Ductile Iron Pipeline System

A technical guide

JINDAL SAW LTD.

TOTAL PIPE SOLUTIONS

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1.1 O.P. Jindal Business Group

The Jindal Group is a US $18 billion conglomerate, which over the last three decades has emerged as one of India's most dynamic business organisations and established leadership position in all its area of activities. Founded by steel visionary Shri O. P. Jindal in the year 1952, with an indigenous single-unit steel plant at Hisar, Haryana, India the group over the last three decades has grown to be a multi-billion US $, multinational and multiproduct steel conglomerate with business interests spanning across the spectrum from mining, power, industrial gases, port facilities, and manufacturing value-added steel products. Growth has been a way of life for the Jindal Group and its motto all along has been 'GROWTH WITH A SOCIAL CONSCIENCE'. The group places its commitment to sustainable development, of its people and the communities in which it operates, at the heart of its strategy and aspires to be a benchmark in this direction for players in the industry world over.

The Group's strength lies in dynamic and aggressive approach in the leaders of the group. Their appetite for growth is enormous and they have a clear vision of being recognized as best in the industry by consolidating its core strengths. Presently, the group has manufacturing outfits across India, US, UK and Indonesia and mining concessions in Chile, Bolivia, Indonesia, Mozambique and marketing representative's offices across the globe.

The technology driven group employs over 60,000 people across the globe. Now headed by Srimati Savitri Devi Jindal, the group is still expanding, integrating, amalgamating and growing.

JINDAL SAW LTD. TOTAL PIPE SOLUTIONS

- **Jindal SAW Ltd.**
- **JITF (Infrastructure, Transportation & Fabrication)**
  - JITF Ecopolis
  - JITF Aquasource
  - JITF Vector
  - Jindal Rail Infrastructure Ltd.
  - JITF Shipyards Ltd.

JSW FOUNDATION

- **South West Port Ltd.**
- **Southern Iron & Steel Company Ltd.**
- **JSW Energy Ltd.**
- **JSW Steel USA Inc.**

JSL JINDAL STAINLESS

- **Jindal Hissar**
- **Jindal BQS Shelter**
- **Artd'inox**

JINDAL STEEL & POWER

- **Jindal Power Ltd.**
- **Jindal Reality Pvt. Ltd.**

1.2 Jindal SAW Limited

At Jindal SAW, the end of a pipe is not seen as a conclusion, but a beginning in itself. The start of endless possibilities, of development, of expansion, of sustained growth that helps the globe and the lives of people. Jindal SAW Ltd. is an integral part of the US $18 billion O.P. Jindal conglomerate. It started operation in the year 1984, when it became the first company in India to manufacture Submerged Arc Welded (SAW) Pipes using the internationally acclaimed U-O-E technology. Jindal SAW has effectively established itself as a global major and a market leader. It is the only company in India that offers total pipe solutions.

Jindal SAW boasts of an inimitable, innovative and process driven business environment with the highest level of quality commitment, which is reassured through the various quality certifications. Its operations are highly structured with three Strategic Business Units:

- Large Diameter Pipes i.e. Submerged Arc Welded (SAW) pipes,
- Seamless Tubes & Pipes
- Ductile Iron (DI) Pipes & Fittings

Every SBU has its own dedicated sales, marketing strategies and operations. With integrated facilities at multiple locations and an ever expanding market opportunity, Jindal SAW Ltd. has diversified from a single product company to a multi-product company, manufacturing large diameter submerged arc pipes and spiral pipes for the energy transportation sector; carbon, alloy and stainless steel seamless pipes and tubes manufactured by conical piercing process used for industrial applications; and Ductile Iron (DI) pipes for water and wastewater transportation.

Besides these, the company also provides various value added products like pipe coatings, bends and connector castings to its clients. What gives Jindal SAW a further edge is the latest technology that it acquires by way of international collaborations and tie-ups. Also adding sheen is the constant focus on in-house research and human resources that separate the Company from others and place it a step ahead of all. Over the years Jindal SAW has continued to gain the confidence and trust of its stakeholders - from employees, associates, shareholders and people whose lives have benefitted by the company's endeavours.

With its vision of sustainable development firmly in place, Jindal SAW has played a leading role in developing livable cities across the world - that in turn has helped transform the lives of people living in them. Besides catering to domestic market, the company has undertaken and successfully completed many projects across the globe. It has to its credit track record of manufacturing and supplying over 12,000 Kms of Line Pipes, of which 6500 Kms of Line Pipes have been exported to major oil and gas companies across the globe. Jindal SAW-IPU Division has completed the production of DI pipes of 21,00,000 MT since it's commissioning in March 2005 and has supplied more than 60,000 Kms of pipes till date to various water utilities in the country and abroad. The company's clientele includes names like Indian Oil Corporation, Gas Authority India Limited, Engineers India Limited, Bharat Petroleum, Hindustan Petroleum Corporation Limited in the domestic sector and Egyptian Natural Gas Company, Bechtel Intec Consortium Shell, Saudi Arabian Oil Company, Enron and many more prestigious names in the international market. For the company, business is not just about deals, in building great products, doing great engineering, and providing tremendous service to customers. Jindal SAW is in constant endeavour not only to achieve customer satisfaction, but customer delight.

1.3 Milestones

Ensuring efficient transportation of oil, gas and water, Jindal SAW helps residents and organizations in numerous cities function efficiently. The pipes are manufactured in the company through energy efficient and ecofriendly processes.

At the very core of Jindal SAW is imprinted the conviction of never being content with the success attained and it is constantly striving for newer horizons. New boundaries, new challenges and new opportunities keep the company driven to surge ahead. Venturing forward into different areas of businesses with Jindal ITF, the infrastructure arm of Jindal SAW, the company is making rapid progress in urban services sectors with:

- Water, Wastewater and Solid Waste Management
- Domestic Transport and Logistics
- Transportation Equipment Fabrication

Having identified the immense potential offered by these sectors for the future, JITF has diversified into five business verticals in these areas: JITF Ecopolis, JITF Aquasource, JITF Vector, JITF Shipyards, and Jindal Rail Infrastructure.

Table 1.3.1 Various plants location, product range, capacities and respective approval certifications of Jindal SAW facilities.

Location	IPU, Mundra, Gujarat, India	Jindal Fittings Ltd, Tembhurni, Sholapur, Maharashtra, India	Jindal SAW Gulf LLC, Abu Dhabi/ Jindal SAW Italia (SERTUBI) Trieste, Italy	EOU, Mundra, Gujarat, India	Kosi Kalan, Uttar Pradesh, India	Nashik, Maharashtra, India
Pipe Type	DI Pipes	DI Fittings	DI Pipes	SAW Pipes	SAW Pipes	Seamless Pipes & Tubes of Carbon, Hot and Cold Finish
Diameter	80mm to 1000mm	80mm to 2200 mm	200 mm to 2200 mm/ 60mm to 800mm	18" to 56" OD	16" to 42" OD	½" to 7" OD
Thickness	As per Indian & International Standards	As per Indian & International Standards.	As per International Standards	Up to 1.0"	Up to 1.0"	3mm to 25mm
Capacity	500,000 MTPA	18000 MTPA	350,000 MTPA/ 80,000 MTPA	300,000 MTPA	200,000 MTPA	200,000 MTPA
Grade	All C Classes and K Classes	All C Classes and K Classes.	All C Classes and K Classes	X-80; NACE & equivalent grades	X-80; NACE & equivalent grades	A106 Grade B, API5L & 5CT

MTPA: Metric Tonnes per annum
OD: Outer Diameter

Table 1.3.2 - Chronology of development of Jindal SAW facilities.

1986	Country's first LSAW Pipes (U-O-E) Mill for Line Pipes commissioned at Kosi Kalan with API an ISO Certification
1992	Bevelling Unit Commissioned at Kosi Kalan SAW Pipes, USA incorporated and commissioned
1993	First major supply of NACE Pipes for Offshore line
1994	Seamless Pipes and Tubes Division Commissioned at Nashik 3 LPE/FBE Coating Plant commissioned at Kosi Kalan
1995	First Export order executed for Line Pipes
1996	CTE Mobile Coating Plant commissioned at Kosi Kalan
1997	Hot Induction Bends Unit established at Kosi Kalan Start up of 4 meter wide Plate Mill at Baytown, USA
1999	Port-based 100% Export Oriented LSAW & HSAW Line Pipe Plants Commissioned at Mundra with API and ISO accreditation Internal coating plant commissioned at Kosi Kalan
2000	3 LPE/FBE Coating Plant commissioned at Mundra Internal Coating Plant commissioned at Mundra
2002	Concrete Wight Coating Plant re-commissioned at Mundra Bevelling Unit commissioned at Mundra.
2003	Additional Plant for 3 LPE/FBE commissioned at Mundra
2004	Third LSAW manufacturing facility commissioned at Samaghogha near port Mundra with accreditation from API and ISO.
2005	Start up of integrated Pipe Unit Ductile Iron Pipe manufacturing plant of 300,000 MT per annum capacity along with Blast Furnace of 300,000 MT per annum capacity and a Coke Oven Plant.
2009	Fourth LSAW manufacturing facility commissioned at Bellary, Karnataka along with internal coating facility with accreditation from API and ISO.
2011	Takeover of industrial assets of Sertubi Spa in Trieste (Italy) manufacturing 80,000 MT of DI pipes in sizes ranging from DN 60 to DN 800 mm diameter.
2013	Commissioning a 350,000 MT Ductile Iron Pipe plant in Abu Dhabi UAE for manufacture of DI Pipes in sizes ranging from 200 mm diameter to 2200 mm diameter. Setting up additional 225,000 MT Ductile Iron Pipe Plant in Samaghogha in Gujarat for manufacture of DI pipes in sizes ranging from DN 80 to DN300 mm diameter.
2014	Commissioning of Ductile Iron Fittings plant in Sholapur, Maharashtra, India having capacity of 1800 MTPA. The plant in capable of manufacturing range DN 80 mm to DN 2200 mm.

1.4 Ductile Iron (DI) Pipes

Ductile Iron pipes are commonly used for potable water and sewage transportation. Metallic pipes, primarily Cast Iron had been used over two centuries ago for Water and Waste water transportation. Ductile Iron pipes which belongs 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 provides an exceptionally long life to serve the water and sanitation networks.

The flexible and leak tight jointing systems in Ductile Iron pipe, 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 solution 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 facilities includes:

- Coke oven battery plant (installed capacity: 200,000 MT per annum)
- Blast furnace (installed capacity: 300,000 MT per annum)
- DI pipe manufacturing facility (installed capacity: 500,000 MT per annum).

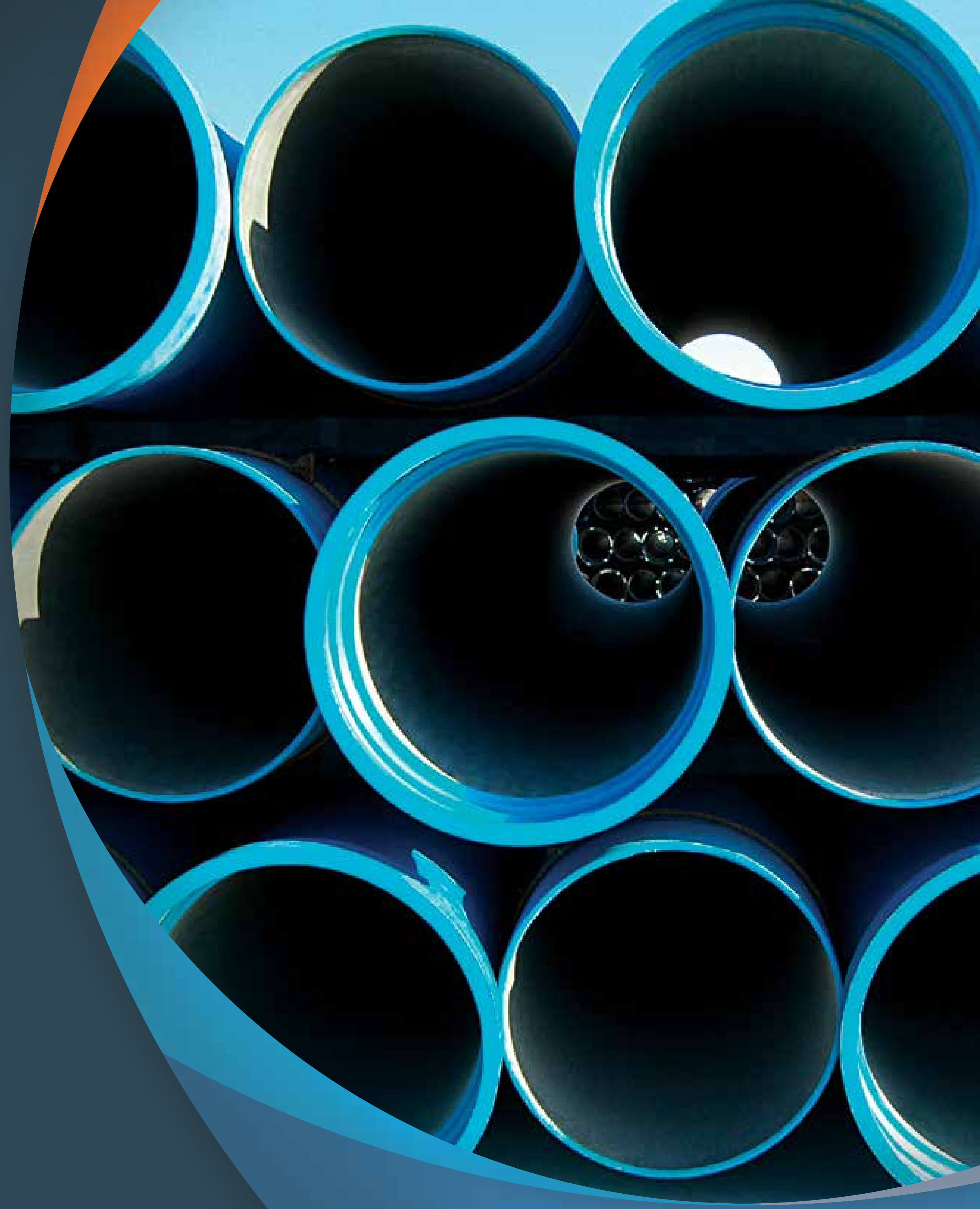
In its quest to be a global leader, Jindal SAW has also taken over the assets of Sertubi Spa in Trieste, Italy. The subsidiary by the name Jindal SAW Italia, Spa will cater to the requirements of Europe and Western countries of globle.

In line with its vision to provide 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, producing pipes of range 200mm to 2200mm.

Quality is the key mantra in 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, BS: EN: 545 and BS: EN: 598.



GENERAL TECHNICAL DATA

2.1 Mechanical Properties of Ductile Iron pipe

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 is 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 maximum, leading to the formation of a stronger, tougher ductile material exceeding grey (or cast) iron in strength, in ductility and in impact strength.

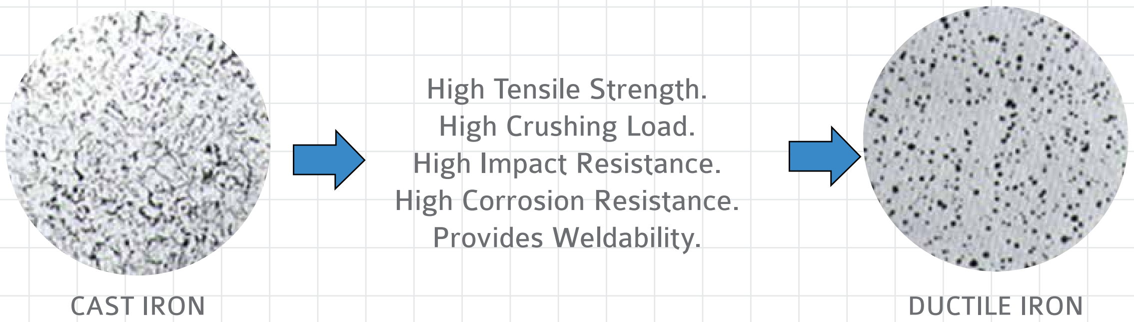


Fig. 2.1: Microstructure transformation of Cast Iron to Ductile Iron

Table 2.1: Mechanical Properties of Ductile Iron pipe

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	Min. 10% upto DN 1000 Min. 7% for diameter > DN 1000
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 50 kg/m^3
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 temp, 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/cm² or 380mpa
Poisson's Ratio	0.275

2.2 Hydraulic Design with Ductile Iron pipe

- 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.

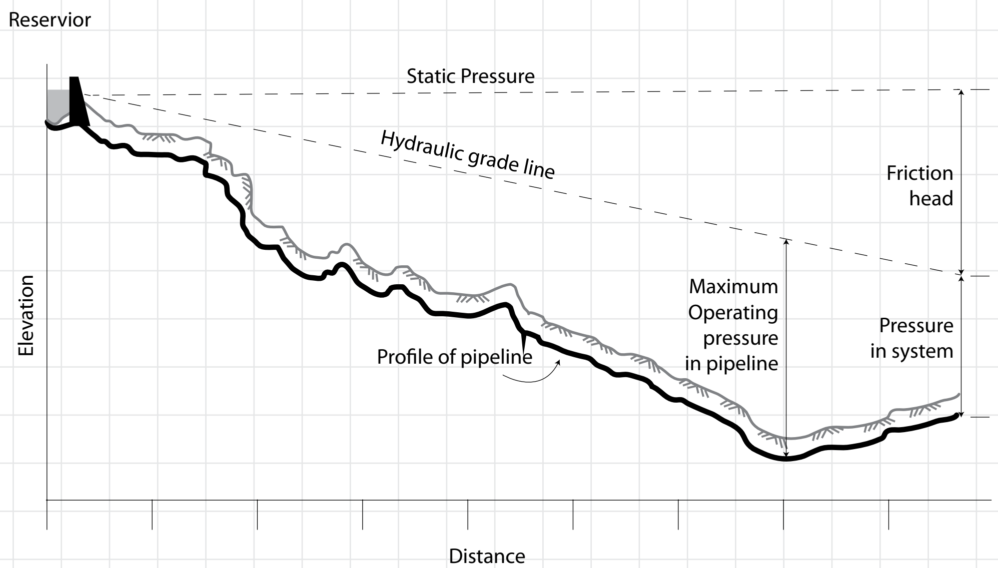


Fig. 2.2: Pressure distribution in gravity transmission mains.

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.

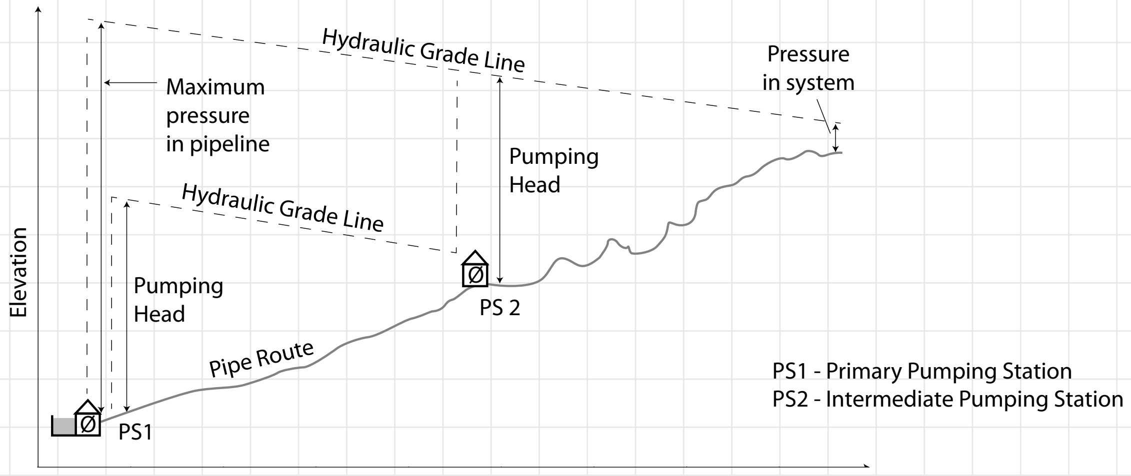


Fig. 2.3: Pressure distribution in pumped transmission main.

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:

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

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

$$Q = \frac{1.98 D^{8/3} i^{1/2}}{n} \qquad \text{Eq - 2.4}$$

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.

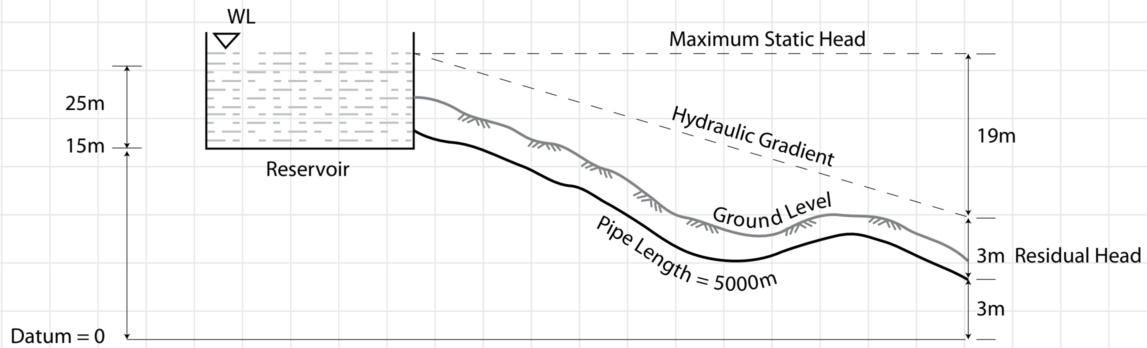


Fig. 2.4: Schematic diagram of Gravity main

Solution:

Assume:
(i) Velocity in the pipeline , v = 1.0 m/sec.
(ii) Calculate the flow diameter of the pipeline,

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

Or, $$D = \left(\frac{4 \times 40}{\pi \times 1000}\right)^{1/2}$$

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 = 250 mm, Q = 40 lps,

Calculate the hydraulic gradient (i) from Table 2.2.2

We get, i = 2.03m /1000 m 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) = 10.15 m

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 distance 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

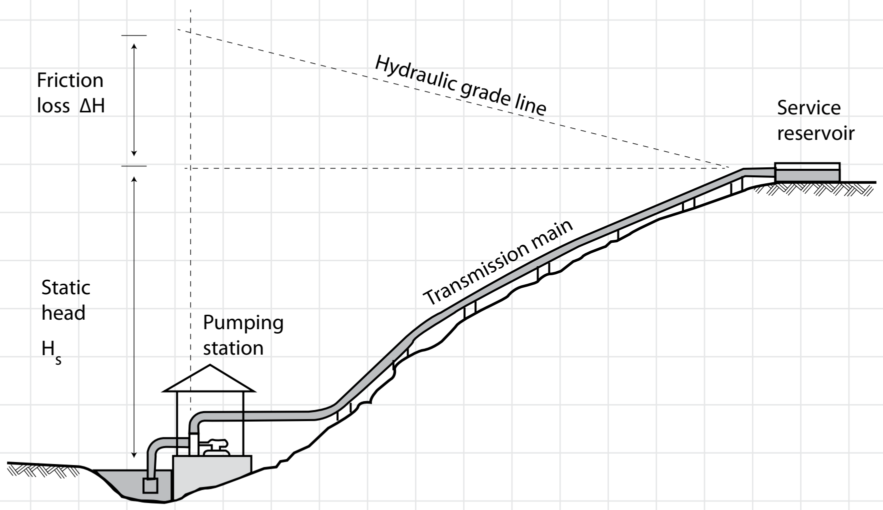


Fig. 2.5: Pumping system for water transmission.

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.

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

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)

Table 2.3: 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	150
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/sec².

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,

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

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),

v = 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/sec²),

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 viscocity 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 = 0.03 mm (for cement lined Ductile Iron pipes)
   ii) k = 0.0013 mm (for Epoxy seal coats).
   iii) k = 0.0015 mm (for Polyurethane line pipes)

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

Note : In the given table 2.2.1 to 2.2.9 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: From 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 2.2.9

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.

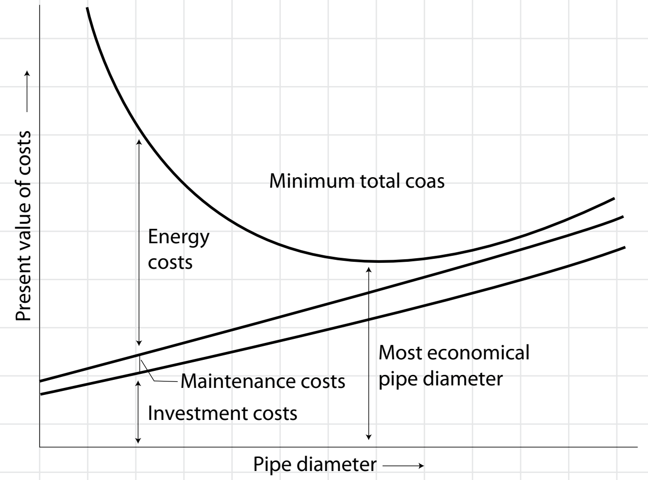


Fig. 2.6: Graph showing relationship of Investment cost, Energy cost and Maintenance cost.

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.
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...

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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 pipe 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 BS EN 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 only.

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 forula 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 meters

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 < 0.3 m.

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 shall be designed for at least β = 0.5 and pipelines laid adjacent to roads shall be designed to withstand the full road loading. For pipelines, which may be exposed to high traffic loading, a factor β = 2 or more may be adopted.

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

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 diameter deflection, in percentage of external diameter D
e = Minimum pipe wall thickness to limit the diametral deflection and bending stress caused by external loads (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 2.1)

Table 2.1: 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
Standart 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% will nomally 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 2.2: 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 provide 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	738 mm	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 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	1.3 M	Given
Unit Weight of Backfill	γ	20 KN/m³	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.

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

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

$= 0.040$ 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.

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

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

= 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	738 mm	ISO 2531 Table D.1
	Wall thickness	t	7.3 mm	- do-
	Allowable deflection	(Δ/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 1, ISO10803
Degree of compaction		Medium	Do
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	7.0 m	Given
Unit weight of backfill	γ	20 KN/m³	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 .

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

or, $q_2 = 0.04 \times (2 / 7.0) \times (1 - 2 \times 10^{-4} \times 700)$

$= 0.010$ 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.

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

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

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

Hence the design is unsafe for DN 700 Class C20.

Choose higher Class of pipe for safe design.

2.4 Technical Specification 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
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 *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 other metals having a minimum mass of 400 gm/m² with finishing layer of Bitumen/Blue epoxy/Red Epoxy as per ISO 8179
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 Dimension

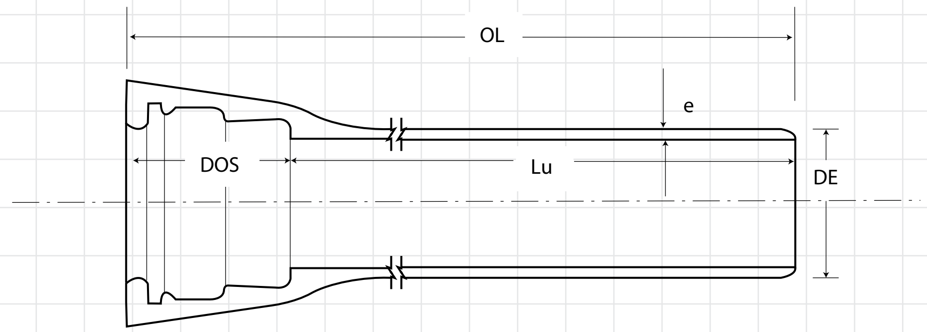


Fig. 2.5 : Dimension of Socket and Spigot pipe.

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 – JAL 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	8.4	10.8
750	790	+1/ -4.3									8.8	11.3
800	842	+1 / -4.5	8.1	9.6	11.1	14.0	16.9	21.0		10.4	9.1	11.7
900	945	+1 / -4.8	8.9	10.6	12.3	15.5	18.8	23.4		11.2	9.8	12.6
1000	1048	+1 / -5.0	9.8	11.6	13.4	17.1	20.7			12.0	10.5	13.5
1100	1152	+1 / -6.0	10.6	12.6	14.7	18.7	22.7			14.4	11.2	14.4
1200	1255	+1 / -5.8	11.4	13.6	15.8	20.2				15.3	11.9	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 3.0 mm

Table 2.5.2: Thickness of Socketed fittings.

Nominal size	Pressure Class	Wall thickness, e (mm)	
DN	C	Nominal	Tolerances
80	100	7.0	-2.30
100	100	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 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 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 C40 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 C20 means the pipe has maximum allowable pressure of 20 bar or 20 Kg./cm². 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.

Table 2.6.1 : 'C' Class pipe – As per ISO 2531 & BS EN 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
DN-100	Bar	bar	Bar
150-200	64	70	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 Socketed Fittings

Pipe size (mm)	Allowable Operating Pressure (PFA in bar			Allowable Maximum Operating Pressure (PFA) in bar			Allowable Site Pressure (PFA) in bar		
DN	K7	K9		K7	K9		K7	K9	
	Indian Standard	Indian Standard	BS EN 545	Indian Standard	Indian Standard	BS EN 545	Indian Standard	Indian Standard	BS EN 545
80	8	64	85	12.5	77	102	17.5	96	107
100	8	64	85	12.5	77	102	17.5	96	107
125	8	64	85	12.5	77	102	17.5	96	107
150	8	64	79	12.5	77	95	17.5	96	100
200	8	62	62	12.5	77	74	17.5	79	79
250	8	54	54	12.5	73	65	17.5	70	70
300	8	49	49	12.5	67	59	17.5	64	64
350	8	45	45	12.5	61	54	17.5	59	59
400	8	42	42	12.5	58	51	17.5	56	56
450	8	40	40	12.5	54	48	17.5	53	53
500	8	38	38	12.5	53	46	17.5	51	51
600	8	36	36	12.5	49	43	17.5	48	48
700	8	34	34	12.5	46	41	17.5	46	46
800	10	32	32	15	43	38	20	43	43
900	10	31	31	15	42	37	20	42	42
1000	10	30	30	15	41	36	20	41	41
1100	29	29	29	35	38	35	40	40	40
1200	28	28	28	34	38	34	39	39	39
1400	28	28	28	33	37	33	38	38	38
1600	27	27	27	32	36	32	37	37	37
1800	26	26	26	31	36	31	36	36	36
2000	26	26	26	31	35	31	36	36	36

2.7 Works Hydrostatic Test Pressure

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

C - class pipe

The internal hydrostatic test pressure shall 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.

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

Nominal Diameter (DN)	Minimum Hydrostatic test pressure at works, MPa Pipes with screwed or welded on flanges			
	PN 10	PN 16	PN 25	PN 40
80 - 300	1.6	2.5	3.2	4.0
350 -600	1.6	2.5	3.2	4.0
700 - 1000	1,6	2,5	3.2	-
1100 - 2000	1.6	2.5	3.2	-

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

Table 2.7.3: 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	-
DN 1100 – DN 2000	1.2	2.5	1.6	2.5	3.2	-

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 shall 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 be not 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:

Table 2.8.1: Thickness of Cement mortar lining

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

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

2.8.4 Standard Cement mortar lining:

The surface of the cement mortar lining shall be uniform and smooth. Trowel marks, protrusion of sand grains and surface texture inherent to the method of manufacture are acceptable. However, there shall 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 shall be as given in Table below.

Table 2.8.2: Recommended Type of cement used for Cement Mortar Linings

Type of Linings	Suitable for Chemical parameters of water
Portland Cement (as per IS 8112 or IS 455)	Soft water with moderate amount of aggressive CO_2. pH range - 6 to 9.
Sulphate Resistant Portland Cement (as per IS 12330 or IS 6909)	Sulphate concentration in water > 3000 mg/litre.
Blast Furnace Slag Cement with Tri Calcium Aluminate (C_3A) content < 3%.	Sea Water Transmission.
High Alumina Cement (as per IS 6452)	For continuous use of pH between 4 and 12 and occasional exposure to pH 3 to 4 and 12 to 13.

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 shall 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 shall 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 shall be not 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

2.10 Joints, Allowable deflection, Type Test

Ductile Iron pipes can be joined by four types of joint which are
1. Simple push on joint.
2. Mechanical joint.
3. Flange joint
4. Restrained joint.

2.10.1 Simple 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 will have 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 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.

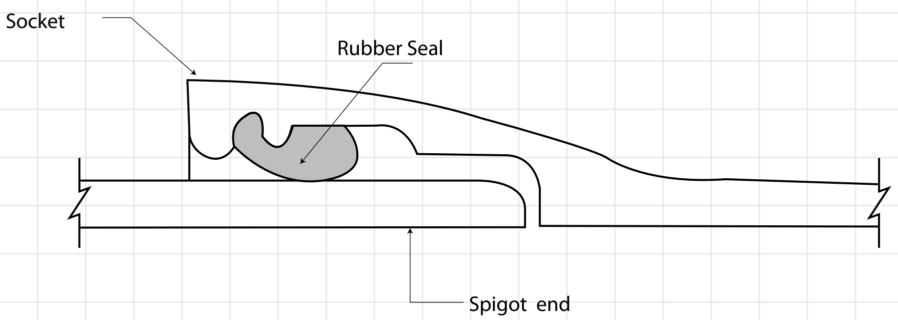


Fig. 2.10.1: Push on Joint

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 will have a circumferential collar to facilitate gripping of the hooks bolts to be used in this joint. In order to complete this joint the metal gland is inserted over the spigot end of one pipe. The gland will have 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.

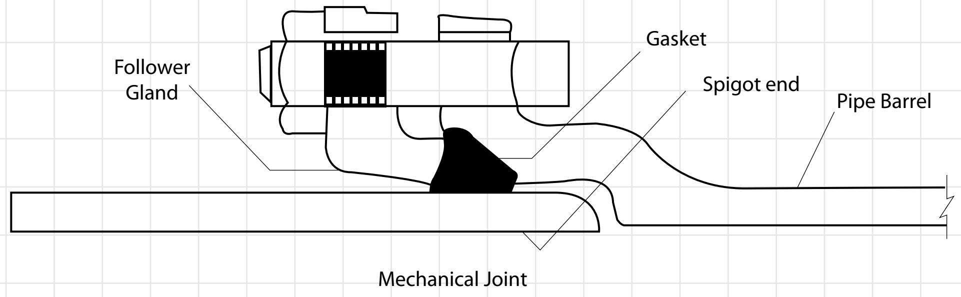


Fig. 2.10.2: Mechanical Joint

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. As Cast flanged pipes:
   In As 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 (in mm)	Pressure Class (N/mm2)
80 - 2200 mm	PN 10
	PN 16
	PN 25
	PN 40

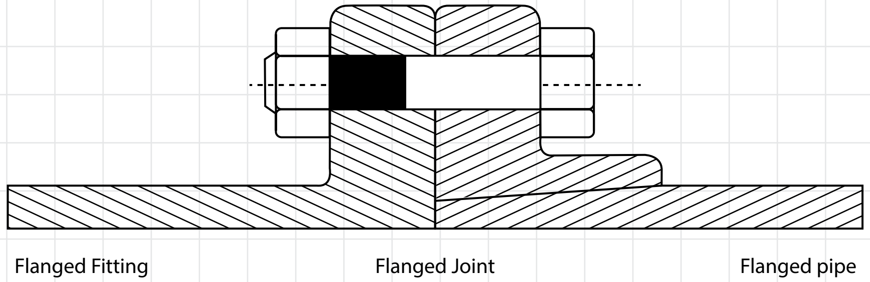
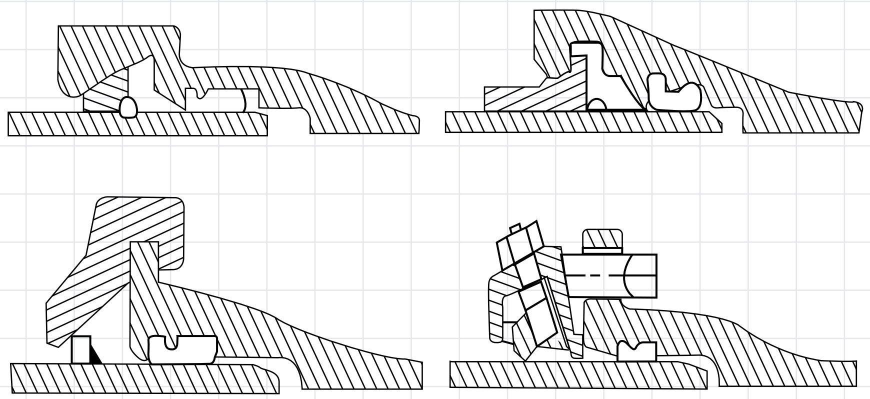


Fig. 2.10.3: Flanged Joint

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 is having 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 in to 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 socket side in to the gland and start tightening using bolts, nuts and washers.
- Complete tightening to esure restrained jointing.



Restrained Joints

Fig. 2.10.4: Different types Restrained Joints

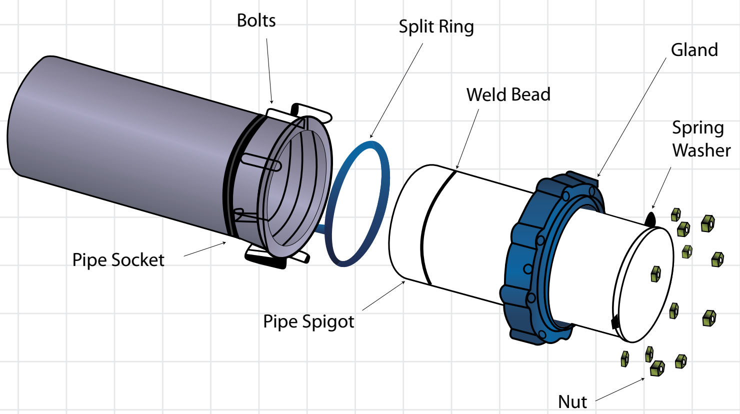


Fig. 2.10.5: Restrained Joint Component

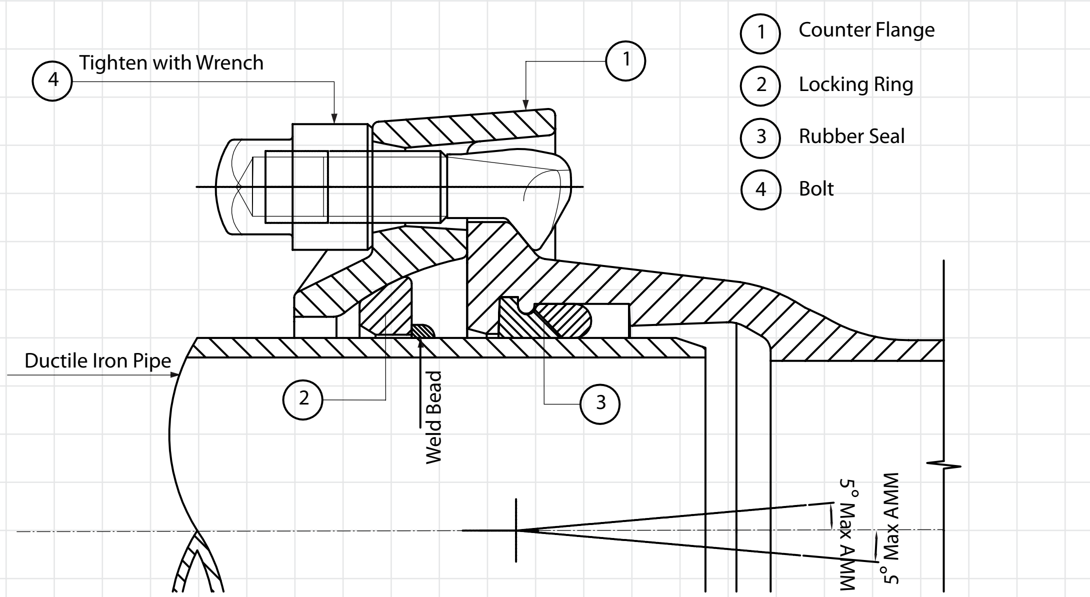


Fig. 2.10.6: JSAW make Restrained Joint

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 twofold;

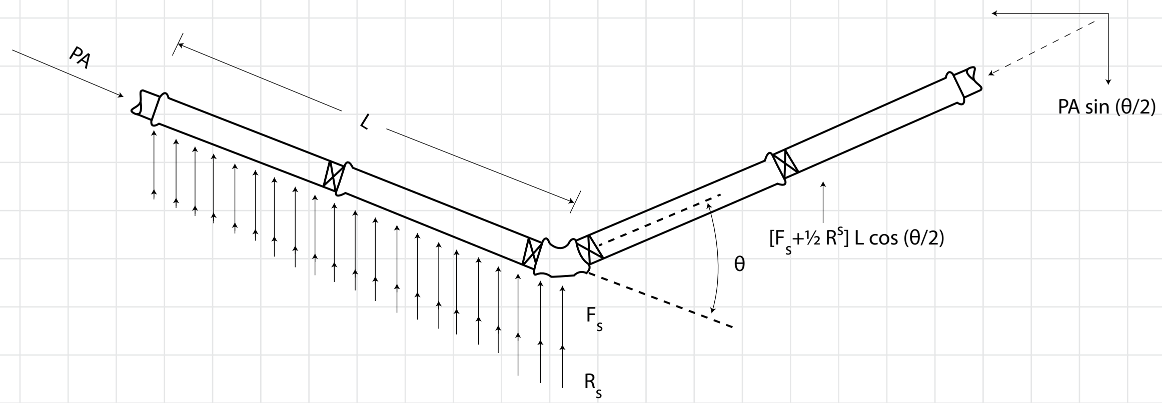
i) the static friction between the pipe unit and the soil

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 calculated 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;

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

Where,

L = Restrained length of pipe in m.

Fs = Unit frictional force (KN/m)

Sf = Factor of Safety (usually 1.5)

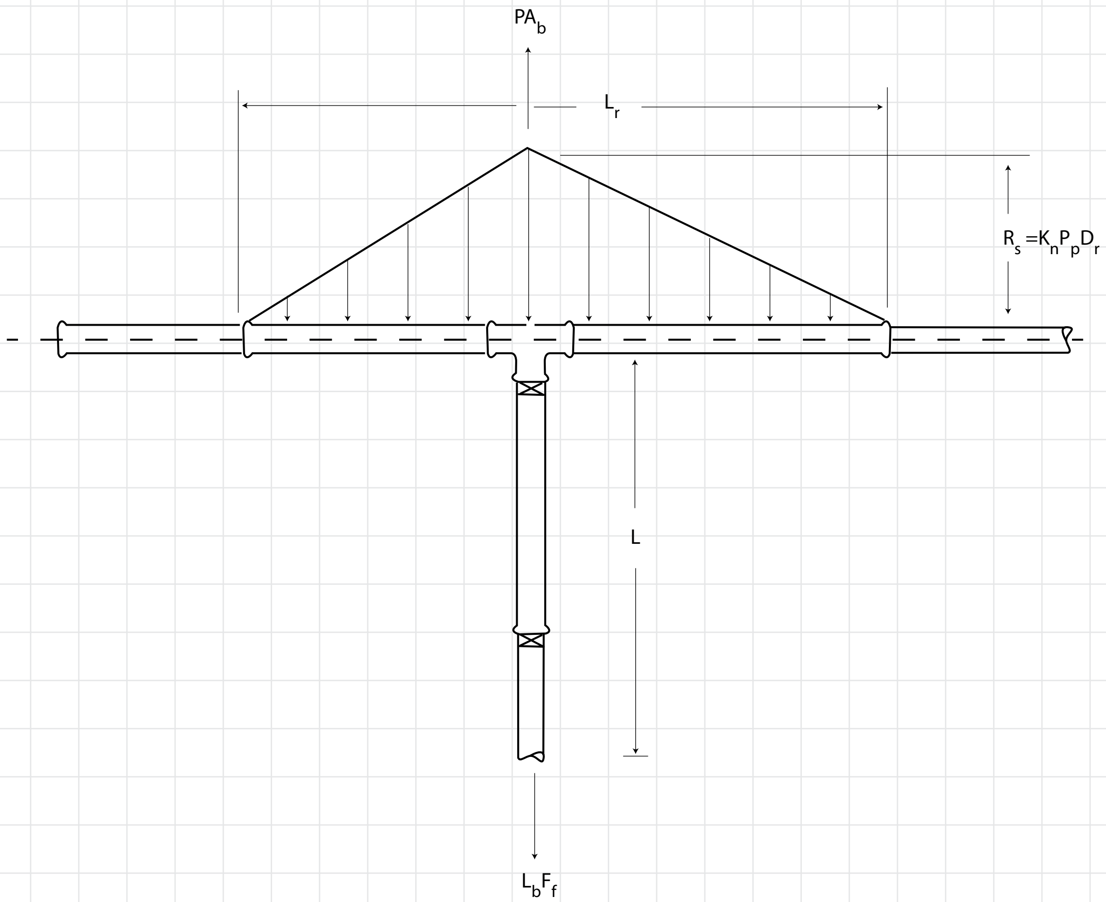
P = Thrust force by internal pressure in KN/m2

A = Cross sectional Area of pipe in m2

θ = Angle of bend (in degrees)

R_s = Maximum unit lateral resistance on pipe.

ii) For Tee:



$$L = \frac{S_f\, PA_b - \tfrac{1}{2}R_s L_r}{F_s}$$

Where:

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

F_s = Unit Frictional force (KN/m)

S_f = Factor of Safety (usually 1.5)

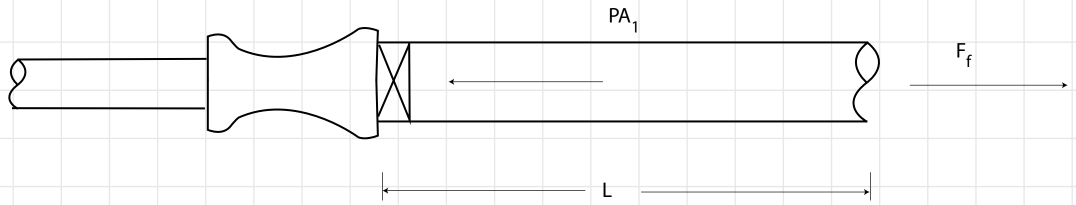
P = Thrust force by internal pressure in KN/m^2

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)

iii) Reducer



$$L = \frac{S_f\, P(A_1 - A_s)}{F_s}$$

Where:

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

F_s = Unit Frictional force (KN/m)

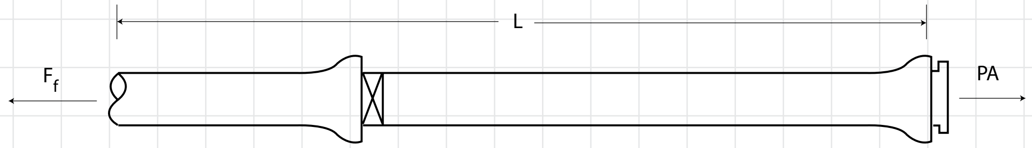
S_f = Factor of Safety (usually 1.5)

P = Thrust force by internal pressure in KN/m2

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

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

iv) For Dead End:



$$L = \frac{S_f\, PA}{F_s}$$

Where:

L = Restrained Length (m)

F_s = 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:

$Fs = Ap\, C + W \tan \delta$

Where:

C = fc Cs From soil classification 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 gainst 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/m2)
D = Pipe Diameter (m)

Unit Bearing Resistance is given by the formula:
Rs = Kn Pp D

Where:
Kn = Trench Compaction factor
D = Pipe Diameter (m)
And

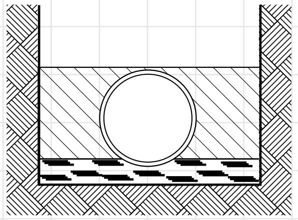
$$P_p = \gamma H_c N_{\varnothing} + 2 C_s N_{\varnothing}$$

Where,
P_p = Passive soil pressure (KN/m²)
γ = Backfill soil density (KN/m²)
H_c = Mean depth from surface to centre line of pipe (m)
C_s = Soil cohesion (KN/m²)
$P_{\varnothing}$ = $\tan^2(45° + ½Ø)$
Ø = Inernal friction of the soil

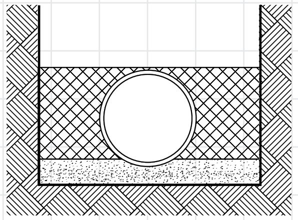
Soil Parameters:

Soil Group	φ	fΦ	Cs (KN/m2)	fc	γ (KN/m3)	Kn Laying Condition (Trench type)		
						3	4	5
GW & SW	35	0.76	0.00	0	17.281	0.6	0.85	1
GP & SP	31	0.8	0.00	0	17.281	0.6	0.85	1
GM & SM	30	0.76	0.00	0	17.281	0.6	0.85	1
GC & SC	25	0.65	10.78	0.4	15.71	0.6	0.85	1
CL	20	0.5	11.98	0.8	15.71	0.6	0.85	1
ML	29	0.75	0.00	0	15.71	0.6	0.85	1
CL, GP & SP	31	0.8	21.56	0	15.71	0.6	0.85	1
ML, GP & SP	31	0.8	14.37	0	15.71	0.6	0.85	1
CH, GP & SP	31	0.8	19.16	0	15.71	0.4	0.6	0.85
MH, GP & SP	31	0.8	11.98	0	15.71	0.4	0.6	0.85

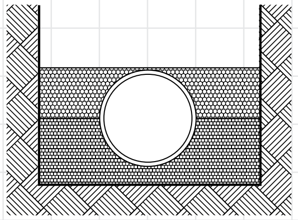
Laying Conditions (Trench Type):


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)

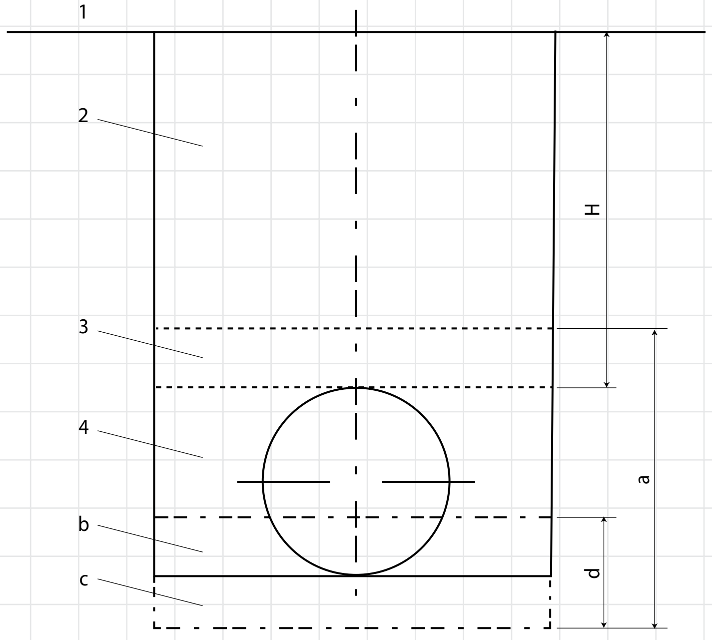
Table 2.10.1 - Length of pipe in metres to be ancnhored on either side of bend (for pressure test = 10 bar)

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	0.352	0.239	0.180	0.146	0.099	0.075	0.070	0.047	0.036	0.035	0.024	0.018	0.888	0.709	0.591
100	0.420	0.286	0.216	0.174	0.118	0.090	0.084	0.057	0.043	0.041	0.028	0.021	1.065	0.852	0.710
150	0.593	0.406	0.309	0.246	0.168	0.128	0.118	0.081	0.061	0.058	0.040	0.030	1.524	1.221	1.018
200	0.759	0.523	0.399	0.315	0.217	0.165	0.151	0.104	0.079	0.075	0.052	0.039	1.974	1.584	1.322
250	0.919	0.637	0.487	0.381	0.264	0.202	0.183	0.127	0.097	0.091	0.063	0.048	2.415	1.941	1.623
300	1.072	0.747	0.573	0.444	0.310	0.238	0.213	0.149	0.114	0.106	0.074	0.056	2.850	2.294	1.920
350	1.218	0.854	0.658	0.504	0.354	0.272	0.242	0.170	0.131	0.120	0.084	0.065	3.269	2.637	2.210
400	1.357	0.957	0.739	0.562	0.396	0.306	0.270	0.190	0.147	0.134	0.094	0.073	3.680	2.973	2.494
450	1.491	1.057	0.819	0.618	0.438	0.339	0.297	0.210	0.163	0.147	0.104	0.081	4.084	3.305	2.775
500	1.622	1.156	0.898	0.672	0.479	0.372	0.323	0.230	0.179	0.160	0.114	0.088	4.489	3.639	3.059
600	1.870	1.346	1.051	0.775	0.558	0.436	0.372	0.268	0.209	0.184	0.133	0.104	5.273	4.286	3.611
700	2.100	1.526	1.198	0.870	0.632	0.496	0.418	0.304	0.238	0.207	0.150	0.118	6.026	4.914	4.149
750	2.210	1.614	1.271	0.916	0.669	0.526	0.440	0.321	0.253	0.218	0.159	0.125	6.400	5.227	4.417
800	2.318	1.699	1.342	0.960	0.704	0.556	0.461	0.338	0.267	0.228	0.167	0.132	6.770	5.536	4.683
900	2.520	1.863	1.478	1.044	0.772	0.612	0.501	0.371	0.294	0.248	0.184	0.146	7.481	6.135	5.200
1000	2.710	2.020	1.610	1.123	0.837	0.667	0.539	0.402	0.320	0.267	0.199	0.159	8.172	6.720	5.706
1100	2.891	2.171	1.738	1.198	0.899	0.720	0.575	0.432	0.346	0.285	0.214	0.171	8.849	7.296	6.207
1200	3.059	2.314	1.860	1.268	0.959	0.771	0.609	0.460	0.370	0.301	0.228	0.183	9.499	7.853	6.692
1400	3.367	2.582	2.093	1.395	1.070	0.867	0.670	0.514	0.416	0.332	0.254	0.206	10.729	8.916	7.627
1600	3.645	2.828	2.310	1.510	1.172	0.957	0.725	0.563	0.460	0.359	0.279	0.228	11.903	9.938	8.530
1800	3.897	3.057	2.515	1.615	1.267	1.042	0.775	0.608	0.500	0.384	0.301	0.248	13.021	10.920	9.402
2000	4.126	3.269	2.707	1.709	1.355	1.122	0.821	0.651	0.539	0.406	0.322	0.267	14.079	11.858	10.241
2200	4.353	3.478	2.896	1.803	1.441	1.200	0.866	0.692	0.576	0.429	0.343	0.285	15.237	12.864	11.130

Note : Length to be anchored shall 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 = 0.406 x 30 = 12.18 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.
0 Lower bedding.
d Bedding.

Fig. 2.10.7: Trench types

The trench types are the following:

a) trench type 1: embedment dumped
b) trench type 2: embedment with very light compaction, greater than 75% standard Proctor density
c) trench type 3: embedment with light compaction, greater than 80% standard Proctor density
d) trench type 4: embedment with medium compaction, greater than 85% standard Proctor density
e) trench type 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 2.10.2: 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° 30'	5.5	90	34
		6	98	37
350-600	2° 30'	5.5	126	24
		6	137	26
700-800	1° 30'	5.5	210	14
		6	229	16
900-2000		5.5	210	14
		6	229	16
2200		6	229	16

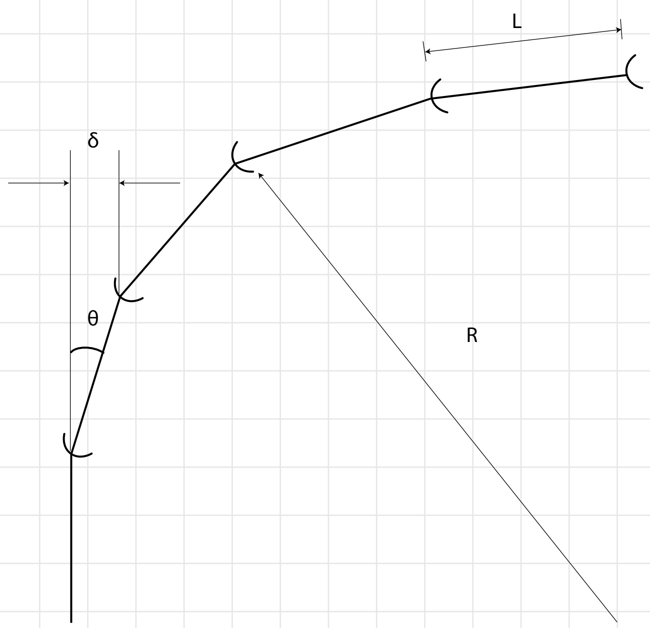


Fig. 2.10.6: Allowable deflection of push on joints

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

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

DN Grouping	80 to 250	300 to 600	700 to 1000	1100 to 200
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 2.10.3: Requirements for Type Test of Ductile Iron pipe.

Test	Test Requirement	Test Conditions	Test Method
Positive Internal hydrostatic pressure	Test pressure : 1.5 PFA +5 bar	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with clause no. 7.2.2 of BSEN 545
	Test Duration: 2 hours		
	No visible leakage	Joint of maximum annulus, deflected	
Negative Internal pressure	Test pressure : 0.9 bar	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with clause no. 7.2.3 of BSEN 545
	Test Duration: 2 hours		
	Maximum pressure change during test period: 0.09 bar	Joint of maximum annulus, deflected	
Positive External hydrostatic pressure	Test pressure : 2 bar	Joint of maximum annulus, aligned with shear load	In accordance with clause no. 7.2.4 of BSEN 545
	Test Duration: 2 hours		
	No visible leakage		
Cyclic Internal hydraulic pressure	24000 cycles	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with clause no. 7.2.5 of BSEN 545
	Test pressure: Between PMA and (PMA-5) bar		
	No visible leakage		

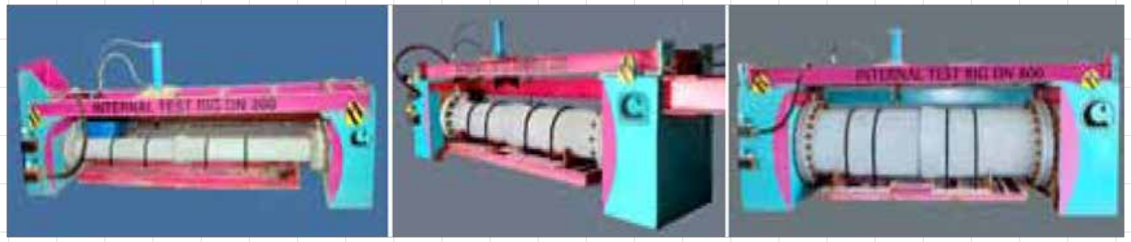


Fig. 2.10.9: Type test facility in JSAW plant

2.10.8 Rubber gaskets for flexible jointing system

Rubber Gasket provides leak tight flexible jointing system in Ductile Iron pipelines. Earlier Natural Rubber were 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 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. 2.10.10: Rubber gasket

A rubber gasket consists of two parts, the harder part called "Heel" and a softer part called "Bulb" as shown in figure 2.10.11.

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.

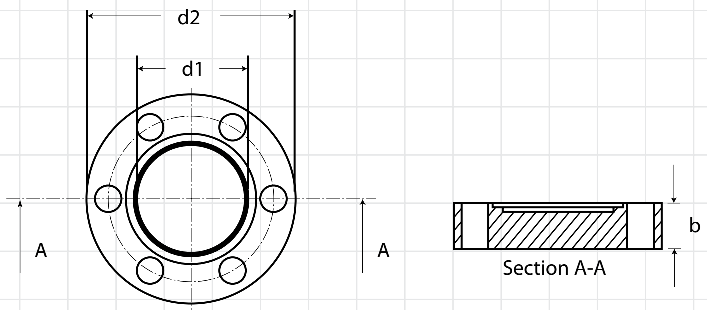


Fig. 2.10.11: Gasket for Flange joints

Table 2.10.4: Dimension details of Rubber Gasket for Flange joints

			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	389
350	358	3	429	429	448	448
400	407	3	480	480	503	535
450	457	3	548	548	548	560
500	508	3	609	609	609	615
600	608	3	720	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	-

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.

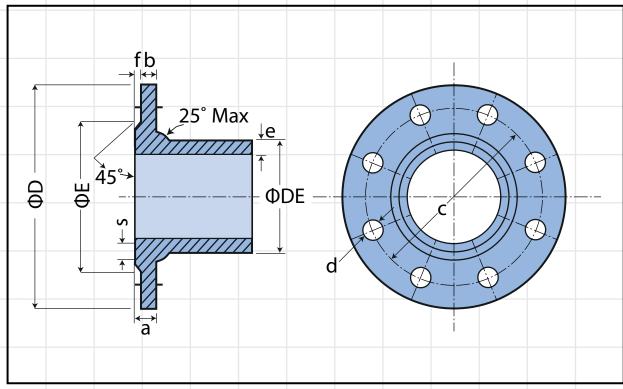
Fig. 2.10.11: Modified gaskets with steel inserts

2.11 Dimension Details- Flanged And Socketed Fittings

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

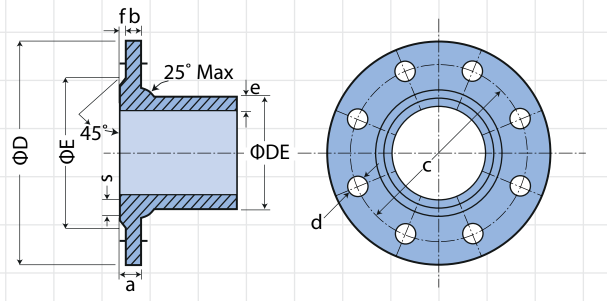


DE -	Pipe outer diameter.
ΦD -	Outer diameter of flange.
ΦE -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe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

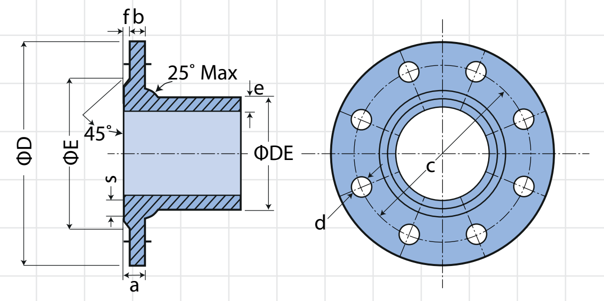


DE -	Pipe outer diameter.
ΦD -	Outer diameter of flange.
ΦE -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe 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	16	8	23	M20
250	274	405	9	319	355	19	3	22	17.5	12	28	M24
300	326	460	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	530	585	26	4	30	24	20	31	M27
500	532	715	12	582	650	27.5	4	31.5	25	20	34	M30
600	635	840	13.2	682	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	1231	1270	48.5	5	53.5	37.5	28	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

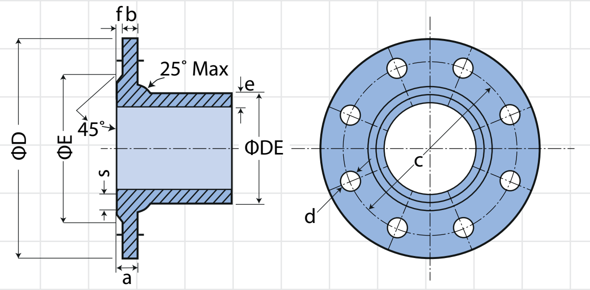


DE -	Pipe outer diameter.
ΦD -	Outer diameter of flange.
ΦE -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe 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	36.5	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

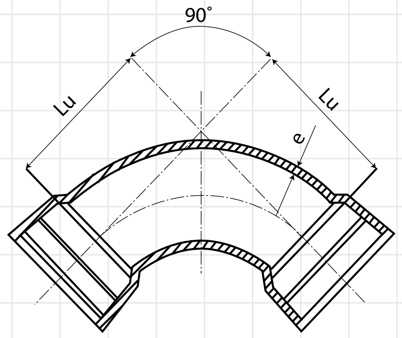


DE -	Pipe outer diameter.
ΦD -	Outer diameter of flange.
ΦE -	Diameter of raised face.
c -	Pitch circle diameter (P.C.D)
b -	Flange thickness.
f -	Thickness of raised face.
a -	Flange thickness + Thickness of raised face.
s -	Maximum thickness of junction point between flange and barrel diameter or pipe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

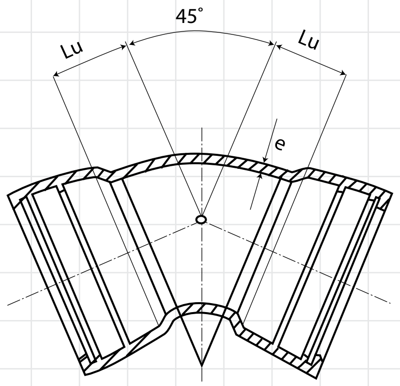
2.11.2 Standard Dimensions of Socketed Fittings for Push on joints:

Double Socket 90° Bends



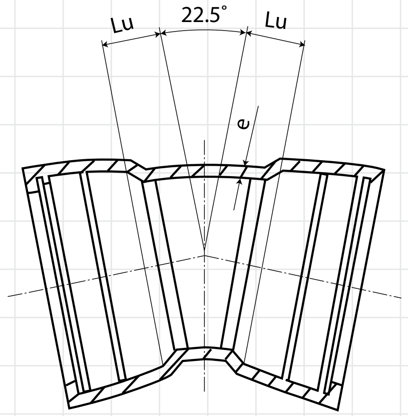
(DN)	e	90°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	100	100
100	7.20	120	100
150	7.80	170	64
200	8.40	220	64
250	9.00	270	50
300	9.60	320	50
350	10.20	370	50
400	10.80	420	40
450	11.40	470	40
500	12.00	520	40
600	13.20	620	40
700	14.40	720	30
800	15.60	820	30
900	16.80	920	30
1000	18.00	1020	30
1100	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	1830	25

Double Socket 45° Bend



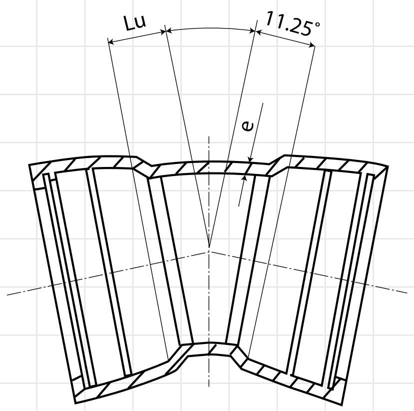
(DN)	e	45°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	55	100
100	7.20	65	100
150	7.80	85	64
200	8.40	110	64
250	9.00	130	50
300	9.60	150	50
350	10.20	175	50
400	10.80	195	40
450	11.40	220	40
500	12.00	240	40
600	13.20	285	40
700	14.40	330	30
800	15.60	370	30
900	16.80	415	30
1000	18.00	460	30
1100	19.20	505	30
1200	20.40	550	30
1400	22.80	515	30
1600	25.20	565	25
1800	27.60	610	25
2000	30.00	660	25
2200	32.4	710	25

Double Socket 22.5° Bend



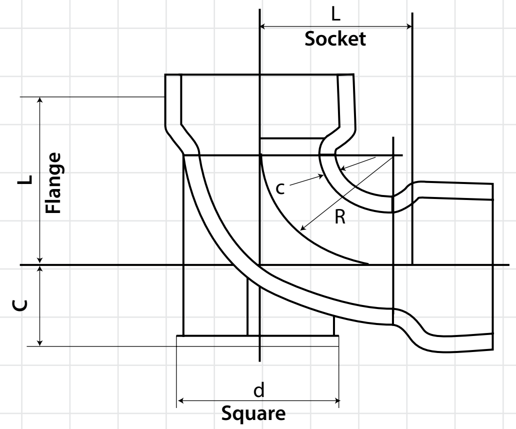
(DN)	e	22.5°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	40	100
100	7.20	40	100
150	7.80	55	64
200	8.40	65	64
250	9.00	75	50
300	9.60	85	50
350	10.20	95	50
400	10.80	110	40
450	11.40	120	40
500	12.00	130	40
600	13.20	150	40
700	14.40	175	30
800	15.60	195	30
900	16.80	205	30
1000	18.00	210	30
1100	19.20	220	30
1200	20.40	240	30
1400	22.80	260	30
1600	25.20	280	25
1800	27.60	305	25
2000	30.00	330	25
2200	32.40	355	25

Double Socket 11.25° Bend



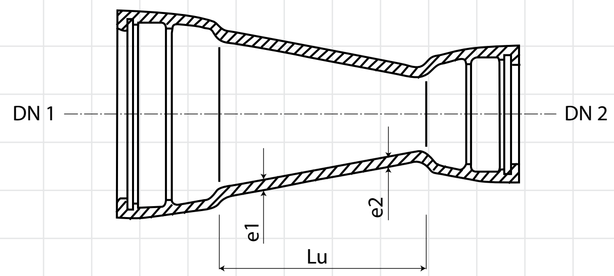
(DN)	e	11.25°	
		Lu	Pressure (Bar)
mm	mm	mm	PFA
80	7.00	30	100
100	7.20	30	100
150	7.80	35	64
200	8.40	40	64
250	9.00	50	50
300	9.60	55	50
350	10.20	60	50
400	10.80	65	40
450	11.40	70	40
500	12.00	75	40
600	13.20	85	40
700	14.40	95	30
800	15.60	110	30
900	16.80	115	30
1000	18.00	120	30
1100	19.20	120	30
1200	20.40	130	30
1400	22.80	130	30
1600	25.20	140	25
1800	27.60	155	25
2000	30.00	165	25
2200	32.40	355	25

Duckfoot Double Socket 90° Bend



DN	e	L	c	d	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
80	7.00	110	110	180	100
100	7.20	130	125	200	100
150	7.80	180	160	250	64
200	8.40	230	190	300	64
250	9.00	280	225	350	50
300	9.60	325	255	400	50
350	10.20	380	290	450	50
400	10.80	430	320	500	40
450	11.40	480	355	550	40
500	12.00	530	385	600	40
600	13.20	630	450	700	40
700	14.40	735	515	800	30
800	15.60	830	580	900	30
900	16.80	930	645	1000	30
1000	18.00	1035	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

Double Socket Concentric Tapers



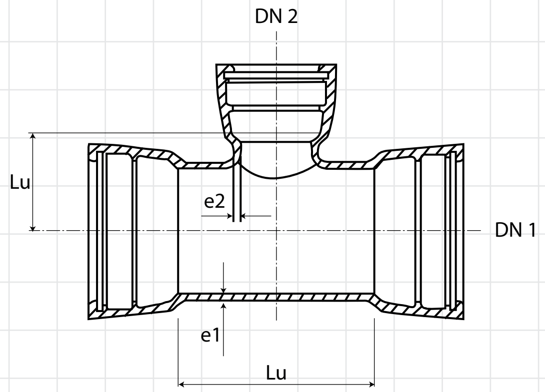
DN 1	DN 2	e1	e2	Lu	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
100	80	7.20	7.0	90	100
125	80	7.50	7.0	140	100
150	80	7.80	7.0	190	64
150	100	7.80	7.2	150	64
150	125	7.80	7.5	100	64
200	100	8.40	7.2	250	64
200	125	8.40	7.5	200	64
200	150	8.40	7.8	150	64
250	125	9.00	7.5	300	50
250	150	9.00	7.8	250	50
250	200	9.00	8.4	150	50
300	150	9.60	7.8	350	50
300	200	9.60	8.4	250	50
300	250	9.60	9.0	150	50
350	200	10.20	8.4	360	50
350	250	10.20	9.0	260	50
350	300	10.20	9.6	160	50
400	200	10.80	8.4	360	40
400	250	10.80	9.0	360	40
400	300	10.80	9.6	260	40
400	350	10.80	10.2	160	40
450	250	11.40	9.0	260	40
450	300	11.40	9.6	260	40
450	350	11.40	10.2	260	40
450	400	11.40	10.8	160	40
500	300	12.00	9.6	360	40
500	350	12.00	10.2	360	40
500	400	12.00	10.8	260	40
500	450	12.00	11.4	160	40
600	350	13.20	10.2	460	40
600	400	13.20	10.8	460	40
600	450	13.20	11.4	360	40
600	500	13.20	12.0	260	40
700	400	14.40	10.8	480	30

Continued...

...continued

DN 1	DN 2	e1	e2	Lu	Pressure (Bar)
mm	mm	mm	mm	mm	PFA
700	450	14.40	11.4	480	30
700	600	14.40	13.2	280	30
800	450	15.60	11.4	480	30
800	500	15.60	12.0	480	30
800	600	15.60	13.2	480	30
800	700	15.60	14.4	280	30
900	500	16.80	12.0	480	30
900	600	16.80	13.2	480	30
900	700	16.80	14.4	480	30
900	800	16.80	15.6	280	30
1000	600	18.00	13.2	480	30
1000	700	18.00	14.4	480	30
1000	800	18.00	15.6	480	30
1000	900	18.00	16.8	280	30
1100	700	19.20	14.4	480	30
1100	800	19.20	15.6	480	30
1100	900	19.20	16.8	480	30
1100	1000	19.20	18.0	280	30
1200	700	20.40	14.4	480	30
1200	800	20.40	15.6	480	30
1200	900	20.40	16.8	480	30
1200	1000	20.40	18.0	480	30
1200	1100	20.40	19.2	280	30
1400	800	22.80	15.6	360	30
1400	900	22.80	16.8	360	30
1400	1000	22.80	18.0	360	30
1400	1100	22.80	19.2	360	30
1400	1200	22.80	20.4	360	30
1500	900	24.00	16.8	360	25
1500	1000	24.00	18.0	360	25
1500	1100	24.00	19.2	360	25
1500	1200	24.00	20.4	260	25
1500	1400	24.00	22.8	260	25
1600	1000	25.20	18.0	360	25
1600	1100	25.20	19.2	360	25
1600	1200	25.20	20.4	360	25
1600	1400	25.20	22.8	360	25
1600	1500	25.20	24.0	260	25
1800	1100	27.60	19.2	480	25
1800	1200	27.60	20.4	480	25
1800	1400	27.60	22.8	360	25
1800	1500	27.60	24.0	360	25
1800	1600	27.60	25.2	360	25
2000	1800	30	27.6	360	25
2200	2000	32.4	30	360	25

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
150	80	7.80	7.00	170	120	64
150	100	7.80	7.20	195	120	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	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	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	210	210	50
300	150	9.60	7.80	265	210	50
300	200	9.60	8.40	325	210	50
300	250	9.60	9.00	380	210	50
300	300	9.60	9.60	440	210	50
350	80	10.20	7.00	185	238	50
350	100	10.20	7.20	205	260	50
350	150	10.20	7.80	265	245	50
350	200	10.20	8.40	325	270	50
350	250	10.20	9.00	380	270	50
350	300	10.20	9.60	440	263	50
350	350	10.20	10.20	495	270	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

Continued...

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DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
400	200	10.80	8.40	325	295	40
400	250	10.80	9.00	385	305	40
400	300	10.80	9.60	440	310	40
400	400	10.80	10.80	560	320	40
450	80	11.40	7.00	190	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	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	275	340	40
500	200	12.00	8.40	330	345	40
500	250	12.00	9.00	390	355	40
500	300	12.00	9.60	450	360	40
500	350	12.00	10.20	505	365	40
500	400	12.00	10.80	565	370	40
500	500	12.00	12.00	680	380	40
600	80	13.20	7.00	200	385	40
600	100	13.20	7.20	220	385	40
600	150	13.20	7.80	280	390	40
600	200	13.20	8.40	340	395	40
600	300	13.20	9.60	455	410	40
600	400	13.20	10.80	570	420	40
600	500	13.20	12.00	685	430	40
600	600	13.20	13.20	800	440	40
700	100	14.40	7.20	230	422	30
700	150	14.40	7.80	285	440	30
700	200	14.40	8.40	345	445	30
700	300	14.40	9.60	460	460	30
700	400	14.40	10.80	575	470	30
700	500	14.40	12.00	690	480	30
700	600	14.40	13.20	810	490	30
700	700	14.40	14.40	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	300	15.60	9.60	465	510	30
800	400	15.60	10.80	580	520	30

Continued...

...continued

DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
800	500	15.60	12.00	700	530	30
800	600	15.60	13.20	815	540	30
800	800	15.60	15.60	1045	565	30
900	150	16.80	7.80	300	540	30
900	200	16.80	8.40	355	545	30
900	400	16.80	10.80	590	570	30
900	600	16.80	13.20	820	590	30
900	800	16.80	15.60	1050	615	30
900	900	16.80	16.80	1170	625	30
1000	150	18.00	7.80	305	590	30
1000	200	18.00	8.40	360	595	30
1000	400	18.00	10.80	595	620	30
1000	600	18.00	13.20	1290	640	30
1000	800	18.00	15.60	1290	665	30
1000	1000	18.00	18.00	1290	685	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	690	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	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	1000	20.40	18.00	1300	785	30
1200	1200	20.40	20.40	1535	805	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	865	30
1400	1000	22.80	18.00	1495	885	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	805	870	25
1500	600	24.00	13.20	1035	890	25
1500	800	24.00	15.60	1270	915	25
1500	1000	24.00	18.00	1500	935	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

Continued...

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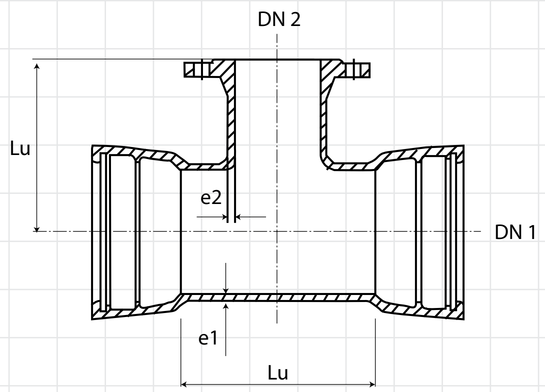
DN 1	DN 2	e1	e2			Pressure (Bar)
				Lu	lu	PFA
1600	800	25.20	15.60	1275	965	25
1600	1000	25.20	18.00	1505	985	25
1600	1200	25.20	20.40	1740	1005	25
1600	1400	25.20	22.80	1970	1030	25
1600	1600	25.20	25.20	2200	1050	25
1800	800	27.60	15.60	1285	1065	25
1800	1000	27.60	18.00	1520	1085	25
1800	1200	27.60	20.40	1750	1105	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

Flange on Double Socket Tees



DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
80	80	7.00	7.00	170	165	10	16
100	80	7.20	7.00	170	175	10	16
100	100	7.20	7.20	190	175	10	16
150	50	7.80	7.00	170	185	10	16
150	80	7.80	7.00	170	200	10	16
150	100	7.80	7.20	195	200	10	16
150	150	7.80	7.80	255	218	10	16
200	80	8.40	7.00	175	225	10	16
200	100	8.40	7.20	200	225	10	16
200	150	8.40	7.80	255	243	10	16
200	200	8.40	8.40	315	258	10	16
250	80	9.00	7.00	180	250	10	16
250	100	9.00	7.20	200	250	10	16
250	150	9.00	7.80	260	268	10	16
250	200	9.00	8.40	315	283	10	16
250	250	9.00	9.00	375	303	10	16
300	80	9.60	7.00	210	290	10	16
300	100	9.60	7.20	210	300	10	16
300	150	9.60	7.80	265	303	10	16
300	200	9.60	8.40	325	320	10	16
300	250	9.60	9.00	380	323	10	16
300	300	9.60	9.60	440	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	445	360	10	16
350	300	10.20	9.60	495	370	10	16
350	350	10.20	10.20	495	380	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

Continued...

...continued

DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
400	250	10.80	9.00	385	390	10	16
400	300	10.80	9.60	440	400	10	16
400	400	10.80	10.80	560	420	10	16
450	80	11.40	7.00	190	385	10	16
450	100	11.40	7.20	215	390	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	400	11.40	10.80	560	450	10	16
450	450	11.40	11.40	620	460	10	16
500	80	12.00	7.00	195	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	390	450	10	16
500	300	12.00	9.60	450	460	10	16
500	350	12.00	10.20	565	480	10	16
500	400	12.00	10.80	565	480	10	16
500	500	12.00	12.00	680	500	10	16
600	80	13.20	7.00	200	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	300	13.20	9.60	570	540	10	16
600	400	13.20	10.80	570	540	10	16
600	500	13.20	12.00	685	560	10	16
600	600	13.20	13.20	800	580	10	16
700	100	14.40	7.20	230	510	10	16
700	150	14.40	7.80	285	520	10	16
700	200	14.40	8.40	345	525	10	16
700	300	14.40	9.60	460	540	10	16
700	400	14.40	10.80	575	555	10	16
700	500	14.40	12.00	690	570	10	16
700	600	14.40	13.20	810	585	10	16
700	700	14.40	14.40	925	600	10	16
800	100	15.60	7.20	235	570	10	16
800	300	15.60	9.60	465	600	10	16
800	400	15.60	10.80	580	615	10	16
800	500	15.60	12.00	700	630	10	16
800	600	15.60	13.20	1045	645	10	16
800	700	15.60	14.40	1045	675	10	16

Continued...

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DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
800	800	15.60	15.60	1045	675	10	16
900	150	16.80	7.80	300	640	10	16
900	200	16.80	8.40	355	645	10	16
900	400	16.80	10.80	590	675	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	400	18.00	10.80	595	735	10	16
1000	600	18.00	13.20	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	200	19.20	8.40	370	765	10	16
1100	400	19.20	10.80	600	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	200	20.40	8.40	375	825	10	16
1200	400	20.40	10.80	605	855	10	16
1200	600	20.40	13.20	840	885	10	16
1200	800	20.40	15.60	1070	915	10	16
1200	1000	20.40	18.00	1300	945	10	16
1200	1200	20.40	20.40	1535	975	10	16
1400	400	22.80	10.80	770	920	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	400	25.20	10.80	810	1060	10	16
1600	600	25.20	13.20	1040	1090	10	16
1600	800	25.20	15.60	1275	1120	10	16
1600	1400	25.20	22.80	1970	1210	10	16
1600	1600	25.20	25.20	2200	1240	10	16

Continued...

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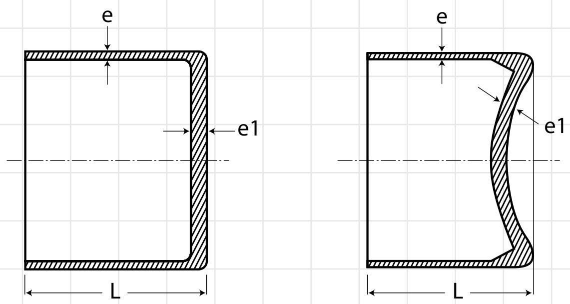
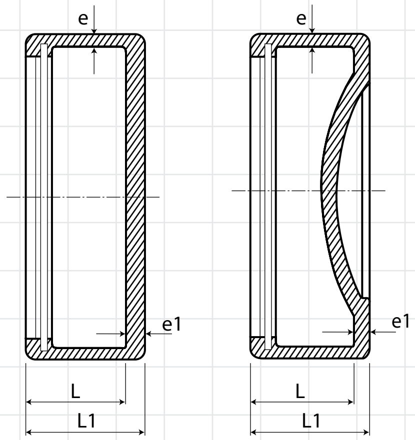
DN1	DN2	e1	e2	Lu	lu	Pressure (Bar)	
						PN10	PN 16
						PFA	PFA
1800	600	27.60	13.20	1055	1200	10	16
1800	800	27.60	15.60	1285	1230	10	16
1800	1000	27.60	18.00	1520	1260	10	16
1800	1200	27.60	20.40	1750	1290	10	16
1800	1400	27.60	22.80	1980	1320	10	16
1800	1600	27.60	25.20	2215	1350	10	16
1800	1800	27.60	27.60	2445	1380	10	16
2000	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

Plugs



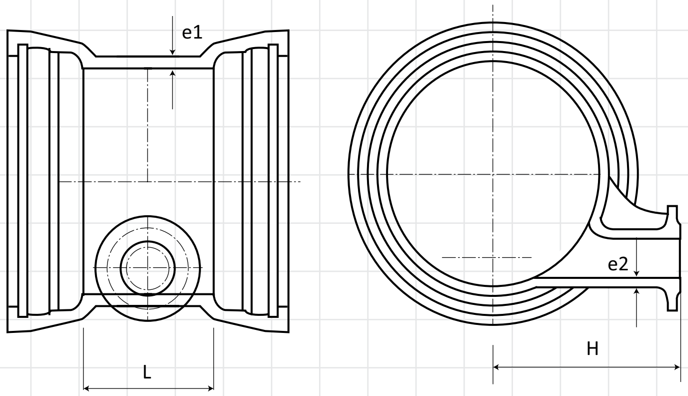
DN	e1	e	L
80	9.5	7.00	200.0
100	10.5	7.20	200.0
150	14.5	7.80	225.0
200	18.0	8.40	250.0
250	19.5	9.00	250.0
300	23.0	9.60	275.0
350	24.0	10.20	275.0
400	25.0	10.80	275.0
450	26.0	11.40	275.0
500	27.0	12.00	275.0
600	29.5	13.20	300.0
700	31.0	14.40	300.0
800	33.0	15.60	300.0
900	35.0	16.80	325.0
1000	37.0	18.00	350.0
1100	39.0	19.20	375.0
1200	41.0	20.40	400.0
1400	22.8	340	1477
1600	25.2	360	1683
1800	27.6	380	1889
2000	30	400	2095
2200	32.4	420	2301

Caps



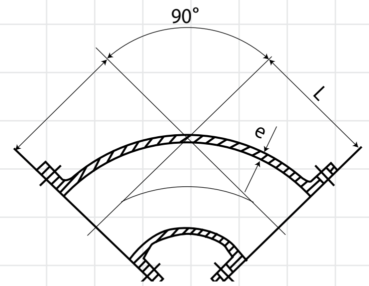
DN	e	e1	L	L1
80	7.00	9.5	115.0	118.0
100	7.20	10.5	103.8	111.0
150	7.80	14.5	111.2	119.0
200	8.40	18.0	117.6	126.0
250	9.00	19.5	124.0	133.0
300	9.60	23.0	129.4	139.0
350	10.20	24.0	129.5	140.0
400	10.80	25.0	131.0	142.0
450	11.40	26.0	142.4	154.0
500	12.00	27.0	143.8	156.0
600	13.20	29.5	146.6	160.0
700	14.40	31.0	176.4	191.0
800	15.60	33.0	188.2	204.0
900	16.80	35.0	204.0	221.0
1000	18.00	37.0	214.8	233.0
1100	19.20	39.0	240.6	260.0
1200	20.40	41.0	264.4	285.0

Double Socket Level Invert Tee with Flanged Branch



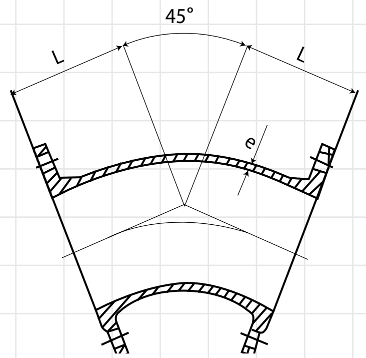
DN	dn	e1	L	e2	H	Pressure (Bar)	
mm	mm	mm	mm	mm	mm	PN 10	PN 16
150	50	7.8	170	7	205	10	16
200	80	8.4	175	7	225	10	16
200	100	8.4	200	7.2	240	10	16
250	80	9	180	7	250	10	16
250	150	7.8	170	7	185	10	16
300	80	9.6	210	7	290	10	16
300	150	9.6	260	7.8	310	10	16
350	100	10.2	205	7.2	330	10	16
400	100	10.8	210	7.2	360	10	16
400	200	10.8	325	8.4	380	10	16
450	100	11.4	215	7.2	390	10	16
450	200	11.4	330	8.4	410	10	16
500	100	12	215	7.2	420	10	16
600	100	13.2	340	7.2	500	10	16
600	250	13.2	295	9	450	10	16
700	150	14.4	285	7.8	520	10	16
750	150	15	360	7.8	500	10	16
800	150	15.6	290	7.8	580	10	16
900	150	16.8	300	7.8	640	10	16
1000	200	18	360	8.4	705	10	16
1100	200	19.2	370	8.4	765	10	16
1200	200	20.4	375	8.4	825	10	16
1400	200	22.8	460	8.4	850	10	16
1500	200	24	465	8.4	900	10	16
1600	400	25.2	700	10.8	950	10	16
1800	400	27.6	715	10.8	1050	10	16

Double Flange 90° Bends



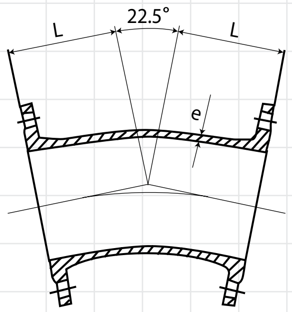
DN	e	90°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	165	10	16
100	7.20	180	10	16
150	7.80	220	10	16
200	8.40	260	10	16
250	9.00	350	10	16
300	9.60	400	10	16
350	10.20	450	10	16
400	10.80	500	10	16
450	11.40	550	10	16
500	12.00	600	10	16
600	13.20	700	10	16
700	14.40	800	10	16
800	15.60	900	10	16
900	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	25.2	1765	10	16

Double Flange 45° Bends



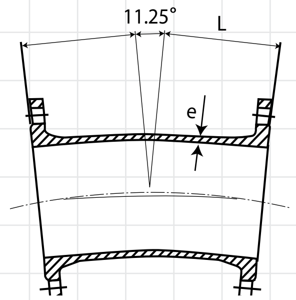
DN	e	45°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	130	10	16
100	7.20	140	10	16
150	7.80	160	10	16
200	8.40	180	10	16
250	9.00	350	10	16
300	9.60	400	10	16
350	10.20	298	10	16
400	10.80	324	10	16
450	11.40	350	10	16
500	12.00	375	10	16
600	13.20	426	10	16
700	14.40	478	10	16
800	15.60	529	10	16
900	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	25.2	845	10	16
1800	27.6	910	10	16
2000	30.0	980	10	16
2200	32.4	880	10	16

Double Flange 22.5° Bends



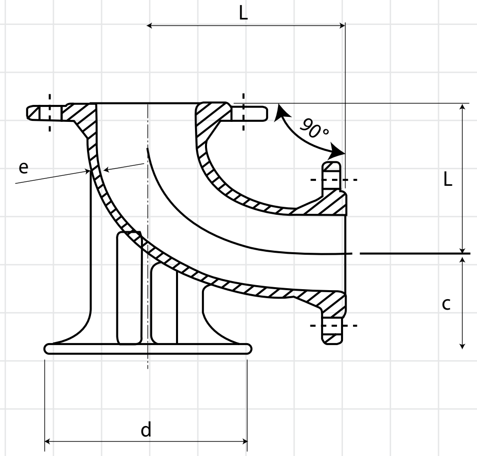
DN	e	22.50°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	105	10	16
100	7.20	110	10	16
150	7.80	109	10	16
200	8.40	131	10	16
250	9.00	190	10	16
300	9.60	210	10	16
350	10.20	210	10	16
400	10.80	239	10	16
450	11.40	350	10	16
500	12.00	375	10	16
600	13.20	426	10	16
700	14.40	478	10	16
800	15.60	529	10	16
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	524	10	16
1600	25.2	845	10	16

Double Flange 11.25° Bends



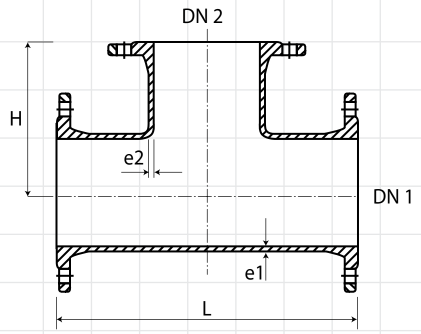
DN	e	11.25°		
		L	PFA (Bar)	
mm	mm	mm	PN 10	PN16
80	7.00	113	10	16
100	7.20	115	10	16
150	7.80	113	10	16
200	8.40	132	10	16
250	9.00	165	10	16
300	9.60	175	10	16
350	10.20	191	10	16
400	10.80	205	10	16
450	11.40	350	10	16
500	12.00	375	10	16
600	13.20	426	10	16
700	14.40	230	10	16
800	15.60	255	10	16
900	16.80	280	10	16
1000	18.00	310	10	16
1100	19.20	694	10	16
1200	20.40	750	10	16
1400	22.80	403	10	16
1600	25.2	845	10	16

Double Flange DuckFoot 90° Bends



DN	e	L	c	d	PFA (Bar)	
mm	mm	mm	mm	mm	PN 10	PN 16
80	7.00	155	110	180	10	16
100	7.20	175	125	200	10	16
150	7.80	230	160	250	10	16
200	8.40	280	190	300	10	16
250	9.00	335	225	350	10	16
300	9.60	385	255	400	10	16
350	10.20	440	290	450	10	16
400	10.80	495	320	500	10	16
450	11.40	545	355	550	10	16
500	12.00	600	385	600	10	16
600	13.20	705	450	700	10	16
700	14.40	810	515	800	10	16
800	15.60	915	580	900	10	16
900	16.80	1020	645	1000	10	16
1000	18.00	1130	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	25.2	1765	1100	1700	10	16
1800	27.6	1970	1240	1900	10	16

All Flanged Tees



Nominal Diameter		e	e1	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
60	50	7	7	330	165	10	16
65	65	7	7	250	125	10	16
80	40	7	7	330	145	10	16
80	50	7	7	330	145	10	16
80	65	7	7	330	145	10	16
80	80	7	7	330	165	10	16
100	40	7.2	7	360	155	10	16
100	50	7.2	7	360	155	10	16
100	60	7.2	7	360	155	10	16
100	80	7.2	7	330	175	10	16
100	100	7.2	7.2	350	175	10	16
125	40	7.5	7	400	170	10	16
125	50	7.5	7	400	170	10	16
125	65	7.5	7	400	170	10	16
150	40	7.8	7	440	185	10	16
150	50	7.8	7	440	185	10	16
150	65	7.8	7	440	185	10	16
150	80	7.8	7	436	200	10	16
150	100	7.8	7.2	440	200	10	16
150	125	7.8	7.5	440	215	10	16
150	150	7.8	7.8	440	218	10	16
200	65	8.4	7	520	215	10	16
200	80	8.4	7	520	225	10	16
200	100	8.4	7.2	515	225	10	16
200	150	8.4	7.8	520	243	10	16
200	200	8.4	8.4	520	258	10	16
250	40	9	7	405	265	10	16
250	50	9	7	405	265	10	16
250	60	9	7	700	215	10	16
250	80	9	7	405	250	10	16
250	100	9	7.2	695	250	10	16
250	125	9	7.5	485	280	10	16

Continued...

...continued

Nominal Diameter		e	e1	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
250	250	9	9	700	350	10	16
300	80	9.6	7	450	290	10	16
300	100	9.6	7.2	800	290	10	16
300	150	9.6	7.8	505	303	10	16
300	200	9.6	8.4	800	350	10	16
300	250	9.6	9	620	323	10	16
300	300	9.6	9.6	800	400	10	16
350	80	10.2	7	850	295	10	16
350	100	10.2	7.2	850	325	10	16
350	150	10.2	7.8	850	325	10	16
350	200	10.2	8.4	850	325	10	16
350	250	10.2	9	850	325	10	16
350	300	10.2	9.6	850	425	10	16
350	350	10.2	10.2	850	425	10	16
400	80	10.8	7	900	325	10	16
400	100	10.8	7.2	900	350	10	16
400	150	10.8	7.8	900	350	10	16
400	200	10.8	8.4	900	350	10	16
400	250	10.8	9	900	350	10	16
400	300	10.8	9.6	900	450	10	16
400	400	10.8	10.8	900	450	10	16
450	80	11.4	7	950	355	10	16
450	100	11.4	7.2	950	375	10	16
450	150	11.4	7.8	950	375	10	16
450	200	11.4	8.4	950	375	10	16
450	250	11.4	9	950	375	10	16
450	300	11.4	9.6	950	475	10	16
450	400	11.4	10.8	950	475	10	16
450	450	11.4	11.4	950	475	10	16
500	80	12	7	1000	385	10	16
500	100	12	7.2	1000	400	10	16
500	150	12	7.8	1000	400	10	16
500	200	12	8.4	1000	400	10	16
500	250	12	9	1000	500	10	16
500	300	12	9.6	1000	500	10	16
500	350	12	10.2	1000	500	10	16
500	400	12	10.8	1000	500	10	16
500	500	12	12	1000	500	10	16
600	80	13.2	7	1100	445	10	16
600	100	13.2	7.2	1100	450	10	16
600	150	13.2	7.8	1100	450	10	16
600	200	13.2	8.4	1100	450	10	16
600	300	13.2	9.6	1100	550	10	16

Continued...

...continued

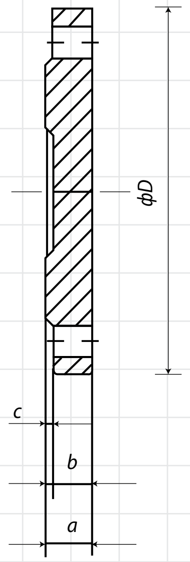
Nominal Diameter		e	e1	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
600	600	13.2	13.2	1100	550	10	16
700	100	14.4	7.2	600	510	10	16
700	150	14.4	7.8	600	520	10	16
700	200	14.4	8.4	650	525	10	16
700	300	14.4	9.6	760	540	10	16
700	400	14.4	10.8	870	555	10	16
700	500	14.4	12	1000	570	10	16
700	600	14.4	13.2	1200	585	10	16
700	700	14.4	14.4	1200	600	10	16
800	100	15.6	7.2	560	570	10	16
800	150	15.6	7.8	620	580	10	16
800	200	15.6	8.4	690	585	10	16
800	300	15.6	9.6	800	600	10	16
800	400	15.6	10.8	910	615	10	16
800	500	15.6	12	1030	630	10	16
800	600	15.6	13.2	1350	645	10	16
800	700	15.6	14.4	1350	660	10	16
800	800	15.6	15.6	1350	675	10	16
900	150	16.8	7.8	650	640	10	16
900	200	16.8	8.4	730	645	10	16
900	400	16.8	10.8	950	675	10	16
900	600	16.8	13.2	1500	705	10	16
900	800	16.8	15.6	1500	735	10	16
900	900	16.8	16.8	1500	750	10	16
1000	150	18	7.8	720	700	10	16
1000	200	18	8.4	770	705	10	16
1000	400	18	10.8	990	735	10	16
1000	600	18	13.2	1650	765	10	16
1000	800	18	15.6	1650	795	10	16
1000	1000	18	18	1650	825	10	16
1100	200	19.2	8.4	760	765	10	16
1100	400	19.2	10.8	980	795	10	16
1100	600	19.2	13.2	1210	825	10	16
1100	800	19.2	15.6	1470	855	10	16
1100	1000	19.2	18	1690	885	10	16
1100	1100	19.2	19.2	1800	900	10	16
1200	200	20.4	8.4	780	825	10	16
1200	400	20.4	10.8	1070	855	10	16
1200	600	20.4	13.2	1240	885	10	16
1200	800	20.4	15.6	1470	915	10	16
1200	1000	20.4	18	1700	945	10	16
1200	1200	20.4	20.4	1950	975	10	16
1400	400	22.8	10.8	1050	950	10	16
1400	600	22.8	13.2	1550	980	10	16

Continued...

...continued

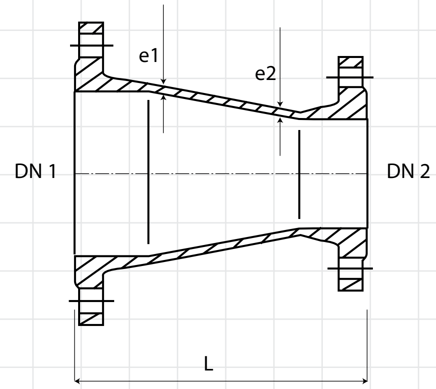
Nominal Diameter		e	e1	L	H	PFA (Bar)	
mm	mm					PN 10	PN 16
1400	1200	22.8	20.4	2015	1070	10	16
1400	1400	22.8	22.8	2200	1100	10	16
1500	400	24	10.8	1070	1005	10	16
1500	600	24	13.2	1350	1035	10	16
1500	800	24	15.6	1570	1065	10	16
1500	1000	24	18	1790	1095	10	16
1500	1200	24	20.4	2010	1125	10	16
1500	1400	24	22.8	2230	1155	10	16
1500	1500	24	24	2340	1170	10	16
1600	400	25.2	10.8	1100	1060	10	16
1600	600	25.2	13.2	1600	1090	10	16
1600	800	25.2	15.6	1835	1120	10	16
1600	1000	25.2	18	2065	1150	10	16
1600	1200	25.2	20.4	2300	1180	10	16
1600	1400	25.2	22.8	2300	1210	10	16
1600	1600	25.2	25.2	2480	1240	10	16
1800	600	27.6	13.2	1440	1200	10	16
1800	800	27.6	15.6	1660	1230	10	16
1800	1000	27.6	18	1880	1260	10	16
1800	1200	27.6	20.4	2100	1290	10	16
1800	1400	27.6	22.8	2320	1320	10	16
1800	1600	27.6	25.2	2540	1350	10	16
1800	1800	27.6	27.6	2760	1380	10	16
2000	600	30	13.20	1705	1310	10	16
2000	1000	30	18.00	2170	1370	10	16
2000	1400	30	22.80	2635	1430	10	16
2200	600	32.4	13.20	1560	1420	10	16
2200	1200	32.4	20.4	1220	1510	10	16
2200	1800	32.4	27.60	2880	1600	10	16

Blank Flanges , Type PN 10 & PN 16



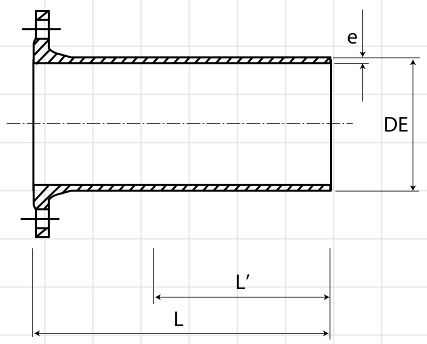
DN	PN 10				PN 16			
	D	a	b	c	D	a	b	c
80	200	19.00	16.0	3.0	200	19.00	16.0	3.0
100	220	19.00	16.0	3.0	220	19.00	16.0	3.0
150	285	19.00	16.0	3.0	285	19.00	16.0	3.0
200	340	20.00	17.0	3.0	340	20.00	17.0	3.0
250	400	22.00	19.0	3.0	400	22.00	19.0	3.0
300	455	24.50	20.5	4.0	455	24.50	20.5	4.0
350	505	24.50	20.5	4.0	520	26.50	22.5	4.0
400	565	24.50	20.5	4.0	580	28.00	24.0	4.0
450	615	25.50	21.5	4.0	640	30.00	26.0	4.0
500	670	26.50	22.5	4.0	715	31.50	27.5	4.0
600	780	30.00	25.0	5.0	840	36.00	31.0	5.0
700	895	32.50	27.5	5.0	910	39.50	34.5	5.0
800	1015	35.00	30.0	5.0	1025	43.00	38.0	5.0
900	1115	37.50	32.5	5.0	1125	46.50	41.5	5.0
1000	1230	40.00	35.0	5.0	1255	50.00	45.0	5.0
1100	1340	42.50	37.5	5.0	1355	53.50	48.5	5.0
1200	1455	45.00	40.0	5.0	1485	57.00	52.0	5.0
1400	1675	46.00	41.0	5.0	1685	60.00	55.0	5.0
1500	1785	47.50	42.5	5.0	1820	62.50	57.5	5.0
1600	1915	49.00	44.0	5.0	1930	65.00	60.0	5.0
1800	2115	52.0	47.0	5.0	2130	70.00	65.0	5.0
2000	2325	55.0	45.0	5.0	2345	75.00	70.0	5.0

Double Flanged Concentric Tapers



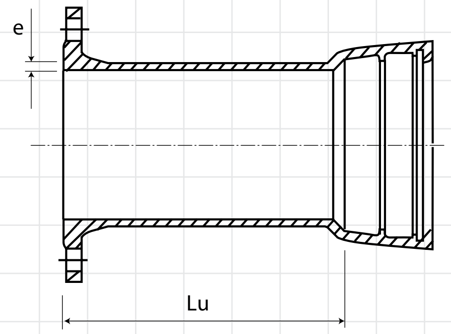
DN	DN 2	e1	e2	L	Concentric	
					PFA	
					PN 10	PN 16
mm	mm	mm			Bar	
80	50	7	7	225	10	16
80	65	7	7	225	10	16
100	40	7.2	7	300	10	16
100	50	7.2	7	300	10	16
100	65	7.2	7	225	10	16
100	80	7.2	7	200	10	16
125	100	7.5	7.2	200	10	16
150	65	7.8	7	300	10	16
150	80	7.8	7	310	10	16
150	100	7.8	7.2	200	10	16
150	125	7.8	7.5	200	10	16
200	125	8.4	7.5	300	10	16
200	150	8.4	7.8	300	10	16
250	200	9	8.4	300	10	16
300	250	9.6	9	300	10	16
350	250	10.2	9	300	10	16
350	300	10.2	9.6	300	10	16
400	350	10.8	10.2	300	10	16
450	350	11.4	10.2	300	10	16
450	400	11.4	10.8	300	10	16
500	450	12	10.8	600	10	16
600	400	13.4	10.8	540	10	16
600	500	13.2	12	600	10	16
700	600	14.4	13.2	600	10	16
800	700	15.6	14.4	600	10	16
900	800	16.8	15.6	600	10	16
1000	900	18	16.8	600	10	16
1100	1000	19.2	18	600	10	16
1200	1000	20.4	18	790	10	16
1200	1100	20.4	18	790	10	16
1400	1200	22.8	20.4	850	10	16
1600	1400	25.2	22.8	910	10	16
1800	1600	27.6	25.2	970	10	16
2000	1800	30	27.6	1030	10	16
2200	2000	32.4	30	1090	10	16

Flange Spigot



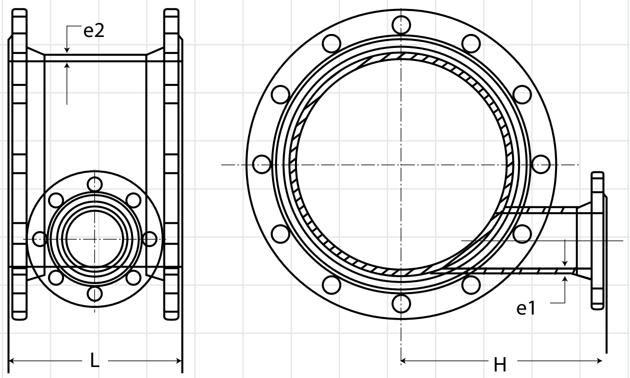
DN	DE	e	L	L'	PFA (Bar)	
					PN10	PN16
80	98	7.0	350	215	10	16
100	118	7.2	360	215	10	16
150	170	7.8	380	225	10	16
200	222	8.4	400	230	10	16
250	274	9.0	420	240	10	16
300	326	9.6	440	250	10	16
350	378	10.2	460	260	10	16
400	429	10.8	480	270	10	16
450	480	11.4	500	280	10	16
500	532	12.0	520	290	10	16
600	635	13.2	560	310	10	16
700	738	14.4	600	330	10	16
800	842	15.6	600	330	10	16
900	945	16.8	600	330	10	16
1000	1048	18.0	600	330	10	16
1100	1152	19.2	600	330	10	16
1200	1255	20.4	600	330	10	16
1400	1462	22.8	710	390	10	16
1600	1668	25.2	780	430	10	16
1800	1875	27.6	850	470	10	16
2000	2082	30.0	920	500	10	16
2200	2282	32.4	990	540	10	16

Flange Socket



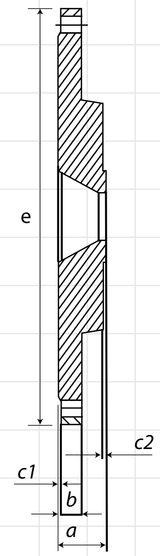
DN	e	Lu	PFA (Bar)	
			PN10	PN16
80	7.0	130	10	16
100	7.2	130	10	16
150	7.8	135	10	16
200	8.4	140	10	16
250	9.0	145	10	16
300	9.6	150	10	16
350	10.2	155	10	16
400	10.8	160	10	16
450	11.4	165	10	16
500	12.0	170	10	16
600	13.2	180	10	16
700	14.4	190	10	16
800	15.6	200	10	16
900	16.8	210	10	16
1000	18.0	220	10	16
1100	19.2	230	10	16
1200	20.4	240	10	16
1400	22.8	310	10	16
1600	25.2	330	10	16
1800	27.6	350	10	16
2000	30.0	370	10	16
2200	32.4	390	10	16

All Flanged Scour Tee



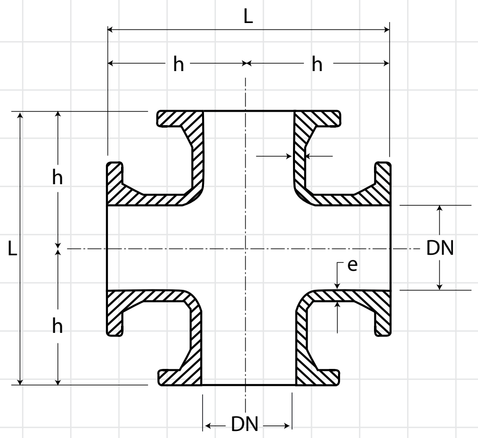
DN	dn	e2	e1	L	h
200	80	8.4	7.0	245	250
250	80	9.0	7.0	250	275
300	80	9.6	7.0	255	300
350	100	10.2	7.2	280	325
400	100	10.8	7.2	280	350
450	100	11.4	7.2	285	375
500	100	12.0	7.2	290	400
600	100	13.2	7.2	295	450
700	150	14.4	7.8	360	500
800	150	15.6	7.8	365	550
900	150	16.8	7.8	370	600
1000	200	18.0	8.4	435	650
1100	200	19.2	8.4	440	700
1200	200	20.4	8.4	445	750
1400	200	22.8	8.4	460	850
1600	400	25.2	10.8	700	950

Reducing Flange – PN 10 & PN 16



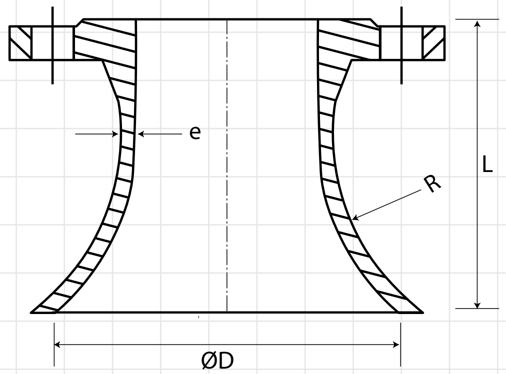
		PN 10					PN 16				
DN	dn	D	a	b	c1	c2	D	a	b	c1	c2
200	80	340	40.0	17.0	3	3	340	40.0	17.0	3	3
200	100	340	40.0	17.0	3	3	340	40.0	17.0	3	3
200	125	340	40.0	17.0	3	3	340	40.0	17.0	3	3
350	250	505	48.0	20.5	4	3	520	54.0	22.5	4	3
400	250	565	48.0	20.5	4	3	580	54.0	24.0	4	3
400	300	565	49.0	20.5	4	4	580	55.0	24.0	4	4
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 Flanged Crosses



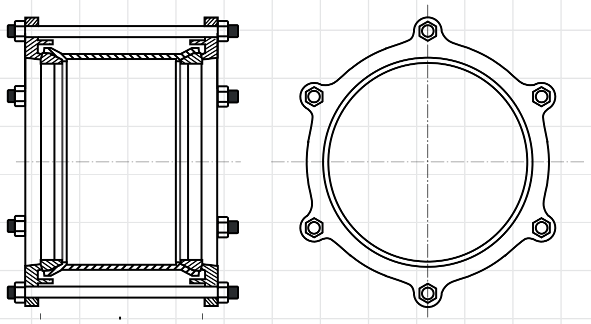
DN	e	L	h	PFA (Bar)	
				PN10	PN16
80	7.0	330	165	10	16
100	7.2	360	180	10	16
150	7.8	440	220	10	16
200	8.4	520	260	10	16
250	9.0	700	350	10	16
300	9.6	800	400	10	16
350	10.2	850	425	10	16
400	10.8	900	450	10	16
450	11.4	950	475	10	16
500	12.0	1000	500	10	16
600	13.2	1100	550	10	16

Flanged Bell Mouth



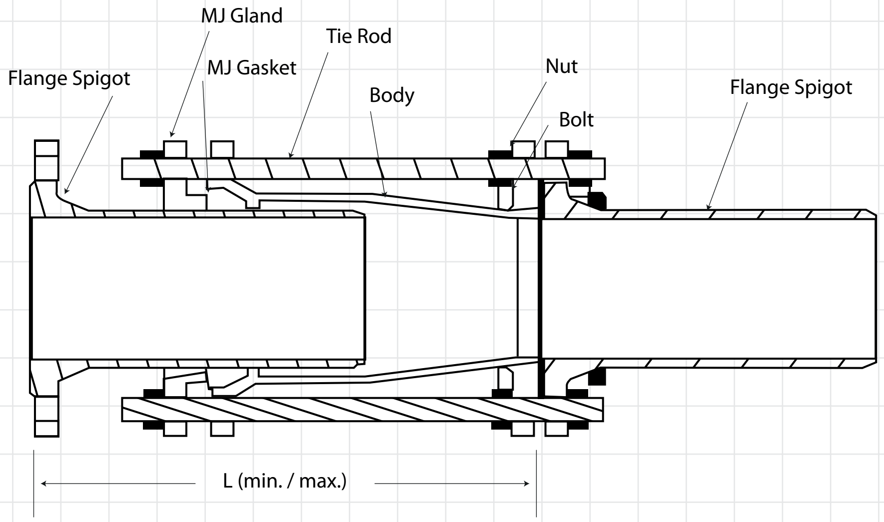
DN	Φ D	e	R	L	PFA (Bar)	
					PN10	PN16
80	160	7.0	100	135	10	16
100	185	7.2	106	140	10	16
150	245	7.5	119	155	10	16
200	310	8.4	137	170	10	16
250	370	9.0	150	190	10	16
300	435	9.6	169	210	10	16
350	495	10.2	181	225	10	16
400	560	10.8	200	245	10	16
450	620	11.4	212	260	10	16
500	685	12.0	231	280	10	16
600	810	13.2	262	300	10	16

Mechanical Joint (MJ) Collar



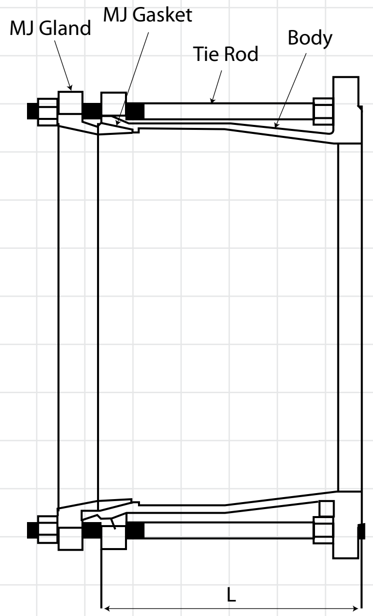
DN	e	L (FACE TO FACE)
80	7.0	230
100	7.2	230
150	7.8	241
200	8.4	246
250	9.0	251
300	9.6	256
350	10.2	271
400	10.8	276
450	11.4	281
500	12.0	296
600	13.2	306
700	14.4	316
800	15.6	316
900	16.8	326
1000	18.0	336
1100	19.2	364
1200	20.4	374

Dismantling Joint



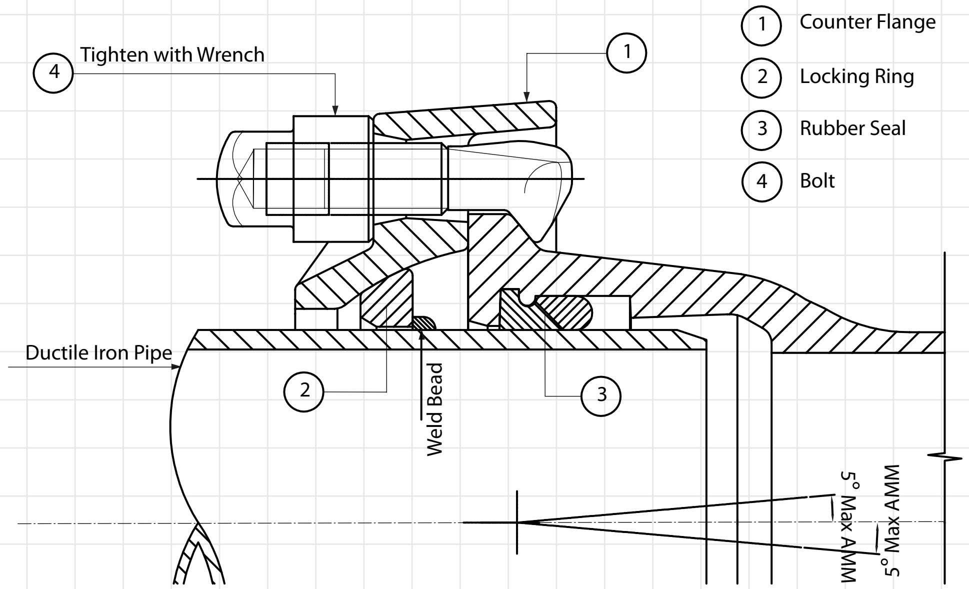
DN	E	L		PFA (Bar)
		Min.	Max.	PN16
80	7.0	380	430	16
100	7.2	380	430	16
150	7.8	380	430	16
200	8.4	390	440	16
250	9.0	445	505	16
300	9.6	450	510	16
350	10.2	455	515	16
400	10.8	460	520	16
450	11.4	515	575	16
500	12.0	520	580	16
600	13.2	580	640	16
700	14.4	590	660	16
800	15.6	600	670	16
900	16.8	660	730	16
1000	18.0	670	740	16
1100	19.2	680	750	16
1200	20.4	690	770	16

Flanged Adapter



DN	E	L	PFA (Bar)
			PN16
80	7.0	245	16
100	7.2	245	16
150	7.8	255	16
200	8.4	263	16
250	9.0	270	16
300	9.6	278	16
350	10.2	290	16
400	10.8	294	16
450	11.4	305.5	16
500	12.0	318	16
600	13.2	333	16
700	14.4	348	16
800	15.6	358	16
900	16.8	373	16
1000	18.0	383	16
1100	19.2	412	16
1200	20.4	427	16

Restrained Joint Details

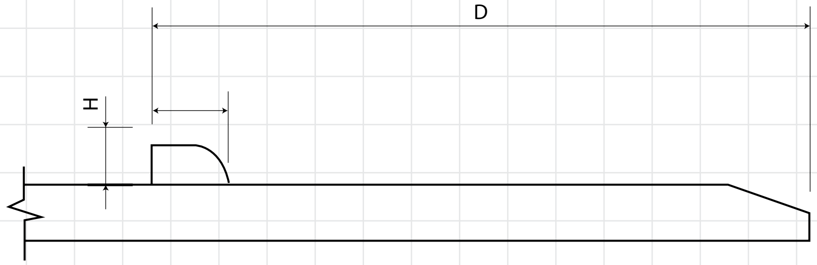


DN	PFA (bar)	PMA (bar)	PEA (bar)	OD of Gland D_{max} (mm)	Gland weight (kg)	Ring weight (kg)	Total Bolt weight (kg)	Total weight (kg)
100	64	77	82	258	5.5	0.7	1.8	8.0
125	64	77	82	285	6.5	0.9	2.7	10.1
150	55	66	71	312	7.5	1.0	2.7	11.2
200	44	53	58	365	10.5	1.3	3.6	15.4
250	39	47	52	454	24.0	3.1	5.1	32.2
300	37	44	49	514	30.0	3.6	6.8	40.4
350	30	36	41	565	33.0	5.0	7.65	45.7
400	30	36	41	618	42.0	5.5	10.2	57.7
450	30	36	41	677	50.8	6.6	11.9	69.3
500	30	36	41	732	55.0	9.0	15.3	79.3
600	27	32	37	843	69.0	11.0	18.7	98.7
700	23	28	33	968	105.0	13.7	26.9	145.8
800	20	24	29	1080	123.0	17.0	30.75	170.7
900	16	19	24	1191	136.0	21.0	30.75	187.75
1000	16	19	24	1306	144.0	24.0	34.6	202.6
1100	16	19	24	1434	152.0	27.0	42.3	221.3
1200	16	19	24	1539	158.0	31.0	44.2	233.2

Bolts Detail and Driving Torque for RJ Bolts

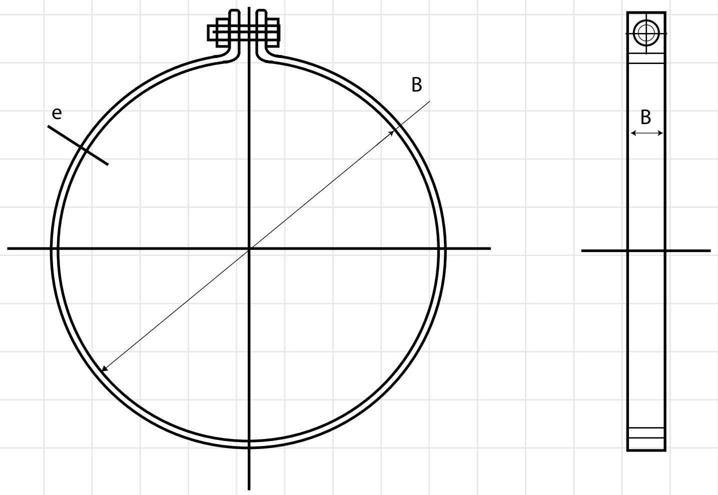
DN	Type of Bolts (size X Length)	No. of Bolts	Driving Torque (N.m)
100	M22 X 74	4	120
125	M22 X 74	6	120
150	M22 X 74	6	120
200	M22 X 74	8	120
250	M27 X 102	6	270
300	M27 X 102	8	270
350	M27 X 102	9	270
400	M27 X 102	12	270
450	M27 X 102	14	270
500	M27 X 102	18	270
600	M27 x 113	22	270
700	M27 x 123	28	270
800	M27 x 123	32	270
900	M27 x 123	32	270
1000	M27 x 123	36	270
1100	M27 x 123	44	270
1200	M27 x 123	46	270

Weld Bead Details for Restrained Joint



DN	D (mm)	W (mm)	H (mm)
100	90 +0 -2	7 +1 -0	3.5 +1 -0
125	92 +0 -2	7 +1 -0	3.5 +1 -0
150	92 +0 -2	7 +1 -0	3.5 +1 -0
200	100 +0 -2	7 +1 -0	3.5 +1 -0
250	110 +0 -2	7 +1 -0	3.5 +1 -0
300	112 +0 -2	7 +1 -0	3.5 +1 -0
350	114 +0 -2	7 +1 -0	3.5 +1 -0
400	113 +0 -2	8 +1 -0	3.5 +1 -0
450	120 +0 -2	8 +1 -0	3.5 +1 -0
500	125 +0 -2	9 +2 -0	4.0 +1 -0
600	130 +0 -2	9 +2 -0	4.0 +1 -0
700	158 +0 -2	10 +2 -0	4.5 +2 -0
800	160 +0 -2	10 +2 -0	4.5 +2 -0
900	155 +0 -2	10 +2 -0	4.5 +2 -0
1000	155 +0 -2	10 +2 -0	5.0 +2 -0
1100	210 +0 -2	10 +2 -0	5.0 +2 -0
1200	230 +0 -2	10 +2 -0	5.5 +2 -0

Guide Copper Ring Detail for Weld Bead Preparation



DN	Copper Ring			Bolt	
	D (mm)	e (mm)	B (mm)	Dia (mm)	L (mm)
100	116	5	40	10	80/50
125	142	5	40	10	80/50
150	168	5	40	10	80/50
200	220	5	40	10	80/50
250	271	5	40	10	80/50
300	323	5	40	10	80/50
350	375	5	40	10	80/50
400	627	5	40	10	80/50
450	477	5	50	10	80/50
500	528	5	50	10	80/50
600	631	5	50	10	80/50
700	734	5	50	10	80/50
800	837	5	50	10	80/50
900	940	5	50	10	80/50
1000	1043	5	50	10	80/50
1100	1149	5	50	10	80/50
1200	1249	5	50	10	80/50

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 is also called pore solution, is always in equilibrium at a high pH (11 -13) due to presence of Calcium, Potassium and Sodium ions brought by the cement.

Iron (base metal for Ductile Iron pipes), when comes 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 shall 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 shall be met:
- Thickness of cement mortar lining shall be within 0.2mm of the original thickness;
- There shall be no visible cracking, blistering or disbanding of the epoxy or polyurethane based coatings.
- There shall be no visible cracking on the rubber gasket; its hardness, tensile strength and elongation shall remain 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	< 2000
Magnesium, Mg ++	<300	<500	NL
Sulphates, SO_4--	< 400	< 2000	NL
Aggressive CO_2	<20	<20	NL
pH	>5.5	> 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 additions 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 is used.

2.12.3 Abrasion Resistance

Cement mortar linings 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 BS EN 598. When tested according to the provisions of the said standard, the pipes shall not have an abrasion depth greater than 0.6mm after 100000 movements (50,000 cycles) for every type of cement lining, or 0.2 mm for epoxy or polyurethane linings.

2.13 Special Lining and Coatings

2.13.1 Seal Coats for Cement Mortar Lining

Epoxy seal coats for Cement mortar lining is to be provided if the customer specifies it. Unless otherwise specified by the purchaser, the minimum Dry Film Thickness (DFT) provided shall be average 70 micron with minimum at one point of 50 micron.The coating shall be a 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 the airless spray guns mounted on a moving boom. If more than one coat is applied, the subsequent coat shall be applied within the time limits, surface conditions and temperature recommended by the manufacturer.

Visual Appearance
The seal coats shall be uniform and when visually examined it shall be 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 BS EN 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 shall 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 shall be uniformly warmed for sufficient time prior to cleaning. The surface temperature shall be maintained at least 5°C above the dew point.

The polyurethane lining shall 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 2.12.1: Polyurethane Lining Thickness

Lining thickness of pipes and fittings for Drinking water transportation		
DN	Mean value x, µm	$(x\text{-}2_s)$, µm
80 - 200	≥1300	≥ 800
>200	≥1500	≥ 800
Lining thickness of pipes and fittings for Waste water 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 shall be average 70 micron with minimum at one point of 50 micron. After curing but prior to laying of pipes, the coating shall be a continuous film, free of thin spots and other imperfections.

Coating application
The pipe coating shall be applied in accordance with the manufacture's recommendations. Application of epoxy coating is carried by airless spray equipment.

Pipe preparation
The pipe exterior is to 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 may 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 shall 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 shall be obtained from the coating manufacturer and its recommendations followed.

Coating Repair
Accessible areas of pipe requiring coating repairs shall be cleaned to remove debris and damaged coating using grinders or other means acceptable to the purchaser. The adjacent coating shall be feathered by sanding, grinding or other methods approved by the purchaser. Accumulated debris shall 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 shall meet the requirements of DIN 30671

Table 2.12.2: General specification of Polyurethane Coating

Materials	
Polyurethane nominal thickness	2000 microns
Polyurethane minimum thickness	1500 microns
Coal tar modified polyurethane, nominal thickness	2500 microns
Coal tar modified polyurethane, minimum thickness	1800 microns
Non-porosity test voltage (Holidays test)	10KV
Impact Test	10 J
Adhesion test	Incision knife edge

Surface preparation

Prior to the application of the polyurethane coating, the surface of the pipes or fittings to be coated shall 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 shall be uniformly warmed for sufficient time prior to cleaning. The surface temperature shall be maintained at least 5°C above the dew point.

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

Finished Polyurethane coating

The polyurethane coating shall 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 µm

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, 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 shall be 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 copolymers. Its density shall be between 910 and 930 kg/m^3. Polyethylene sleeves are stored in cool dry store, away from direct sunlight or excessive heat.

Table 2.12.3: Lay Flat width of tubular polyethylene for use with pipeline incorporating flexible

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 shall not be less 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 shall not be less than 8.3 MPa.

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

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

Table 2.13.4: Criteria for selection of special lining and coatings for Ductile Iron pipes

Parameters				Corrosivity			Protection Systemz		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

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 2.13.1: 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 2.13.1: 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).

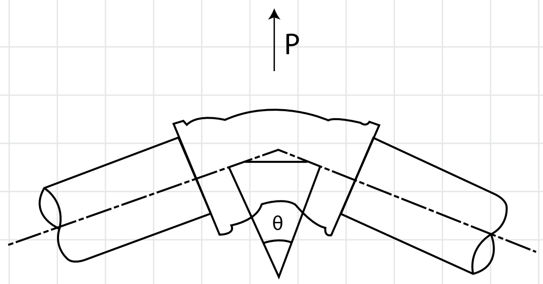
2.15.1 Principles for design of Thrust block.

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 is given below:

a) At Bend.

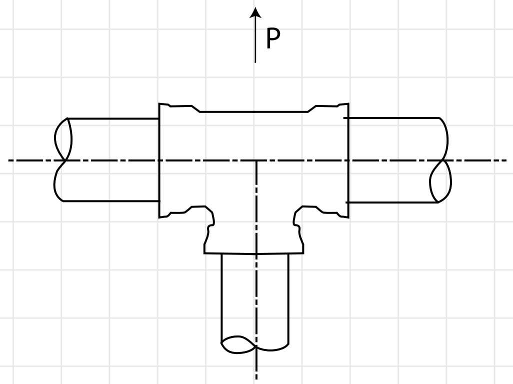


$$P = 2pA \sin \frac{\theta}{2}$$

Where,

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

b) At Tee

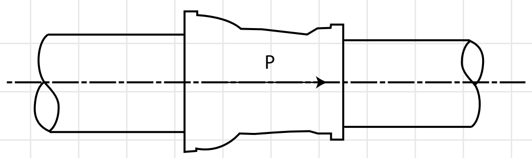


P = pA

Where,

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

c) At Reducer



P = p (A-a)

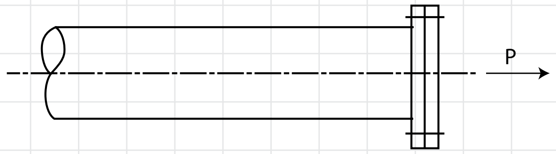
Where,

P = Thrust force.

p = Internal pressure

(A – a) = Difference in Cross Sectional area

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

Example: 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

12.15.2 Calculation for Restraining of thrust in forces 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 shall 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 sof 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

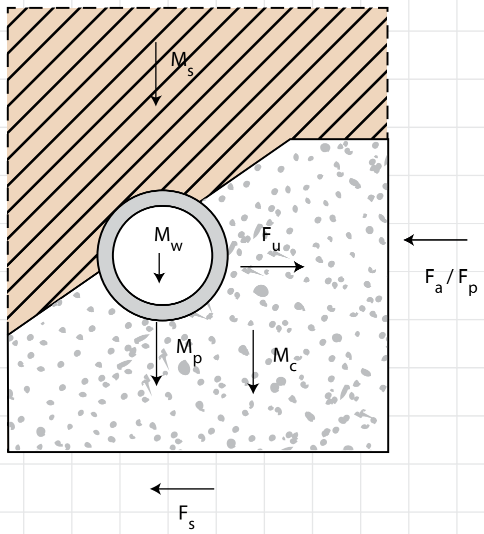


Fig. 12.15.1: Schematic diagram of Thrust forces acting on pipe and surrounding soil.

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 12.15.3: Friction between thrust block and different type of soil is given below:

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.

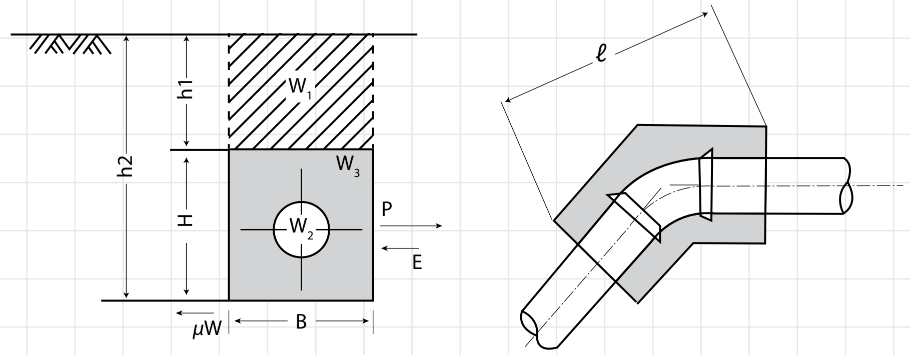


Fig. 12.15.2: Schematic diagram of Thrust forces Horizontal bend.

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.

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

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:

$P < \mu W + E$

NB: 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:

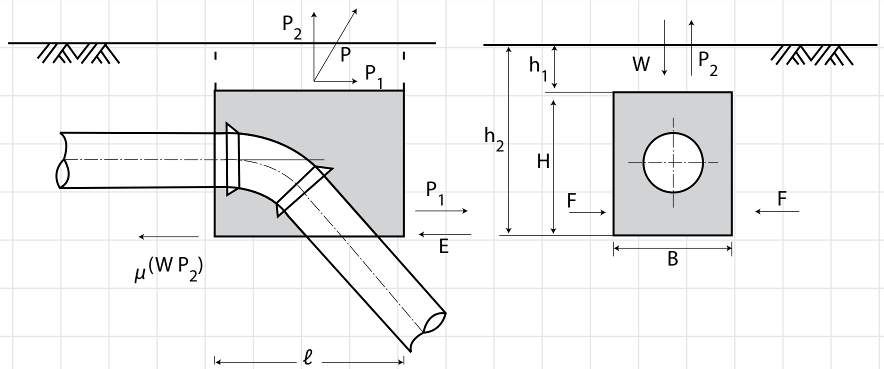


Fig. 12.15.3: Schematic diagram of Thrust forces acting on upward vertical bend:

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 shall be designed to satisfy the following conditions.

- Against the horizontal component of the thrust force.

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

- 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

$C_e{}^1$ = $\tan^2(45°-\phi/2$

NB: 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

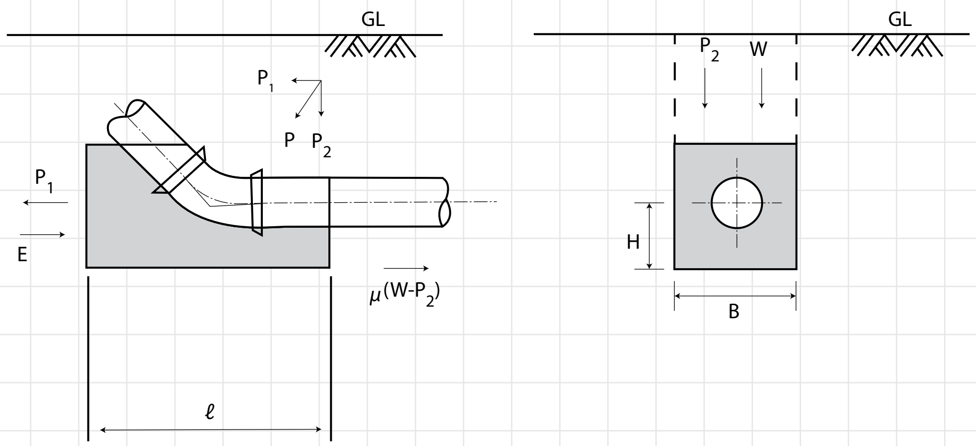


Fig. 12.15.4: Schematic diagram of Thrust forces acting on downward vertical bend:

Concrete block shall 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 countermeasure should be required.

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

12.15.3 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.

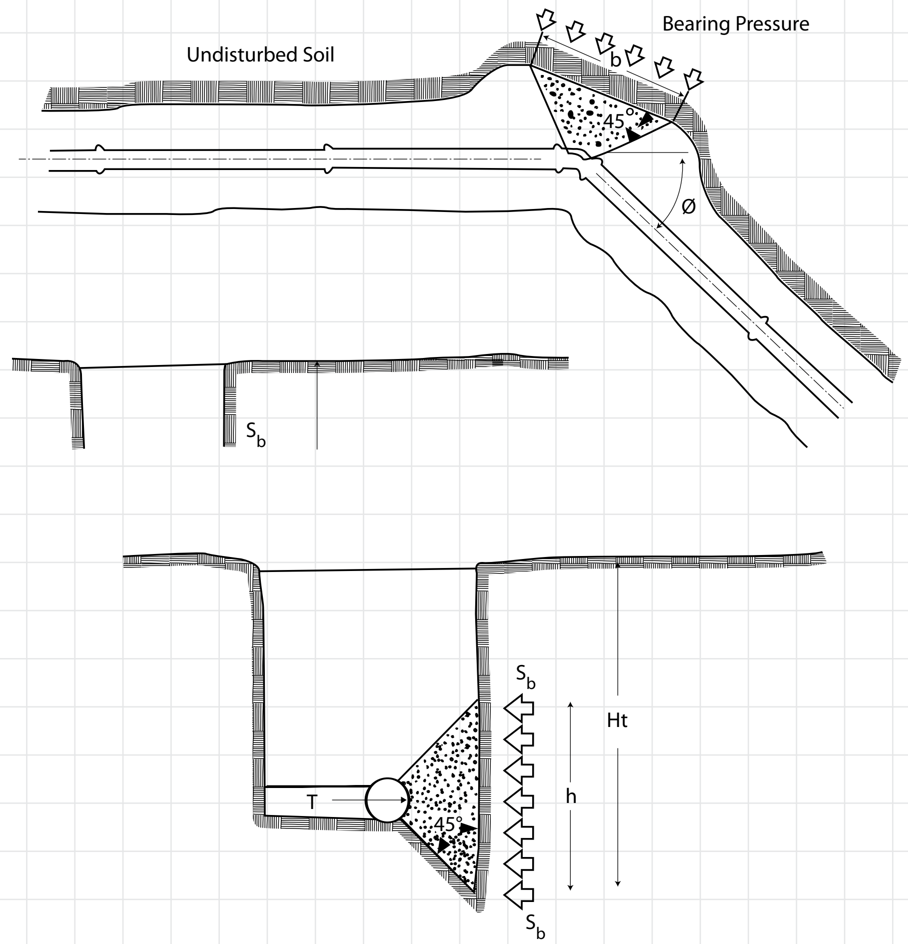


Fig. 12.15.5: Concrete Block with Joint exposed.

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 following;

- 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

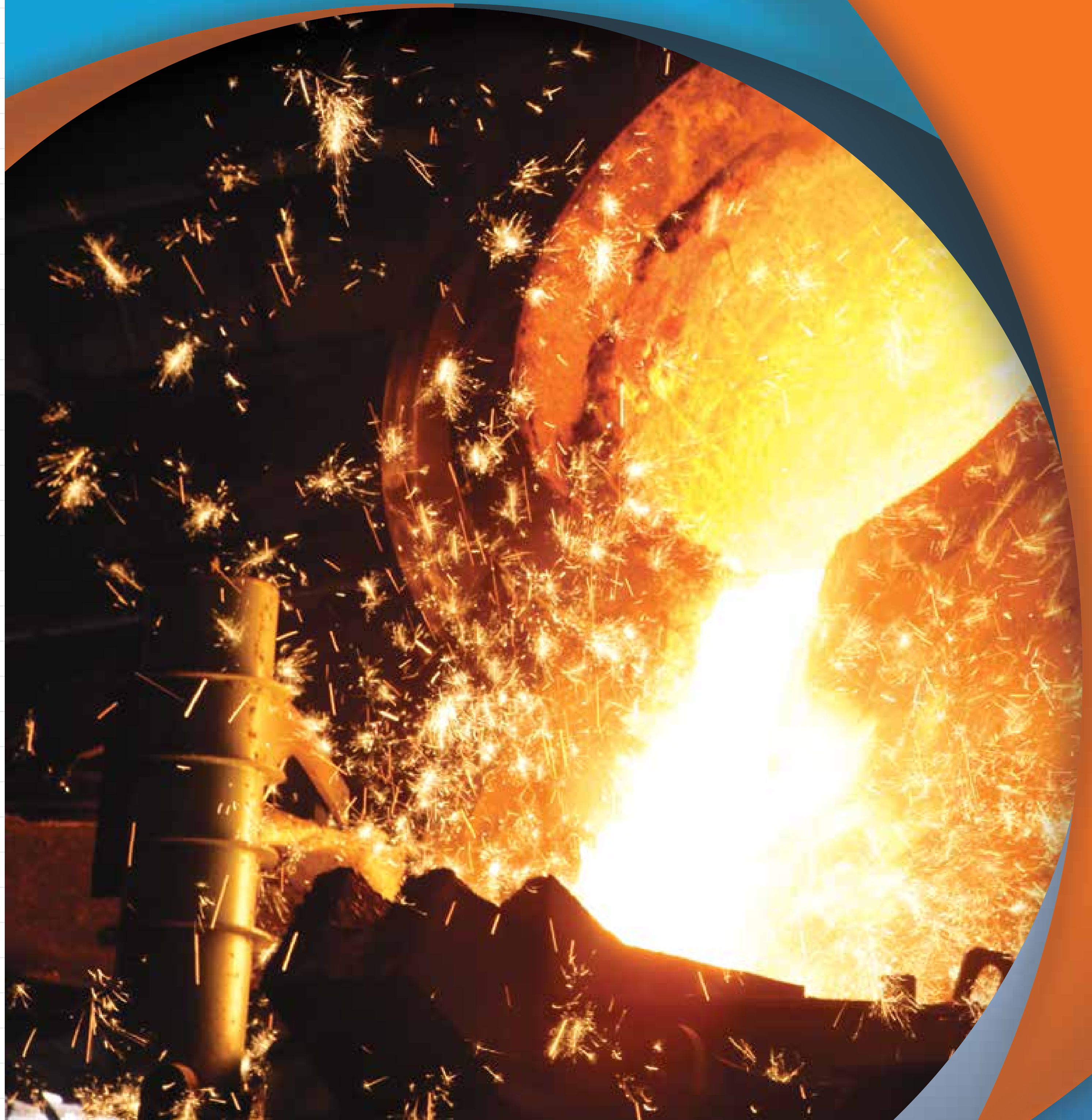
Table 12.15.5: Friction coefficient between pipe or concrete and soil

Type of Soil	Friction coefficient
Gravel	0.6
Clay	0.2 – 0.5
Dry Sand	0.5
Wet Sand	0.33

Table: 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



Molten Iron Preparation

Molten metal is produced in the blast furnace. The super heating and chemistry correction of the molten metal is done in 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. Ductile Iron pipes, 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 melt using electric arc and applied to the external surface of pipe by spraying evenly.

Hydrostatic Testing

After annealing, bell and spigot end, internal and external surface of Ductile Iron 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

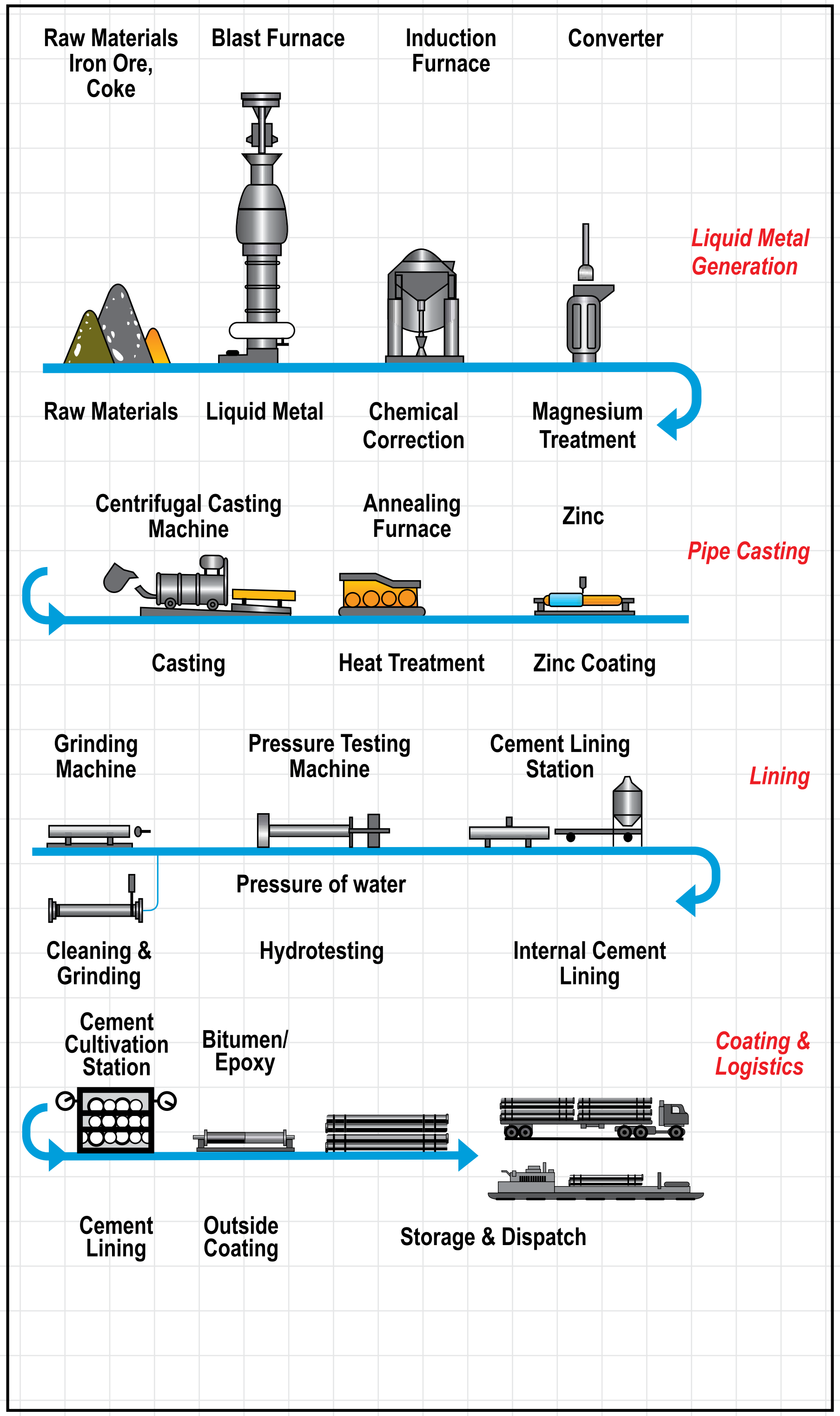
A mixture of cement, sand and water as per specified proportion is pumped through a lance into the pipe spinning at low speed. The pipe is then rotated at high speed where excessive water from the cement slurry is discharged leaving behing dense cement mortar lining the internal surface of the pipeline. 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 trace of dripping or flowing. The pipes after coating are transferred to drying chamber.

Marking, Packing and Shipping

The pipe 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 external surface of pipes. After marking the pipes are transferred to yard for final inspection and despatches to respective clients.



QUALITY ASSURANCE PLAN

4.1 General

Quality control (QC) is the collection of methods and techniques for ensuring that a product is produced and delivered according to given requirements. Quality is measured by the degree of conformance to predetermined specifications and standards, and deviations from these standards can lead to poor quality and low reliability. Efforts for quality improvement are aimed at eliminating defects; reduction of rejection and hence overall reductions in production costs. Quality checks are done on Ductile Iron pipe includes following parameter:-

1. **Thorough check of all raw materials for compliance with respective national and international standard specification.**
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

Quality control (QC) is the collection of methods and techniques for ensuring that a product is

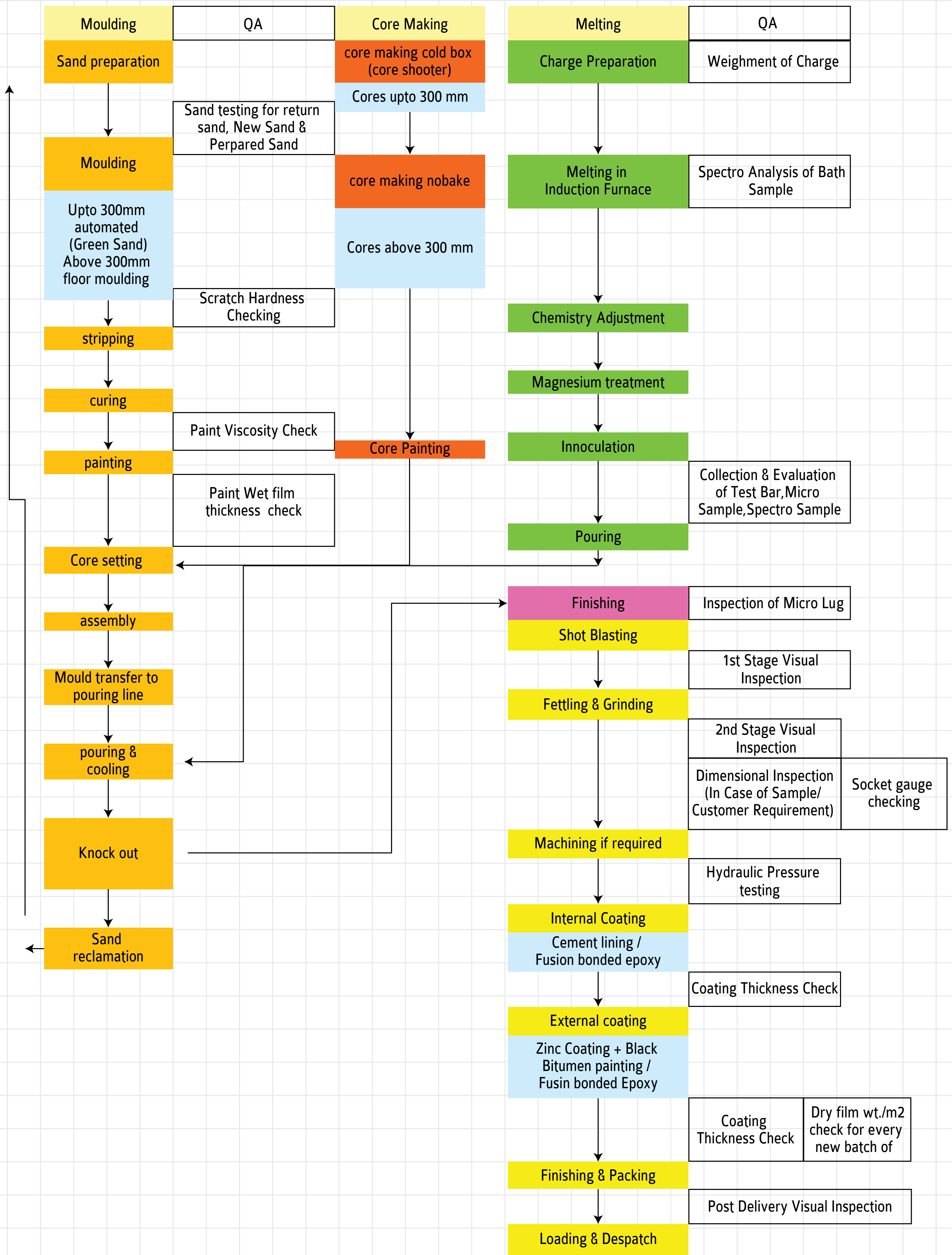
4.2.1 Ductile Iron pipes

All the above test are carried out at the 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

Process Flow Chart Jindal Fittings Limited



4.3 Sample size

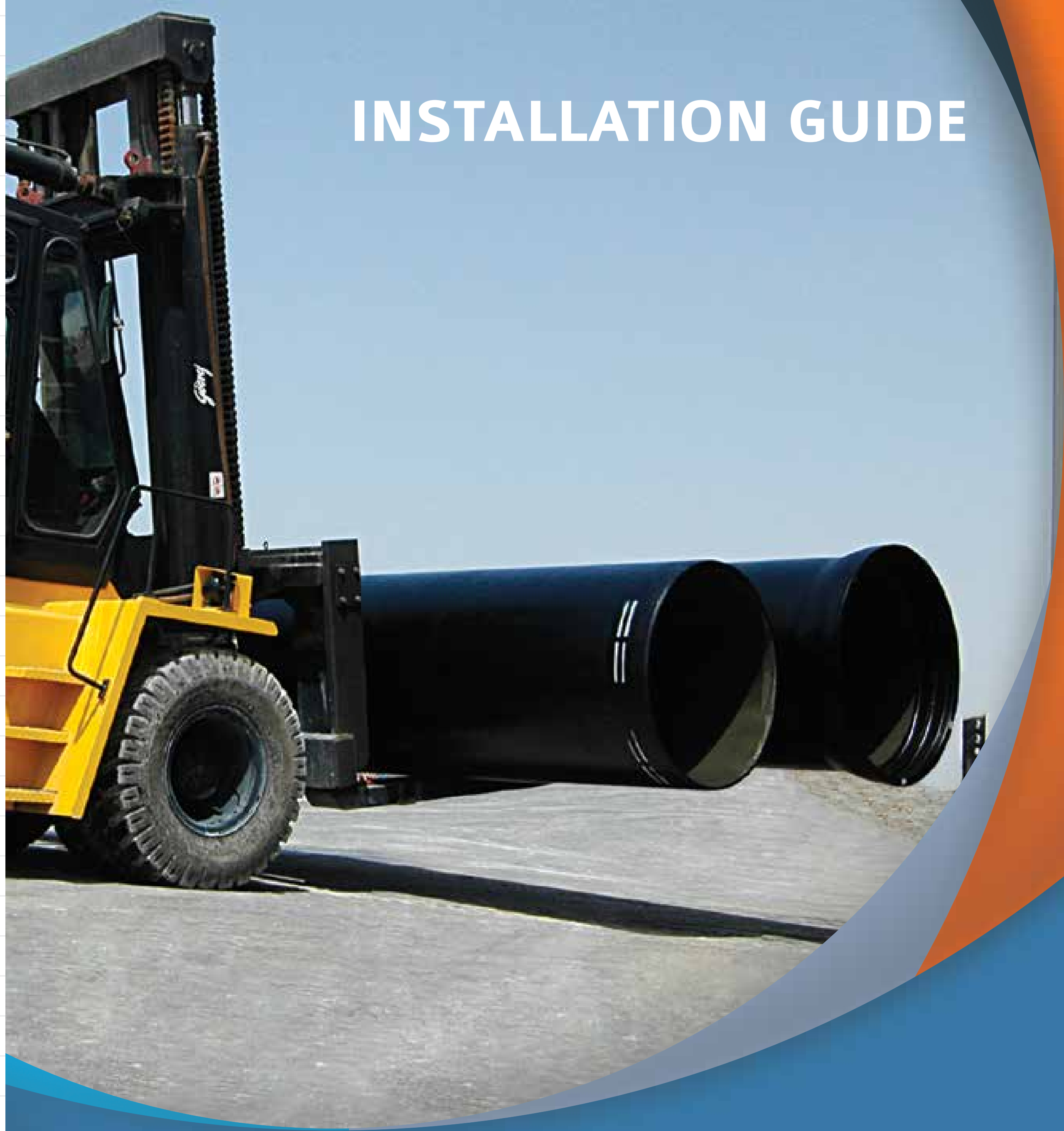
To carry out the inspection it's practically not possible to check each and every pipe. Hence the sample pipes are segregated from the LOT. The sample size should be as follows:

Table: 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



Bundled pipe

Bundling of DI pipe is done mostly for break-bulk shipment. Bundling is sometimes also done for facilitating the loading of small sizes pipe (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 batten placed parallel to each other at the bottom. Separator wooden batten 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 in each bundle with the help of metal tags or self adhesive stickers.

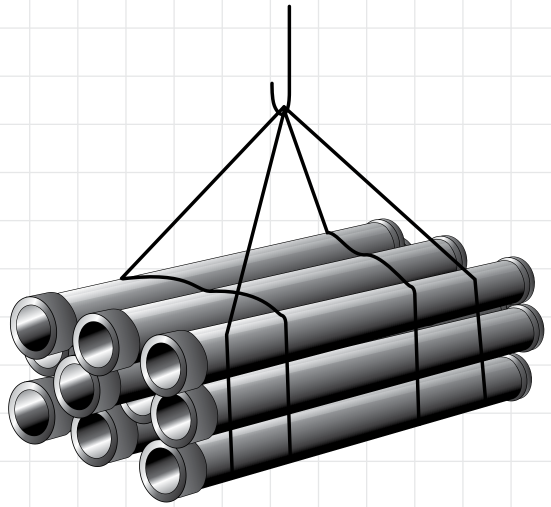


Fig. 5.1.1: Building of pipes for break-bulk shipment.

Loose pipes

In both type of shipment i.e. break-bulk or container shipment the pipes of sizes DN200 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, 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 forklift. When chains and hooks are usedfor lifting pipe, it should be lifted one by one. The hooks and chains should be used of correct sizes and always padded hooks are to be used. For lifting multiple pipes at a time spreader bar should be used. When fork lift trucks are used for unloading pipes, ensure that the fork blades do not damage the pipe or external coating.

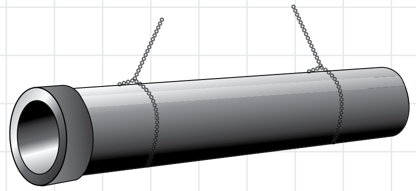


Fig. 5.2.1: Lifting of pipes with sling

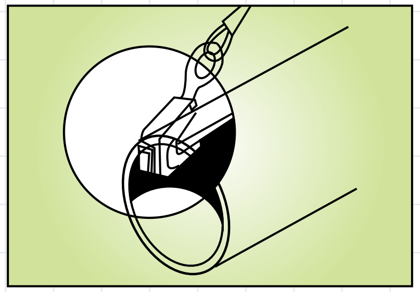


Fig. 5.2.2: Lifting of pipes with hooks

Loading and Transportation

All pipes shall 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.

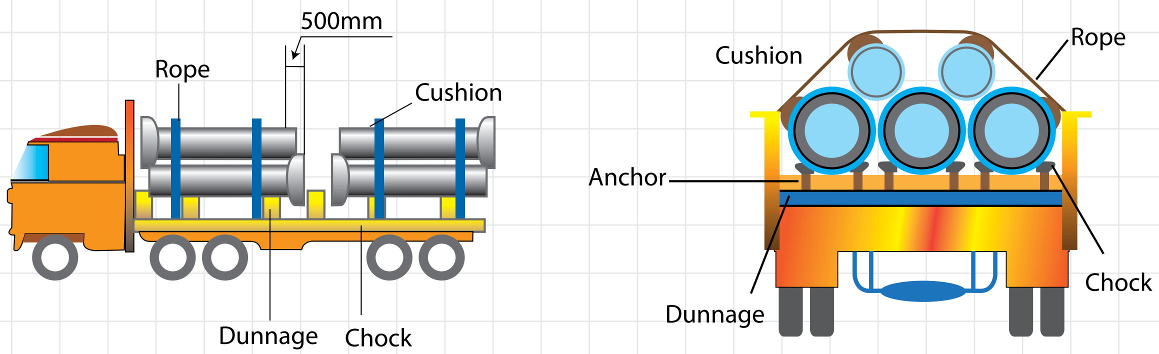


Fig. 5.2.3: Arrangement of pipes for transportation on road.

Unloading

When cranes are used for off-loading individual pipes, slings of lifting beams with the purpose designed padded hooks shall always be used. In no circumstances wire ropes, chains, unpadded metal hooks or lifting hooks shall 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 shall 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 5.1). Loose pipe should be stacked on a bottom base of wooden bearing having thikness at least 100mm.

Table 5.1 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. Forklifts 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 shall be used, which are in direct contact with the pipe.

Following precautions shall 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, so as 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 Storage

Methods of stacking loose pipes.

5.3.1 Square Stacking

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

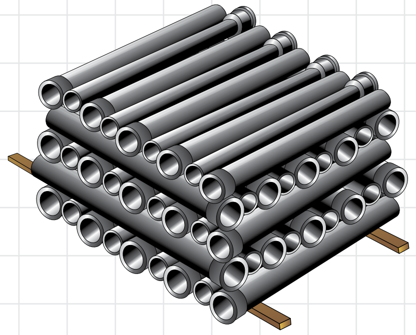


Fig. 5.3.1: Square Stacking of DI Pipes

5.3.2 Parallel Stacking

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

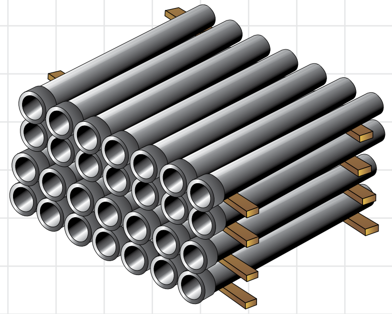


Fig. 5.3.2: Parallel Square Stacking of DI Pipes

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 shall be in same direction. In successive layers, the pipe shall be reversed. It is absolutely essential that pipes at the ends of the bottom layer shall be securely chocked along their length. There is no restriction in the number of pipes along the bottom layer.

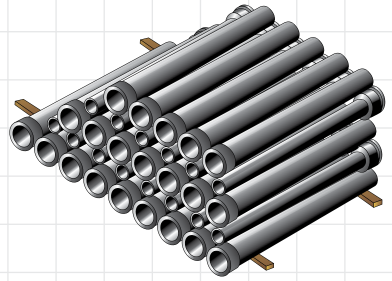


Fig. 5.3.1: Pyramid Stacking of DI Pipes.

5.4 Lowering

5.4.1 Trench Width

Excavation may be done by hand or by machine. The trench shall be so dug that pipe may be laid to the required gradient and at the required depth. The width of the trench at bottom shall provide not less than 200 mm clearance on both sides of the pipe. Additional width shall 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:-

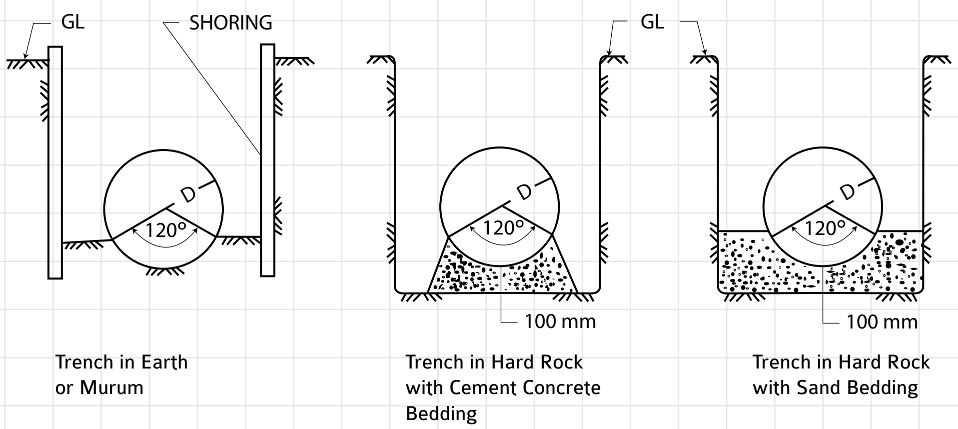


Fig. 5.4.1: Position of DI Pipes in different bedding conditions

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 of the ground, to ensure a proper balance.
- Where lifting equipment is not available, small diameter pipes to 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 joint are:

- Cleanliness of all parts;
- Correct location of components;
- Centralization of spigot within socket; and
- 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.

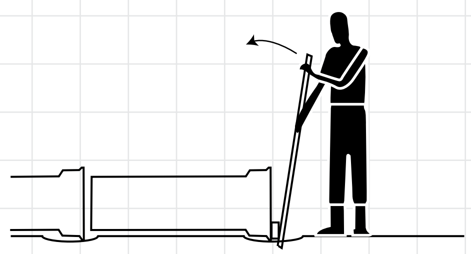
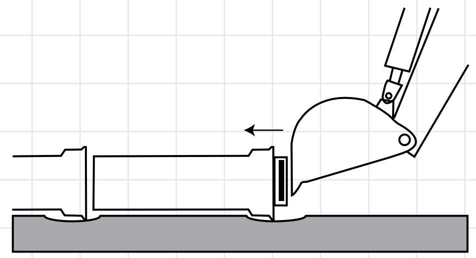
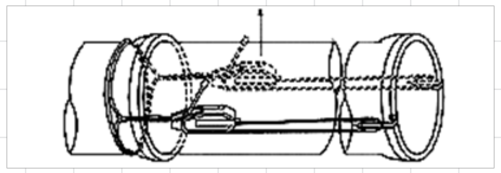
CROWBAR METHOD(for DN 80 to 150) The crowbar levers against the ground. The pipe socket face must be protected with a piece of hard wood. The jointing done by the leverage of the crowbar.	
EXCAVATOR BUCKET (for all Diameter) The hydraulic force of the arm of a mechanical excavator can be effectively 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 Ton, steel cable and rubber protected hooks • DN 350 to 600: TIRFOR type winch, capacity 3.5 Ton, steel cable and rubber protected hooks • DN 700 to DN1200: Two TIRFOR type winches, capacity 3.5 Ton, placed diametrically opposite. Two steel cables and two rubber protected hooks.	
#Any of the above method as found suitable may be used.	

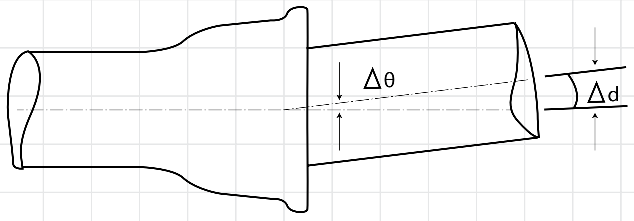
Fig. 5.5.1: Push on jointing method for DI Pipes.

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 sizes up to and including DN 300 and for larger sizes where the pipes are to be checked and ascertained as being suitable for cutting, the diameter will be within the ovality tolerances guidance should be sought as to re-rounding.

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 2.10.2

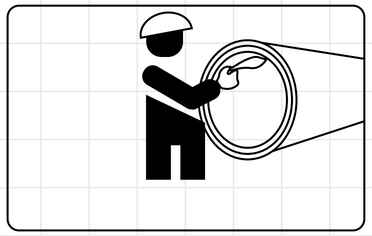
5.5.4 Lubrication

A layer of lubrication is to 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.

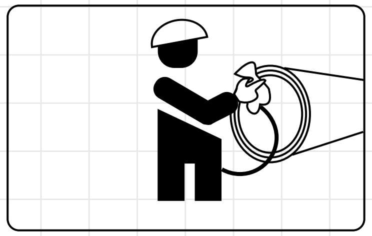
5.5.5 Jointing of Push On Joint

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

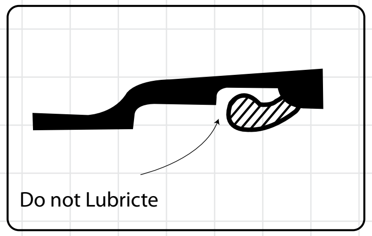
- Clean the inside of socket groove where gasket heel is to be inserted using a wire brush and a rag.



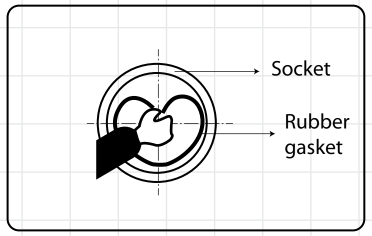
- Clean gasket and insert to socket with the squre section gasket heel in the retaing groove



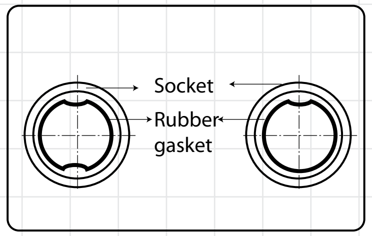
- Coat with lubrication paste on the spigot end of the pipe and the exposed surface of the gasket.



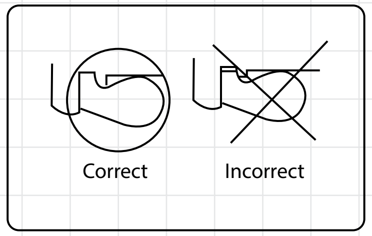
- The insetion of DN 80 and DN 150 gaskets may be facilitated by turing the gasket inside out, gripping one end with retaining heel uppermost and floding the free end down.



- The insertion of DN 200 and larger gaskets is faciltaed by folding the gasket as shown by looping it into a heart shape with the gasket bulb towards the back of the socket. For DN800 - 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 by two at the outside of spigot end gently as shown in figure.

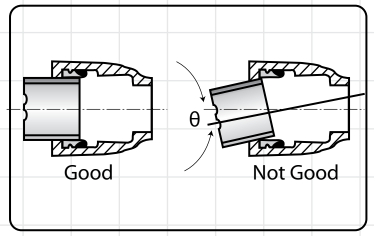


Table 5.2: Insertion Depth for Socketed Joints

DN	Insertion Depth for TJ pipe		Insertion Depth for AJ pipe	
	Maximum	Minimum	Maximum	Minimum
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	98	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	-	-

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.

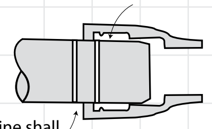


Fig. 5.5.2: Figures showing push-on jointing porcedures for DI pipes.

d) **Joint Dismantling**

- Socketed joints can usually be separated by using lifting equipment approprated to the size of the pipe. Secure a webbing sling, of suitable size and strength, around the pipe near the end farthest from the joing to be dismatled. This is then attached to the lifting equipment and the pipe is raised and lowered, witing the specified deflection limaiations, whilst at the same time exerting slight pulling force, so that the spigot is "walked" out of the socket.

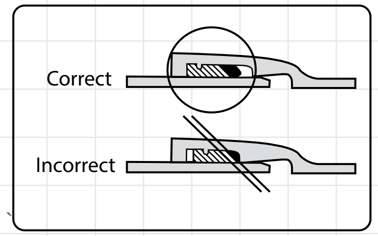


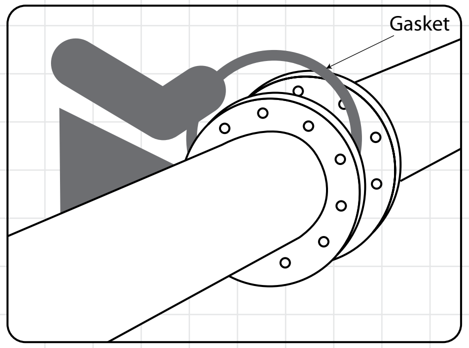
Fig. 5.5.3: Correct position of Rubber Gasket in push-on joint.

Table 5.3: Depth of Insertion of Socket (P)

DN (mm.)	P (mm.)	DN (mm.)	P (mm.)
80	87	750	145
100	87	800	155
150	87	900	170
200	95	1000	180
250	100	1100	190
300	105	1200	205
350	105	1400	235
400	110	1500	250
450	110	1600	265
500	115	1800	295
600	120	2000	325
700	140	2200	330

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.



5.5.6.1 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.

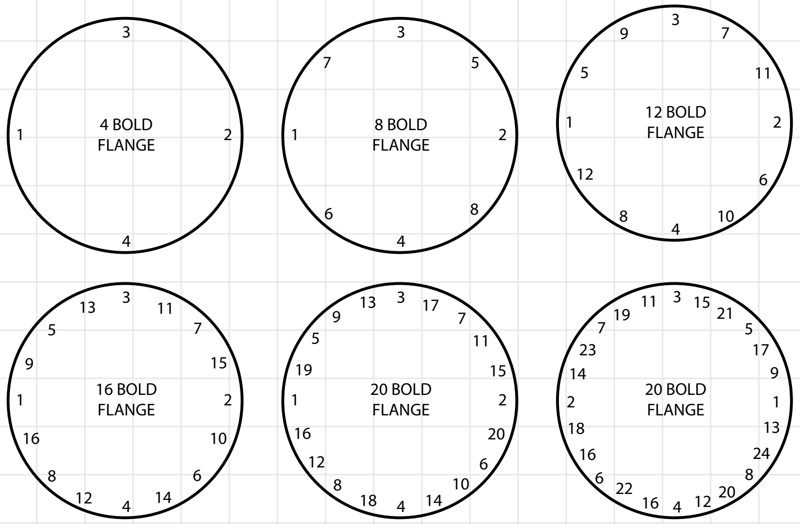


Table 5.4 : Bolting Torques required for tightening of flanged joints.

Class	PN -10 Flanged Joints - Approx Bolting Torque (N-m)			PN -16 Flanged Joints - Approx Bolting Torque (N-m)			PN -25 -Flanged Joints - Approx Bolting Torque (N-m)			PN -40 Flanged Joints - Approx Bolting Torque (N-m)		
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			

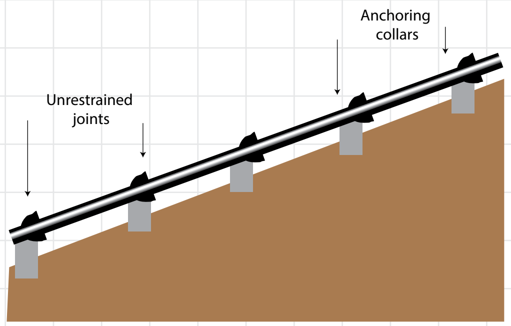
5.6 Pipe laying in hilly terrain.

The push-on joint 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.

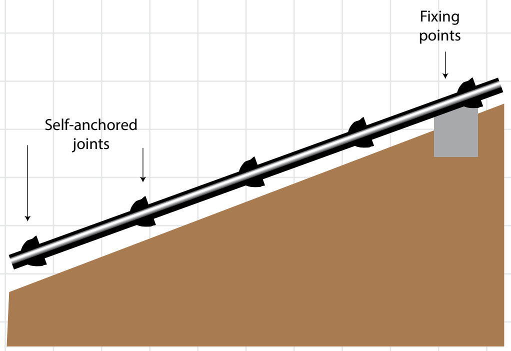


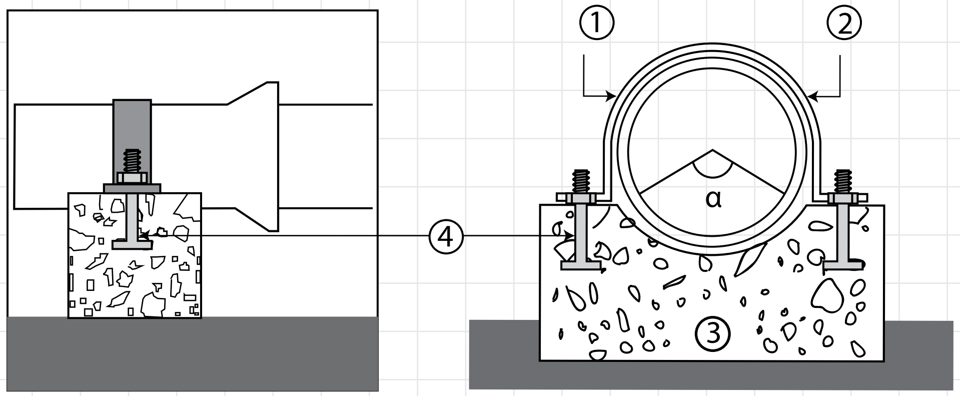
Fig. 5.6.1: Laying of DI pipes on steep inclines

Basic precaution during pipe bed preparation

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

Basic precautions during laying of pipe

1. In push on joint the direction of 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.

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

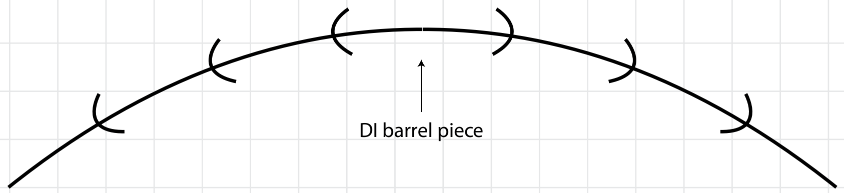


Fig. 5.6.3: Socket position of pipes - Vertical curvature

5. All Fittings should be suitably anchored against displacement.
6. Ensure adequate engagement of spigot in the socket. All spigots should be marked with depth of socket before laying and care should taken to see that all joints are completely assembled upto the required mark.
7. The joint deflection should not be more than the recommended deflection.
8. 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.

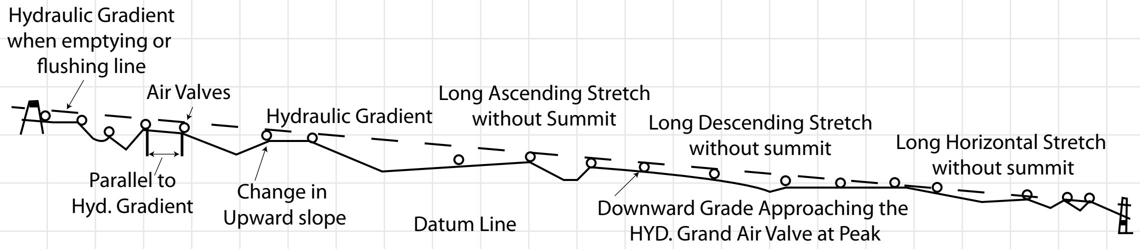


Fig. 5.6.4 : Location of Air Valves

5.7 Bridge Crossing with Push on Joint (DI pipes)

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)
- the 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

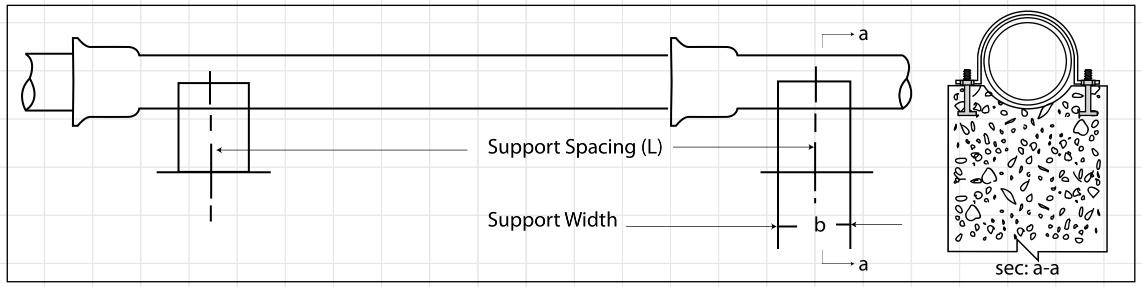


Fig. 5.7.1: Position of pipe support

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 below.

Pipe support:

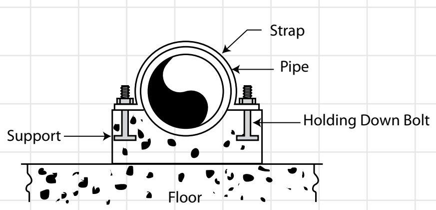


Fig. 5.7.2: DI pipe support with strap

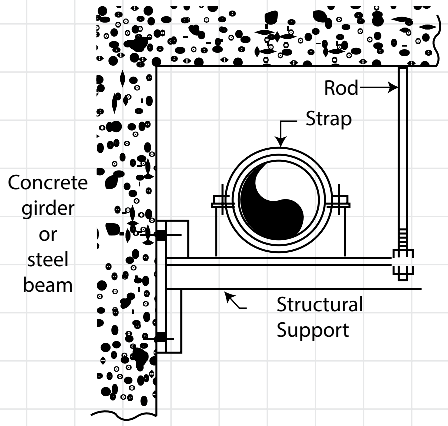


Fig. 5.7.3: DI pipe support under concrete cantelever

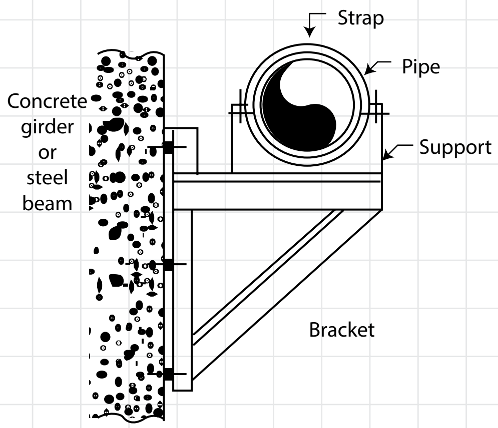


Fig. 5.7.4: DI pipe support on steel bracket

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 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, shall 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.

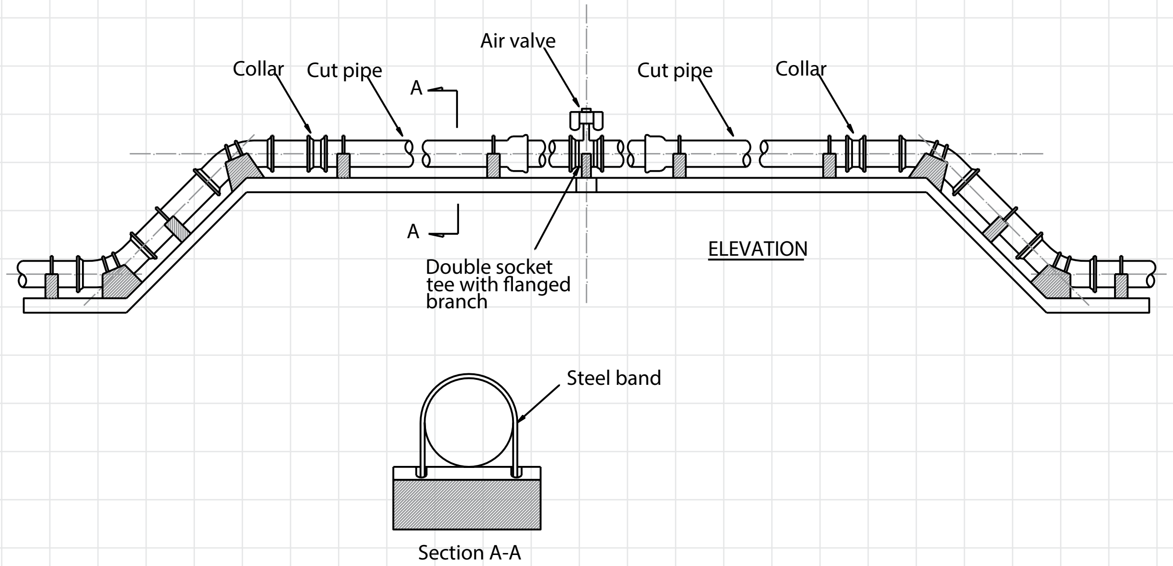


Fig. 5.7.5: Overground pipe support arrangement for DI pipes.

5.8 Backfilling

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 1 m. from the pipe-crown for DI Pipes
- Use of natural granular material up to size 50 mm to be used
- Proper backfill compaction is 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 1 metre.

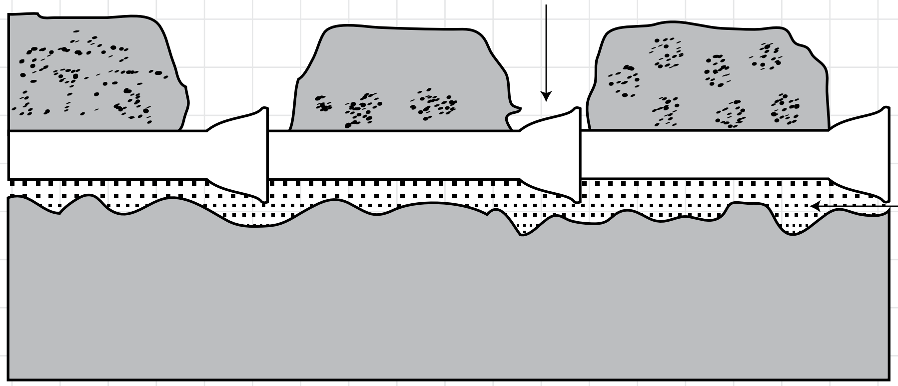


Fig. 5.8.1: Backfilling with open joints for hydrotesting of pipeline.

5.9 Hydrotesting of DI Pipe Line At Site

Hydro testing at site is done to check the leak tightedness 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

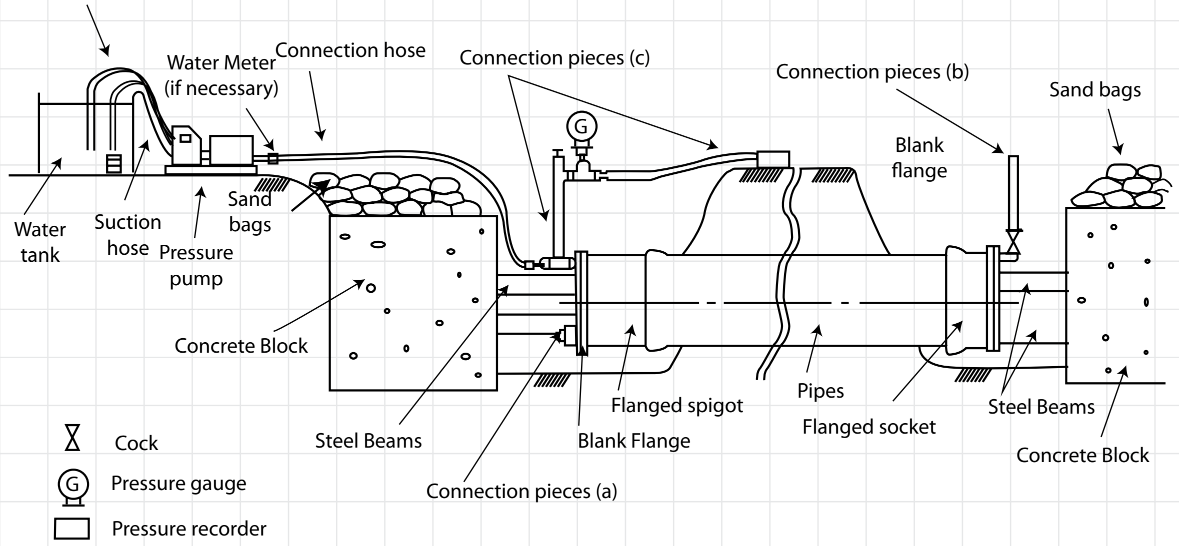


Fig. 5.9.1: Arrangement for Hydrotesting of pipe.

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 subsequently to be demolished, rather than risk movement of the stop ends during testing. Hydraulic jacks may by 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) shall be calculated from the Maximum Design Pressure (MDP) as follows:

- Surge calculated
  $STP = MDP_c + 1$ bar

- Surge not calculated
  $STP = MDP_a \times 1.5$
  $STP = MDP_a + 5$ bar
  which ever is the least

where

MDP_c = Maximum Design Pressure, when the surge is calculated
MDP_a = Maximum Design Pressure, when there is a fixed allowance for surge

5.9.5 Test Procedure

- After the line is filled up with water, it should be left in that condition for 24 hours, to allow the cement mortar lining to absorb water and the dissolved air to come out.
- The pressure in the pipeline should be raised steadily until the site test pressure is reached in the lowest part of the section
- The pressure should be maintained, by pumping if necessary, for a period of 1 hour
- The pump should then be disconnected and no further water permitted to enter the pipeline for a period of 1 hour
- At the end of this period, the original pressure should be restored by pumping and the loss measured by drawing off water from the pipeline until the pressure reached at the end of the test is reached again
- **The acceptable loss should be clearly specified and the test should be repeated until this is achieved. The generally accepted loss for DI Pipe is 0.02 litres/mm, of nominal bore per kilometer of pipeline per 24 hours per bar of pressure applied head (calculated as the average head applied to the section under test). The rate of loss should be plotted graphically to show when absorption is substantially complete**

5.9.6 Testing of Non-Pressure Conduits

In case of testing of non pressure conduits the pipe line shall be subject to a test for of 2.5 meters 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 shall 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 may be used to detect leaks in pipelines laid in waterlogged ground.

After all section has 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 with 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 are under acceptable limit.

5.11 Pipe cutting

5.11.1 Pipe Cutting

The Ductile Iron is required to cut in parts for so 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 following cutting tools

1. **Abrasive Wheel:** Ductile Iron Pipe may be cut using an abrasive wheel cutter. Abrasive wheel of diameter 300 mm, 350 mm or 400 mm shall be used of Arbor size 20 mm , 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:-

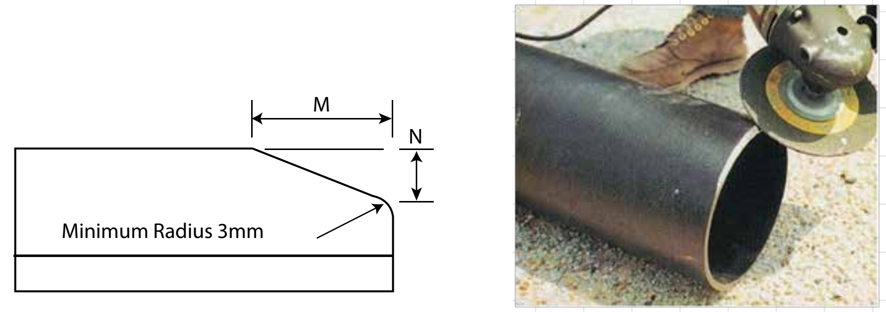


Fig. 5.11.4: Chamfering of DI pipe cut ends

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

5.12 Repairs and Maintenance

5.12.1 Repairing procedure for Ductile Iron Pipe

In normal working condition Ductile Iron pipes does not burst as it is designed with a factor of safety as 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 situation:-

- 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 use preferably 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 should not be any 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.
- Ensuring the correct position of the various components.
- Proper alignment of the spigot within the socket of existing pipeline.
- Ensure the 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 50 mm 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:

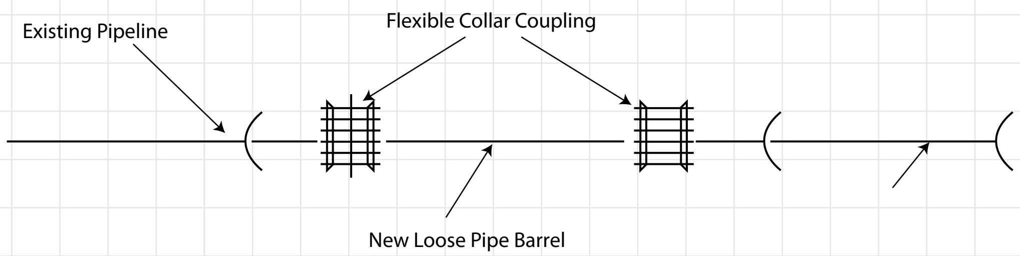
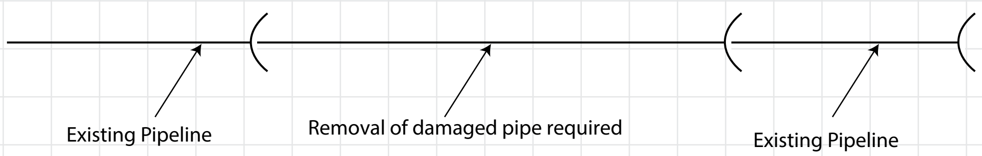
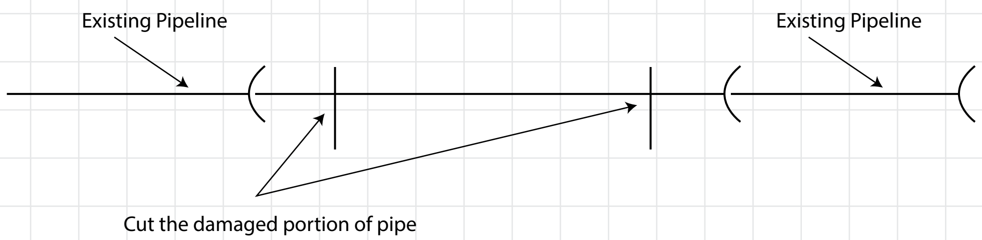


Fig. 5.12.1: Schematic diagram for repair of damaged portion of DI pipe.

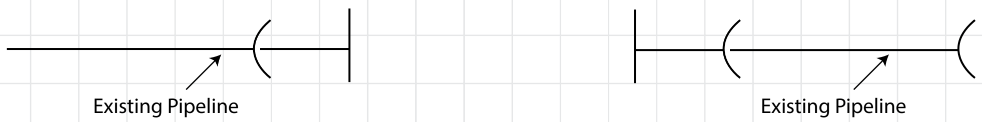
3. **Removal of a complete pipe length from existing pipeline:** When the entire length of pipe from the existing pipe line needs to be replaced the following steps has to be adopted:



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 to be cut in two parts with the help of angle grinder so that there should be 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 is installed in the gap so created between the two cut pieces to complete the repairing of the damaged portion.

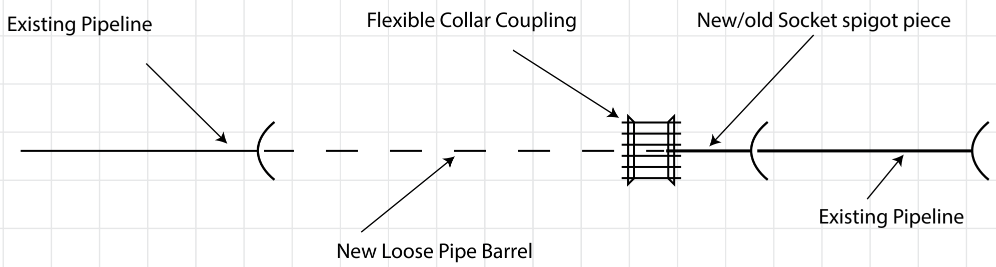
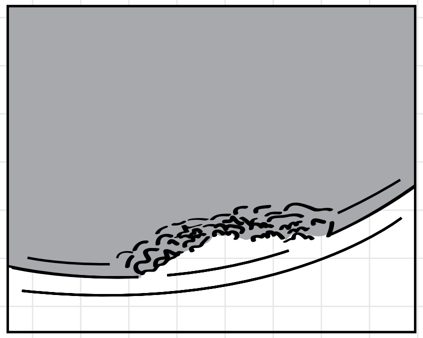


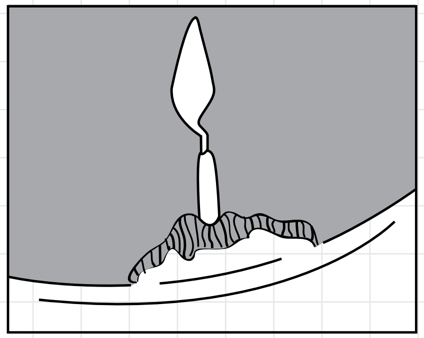
Fig. 5.12.2: Schematics showing removal of complete pipeline with new DI pipe.

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.

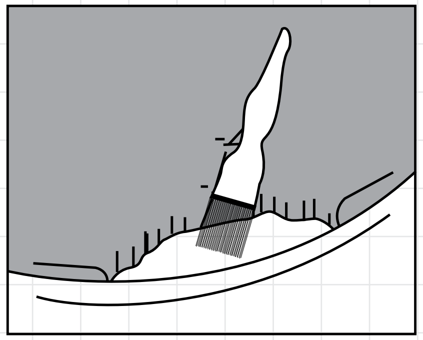
4. **Cement mortar lining repairs:** In the event that an area of Cement Mortar lining is damaged, repairs can be simply made by applying the cement Mortar paste of Portland/High Alumina/Sulphate resistant cement (as the case may be) to two parts of fine sand as per the procedure given below:
   a. After identifying the damaged area of mortar lining if possible position the pipe or fittings with damaged area at the invert level.



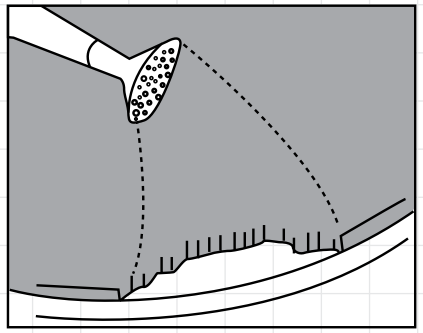
   b. Carefully chip out the damaged lining area. Undercut the edges of the surrounding sound lining to form a 'Key' for the repair.



   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.

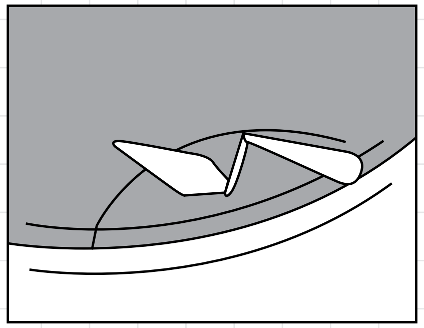


Fig. 5.12.3: Figures showings repair of Cement Mortar lining in DI pipes.

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 may get damaged during transport, and handling.
For slight damage (in small area and 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 is sufficiently dried 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.

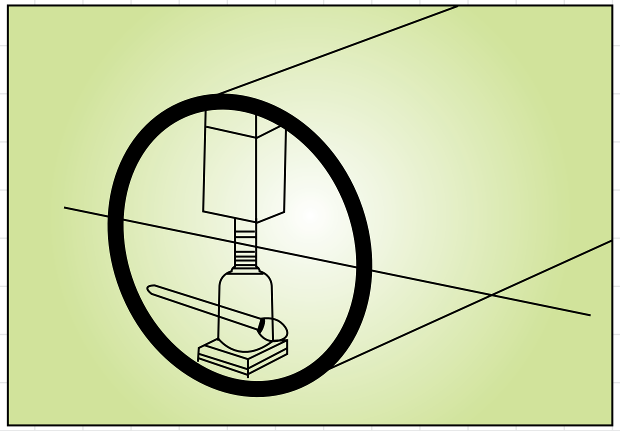


Fig. 5.12.4: Ovalty Correction (Method A)

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.

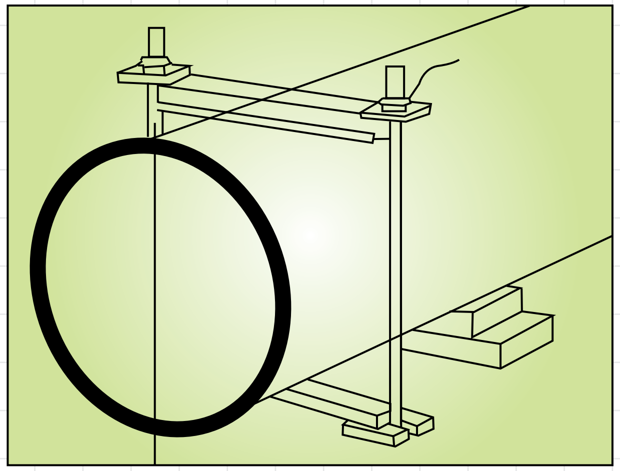
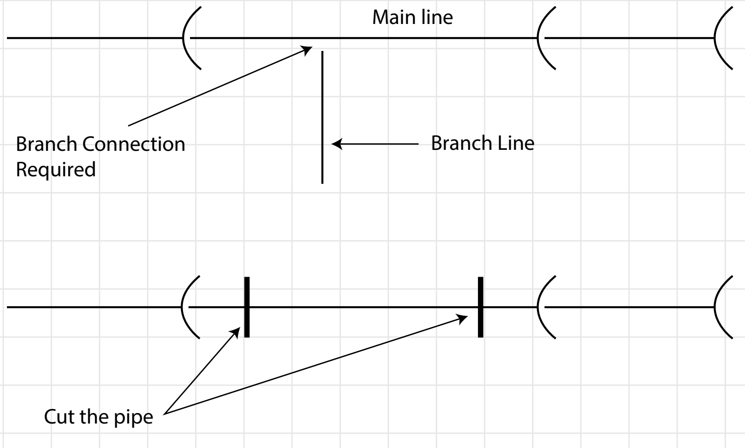


Fig. 5.12.5: Ovalty Correction (Method B)

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.

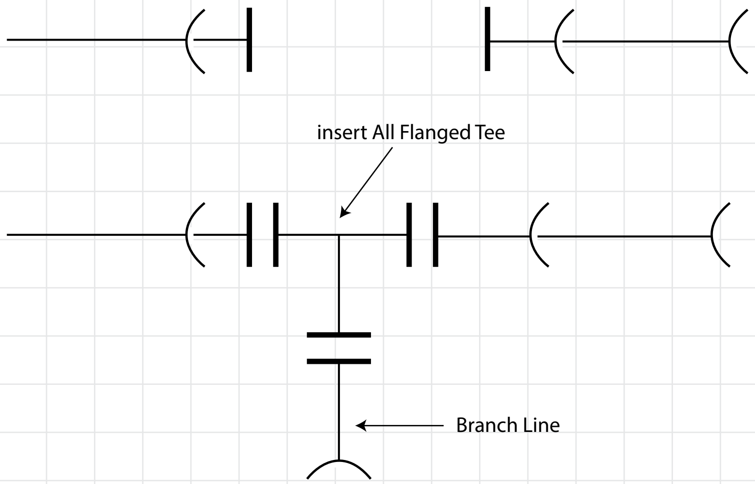


Fig. 5.12.6: Schematic showing procedure for taxing branch connection with All Flanged Tee.

   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 to be cut with the help of angle grinder so that there should be 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 is installed in the gap so created between the cut pieces to complete the installation of Tee with the existing pipe line.

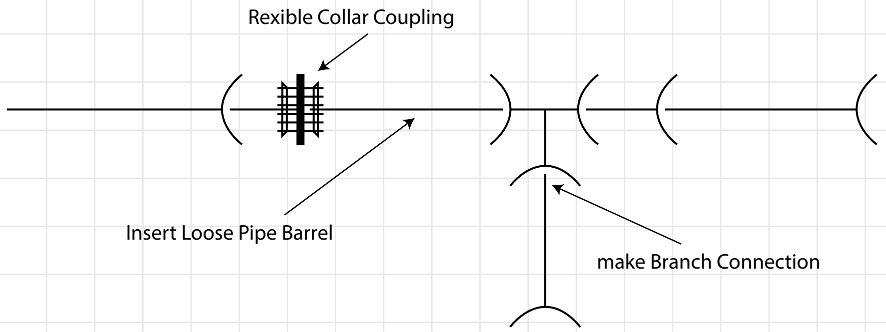


Fig. 5.12.7: Schematic showing procedure for taxing branch connection with Socketed Tee.

   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.

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

Fig. 5.12.8: Tapping size in DI pipes

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

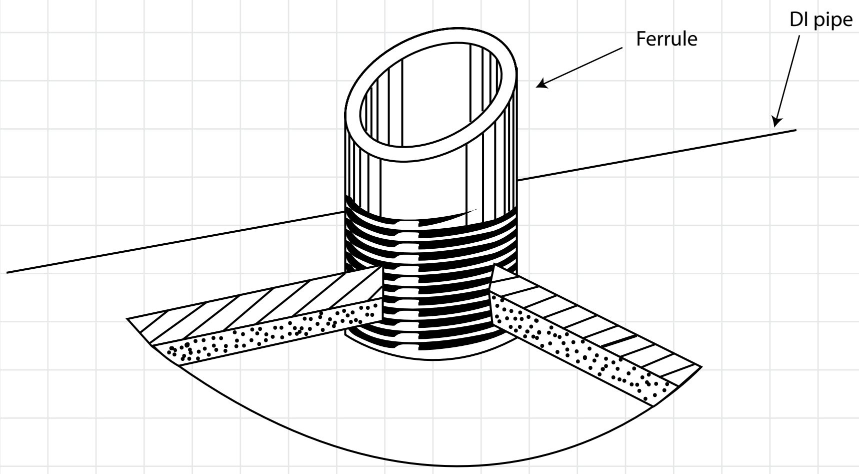


Fig. 5.12.9: Threaded Tapping in Ductile Iron pipes.

6.0 REFERENCES

Jindal SAW Ltd confirms 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	D.I. Pipes	IS: 8329- 2000	Centrifugally cast (spun) Ductile Iron pressure pipes for water, gas and sewerage - Specification
2	D.I. 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: 8112-1989	Ordinary Portland Cement - specification
	Portland Slag Cement	IS: 455 – 1989	Portland Slag Cement - specification.
	Sulphate resistant Cement	BS 4027:1996	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 or gas application.
		ISO: 7186	Ductile Iron products for sewerage application
		BS EN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.
		BS EN 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 or gas application.
		BS EN: 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.
		AWWA C110	Ductile Iron and grey Iron fittings, 3 In. through 48 IN. (76 mm through 1219 mm) for water.
3	Rubber Gaskets	ISO: 4633	Rubber seals - Joint rings for water supply, drainage & sewerage pipelines.
		BSEN: 681-1	Elastomeric seals- Material requirements used in water & drainage applications Part1 - Vulcanized rubber.
4	Cement Mortar lining	ISO: 4179	Ductile Iron pipes and fittings for pressure and non pressure pipelines - cement mortar lining.
		BS EN: 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.
		BS EN: 196-1	Methods of testing Cement Part 1 Determination of strength.
		BS EN: 197-1	Cement - Part 1, composition, specification and conformity criteria for common cements.
		AWWA C104	Cement Mortar Lining for DI pipe and Fittings for water.
5	Cement Mortar lining with Seal coat	ISO: 16132	Ductile Iron pipes and fittings - Seal coat for Cement Mortar linings.

6	Zinc coating with finishing layer of Bitumen	ISO: 8179-1	Ductile Iron pipes - External Zinc based coating Part 1: Metallic Zinc with finishing layer
		BS EN: 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	BS EN 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 pipe lines - Polyethylene sleeving for site application
9	External Poly ethylene coating	BS EN 14628	Ductile Iron pipes, fittings and accessories - External polyethylene coating for pipe - Requirement and test methods.
10	External polyurethane coating	BS EN : 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.	BS EN 545	Ductile Iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.
		ISO: 14713	Protection against corrosion of iron and steel in structures-Zinc and aluminium coatings - Guidelines.
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.

Design standards

S. No.	TOPIC	Standards Ref. No.	Title of the standards
1.0	DI PIPE	ISO: 10803	Design methods of Ductile Iron pipes
		AWWA C150	Thickness design of Ductile Iron pips
		AWWA M11	Steel Pipe - A Guide for designing & Installation.

6.3 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
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 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
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
Gallons	4.545 litres
Grams/liter	1000 parts/million
Hectares	2.471 Acres
Horsepower	550 foot-lbs/sec
Horsepower	0.7457 kilowatts
inches	2.540 centimeters
inches	25.4 millimeters (mm)
Inches/sec	2.540 x 10-2Meters /sec
inch	1.0 x 10-3Mils
Ounces (fluid)	1.805 cubic metrs

Unit	Conversion
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	2.31ft 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 107square 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)	1003 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

6.0 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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