Arrangement for DI Pipes

Backfilling Requirements

- Backfilling operations should immediately be done after the laying of pipes.
- In order to minimize misalignment of the bed, backfill material should not be placed on a pipe until the next pipe is laid and jointed.
- If joints are to be individually inspected during hydrostatic testing, the joints are to be left open.
- It is important to backfill over the barrel of each pipe and to compact the backfill to prevent movement of pipes during the hydro testing process.
- On pipes greater than DN 600 special attention should be given to the compaction of the backfill material behind the socket of the pipe. Sand bag placed behind the socket is very helpful against socket movement at the time of testing.
- Neither topsoil nor material harmful to the pipeline should be used in backfilling.
- The trench should be backfilled with selected material from the excavation to preserve, as far as possible, the original soil sequence and should be compacted to minimize subsequent settlement.

Basic precautions during backfilling:

- Normal burying depth is 1m from the pipe-crown for DI Pipes.
- Use of natural granular material up to size 50mm to be used.
- Proper backfill compaction is a must before sectional hydro-testing to avoid pipe joint displacement/ Pipe snaking during hydro testing.
- For joints where deflection is more than 1°, the backfilling should be compacted on the two sides of the socket for at least 1m.

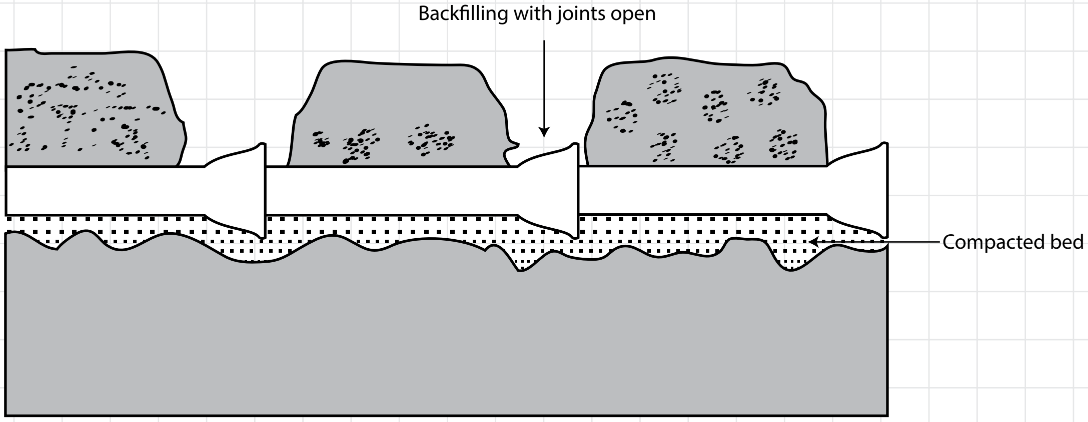


Fig. 5.8.1: Backfilling with Open Joints for Hydrotesting of Pipeline

Hydrotesting of Ductile Iron Pipeline at Site

Hydro testing at site is done to check the leak tightness of the joints, once the pipe is laid in the ground.

5.9.1 Hydrostatic Testing

The complete pipeline may be tested either in one length or in sections. However sectional testing (for a stretch of 500m to 1000m) is preferred as it ensures the efficacy of laying step by step. The length of section should be decided by considering:

- Availability of suitable water
- Number of joints to be inspected
- Difference in elevation between one part of the pipeline and another

Testing of the pipeline should be done in the following order:

- Backfilling
- Preparation of testing & installation of testing equipment
- Filling up the pipeline and conduction of actual test
- Leak detection and mending of leaks, if any
- Disinfection and commissioning

5.9.2 Backfilling

Backfilling should be done as mentioned in Section 5.8

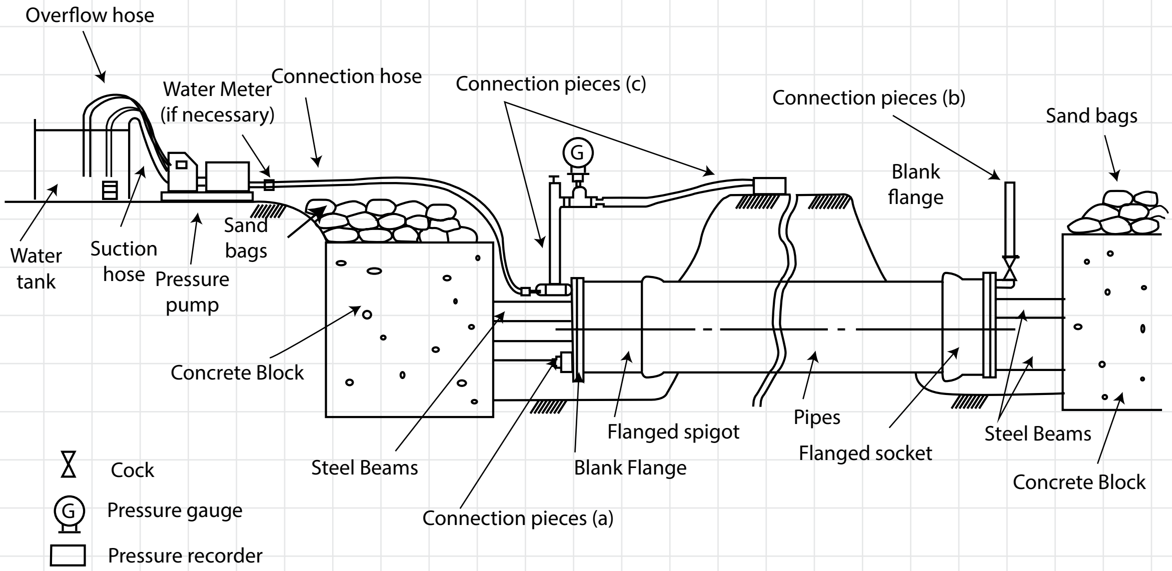


Fig. 5.9.1: Arrangement for Hydrotesting of Pipe

5.9.3 Preparation for Testing

- The testing should be done for shorter sections (say 500m)of pipeline, which may be extended to larger sections (say 1000m) once experience is gained.
- Each test section should be properly sealed off, with special stop ends, designed for the safe introduction and disposal of water and release of air, which should be secured by adequate temporary anchors.
- The thrust on the stop ends should be calculated on the full spigot external diameter and on the anchors designed to resist it.

- It may often be economical to provide a concrete anchor block, which has to be subsequently demolished, rather than risk movement of the stop ends during testing. Hydraulic jacks may be inserted between temporary anchors and stop ends to take up any horizontal movement of the temporary anchors.
- All permanent anchors should be in position and if of concrete, should develop adequate strength before testing begins.
- The section under test should be filled with clean, disinfected water, taking care that all air is displaced through vents at high points.
- After filling, the pipeline should be left at working pressure for a period in order to achieve conditions as stable as possible for testing.
- Pressure measurements are to be made at the lowest point of the section, and to ensure that the maximum pressure is not exceeded.

5.9.4 Test Pressure

For Ductile Iron pipe, the System Test Pressure (STP) should be calculated as Maximum of the following:

a) Max^{m} working pressure x 1.5
b) Max^{m} Working Pressure + Surge + 5 bar

5.9.5 Test Procedure

Following testing procedure should be adopted:

- The pipeline should be filled slowly and care should be taken to vent all high points and expel all the air. Vents shall remain open until water flows from them at a steady state.
- Sufficient time should be allowed after the pipeline has been filled, for adsorption of water into cement mortar linings.
- Pressurize the pipeline to the System Test Pressure (STP) and leave until stable conditions are achieved.
- Steadily increase the pressure until the desired System Test Pressure (STP) is reached at the lowest point.
- Maintain pressure for two hours by pumping if necessary and make up water should be measured by suitable measurement.
- All exposed pipe, joints, fittings, valves, hydrants etc. should be examined carefully during the test.
- Damaged or defective pipe, fittings, valves or hydrants etc. that are discovered during the test should be repaired or replaced and the test should be repeated until it is satisfactory.

The measured make up water or water loss at the end of the the test period should not exceed the value calculated using following formula:

$$\Delta V_{max} = 1.2\ V.\Delta p \left[\frac{1}{E_W} + \frac{D}{e.E_R}\right]$$

Where:

ΔV_{max} = Allowable loss in liters
V = Volume of the tested pipeline section in liters
Δp = Allowable pressure loss in kilopascals
Ew = Bulk modulus of water in kilopascals
D = Internal diameter of pipe in meters
e = Wall thickness of the pipe in meters
ER = Modulus of elasticity of the pipe in meters
1.2 = Allowance factor (e.g. for air content) during the pressure test

5.9.6 Testing of Non-Pressure Conduits

In case of testing of non pressure conduits the pipe line should be subject to a test for of 2.5m head of water at the highest point of the section under test for 10 minutes. The leakage or quantity of water to be supplied to maintain the test pressure during the period of 10 minutes should not exceed 0.2 liters/mm dia of pipes per kilometre length per day.

5.9.7 Detection of Leaks

Fault identification and rectification is the primary purpose of Hydrotesting. Consideration should be given to leak detection methods such as:

- Visual inspection of pipelines, especially each joint, if not covered by the backfill
- Aural inspection, using a stethoscope or listening stick in contact with the pipeline
- Use of electronic devices like leak noise correlators, etc.
- Use of a bar probe to detect signs of water in the vicinity of joints, if backfilled
- Where there is difficulty in locating a fault, the section under test should be subdivided and each part tested separately

NOTE: A pneumatic test with an air pressure not exceeding 2 bars can be used to detect leaks in pipelines laid in waterlogged ground.

After all sections have been jointed together on completion of section testing, a test should be carried out on the complete pipeline. During the test, all work, which has not been subject to sectional tests, should be inspected.

5.9.8 Disposal of Water

It is important to ensure that proper arrangements are made for the disposal of water from the pipeline after completion of hydrostatic testing and consent which may be required from land owner and occupiers, and from river drainage and water authorities have been obtained.

5.10 Disinfection

Pipeline Disinfection and Commissioning

- After completion of the pipeline laying it should be ensured that if the pipeline is intended to carry potable water, it should be thoroughly flushed with clean water free from impurities.
- The pipe line should be disinfected by contact for 24 hours with water containing at least 20 mg/l of free chlorine, then emptied and filled with potable water. The emptied chlorinated water should be treated or should be diluted for the chlorine to an acceptable level before discharge into sewer/drain/watercourse.
- After filling the pipeline with potable water, it should be kept for further 24 hours. Samples should be taken for bacteriological examination at a number of points along the pipeline and at all extremities to ensure the quality of water and the chlorine concentration.
- The pipeline should not be brought into service until the water at each sampling point, having stood in the pipeline for 24 hours, has maintained a satisfactory potable standard and is under acceptable limit.

5.11 Pipe Cutting

5.11.1 Pipe Cutting

The Ductile Iron is required to be cut in parts for many reasons. The following are the few situations during which we have to cut the pipes:

a. Whenever short pieces are required during installation
b. At places where the pipeline accessories such as valves etc are installed
c. To carry out repair works after installation
d. To remove the damaged portion caused due to bad handling

DI Pipe can be cut using the following cutting tools:

1. **Abrasive Wheel:** Ductile Iron pipe can be cut using an abrasive wheel cutter. Abrasive wheel of diameter 300mm, 350mm or 400mm should be used of Arbor size 20mm, 25mm made up of abrasive grain comprising of premium Silicon Carbide and Aluminum Oxide. Cut ends and rough edges should be ground smooth for push-on connections. The cut end should be beveled to the approximate profile of the factory-supplied end.

2. **Milling Cutter:** Several types of milling pipe cutters are available which operate hydraulically, pneumatically or electrically, or are self-powered by a gasoline engine. The milling-type cutter will normally cut pipe from 150mm through 1600mm diameter. This type of cutter is usually supplied with an air motor which also makes submarine cuts possible. The set-up time for this cutter is usually less than ten minutes. It requires a minimum clearance of 300mm and has a cutting speed of approximately one minute per inch of pipe diameter.

3. **Reciprocating Power Saws:** Reciprocating Power Saws may also be used for cutting Ductile Iron pipe. These tools are usually electrically driven and for this reason they are principally used in depots or workshop where power supply is available.

5.11.2 Preparation of Field-Cut Joints

Field cuts that will be assembled with mechanical joints will require little or no preparation other than cleaning. When a torch cut is made, the last few inches of the plain end need to be cleaned of any oxides, slag or other protrusions.

When the cut end is to be assembled in a socket of the Ductile Iron pipe, an adequately smooth (without sharp edges) bevel should be ground or filed on the cut edge to prevent damage to or dislodgement of the gasket during assembly. The following dimension to be achieved by grinding of cut edges of Ductile Iron pipe before installation:

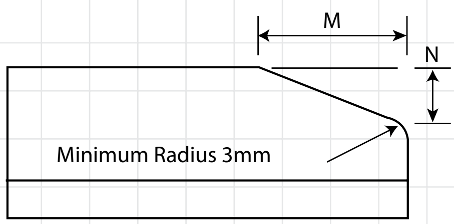


Fig. 5.11.1: Chamfering of DI Pipe Cut Ends

Table 5.11.1: Chamfering Dimensions

Nominal Size, DN	M	N
mm	mm	mm
80	9	3
100	9	3
125	9	3
150	9	3
200	9	3
250	9	3
300	9	3
350	12	3
400	12	3
450	12	3
500	12	3
600	12	3
700	15	5
750	15	5
800	15	5
900	15	5
1000	12	5
1100	12	5
1200	12	5
1400	20	7
1600	20	7
1800	20	8
2000	25	8
2200	25	9

All dimensions are in millimetres.

5.12.1 Repairing Procedure for Ductile Iron Pipe

In normal working conditions, a Ductile Iron pipes does not burst as it is designed with a factor of safety - 2.5 to 3. The nodular microstructure of Ductile Iron pipes, imparts high mechanical strength properties. The repairing of the Ductile Iron is required in following situations:

- Insertion of DI fittings for taking out a branch or installation of air relief valve/check valve etc.
- Replacement of the damaged portion of pipe line
- There is a failure in the Ductile Iron pipe

At first a thorough study of the damaged portion is necessary. Following steps to be performed to carry out the repairs:

- Clear marking of the damaged portion all around the circumference of the damaged DI pipe.
- Marking of damaged portion can be achieved by end wrap of a strip of sheet metal with parallel sides.
- The cutting of pipe is done on the marking and the cut should be made at right angles to the axis of the pipe.
- It is advised to preferably use an angle grinder for cutting the Ductile Iron pipes.
- Normally two cuts will be required to remove the damaged portion and it should be made on either side of the damaged pipe.

Necessary care should be taken to ensure that there is no damage/disturbance to the existing pipeline on either side of the damaged pipeline.

5.12.2 Basic Requirements of Restoration of Damaged Joints

- Remove the damage portion from the existing pipe line very carefully.
- Cleaning of all parts of the existing pipeline, particularly the joint areas/surface. If required, scraping of DI pipe surface to be done using wire brushes.
- Ensure the correct position of the various components.
- Ensure proper alignment of the spigot within the socket of existing pipeline.
- Ensure proper/correct gap between the end of the spigot and back of the socket.

5.12.3 Corrective Measure for Different Types of Damage

1. **Hole in pipe:** If there is a hole in the pipe of the size less than 50mm dia, make the hole of little bigger size with the help of a drill. After that tap and put a screwed plug in the hole. This will repair the pipe hole permanently.

2. **Repairing a crack/damage portion of pipe:** When a section of the pipe is required to be repaired by removing the crack/damage portion of the pipe two numbers of mechanical joint collars are to be installed so that it connects the new piece to the original pipe as shown in the sketches below:

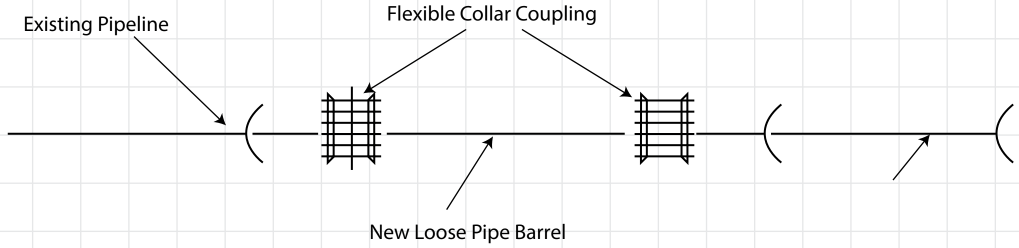
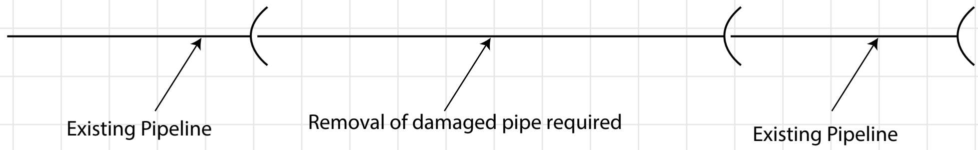
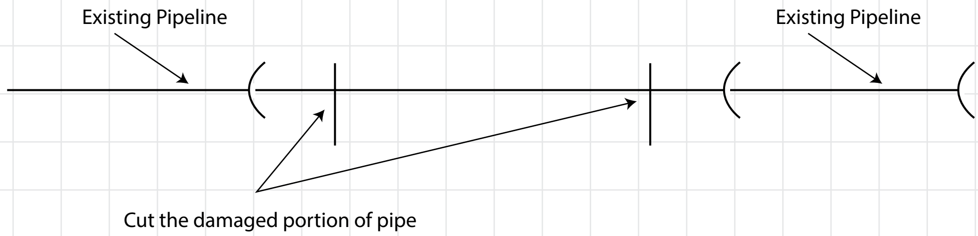


Fig. 5.12.1: Schematic Diagram for Repair of Damaged Portion of DI Pipe

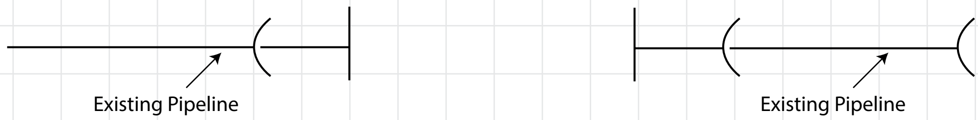
3. **Removal of a complete pipe length from existing pipeline:** When the entire length of pipe from the existing pipe line needs to be replaced, the following steps have to be adopted:



a. The pipe has to be divided in parts and marked clearly using strip metal as described above for cutting by an angle grinder.
b. After cutting remove the cut parts carefully without disturbing the existing pipeline.



c. The new pipe should fit in the length as that of damaged pipe previously occupied.
d. The new pipe should be cut in two parts with the help of angle grinder so that there is a little gap in between the cut pieces after installation with existing pipeline.



e. Mechanical joint collars should used to put the cut parts in position and installed in the gap so created between the two cut pieces, to complete the repairing of the damaged portion.

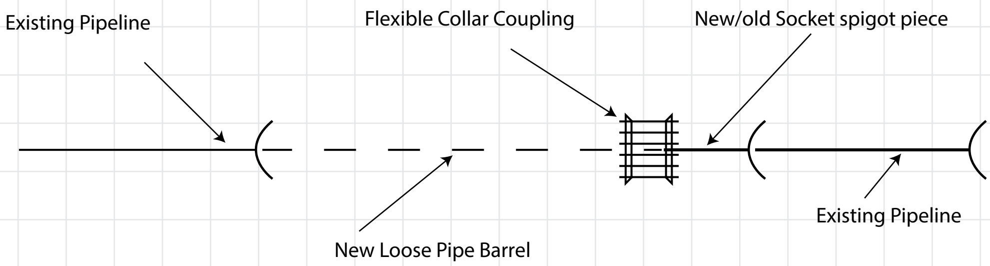
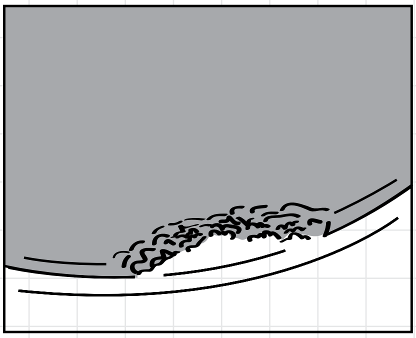


Fig. 5.12.2: Schematics Showing Removal of Complete Pipeline with New DI Pipe

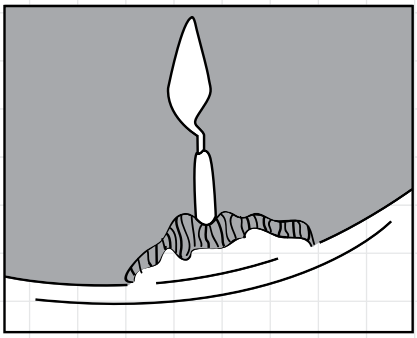
f. Once the jointing procedure is completed the repaired pipe section should be partially covered with the backfill material to avoid the uplifting during pumping operation, keeping the joint exposed for inspection.
g. The pipe section should be put in operation slowly keeping a constant watch on the repaired portion of the pipe section.
h. If any defect such as leakages etc. is noticed after resuming the pumping, it should be immediately stopped and the defect should be rectified before resuming the pumping again.

4. **Cement mortar lining repairs:** In the event that an area of Cement Mortar lining is damaged, repairs can be simply made by applying the cement Mortar paste of Portland/High Alumina/Sulphate resistant cement (as the case may be) to two parts of fine sand as per the procedure given below:

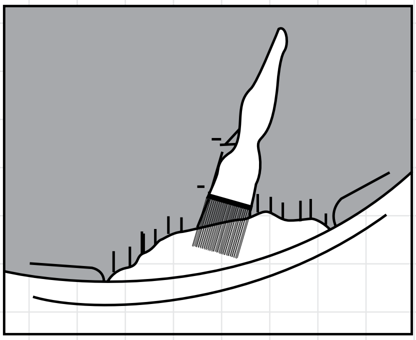
   a. After identifying the damaged area of mortar lining, if possible, position the pipe or fittings with damaged area at the invert level.



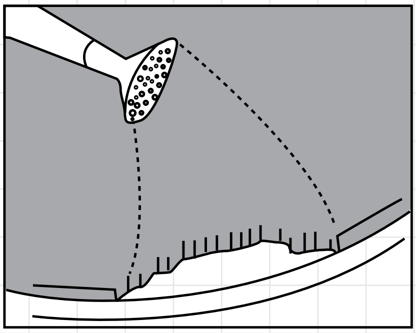
   b. Carefully chip out the damaged lining area. Undercut the edges of the surrounding sound lining to form a 'Key' for the repair.



   c. Clean away all loose debris from the damaged area using a brush exposing the bare metal.



   d. Thoroughly wet the exposed metal surface & the edges of the lining around exposed area by spraying water.



e. Prepare the mortar for repair. This should be stiff and consist of one part cement to 1.5 parts dry washed coarse sand (by mass) and be mixed with fresh potable water.
f. Place the mortar with a hand trowel (or float for large areas), and work it well into the edges of existing lining.

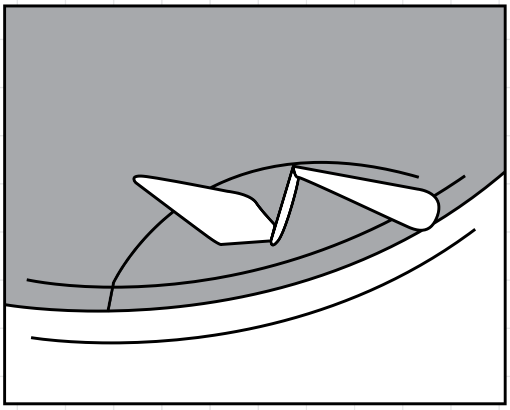


Fig. 5.12.3: Figures Showings Repair of Cement Mortar Lining in DI Pipes

g. Built up the repair to a thickness just above that of the original lining and finally smooth down to the required thickness using a piece of wood against the pipe end, if appropriate, to produce a square end.
h. Cover the repaired portion with a wet sack or similar to prevent rapid evaporation until mortar is sufficiently hardened. The wet sack should be kept for sufficient time to allow proper curing of the freshly applied cement mortar.

5. **Repair of external coating:** The pipe external coating can get damaged during transport, and handling.
For slight damage in small area and where Zinc coating is not detached, no repair is required.
For extensive damage where, bare pipe surface is exposed, repairs are required. The following steps should be followed:

a. Place the damaged portion of the pipe in workable position.
b. Clean the damaged surface with brush, sand paper and finally by clean cloth.
c. Use coating material as recommended by manufacturer and apply as per their approved procedure. The coating material as suggested should be applied by brush.
d. Protect the repaired portion from dust until it is sufficiently dry before being used for pipe laying.

6. **Repair of Damaged/deformed Spigot (Ovality Correction):** Transport and handling may cause sufficient pipe ovality to impede correct assembly of the components. The following methods are applied for Ovality correction for pipe size > DN 400mm.

Method A: Ovality Correction

The use of this method is recommended where it is possible to remove the tackle after ovality correction and subsequent jointing:

- Position the timber and jack (approximately 5 tonnes capacity) near the face of the spigot end and at 90° to the major axis. Rubber pads should be placed in position to prevent possible damage of the pipe lining. Extend the jack, until the major axis has been adjusted to specified limit. Complete the jointing operation with the major axis of spigot vertical. After jointing remove the tackle.

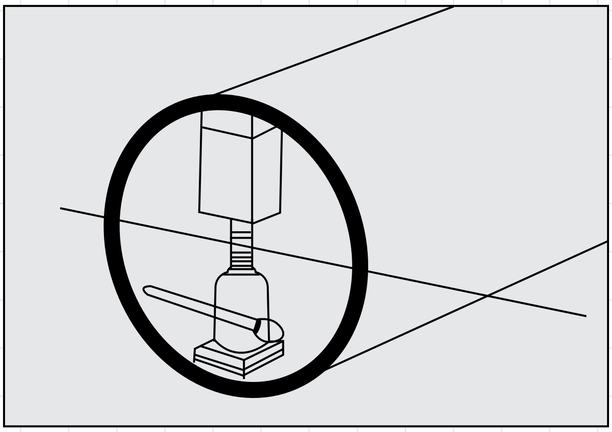


Fig. 5.12.4: Ovalty Correction (Method A)

Method B: Ovality Correction

The use of this method is recommended where it is not possible to remove the tackle described in Method A, after ovality correction and subsequent jointing.

- Place the tackle around the spigot end of the pipe at a position approximately 450mm from the pipe end with major axis of the spigot vertical. Where pipes are sleeved or tape wrapped, rubber pads or similar should be placed between the re-rounding tackle and the protection system to prevent damage.
- Tighten the two nuts evenly until the major axis has been reduced to the approximate limits. Complete the jointing operation with a major axis of the spigot vertical. After joining remove the tackle.

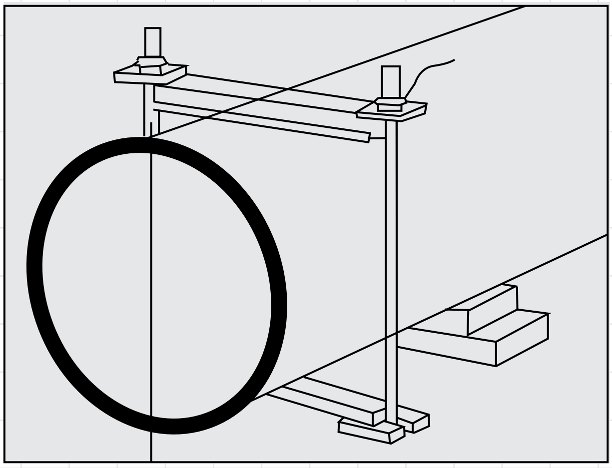
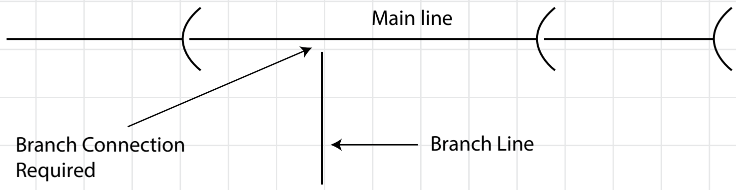
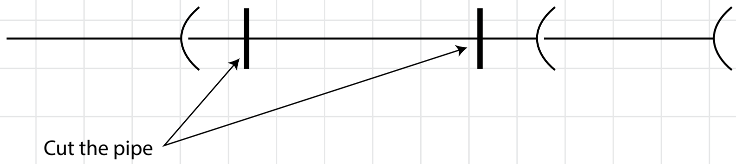


Fig. 5.12.5: Ovalty Correction (Method B)

7. **Taking out a branch from existing pipeline:** A 90˚ branch connection can be made from the existing pipeline as follows:

   a. The pipe has to be divided in parts and marked clearly using strip metal as described above for cutting by an angle grinder.





   b. After cutting remove the cut parts carefully without disturbing the existing pipeline, if any.

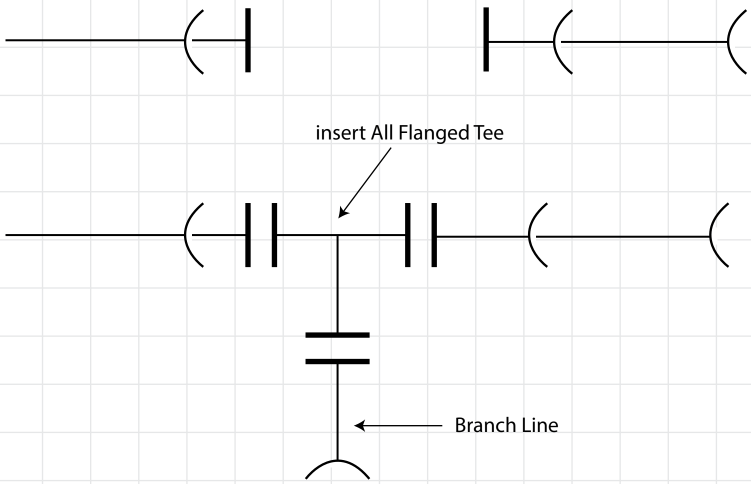


Fig. 5.12.6: Schematic Showing Procedure for Taxing Branch Connection with All Flanged Tee

   c. The new pipe piece along with the Tee and Mechanical collar joint should fit in the length as that of cut pipe previously occupied.

   d. The new pipe should be cut with the help of angle grinder so that there is a little gap available after installation of cut piece and Tee with existing pipeline.

   e. Mechanical joint collars should used to put the cut parts in position and installed in the gap, created between the cut pieces, to complete the installation of Tee with the existing pipe line.

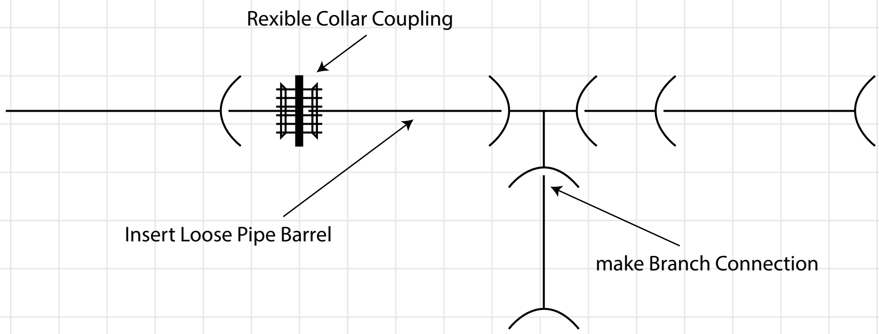


Fig. 5.12.7: Schematic Showing Procedure for Taxing Branch Connection with Socketed Tee

f. Once the installation procedure is completed the newly installed pipe section should be partially covered with the backfill material to avoid the uplifting during pumping/operation, keeping the joint exposed for inspection.

g. The pipe section should be put in operation slowly keeping a constant watch on the joint portion of the installed pipe section.

h. If any defect such as leakages etc. is noticed after resuming the pumping, pumping should be immediately stopped and the defect should be rectified before resuming the pumping again.

8. **House Service Connections:** House Service connections can be made from a DI pipe by direct tapping. Threaded tapping up to 20mm size can be made directly from any size of DI pipe. For tapping above 20mm, the sizes of DI pipes is recommended in the table below. To avoid any dissimilar metal corrosion it is recommended that suitable protection be applied to the service connection areas.

Table 5.12.1: Tapping Size in DI Pipes

Tapping Size (in mm)	Nominal Size of DI pipe (DN)					
	80	100	150	200	250	300+
12						
20						
25						
32						
40						
50						

Conventional or External Seal type   External Seal type only   Use Saddles, Tees, etc

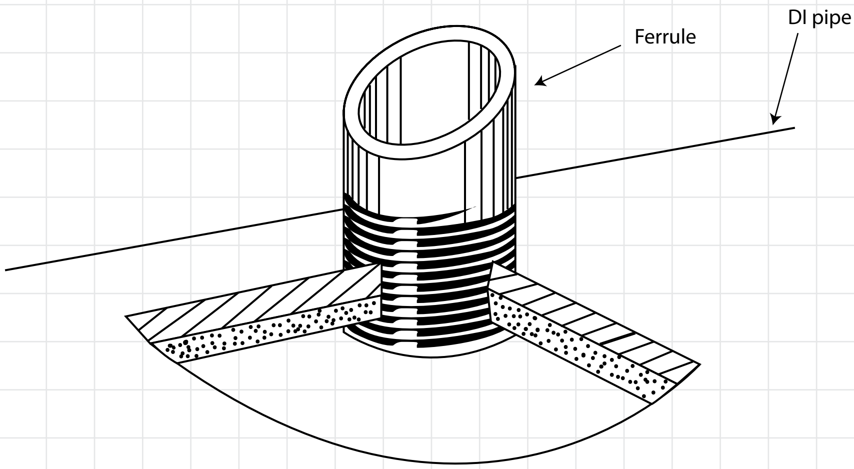


Fig. 5.12.8: Threaded Tapping in Ductile Iron Pipes

6.0 References

Jindal SAW Ltd. conforms to various nation and Internal standards for manufacturing of Ductile Iron pipes.

6.1 Indian (National) Standards

S. No.	Topic	Standards Ref. No.	Title of the Standards
1	DI Pipes	IS: 8329 - 2000	Centrifugally cast (spun) Ductile Iron pressure pipes for water, gas and sewerage - Specification
2	DI Fittings	IS 9523 - 2000	Ductile Iron Fittings for pressure pipe for water, gas and sewerage - Specification
3	Rubber Gaskets	IS: 5382 - 1985	Specification for Rubber Sealing Rings for gas mains, water mains & sewers
4	Laying & Jointing	IS: 12288 - 1987	Code of practice for use & laying of Ductile Iron pipe
5	Cements		
	Ordinary Portland Cement	IS: 8112 - 2013	Ordinary Portland Cement 43 Grade - Specification
	Portland Slag Cement	IS: 455 - 1989	Portland Slag Cement - Specification
	Sulphate Resistant Cement	IS: 12330 - 1998	Specification for Sulphate resisting Portland cement
	High Alumina Cement	IS:6452 - 1989	High Alumina Cement for structural use - Specification

6.2 International Standards

S. No.	Topic	Standards Ref. No.	Title of the Standards
1	Ductile Iron Pipes	ISO: 2531	Ductile Iron pipes, fittings, accessories and their joints for water application
		ISO: 7186	Ductile Iron products for sewerage application
		BSEN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods
		BSEN 598	Ductile Iron pipes, fittings, accessories and their joints for sewerage applications - Requirements and test methods.
		AWWA C 151-2002	Ductile Iron pipe, centrifugally cast for water
2	Ductile Iron Fittings	ISO: 2531	Ductile Iron pipes, fittings, accessories and their joints for water application
		BSEN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods
		AWWA C110	Ductile Iron and grey Iron fittings, for water
3	Rubber Gaskets	ISO: 4633	Rubber seals - Joint rings for water supply, drainage & sewerage pipelines - Specification for mateirial
		BSEN 681-1	Elastomeric seals- Material requirements for pipe joint seals used in water & drainage applications Part1 - Vulcanized rubber

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S. No.	Topic	Standards Ref. No.	Title of the Standards
4	Cement Mortar Lining	ISO: 4179	Ductile Iron pipes and fittings for pressure and non pressure pipelines - Cement mortar lining
		BSEN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods
		BSEN 196-1	Methods of testing Cement Part 1 Determination of strength
		BSEN 197-1	Cement - Part 1, composition, specification and conformity criteria for common cements
		AWWA C104	Cement mortar lining for DI pipe for water
5	Cement Mortar Lining with Seal Coat	ISO: 16132	Ductile Iron pipes and fittings - Seal coat for Cement Mortar lining
6	Zinc Coating with Finishing Layer	ISO: 8179-1	Ductile Iron pipes - Exteranl Zinc based coating, Part 1 - Metallic zinc with finishing layer
		ISO: 8179-2	Ductile Iron pipes - Exteranl Zinc coating, Part 2 - Zinc rich paint with finishing layer
		BSEN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods
		BS: 3416	Specifications for Bitumen based coating for cold application, suitable for use in contact with water
7	Epoxy Coating	BSEN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods
		BSEN 14901	Ductile Iron pipes, fittings and accessories - Epoxy coating (heavy duty) of Ductile Iron fittings and accessories - Requirement and test methods
8	Polyethylene Sleeving (on site application)	ISO: 8180	Ductile Iron pipelines - Polyethylene sleeving for site application
9	External Polyethylene Coating	BSEN 14628	Ductile Iron pipes, fittings and accessories - External Polyethylene coating for pipe - Requirement and test methods
10	External Polyurethane Coating	BSEN 15189	Ductile Iron pipes, fittings and accessories - External Polyurethane coating for pipe - Requirement and test methods
11	Alloy of Zinc & Aluminum With or Without Metals having Minimum Mass of 400 gm/m2	BSEN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.
		ISO: 14713-1	Zinc coating - Guidelines and recommendations for protection against corrosion of iron and steel in structures Part 1 - General principles of desing and corrosive resistance
12	Laying and Jointing of Ductile Iron Pipes	AWWA C 600	Installation of Ductile Iron water mains and their appurtenances.
13	Restrained Joints	ISO: 10804	Restrained joint system for Ductile Iron pipelines Part 1 - Design rules and Type Testing
14	Internal Polyurethane Coating	BS EN 15655	DI pipes, fittings and accessories - Internal Polyurethane lining for pipes and fittings - Requirements and test method

6.3 Design standards

S. No.	Topic	Standards Ref. No.	Title of the Standards
1.0	DI Pipes	ISO: 10803	Design methods of Ductile Iron pipes
		AWWA M41	Steel Pipe - A Guide for designing & Installation

6.4 Conversion Factor

Unit	Conversion
Kilograms	2.2046 Pounds
Kg/sq.cm	14.22 pounds/sq. inch (psi)
Kilometres	3281 feet
Kilometers	0.6214 miles
Kilometers/hour	0.9112 feet/sec
Kilometers/hour	27.78 centimetres/sec
Kilometers/hour	0.2778 m/sec
Kilowatts	14.33 kg-calories/min
kilowatts	1.341 horsepower
Litres	0.2642 gallons (US)
Litres	61.02 cubic inches
Liters	0.03531 Cubic Feet
Meters	3.281 feet
Meters	39.37 inch
Metrs	1.094 yards
Meters of water	0.09803 Bars
Miles	5280 Feet
Miles	1.609 kilometers
Miles/min	88 feet/sec
MGD	4.545 MLD
MLD	0.01157 m3/sec
Milligrams/liter	1 part/million
Meters/sec	3.281 feet/sec
Megapascal (Mpa)	10.197 kg/cm2
Newton	0.1 kgf
Newton/mm2	1 Mpa
Newton/cm2	0.1 kg/cm2
Acres	4047 sq.m
Atmosphere	1.01325 bars
Bars	0.98692 Atmosphere
Bars	1.02 kgs/sq.cm
Bars	14.50777 pound/sq.in
Bars	10.20 meters of water/head
Centimeters	0.3937 inches
Cubic Centimeters	3.531 x 10-5 cubic feet
Cubic meters	264.20 Gallons (US)
Cubic meters	1000 litrs
Cubic feet	0.02832 cubic meters
Cubic meters	35.31 cubic feet
Cubic meters	1.308 cubic yards
Feet	30.48 centimeters
Gallons	4.545 x 10-3 cubic meters
	Continued...

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Unit	Conversion
Gallons	4.545 litres
Grams/liter	1000 parts/million
Hectares	2.471 acres
Horsepower	542.476 foot-lbs/sec
Horsepower	0.735 kilowatts
Inches	2.540 centimeters
Inches	25.4 millimeters (mm)
Inches/Sec	2.540 x 10-2 meters/sec
Inch	1000 Mils
Ounces (Fluid)	2.841×10^{-5} cubic meters
Ounces	28.3495 grams
Pounds	16 ounces
Pounds/Sq. Inch	0.06803 atmosphere
Pounds	453.5924 grams
Pounds	4.448 newtons
Pounds/Sq.foot	4.883 kgs/sq.meter
Pounds/Sq. Inch	2.31 ft of water (at 62of)
Pounds/Sq. Inch	0.0703 kilograms/sq. cm.
Pounds/Sq. Inch	6.895 kilopascals (kpa)
Square Feet	0.0929 sq. meters
Square Feet	2.296 x 10-5acres
Square Miles	640 acres
Square Miles	2.788 x 107 sq. feet
Square Inches	6.452 sq. cm.
Square Kilometrs	247.1 acres
Square Kilometers	1.076 x 107 sq. feet
Square Meters	10.76 sq. feet
Square Miles	2.590 sq. kilometres
Tons (Metric)	1000 kilograms
Tons (Metric)	2205 pounds
Watts	0.7375 foot-pounds/sec
Watts	1.341 x 10-3 horsepower
Yard	0.9144 meters
Cusec	0.028 m3 sec
Cumec	35.31 cusec
Cumecs	M^3/sec

Abbreviations

AC	Alternating Current
AJ	Automatic Joint
API	American Pipe Institute
AWWA	American Water Works Association
BHN	Brinnel Hardness Number
BS	British Standard
BSI	British Standard Institute
°C	Degree Celsius
CML	Cement Mortar Lining
CTE	Coal Tar Epoxy
DFT	Dry Film Thickness
DI	Ductile Iron
DN	Nominal Diameter
DVGW	Deutscher Verein des Gas- und Wasserfaches e.V. (German Technical and Scientific Association for Gas and Water)
DWI	Drinking Water Inspectorate
e	Nominal Wall Thickness
EN	EUROPAISCHE NORM (European Standard)
Eq	Equation
FBE	Fusion Bonded Epoxy
i	Slope
ID	Internal Diameter
IS	Indian Standard
ISO	International Standard Organization
J	Joule
°K	Degree Kelvin
Kg /cm2	Kilogram per square centimeter
L	Length
Lu	Nominal Length
LSAW	Longitudinal Submerged Arc Weld
MDP	Maximum Design Pressure
MGD	Million Gallons Per Day
MLD	Million Litres Per Day
MJ	Mechanical Joint
mm	Millimeter

Mpa	Megapascal
m/s	Meter Per Second
MT	Metric Tonne
MTPA	Metric Tonne Per Annum
NACE	National Association of Corrosion Engineers
NL	No Limit
OD	Outer Diameter
PEA	Allowable Site Test Pressure
PFA	Allowable Operating Pressure
PMA	Allowable Maximum Operating Pressure
PN	Nominal Pressure
PS	Pumping Station
Q	Discharge
SAW	Submerged Arc Weld
STP	System Test Pressure
TJ	Tyton Joint
V	Velocity
3LPE	3 Layered Poly Ethylene
WRAS	Water Regulatory Authority Scheme

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• HOT INDUCTION BENDS • CONNECTOR CASINGS • CLAD PIPES

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