FIBERSTRONG™

Installation Guide
For Above Ground Pipe Systems

Glass Reinforced Polyester Pipe Systems

FUTURE PIPE INDUSTRIES

www.futurepipe.com

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Installation Guide
For Above Ground Pipe Systems

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PREFACE

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For any technical query, please consult **Future Pipe Industries L.L.C.**

For shortening, **Future Pipe Industries L.L.C.** is referred to by "**FPI**" or the "**Manufacturer**".

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1. INTRODUCTION

Fiberstrong is a flexible corrosion resistant pipe system intended for belowground or aboveground use. They consist of a Thermosetting Chemical resistant resin and Fiberglass Reinforcements. The pipe might also include fine Silica sand aggregates in the structural wall according to ISO 10639 / AWWA C-950. This manual deals with the handling, installation and testing of the glass reinforced pipe system. Pipe diameter ranges from 300 mm up to 3000 mm with a pressure class of up to 16 bar.

This manual should be carefully read by the Contractor responsible for installing the pipes, as well as by the design Engineer. This information should be considered only as a guide. The Engineers or others involved in pipeline design or installation should establish for themselves the Procedure(s) suited to the site conditions. Sound engineering practices should always be followed.

Our site service representatives are at the disposal of the Contractor in order to advise on the handling and installation of the pipes.

1.1 Responsibilities of Future Pipe Industries Site Supervisors

The responsibilities of our site supervisors are: Periodic visits to the job site throughout the duration of pipe installation to advise the contractor on the proper and applicable handling, storage, installation, jointing and site testing procedures necessary to achieve a satisfactory pipe installation. Those procedures are detailed in this manual.

Figure 1 - FPI Site Supervisor

It is the responsibility of the Contractor to make available the "INSTALLATION GUIDE FOR ABOVEGROUND PIPE SYSTEMS" to his installation crew, and to ensure that they are familiar with, and understand the procedures described therein.

It is the responsibility of the Contractor to strictly follow and implement the installation procedures published in this installation guide, as well as any additional advice given by our site representative. The pipe manufacturer shall not be liable for any failures related to installation arising from failure of the Contractor to follow and implement our written installation instructions and any additional advice or recommendation made by our field representative.

2. HANDLING

2.1 Receiving

Generally, pipes will be handed over to the Contractor or his representative at the factory or at the job site as agreed upon in the Contractor's purchase order. Inspection is thoroughly made by the factory loading staff of the goods being loaded.

The Contractor should make the following inspection at the time of the reception of the goods:

Each item should be inspected with care upon its arrival.

Total quantity of pipes, couplers, rubber rings, fittings, lubricant, etc.... should be carefully checked against the delivery notes.

Any damaged or missing item must be pointed out to the dispatcher or driver and noted on the delivery note.

Materials that have been damaged during transportation should be isolated and stored separately on site, until the material is checked by our site representative and repaired or replaced.

Note 1: Damaged material must not be used before it is repaired.

Figure 2 - Receiving of Pipe in the Factory

Figure 3 - Transporting Pipes to Site

Figure 4 - Unloading Pipes

2.2 Unloading Pipes

Unloading at the job site must be carried out carefully under the control and responsibility of the Contractor. Care should be taken to avoid impact with any solid object (i.e. other pipes, ground stones, truck side etc.).

2.2.1 Unloading by Hand

Unloading by hand with two men is only allowed for small diameter pipes, not exceeding 40 kg weight.

2.2.2 Mechanical Unloading

Flexible slings or straps should be used combined with a mobile crane. When unloading is done with a mobile crane, care must be taken that the pipes do not slide off the slings. Therefore, it is recommended to use two slings or nylon lifting straps to hold and lift the pipes. Steel cables or chains must not be used for lifting or handling pipes. The pipe can also be lifted with one sling or strap balanced in the middle with the aid of a guide rope. To lift a unitized package, two support points are always required.

Caution: Hooks must not be used at the pipe ends to lift the pipes, nor should the pipe be lifted by passing a rope or sling through the pipe.

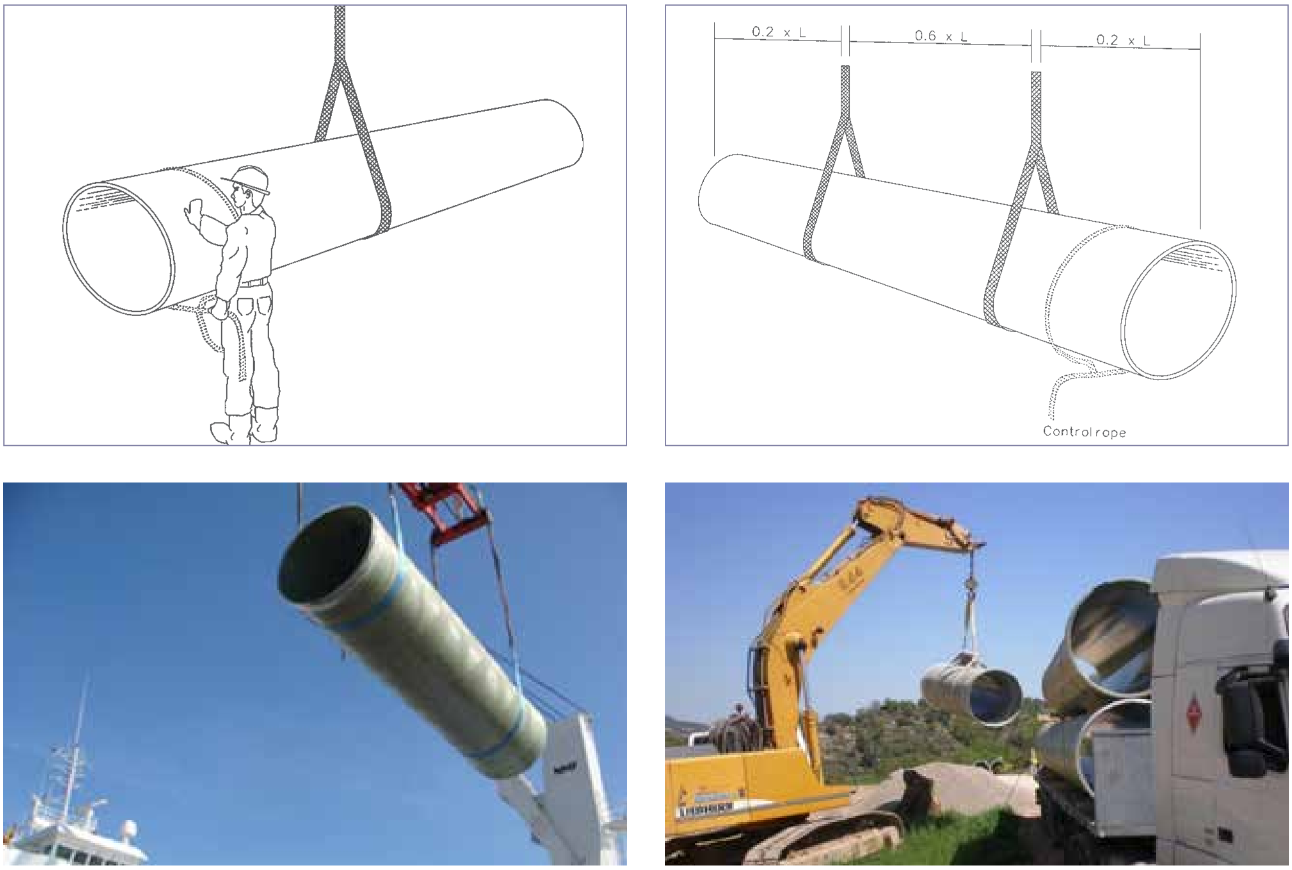


Figure 5 - Lifting Single Pipe

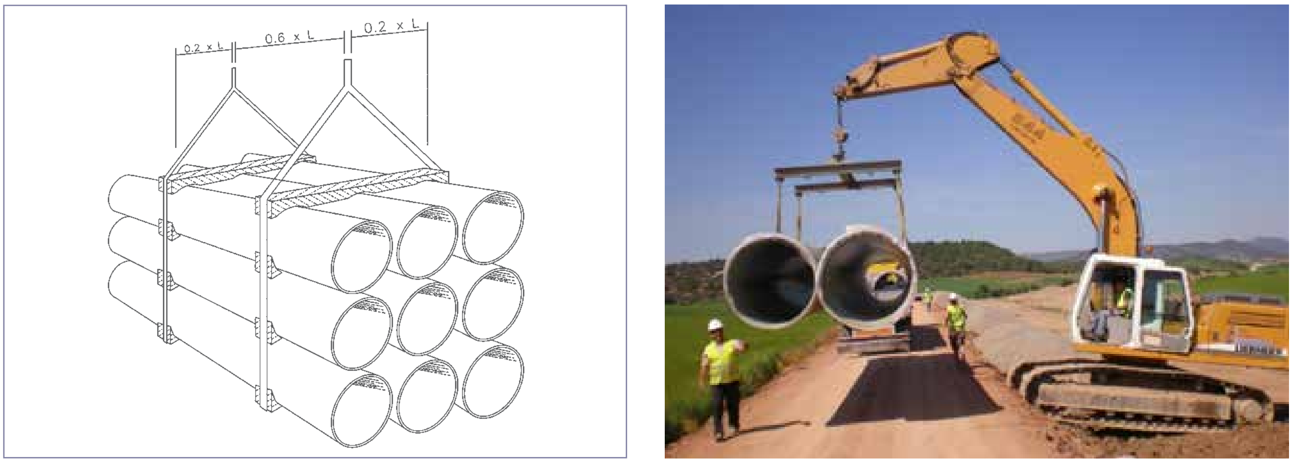


Figure 6 - Lifting Unitized Package

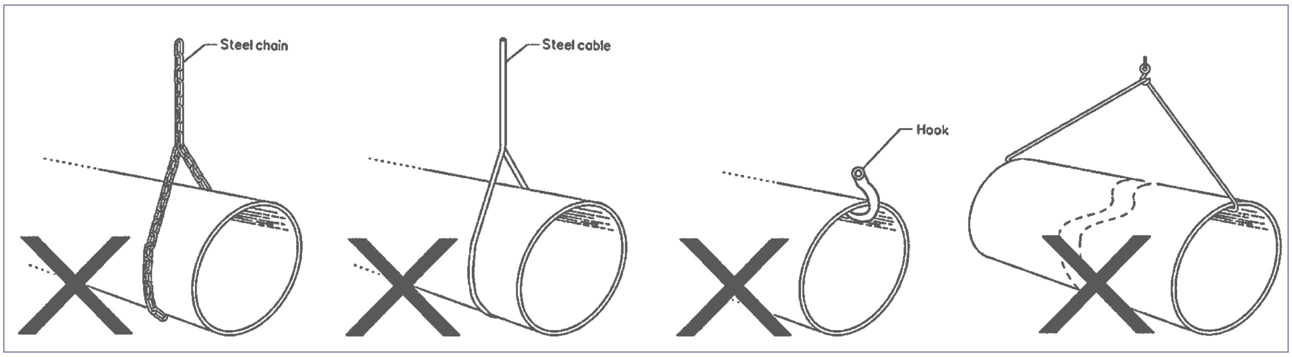


Figure 7 - Wrong Lifting Practices (to be avoided)

2.3 Unloading Couplings

Couplers shall be unloaded with care. They must not be thrown off the truck on the ground. In general, couplers are strapped and bundled in the factory and can be off loaded like the pipes.

2.4 Storing Rubber Gaskets and Lubricant at Site

Rubber gaskets are delivered in closed bags from the factory. They must be stored in their original packing in a cool, dry, shaded area, protected from direct sunlight, until they are ready for use. In case a longer storage is expected (more than 3 months), then a cold storage (AC room) with a maximum temperature of 25°C and a maximum relative humidity of 75%, is required for the rubber rings storage. Rubber gaskets shall be used on the FIFO principle (First IN - First Out) so that the most recent received gaskets remain in inventory.

Vegetable based lubricant should be carefully stored in shaded area. Partially used buckets should be sealed to prevent contamination of the lubricant.

In case the pipes will be delivered with couplers mounted in factory, the storage time of such pipes shall not exceed 3 months without cover in order to avoid deterioration of the rubber.

2.5 Storing Pipes on Site

2.5.1 Distribution along the Trench

It is preferable to unload pipes alongside the trench directly from the truck. If the trench is opened, string out the pipes on the opposite side to the excavated earth. Allow sufficient space between the pipes and the trench for excavator, cranes, etc. Avoid placing the pipes where they can be damaged by traffic or blasting operations. If possible, store the pipes on soft level ground (e.g. sand) or timber bearers.

Caution:

- Pipes must not be stored on rocks. Always use flat timber supports at maximum 3 meters spacing.
- Nesting of the pipes during transportation or storage at site is strictly not allowed!

2.5.2 Storing in Stockpiles

Care must be taken that the storage surface is levelled, firm, and clear of rocks or solid objects that might damage the pipes. Store the pipes in separate stockpiles according to their class and nominal diameter. If it is necessary to stack pipes, it is best to stack on flat timber supports at maximum 3 meters spacing. The maximum stack height is 2.5 meters approximately. Wooden wedges, which are used in order to prevent the pipe stack from sliding, should be placed on both sides of the stack on the timber bearers, as shown in Figure 8. This height is limited for safety purposes and to avoid excessive loads on the pipe during storage.

Unlike thermoplastics (e.g. PVC), storage in direct sunlight has no effect on the service performance of the pipes. They have a resin rich outer layer offering enough protection against UV radiation.

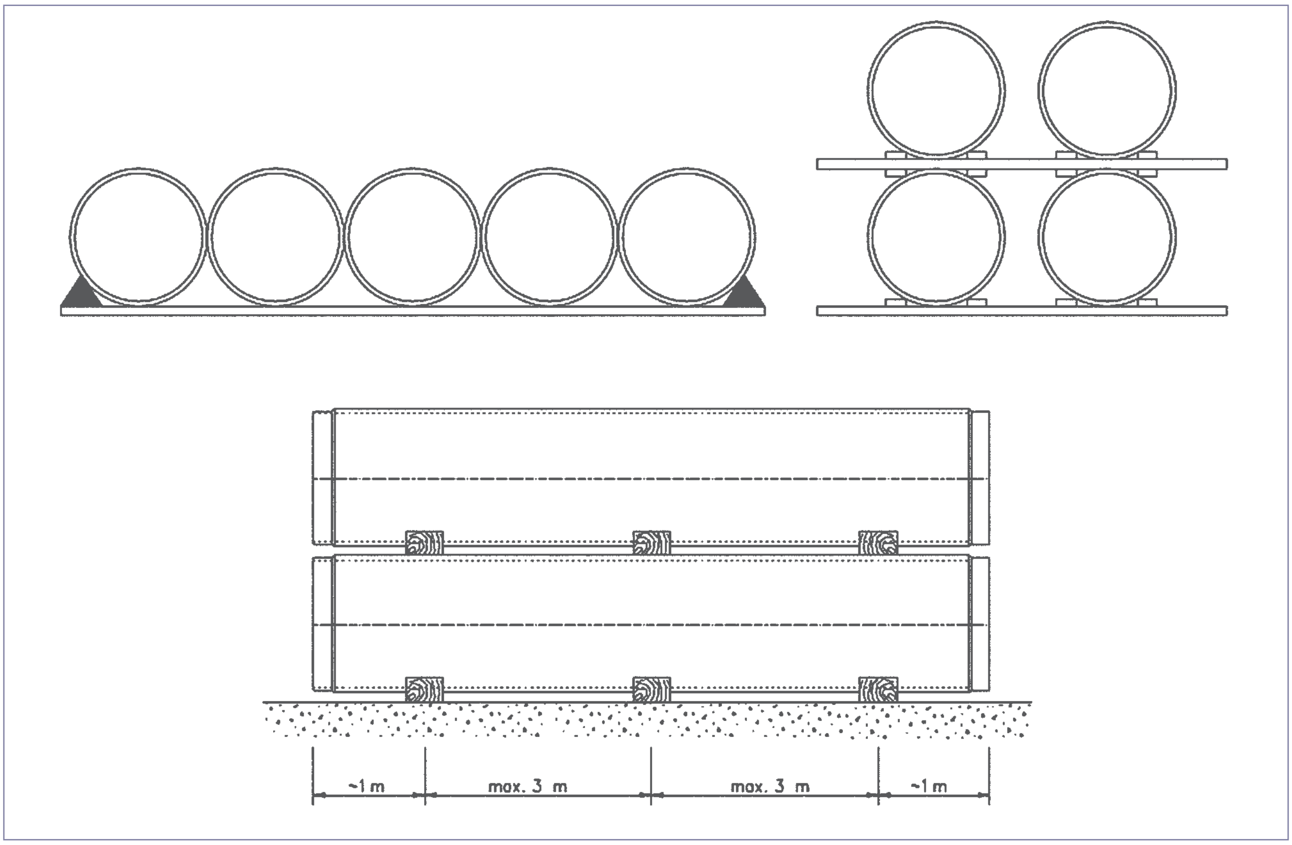


Figure 8 - Pipe Stacking

The change in appearance the pipe undergoes when exposed to sunlight over an extensive period of time, is a surface phenomenon caused by UV effect on the outer layer. The result is the appearance of a chalky layer on the pipe external topcoat and does not affect the structural wall nor the performance of the pipe. For pipes expected to be stored for long periods (more than six months) in direct sunlight, it is recommended to protect them by using covers (e.g. Tarpaulin) in order to avoid discoloration.


Figure 9 - Pipe Storage

3. INSTALLATION OF ABOVEGROUND PIPES

3.1 Introduction

An outstanding application of Fiberstrong pipes is the aboveground installations. The use of the standard Fiberstrong systems without end thrust capabilities, makes special consideration of the forces resulting from the internal pressure. All components that represents a change in the cross section of the pipe or in direction, must be installed in thrust blocks to provide the adequate support and resistance to the induced resultant forces.

The aboveground installation of Fiberstrong pipes will require that all misalignments must be minimized. Additionally, the supporting system must ensure the stability of the pipes and couplers.

Aboveground systems shall use pipes of minimum stiffness SN 5000.

3.2 Supporting of Pipes

In general, pipes are supported along the span length placing a support on either side of the joint. For a low pressure pipeline, PN1, a supporting system with a direct support under the joint can be used (see Figure 10).

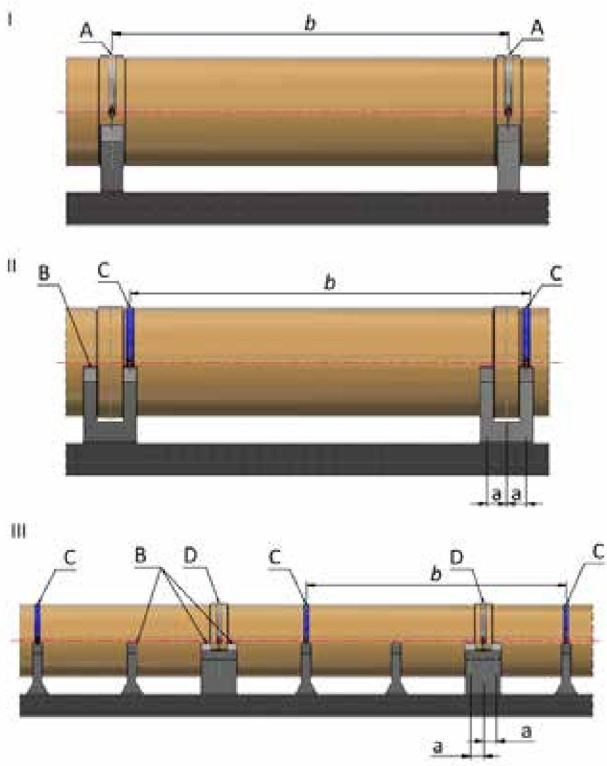
When using Fiberstrong pipes in above ground applications, the supports must be designed in such way that longitudinal expansion of the pipes will be allowed. It is essential that the pipe movements are guided and controlled ensuring that all pipe sections are stable, and that longitudinal movement of the pipe doesn't exceed the couplers capability.

To achieve that, each pipe must be supported by at least two cradles, of which only one of these acts as anchor and the rest as guiding system. Anchors acts as fix points and guides are designed to allow longitudinal expansion. Both, anchors and guides restrain lateral movements. When supporting only under the couplers, this cradle is used as anchoring point for the coupler. For pipes supported in more than two cradles, the cradle closest to the middle of the pipe will be used as an anchor.

The anchors should be located with regular spacing in order to ensure even distribution of longitudinal pipe expansion within the limits of the joints.

Pipe end stability is ensured by the dead weight of pipe and water. However, in some cases, it could be necessary to anchor also the coupler to ensure the pipe end stability.

The pipe supports should be in straight alignment. The maximum deviation from the straight alignment must be the lesser of 0.1% of the span length or maximum misalignment of pipe ends in the joints as specified in **4.4.3.3 Joint misalignment**.



I System supported on coupler
II Two Cradles
III Multiple Cradles

A. Coupler with Anchor
B Guide
C. Pipe Anchor
D. Coupler Anchor if necessary

a = maximum distance from the centerline of the joint to centerline of a support, see Table 1

b = maximum distance between two pipe anchors.

Figure 10 - Shows different pipe support configurations

DN	a
DN ≤ 500	max. 250 mm
600 ≤ DN ≤ 1000	max. 0.5 x DN
DN > 1000	max. 500 mm

Table 1 - Maximum distance from the centerline of the joint to centerline of the closest support.

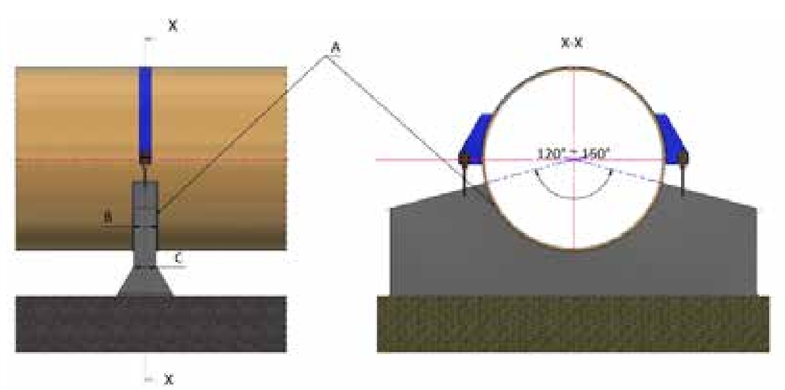
3.2.1 Support design
The supports must avoid local stresses like point or line loading on the pipes, this is achieved by supporting the pipes in cradles. Cradles are typically made in concrete or steel with a supporting angle of 120° - 150°. The supporting angle will be ±5° of the chosen angle.

The cradles will have a minimum width C (see figure 11) according Table 2.

DN	C
DN < 1000	150 mm
1000 ≤ DN ≤ 2000	200 mm
DN > 2000	250 mm

Table 2 - Minimum cradle width.

The inside of the cradles must be covered with a liner of 5 mm thickness to avoid direct contact between pipe and cradle. Liners must be made from materials that are resistant to the environment of use. High friction liners are used at anchors and low friction liners are used at guides. Low friction liner criteria are fulfilled by using UHPE materials and high friction by 60-70 Shore A Thermoplastic Polyurethane.



A Cradle liner, minimum thickness is 5 mm

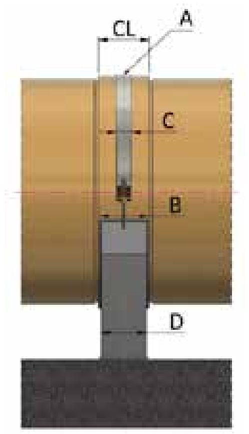
B Cradle liner 25 mm larger than cradle sizes

C Cradle width

Figure 11 - Cradle design for support under the pipe

The diameter of the finished cradle with the cradle liner included must be 0.5% (±0.25%) larger than the outer diameter of the pipe without pressure.

If pipeline characteristics allows for installation type I in Figure 10, the cradle design for the support under the coupler can be as described in Figure 12.



A Anchor lined strap

B Cradle liner 25 mm larger than cradle sizes

C Anchor strap width, minimum 30% of CL

D Cradle width, 90% of CL

CL Coupler length

Figure 12 - Cradle design for support under coupler

3.2.2 Loads on supports

The supports should be designed to withstand the loads caused by:

- external loads, like wind and snow
- weight of pipe and fluid
- reaction forces caused by internal pressure
- friction induced in couplers and against guides
- head loss in the pipe

The complete design of the support is the responsibility of the owner's engineer based upon the actual loads.

Table 3 provides approximate axial forces that should be considered in the design of support cradles. These loads result from the interaction of contraction and elongation of pipe during operation, and the frictional resistance in the rubber joints.

DN	PN 6	PN 10	PN 12	PN 16
300	5	6	7	7
350	6	6	7	8
400	6	7	8	8
450	6	7	8	9
500	7	8	9	10
600	8	9	10	11
700	8	10	11	12
800	9	11	12	14
900	10	12	13	15
1000	11	13	14	16
1200	12	15	17	19
1400	14	17	19	21
1600	15	19	21	24
1800	17	21	23	27
2000	18	23	25	29
2200	20	25	28	32
2400	22	27	30	35
2600	23	29	32	37
2800	25	31	34	40
3000	26	33	37	43

Table 3 - Typical axial loads due to pipe expansion/contraction and friction at rubber joints in kN.

Frictional force between pipe and guide should be determined based on total compression between pipe and cradle and the frictional coefficient between the pipe material and the cradle liner.

3.3 Anchor design

The function of the anchor support is to create a fix point. This prevents the pipe moving in the vertical direction and in a controlled way in the longitudinal direction. It also transfers the longitudinal loads (see 3.2.2) acting on the pipe to the supports.
The anchor should be designed to give enough strap tension without overloading the strap or the pipe when variation of temperature and/or pressure causes diametral expansion of the pipe.

GRP pipes develops high hoop strains. That means the anchor clamp should be designed with elastic elements to compensate such strains. The elastic elements should be designed to offer enough strap tension at low pressure not overloading the pipe when higher working pressure is applied.

Figure 13 shows a typical design of the steel clamp with elastic elements produced with disc springs.

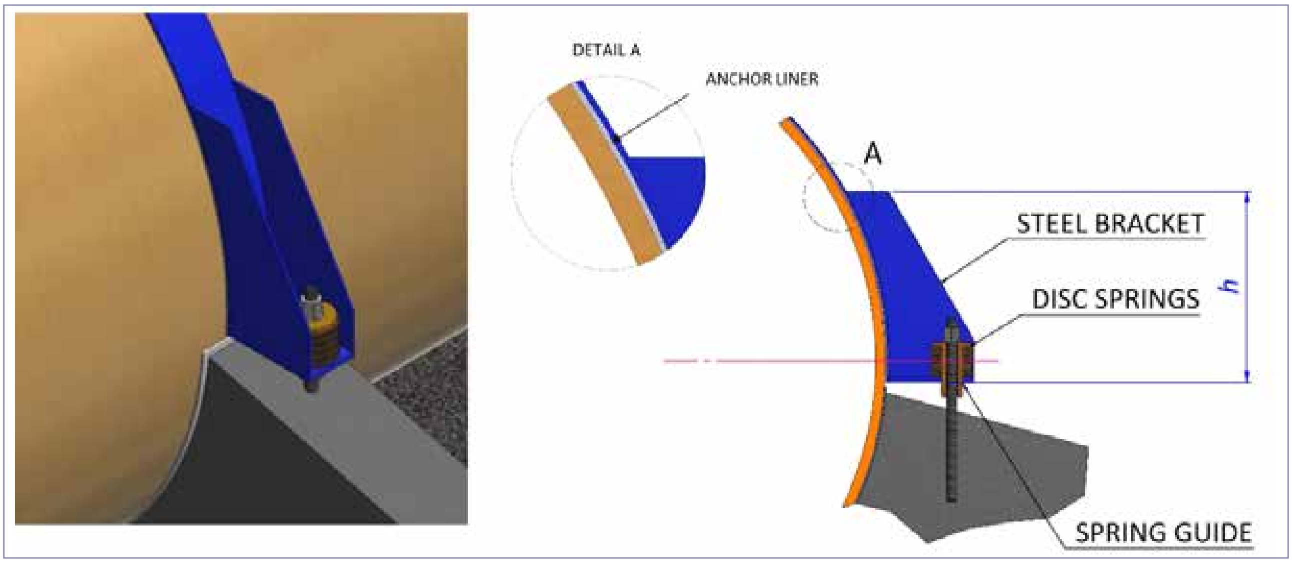


Figure 13 - Typical clamp Design

The height of the bracket *h* must ensure that bending of the bracket due to clamping load, is not point loading the pipe. Recommended h values are given in Table 4

Pipe DN	Bracket Height h [mm]
300≤DN≤400	170
450≤DN≤600	250
700≤DN≤900	300
1000≤DN≤1300	350
1400≤DN≤2000	450
2100≤DN≤3000	550

Table 4 - Recommended bracket height.

The design of the clamp will depend of the characteristics of the pipe system such as DN of the pipe, maximum working pressure and the maximum slope of installation.

Typically, the strap and cradle are mounted with a high friction liner (see figure 13) type 60-70 Shore A Thermoplastic Polyurethane to increase the effect of the clamping loads.

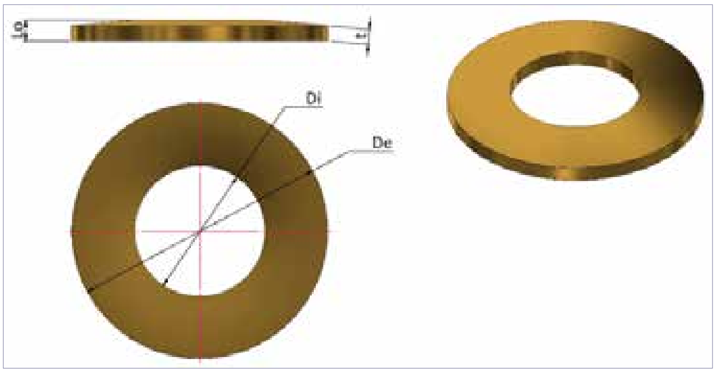


Figure 14 - Belleville Disc Spring

To provide enough elasticity for accommodating the strain differences, the clamps are equipped with elastics elements typically formed by Belleville disc springs.

When calculating the anchoring elements, attention must be drawn to the loading conditions of the pipe system. Typical loading conditions are given in table 5.

Characteristic	Loading Conditions
Maximum Working Pressure	PN
Maximum Surge Pressure	1.4 x PN
Maximum Field Pressure Test	1.5 x PN
External load on the pipe projected area	2.5 kN/m^2
Density of fluid	1000 kg/m^3
ΔT empty pipe after installation	±50°C
ΔT filled pipe after installation	±20°C

Table 5 - Clamp design loading conditions

Full detailed design of the anchoring system will be provided upon request.

Ensure that each pipe is anchored while installation is progressing. Due to thermal variations during installation, if pipes are not individually secured, they can cumulate all expansion or contraction movements without control.

3.4 Guide design

Guides are designed as cradles with low-friction liners. The friction factor between pipes and the liner must be less than 0.3. This requirement is fulfilled by using liners like UHPE. The liner material must withstand the effects of the environment.

The liner should be permanently attached to the guide cradle.

In many situations, the weight of pipe and fluid is enough to ensure the stability of a pipe in the guide. There are cases in which the ends of pipes may lift from guides as a result of a combination of high-compression forces in the fluid, pipe to coupler angular deflection and/or misalignments of pipe ends (see Figure 15).

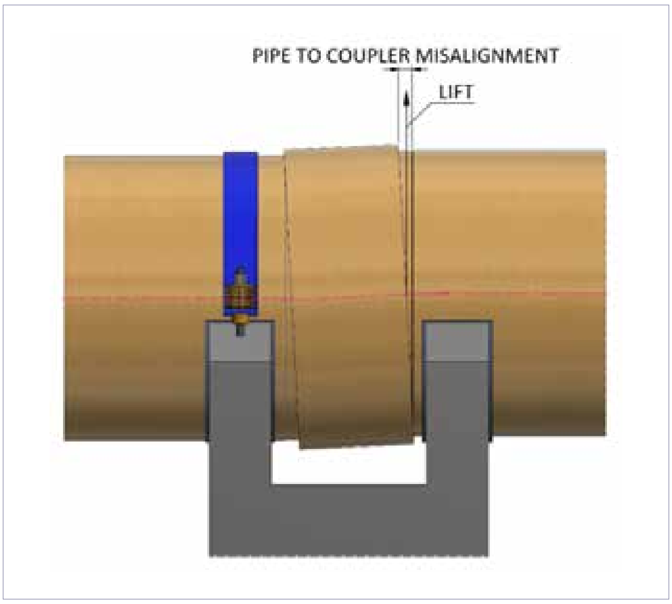


Figure 15 - Instability of pipe ends on guides

If the lifting force becomes large enough to lift pipe end, then pipe ends must be secured. This is done by clamping the coupler to the foundation supporting the joint (see Figure 16). The clamp design used for anchoring the pipes, is used for clamping the couplers to foundations.

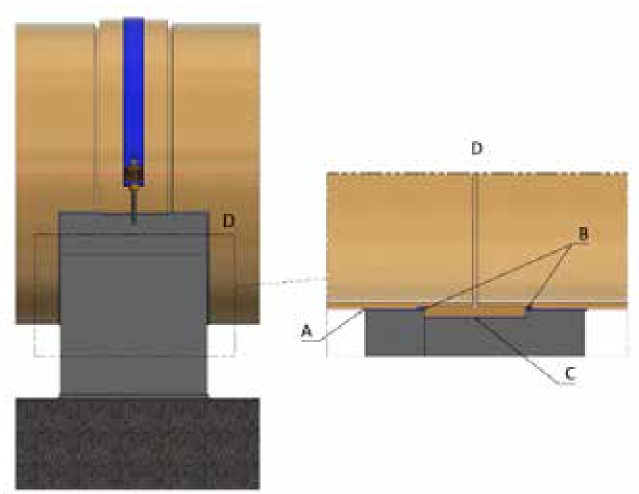
The minimum length of pipe or support spacing (size D in Figures 17 and 18) to ensure stability without clamping the ends will depend of the supporting configuration. In general, the minimum support spacing for not anchoring the couplers is given in Table 6.

Nominal Pipe Diameter	PN 6	PN 10	PN 12	PN 16
300 ≤ DN ≤ 500	CA	CA	CA	CA
500 < DN ≤ 900	CA	CA	CA	CA
900 < DN ≤ 1800	4	6	8	CA
1800 < DN ≤ 3000	2	3	4	5

CA: Coupler anchored

Note: Maximum slope of installation 30°

Table 6 – Minimum support spacing for not anchoring the couplers



A cradle liner
– high friction for anchors
– low friction for guides

B sealing compound

C High friction cradle liner

Figure 16 - Anchored Coupler

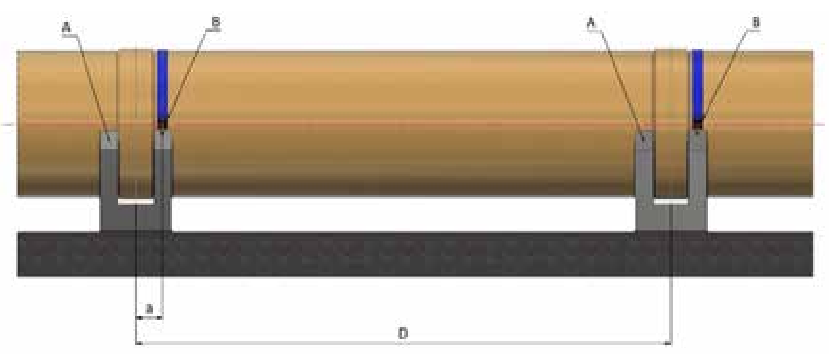
When couplers are embedded it must be ensured that the gap between coupler and pipe is kept free from concrete, e.g. by applying sealing compound "B", see Figure 16.

3.5 Maximum Supporting Spacing

The maximum support spacing, D, is calculated based on the short and long term properties of the pipe and the loading conditions. Typically, there can be two different supporting spacing situations, pipe on two cradles and pipe on more than two cradles.

Table 7 gives maximum support spacing. The values given are based in the loading conditions of Table 5 and pipe support as shown in Figures 17 and 18.

In the event of two supports, the maximum spacing length, will be understood as the maximum pipe length.



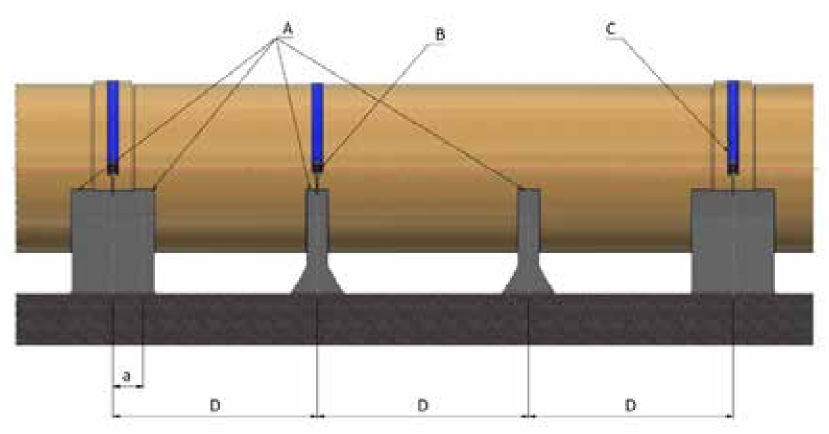
A Guide

B Anchor

D Pipe length

a Maximum distance from centerline of coupler to centerline of a support, see Table 1

Figure 17 - Pipe supported in two cradles



A Guide

B Anchor

C Coupler anchor if necessary

D Support spacing from center to center

a Maximum distance from centerline of coupler to centerline of a support, see Table 1

Figure 18 - Pipe supported in multiple cradles

DN	PN 6	PN 10	PN 12	PN 16
300	3.0	3.0	2.5	2.5
350	3.5	3.0	2.5	2.5
400	3.5	3.5	3.0	3.0
450	4.0	4.0	3.5	3.5
500	4.0	4.0	4.0	4.0
600	4.5	4.5	4.5	4.5
700	5.5	5.0	5.0	5.0
800	6.0	5.5	5.5	6.0
900	6.5	6.0	6.0	6.5
1000	7.0	6.5	6.5	7.0
1100	7.5	7.5	7.5	7.5
1200	7.5	7.5	7.5	8.0
1300	8.0	8.0	8.0	8.0
1400	8.0	8.0	8.0	8.5
1500	8.5	8.5	8.5	8.5

DN	PN 6	PN 10	PN 12	PN 16
1600	8.5	8.5	8.5	9.0
1700	8.5	9.0	9.0	9.0
1800	9.0	9.0	9.0	9.5
1900	9.0	9.0	9.0	9.5
2000	9.5	9.5	9.5	10.0
2100	9.5	9.5	9.5	
2200	9.5	9.5	9.5	
2300	10.0	10.0		
2400	10.0	10.0		
2500	10.0			
2600	10.0			
2700	10.5			
2800	10.5			
2900	10.5			
3000	11.0			

Table 7 - Maximum support spacing or Pipe length D

4. JOINTS

4.1 Double Bell Coupling

4.1.1 Joint Angular Deflection

Double bell coupler joints, used to join pipes, allows for a certain angular deflection. The maximum angular deflection of the joint, pipe to pipe, distributed equally on both sides of the joint, is given with respect to the pipe nominal diameter, in Table 8.

DN	Angular deflection
≤ 500	3
500 < DN ≤ 900	2
900 < DN ≤ 1,800	1
> 1,800	0.5

Table 8 - Maximum allowable Double Bell Coupler joint angular deflection

Nevertheless, the angular deflection at coupler joints must be limited to a result of the supporting system and the installation process. Aboveground pipes shall be installed in straight alignment while changes in line direction must be achieved by bends with thrust restraints. Installation angular deflection at coupler joints for pipes shall not exceed the values given in Table 11 (see clause 4.4.3.1).

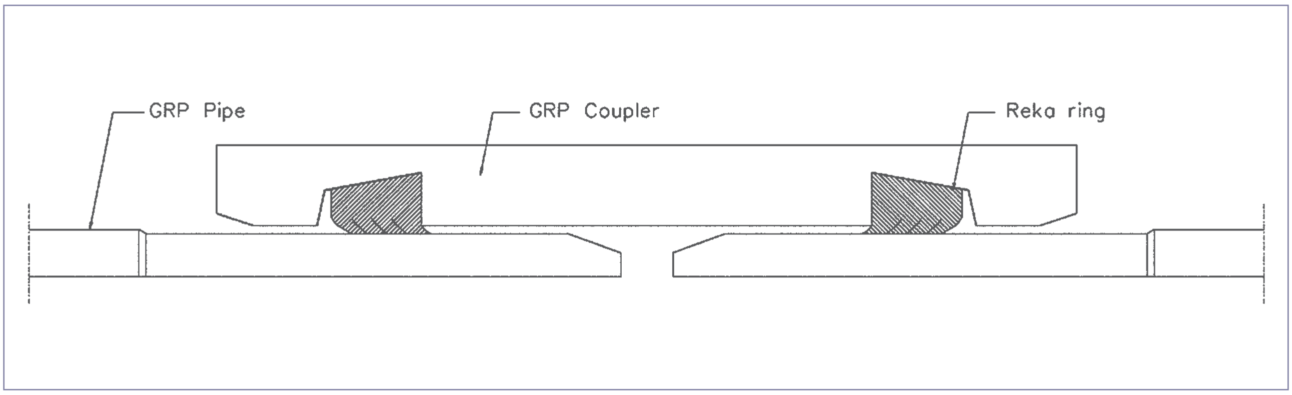


Figure 19.a - Double Bell Coupler cross-section

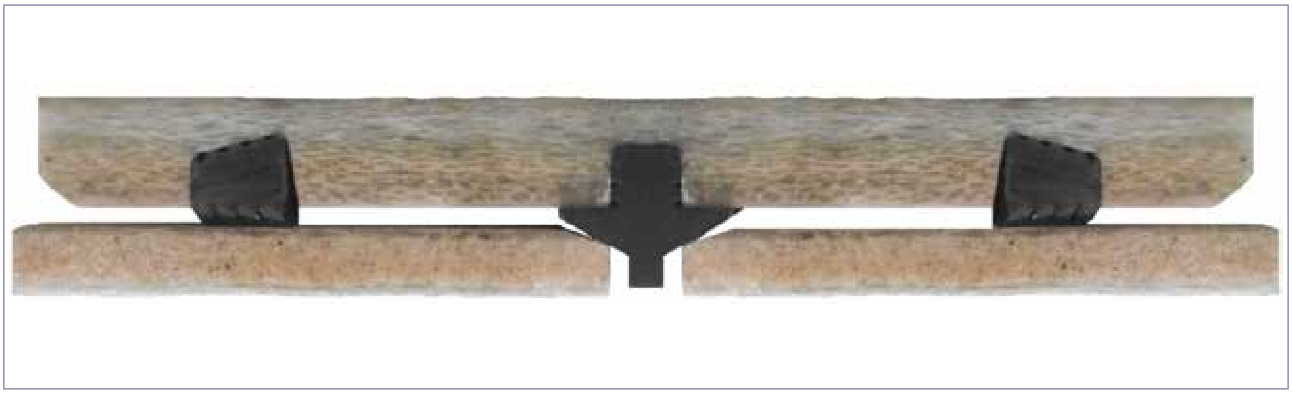


Figure 19.b - Double Bell Coupler with center register cross-section

4.1.2 Joint Lubricant
For lubricant, use only a vegetable based soft soap, available from the pipe manufacturer. In dusty conditions lubricate generously the coupler only. The recommended amount of joint lubricant required is shown below.

DN	Kg/coupler
300	0.05
350 - 500	0.1
600 - 800	0.12
900 - 1000	0.2
1100 - 1200	0.25
1300 - 1400	0.3
1500 - 1600	0.4
1700 - 1900	0.45
2000 - 2200	0.5
2400	0.75
2600	1
2700 - 3000	*

*Please consult Future Pipe Industries

Table 9 – Lubricant Consumption

Caution: Never use petroleum-product grease or automotive oils to lubricate the joint, as they will damage the rubber rings.

4.1.3 Preparation of the Double Bell Coupler
If coupler is not previously installed in the factory, the sealing REKA rubber rings must be fitted into the coupler (see Figure 19.a and 19.b for the correct positioning) just before the installation starts. Avoid damage and contamination when installing gaskets.

- For large sizes lay the coupler horizontally for better control and safety.
- Clean the groove in the coupler and the rubber ring before inserting it.
- Insert the rubber ring into the groove, leaving uniform loops extending out of the groove. There should be one loop for every 500 mm of ring circumference. Do not lubricate the rubber or the groove at this stage.
- With uniform pressure, push all the loops simultaneously into the groove.
- Make sure that the compression in the ring is uniformly distributed all around the circumference.
- Install the rubber center register in case they are provided by FPI and the GRP couplers contains a central groove.

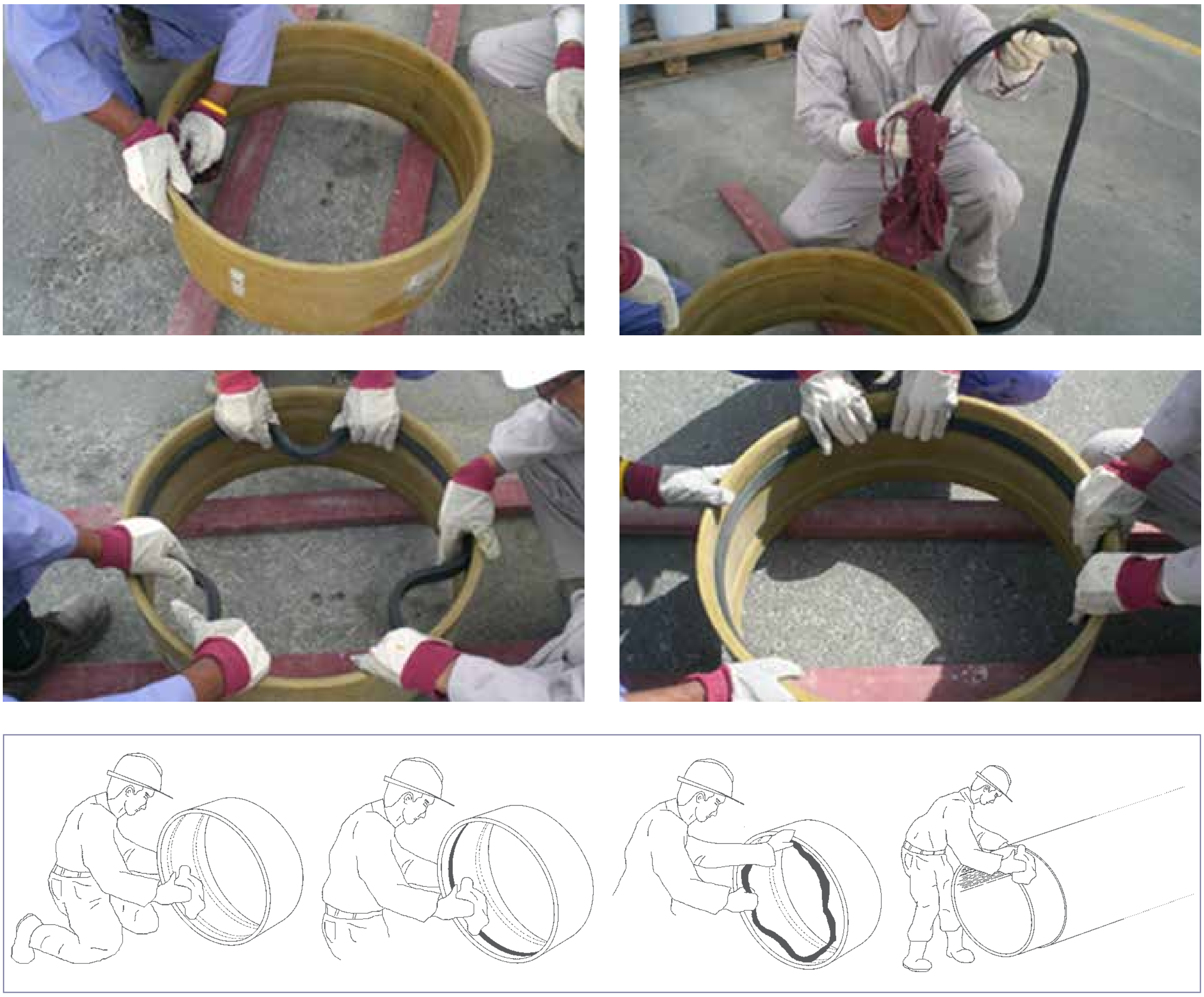


Figure 20 - Mounting the Rubber Ring inside Coupler, Step by Step

4.1.4 Mounting the Coupling on the Pipe
Clean the coupler and the pipe ends with a firm brush and inspect them thoroughly. Lubricate the pipe end and the coupler rubber ring by means of a dry clean piece of cloth or a sponge.

For small diameter pipes (DN ≤ 350 mm) the coupler can be mounted by hand or with a crow bar. Use a timber block to protect the coupler and force the coupler into the correct position that is indicated by the home line on the pipe spigot.

For pipes with diameters above 350 mm, a come-along type puller is used. This apparatus is fixed to the outside of the pipe by friction.

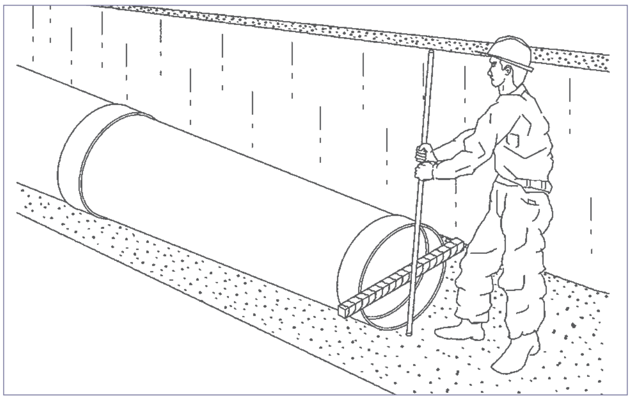


Figure 21 - Mounting the coupler for DN ≤ 350 mm

Caution: Under no circumstance should brute force be applied to mount the coupler. The pipes and couplers are dimensioned within tolerances that allow jointing to be carried out without using excessive effort.

Figure 22 - Mounting the coupler on the pipe

4.1.5 Inserting the Pipe in the Coupling

Joints should be made following the procedures shown in Figure 23 and Figure 24. A steel strap with rubber lining must be fixed on the installed pipe at the home line in order to stop the insertion of the pipe in the coupler at the pipe home line. Alternatively, a wooden spacer may be used inside the couplers to maintain the correct spacing.

All spacers must be removed immediately after jointing the pipes. Spacers may damage air valves and other valves fitted in the system if they are not removed before the hydrostatic test. Before insertion, the two pipes should be perfectly aligned and levelled to avoid any damage to the rubber rings.

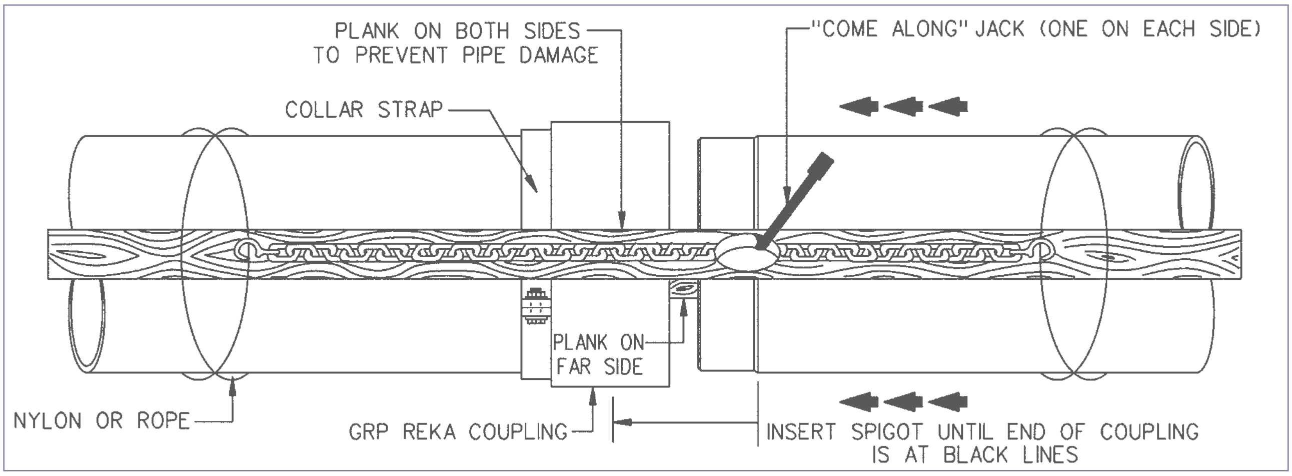


Figure 23 - Pipe Jointing using a "come along" jack / puller

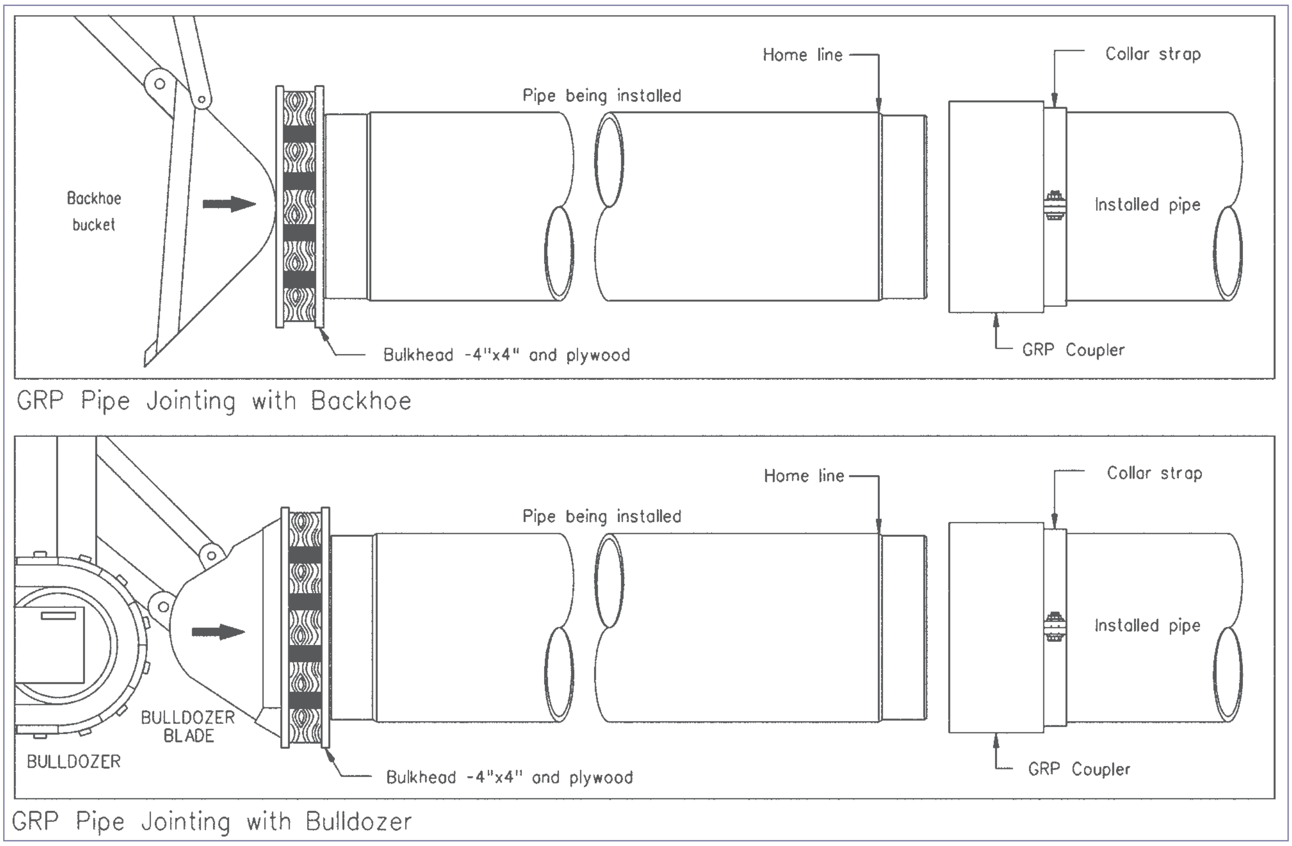


Figure 24 - Pipe Jointing using construction equipment

Working with mounting equipment, although very efficient, should not be carried out by unskilled workers. Risks of damaging or dislodging a rubber ring should not be disregarded. It is essential to push the coupler to the home line and not beyond, otherwise the pipes in the coupler will touch each other and will consequently not allow for any expansion or deflection inside the joint. Only skilled operators should attempt to use the boom of an excavator to push either coupler or pipe, as the direction of the applied force is not under control and might damage the pipes and/or the coupler. No steel tools should come into direct contact with the edges of the pipe or its external surface. Pipe edges should be protected with a timber.

4.2 Lamination Joints

This joint is made from glass fiber reinforcement embedded in resin. The length and thickness of the joint depends on the diameter and the pressure.

This type of joints requires special working conditions and should be performed only by skilled workers. Always consult the pipe manufacturer before performing lamination joints.

4.3 Flanged Joints

Flanged pipes and fittings can be provided for use inside valve chambers or to connect to other piping material (e.g. Steel or Ductile Iron). Contact our engineers for flange thickness before ordering flange bolts as they are thicker than steel flanges

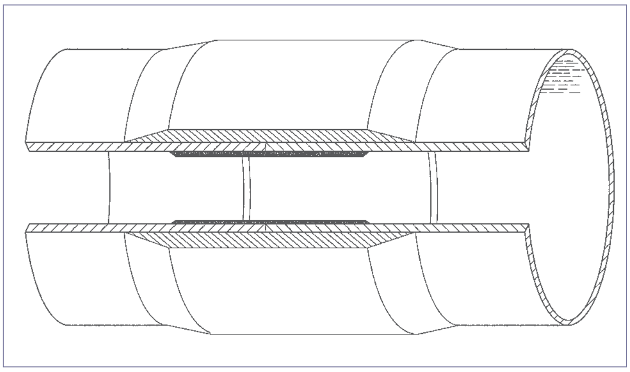


Figure 25 - Lamination Joint

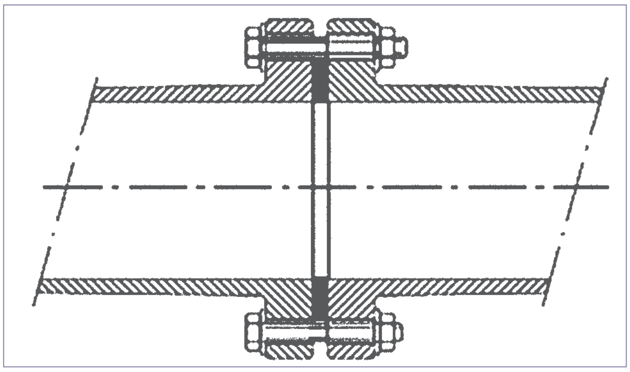


Figure 26 - Flange Joint

4.3.1 Tightening of Flanges

Tightening of the bolts of a flange connection must be done according to the diagonal sequence as shown in Figure 27. The flange must be connected perpendicular to the axis of the pipe. GRP flanges must always be installed tension free. Therefore, flanges must be accurately aligned. Pipelines must never be pulled by means of the flange bolts nor mechanical tools (crowbar, jacks, etc.). If a GRP pipe is connected to a metal pipe, this metal line must be anchored to prevent any movements or loads being transmitted to the GRP line. Tightening of the bolts of a flanged joint shall be executed first diagonally, and second clockwise:

- Diagonally as per the bolt torque sequence shown on Figure 27 for flanges with more than 20 bolts, similar alternating bolt tightening sequences shall be used, as detailed in the method statements. Bolts shall be tightened, following the bolt torque sequence, first up to 60% of the recommended value and second up to 100% of the recommended value.

- Clockwise using the recommended bolt torque. This step must be repeated until all bolts have been assembled at the prescribed bolt torque.

- In case bolts are not properly lubricated, or when the flange joint is not sealing, it is allowed to increase the bolt torque value up to a maximum of 150% of the recommended bolt torque.

- Bolts and nuts must have washers to avoid exceeding the permitted surface stress.

- Flanges must be properly aligned and shall to be subjected to any overload to meet each other

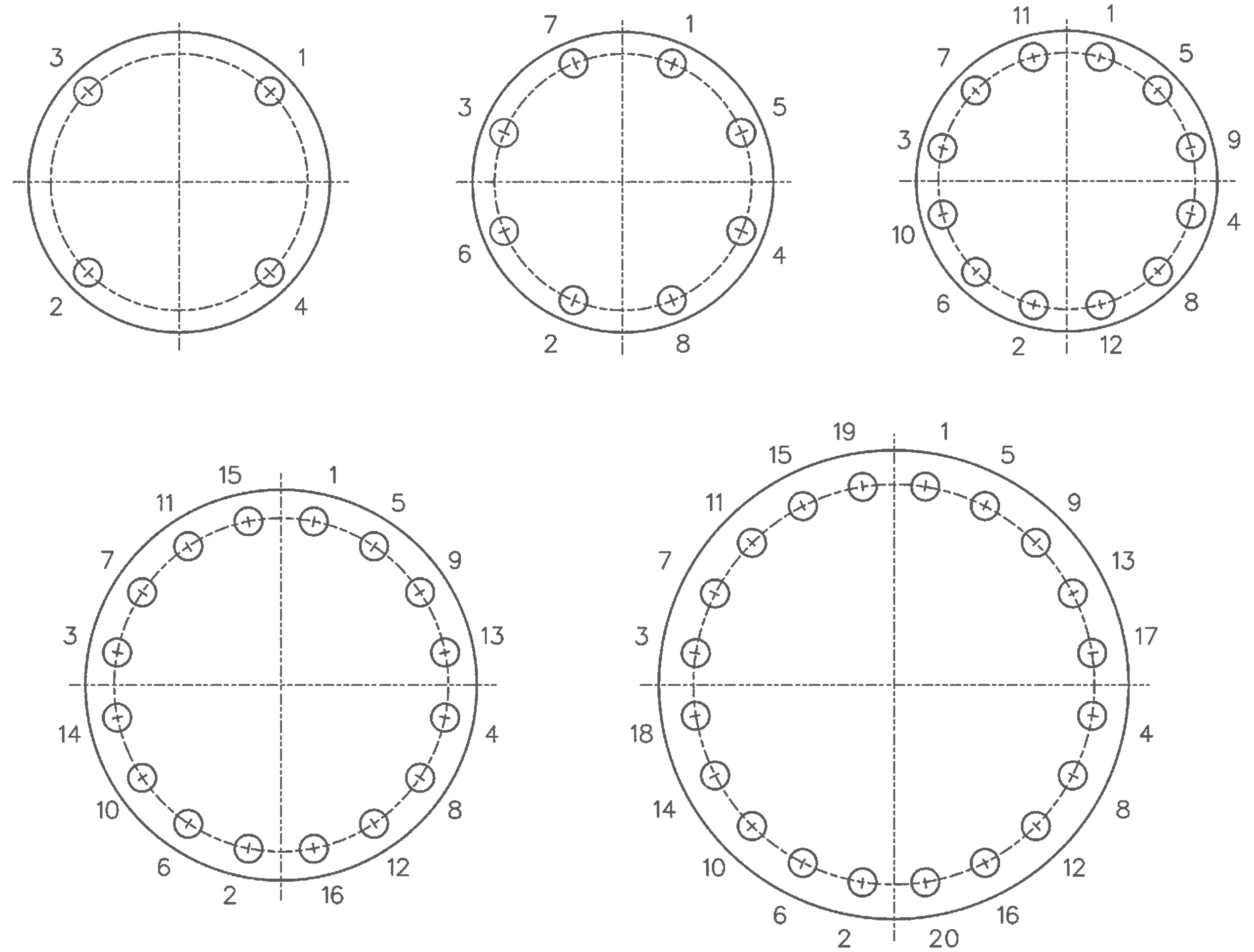


Figure 27 - Bolt Tightening Sequence

Note 2: For ease of tightening of the flange, there should be a minimum clearance of 2 mm between the flange hub and the box spanner. This can be checked prior to mounting the flange by inserting the applicable bolt, washer and box spanner into the flange bolt hole. The clearance between the flange hub and box spanner shall be 2 mm as a minimum. This can be checked using a 2 mm shim and while the bolt is gently pushed down towards the hub (this is when the gap is minimum).

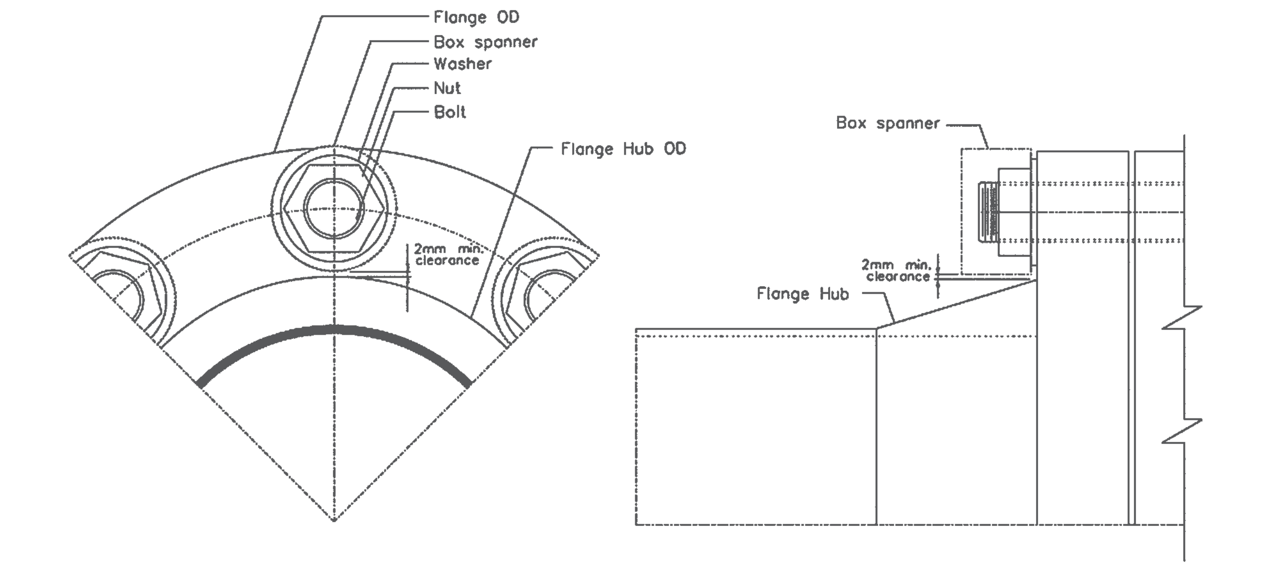


Figure 28 - Minimum required clearance between flange hub and box spanner (while tightening the flange assembly)

DN	Torque Nm		
	Kroll & Ziller Gasket		
	PN ≤ 12.5	PN 16 - 20	PN 25
25	-	-	10
40 - 50	-	-	15
80 - 100	-	-	15
150 - 200	-	35	50
250 - 300	50	50	75
350 - 500	75	90	125
600 - 700	100	200	300
750 - 800	200	300	300
900 - 1400	300	400	550

DN	Torque Nm	
	O-ring seal	
	PN ≤ 12.5	PN 16 - 25
1500 - 1800	100	200
1900 - 4000	100	-

Table 10 - Recommended Bolt Torque Values (N.m)

4.4 Joining with Double Bell Coupler Joints

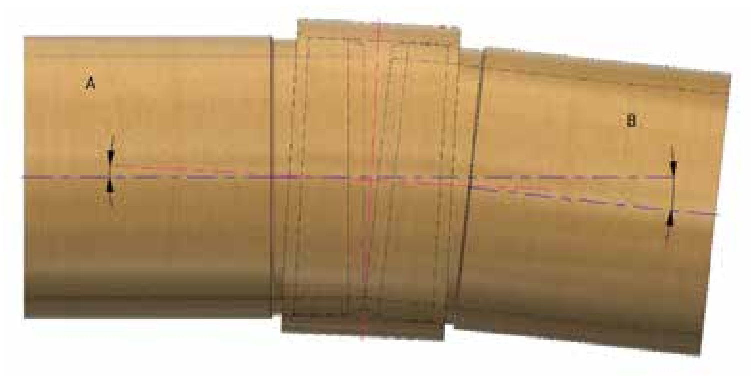
4.4.1 Gap Between Pipe Ends

Aboveground pipelines are subject to important thermal expansion due to ambient temperature variations, especially in the construction process. Because of this, the pipes must be joined with enough gap space between spigots to avoid contact between them at any moment (see 4.4.3.4).

4.4.2 Angular deflection at joints

In aboveground systems the pipe must be installed in straight alignment. However, some angular deflection may occur due to the installation process. These deflections must be controlled to ensure a correct performance of the system.

There are two types of deflection to consider, pipe to pipe angular deflection and coupler to pipe deflection as shown in Figure 29.



A coupler to pipe angular deflection

B pipe to pipe angular deflection

Figure 29 - Angular Deflections at coupler

The coupler to pipe angular deflection is influenced by other factors in addition to the initial pipe installation. These can be deflections due to loads and/or support settlement.

Pipe deflections due to loads are caused by forces produced by the weight of fluid in the pipe, external loads and pressure within the pipeline. These forces can result in significant pipe to coupler deflections which, if acting in a similar plane to the initial installation deflection, may result in the total deflection at the coupler exceeding the allowable limits. An exaggerated example of this effect is shown in Figure 30.

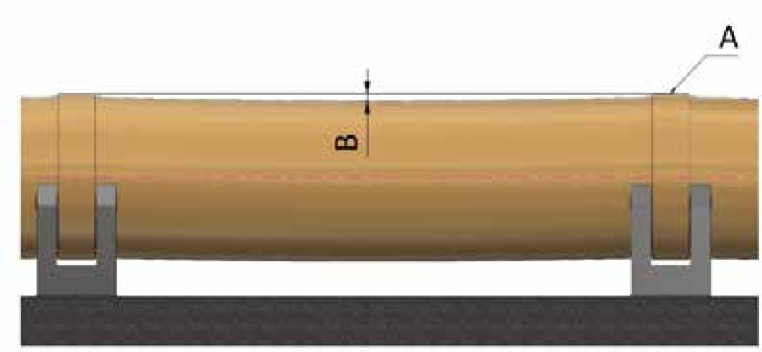


Figure 30 - Vertical Pipe Deflection

To take into consideration all these forces and not exceed the joint limitations, the initial coupler angular deflection must be limited (see 4.4.3.1).

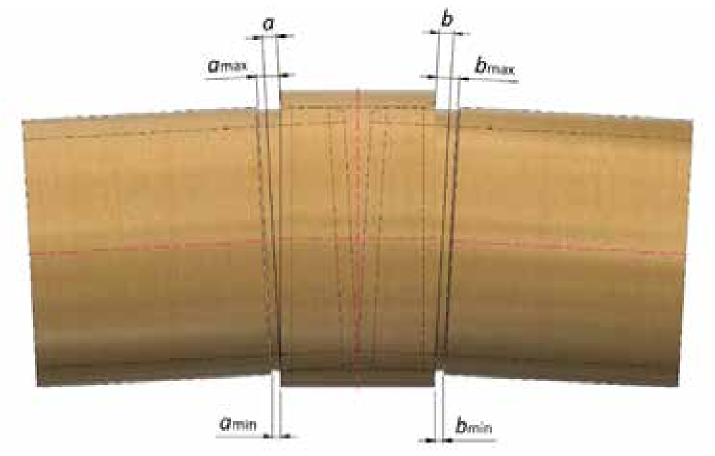
4.4.3 Checking the Installed Joint

The quality of the installed joint must be checked as soon as possible after joining since corrections can be difficult when the coupler gaskets have settled. The joint must also be checked after filling and pressurizing the pipeline, see Section 7.

Note 3: The installed joint should be checked at normal temperatures. High or uneven pipe temperatures, as caused by direct sunlight, will affect the results of the checks.

4.4.3.1 Angular Deflection

The coupler to pipe angular deflection is measured as an angular offset, see Figure 31.



a coupler offset (left pipe) = $a_{max} - a_{min}$
b coupler offset (right pipe) = $b_{max} - b_{min}$

a_{min} minimum coupler offset (left pipe)
a_{max} maximum coupler offset (left pipe)
b_{min} minimum coupler offset (right pipe)
b_{max} maximum coupler offset (right pipe)

Figure 31 - Measurements for angular offset

Coupler offset a and b should be measured as follows:

Find the maximum and the minimum distance between the homeline and the face of the coupler. Subtract the minimum measured value from the maximum measured value.

The total coupler to pipe offset $L_{off,tot}$ is calculated by adding a and b:

$$L_{off,tot} = a + b$$

The total coupler to pipe offset $L_{off' tot}$ must be smaller or equal to the maximum allowable coupler offset $L_{off,max}$:

$$L_{off,tot} \leq L_{off,max}$$

With

$$L_{off,max} = DN \times \frac{\alpha\_max \times \pi}{180}$$

Note 4: This calculation of the offset is only valid for installation conditions.

The maximum pipe to pipe angular deflection for empty pipes installed in straight alignment is according Table 11.

DN	α (degree)
≤ 500	1
500 < DN ≤ 900	2/3
900 < DN ≤ 1800	1/3
> 1800	1/6

Table 11 - Maximum allowable installed angular pipe to pipe deflection, α, in degree.

4.4.3.2 Coupler Position

The coupler must be mounted centric relative to the joint within a tolerance of +/– 10 mm. The coupler position can be measured with reference to the home lines. The average distance from the home line to the coupler edge is taken at each side of the coupler as (see Figure 31):

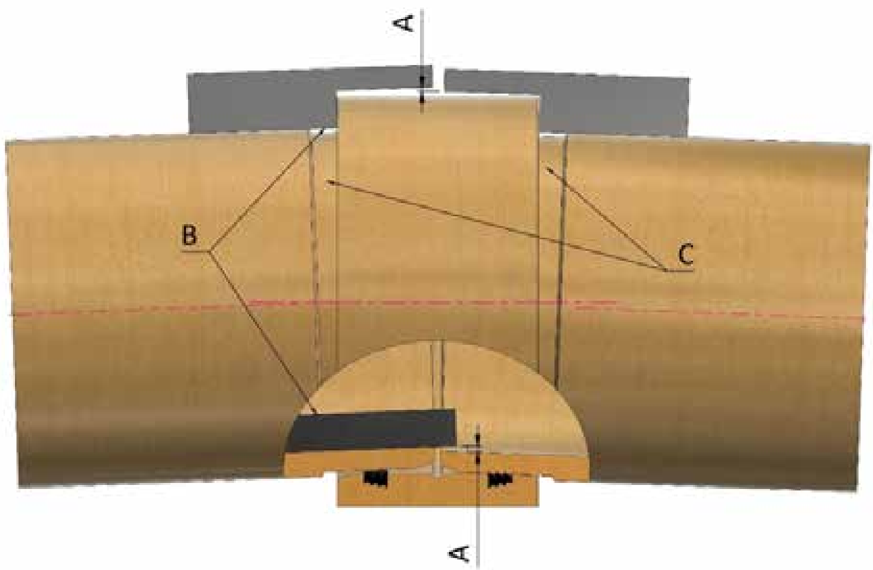
$$a_{ave} = (a_{max} - a_{min})/2$$
$$b_{ave} = (b_{max} - b_{min})/2$$

The coupler position relative to the centre of the joint can be calculated as:

$$-10 \text{ mm} \leq (a_{ave} - b_{ave})/2 \leq 10 \text{ mm}$$

4.4.3.3 Joint misalignment

Maximum misalignment of pipe ends must not exceed the lesser of 0.5% of pipe diameter or 3 mm. The misalignment can be measured with two identical notched rulers pressed against the pipe at both sides of the coupler, see Figure 32. If the depth of the machined spigot surface is different for the two pipes, the measured misalignment shall be corrected accordingly. For pipes 700 mm and larger the misalignment can be measured with a ruler from the inside of the pipe, see Figure 32.



A joint misalignment

B rulers

C machined spigot surfaces (measure gaps between rulers and spigot surface)

Figure 32 - Joint Misalignment

4.4.3.4 Gap between pipe ends

The gap between pipe ends is checked by measuring the distance between the home lines (see Figure 33).

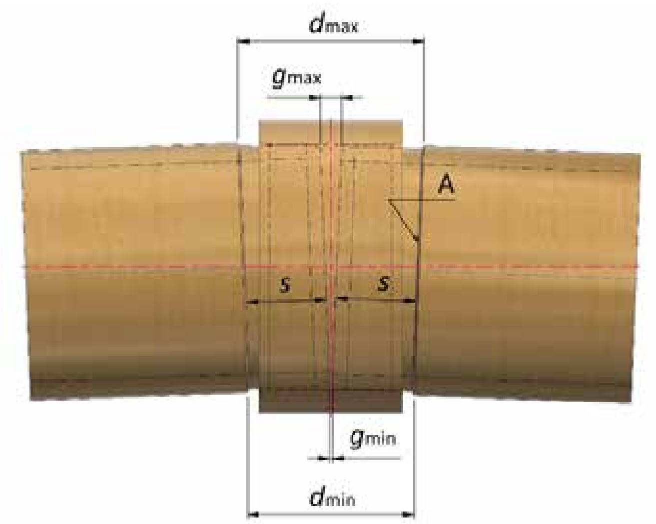
The gap, g, is calculated using following formulas:

$$g_{min} = d_{min} - 2\,s$$
$$g_{max} = d_{max} - 2\,s$$

Where

g_{min} minimum measured gap between pipe ends
g_{max} maximum measured gap between pipe ends
d_{min} minimum measured distance between home lines
d_{max} maximum measured distance between home lines
s distance from the pipe end to the home line

For pipes DN700 and larger the gap can be measured directly from the inside of the pipe.



A homeline
d_{min} minimum measured distance between homeliness
d_{max} maximum measured distance between homeliness
s distance of homeline from end of pipe
g_{min} minimum measured gap between pipe ends
g_{max} maximum measured gap between pipe ends

Figure 33 - Gap between pipe ends

A gap of 25 mm between spigots is enough with maximum pipe length of 12 m. Maximum gap between pipe ends is 30 mm.

For joints resulting in angular deflection after the installation, the gap will vary around the circumference of the pipe. In such cases the minimum gap shall be within the limitations stated above while the maximum gap should under no circumstances exceed 60 mm. The given gap requirements shall be measured when the pipe is not under pressure.

4.4.3.5 Adjusting joints

The joint should be adjusted if any of the checks described in the preceding clauses fall outside the specified limits. The necessary adjustments of coupler or pipe position should be made carefully, avoiding concentrated loads or impact loads that might damage the pipe or the coupler.

5. TOOLS

For the installation of pipes and fittings, below is a summary of the required tools per installation crew:

- Come along Jack or puller (min. 3 Tons capacity, 2 nos. for diameters less than DN450 and min. 6 Tons capacity, 4 nos. for larger diameters).
- Steel Clamps with rubber lining (internal diameter shall be equal to the pipe outside diameter, 4 half-moon pieces are required).
- Nylon slings (min. 3 Tons capacity for diameters less than DN450 and min. 6 Tons capacity for larger diameters).
- Spirit level
- Wooden bulkhead
- Centre finder for alignment
- Spanners as per the bolts size (for flange and clamps installation)
- Torque wrench with sockets as per the bolts size (for flange installation)

Figure 34 - Required tools for site installation.

6. SPECIAL REQUIREMENTS

6.1 Pipeline Closures

For a closure in a line it is required to order a special pipe from the factory with double width calibration. The Contractor should clearly indicate in his order that a pipe closure is required. In closure pipes, the length of the spigot machining is equal at least to the width of the coupler plus 30 mm. In case of export jobs or where the site is very far from the factory, cutting and machining of closure pipes must be carried out on site. Supplementary instructions for export projects will be provided.

Before ordering a closure pipe, the Contractor should measure accurately the gap between the two ends of the line. The length of the pipe to be fitted must be 32 mm less than the measured length to allow a gap of 16 mm between the jointed ends in both couplers. Mark the home line on the machined ends if necessary and lubricate them abundantly. The assembly of the pipe closure is made as indicated in Figure 35 below.

Mount and anchor the closure pipe on its supports aligned with the adjacent pipes and with equal clearance on either side. If the pipe is not perfectly aligned, the assembling process of closing pipe will be difficult.

Caution: When pulling the couplers over the insertion piece, it is necessary to pull the second rubber ring smoothly over the chamfer of the pipe to avoid damaging the rubber ring. For that purpose, use approved lubricants abundantly.

The closure piece can be installed as indicated below. Installing the closure piece between a fitting (or rigid structure) and a pipe is not recommended.

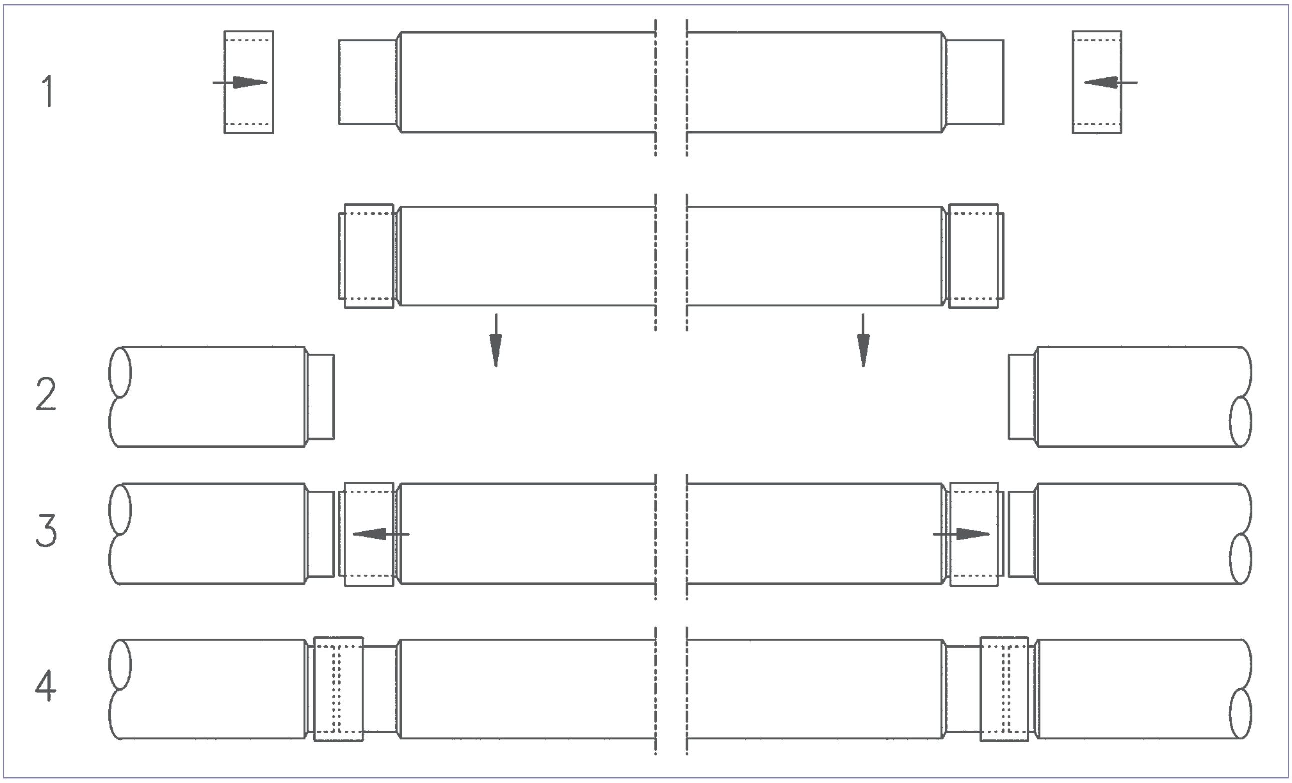


Figure 35 - Pipeline Closure

6.2 Thrust Blocks and Anchoring

Thrust blocks should be used in pipeline systems with Non-restrained joints such as the Double Bell Coupler. They are needed to balance the generated hydraulic thrust loads expected at locations like:

- Changes of direction (bends, Tees, Wyes),
- Cross section changes (reducers),
- Valves and hydrants,
- Dead ends

The thrust blocks must be dimensioned and designed according to the expected thrust load (during operation and site hydrotest) as well as native soil properties. Thrust blocks must completely encase the fitting (except at the joint area). The outlet part of the encased fitting in the concrete block shall be rubber wrapped as shown in Figure 37. Rubber wrapping is needed as well at wall and concrete structure penetrations.

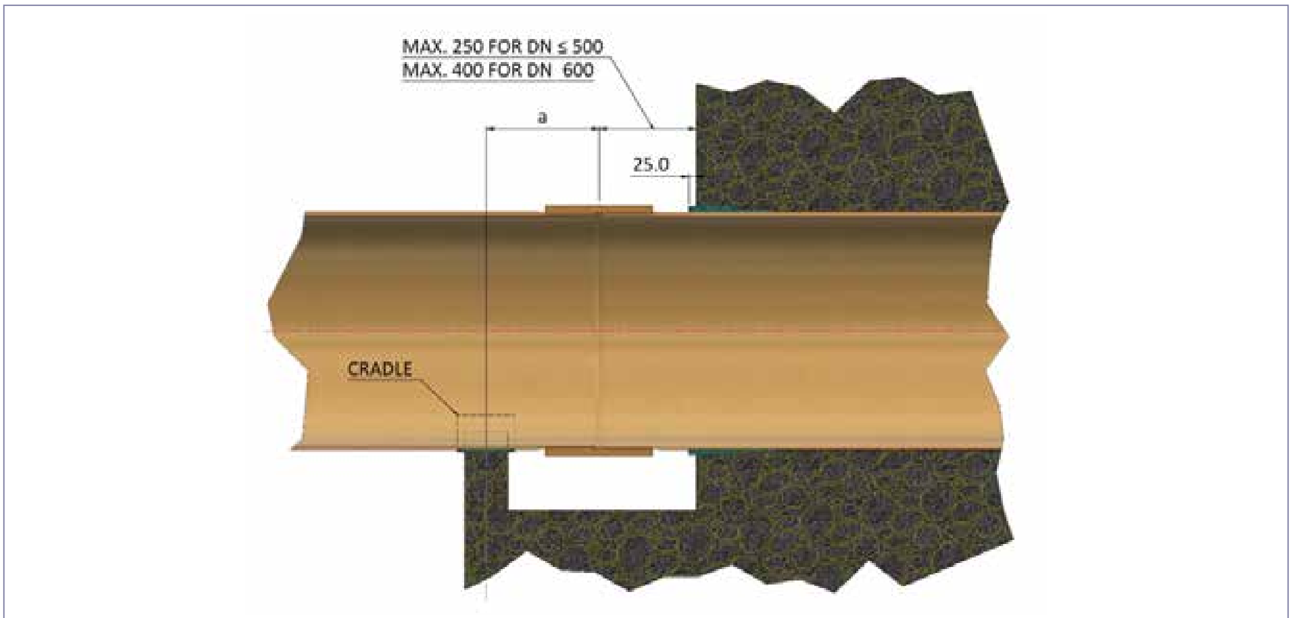


Figure 36 - Thrust concrete block interface

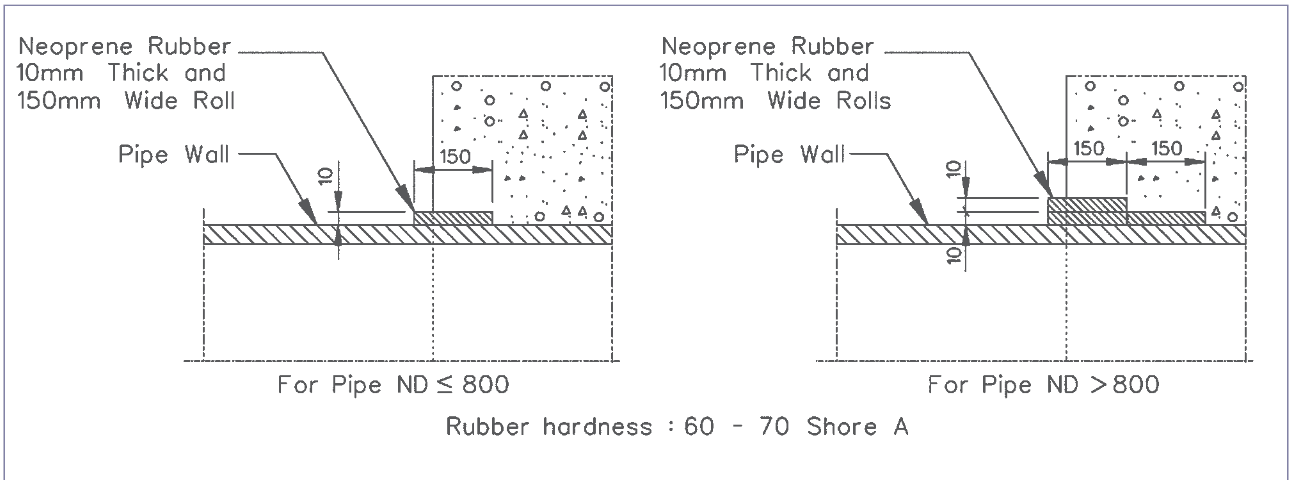


Figure 37 - Rubber wrapping (60-70 Shore A Hardness)

6.3 Concrete Encasement

Pouring concrete around the pipe results in uplifting forces that can damage the pipe and/or joint. To avoid such movement, the pipe should be anchored downward by straps hooked to a rigid base. The straps should be of flat material of minimum 25 mm width and strong enough to withstand flotation uplift forces. The distance between straps should not exceed 4 meters with a minimum of two straps per section length. Straps should not be over tightened to avoid pipe "ovalization".

The pipe should be supported in such a way that the concrete can easily flow completely around and fully underneath the pipe. Also, the supports should result in an acceptable pipe shape (less than 3% deflection and no bulges or flat areas).

The concrete must be placed in stages allowing enough time between layers for the cement to set. This is to avoid excessive, buoyant forces or shrinkage stresses exerted on the pipe. The Maximum lift height depends of the pipe Stiffness class:

- Stiffness Class 5'000 N/m2, maximum of 450 mm or 1/3 pipe diameter.
- Stiffness Class 10'000 N/m2, maximum of 600 mm or 1/2 pipe diameter.

Note 5: This applies to pipes installed on slopes up to 15° (a 1:4 slope). In case of pipe installation on slopes greater than 15°, please consult Future Pipe Industries for the recommendations.

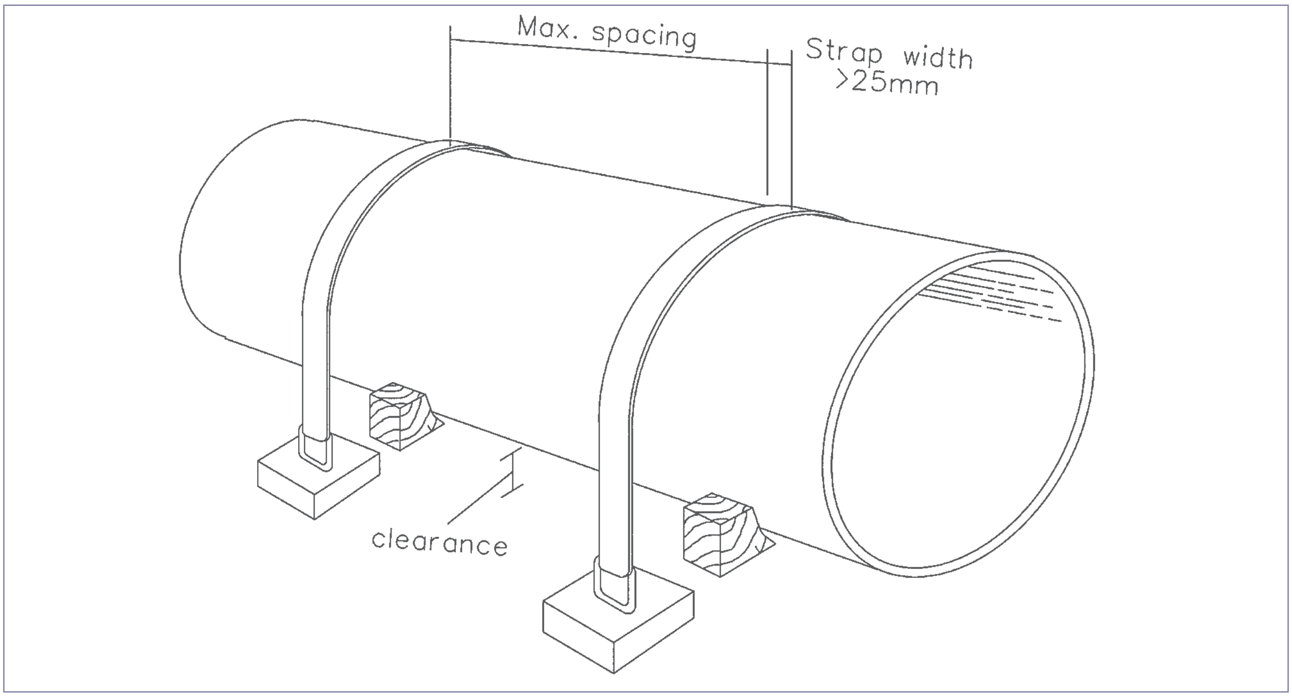


Figure 38 - Anchoring of Pipes Prior To Concrete Pouring

6.4 Fittings for Valve Chambers

One of the advantages of GRP pipe systems is the "Customized Fittings". Using a GRP pipe system greatly simplifies the valve chamber design and eliminates unnecessary flanged joints. Please refer to Figure 39a and 39b reflecting the acceptable scenarios of pipe arrangement in the valve pits.

Valves must be sufficiently anchored to take the thrust force. The valve pit base shall be designed rigid enough to take this force.

Using Puddle Flange

TThis method (Figure 39b) can be used for anchoring any valve with any pressure. The puddle flange is placed on the compression side of the valve directly loading the chamber wall which acts as a thrust stop.

Figure 39a - Valve Chamber arrangement(s)

The following guidelines should be observed in designing the arrangement:

- A "special" pipe will have a GRP puddle flange fabricated on the compression-side which is embedded into the valve chamber wall acting as an anchor.
- The weight of the valve is to be supported from the base of the valve chamber, and the valve chamber must be designed to accept the full axial thrust of the valve. A concentration of reinforcement bars will be required to accept the axial forces from the embedded puddle flange.
- The valve chamber is to be designed as a thrust block to resist axial thrust.
- The "special" pipe within the valve chamber will be reinforced to accept the axial loads and local stresses at the interior face of the concrete chamber. Please advise FPI of maximum anticipated thrust loads so that the proper reinforcement for the "special" pipe can be designed.

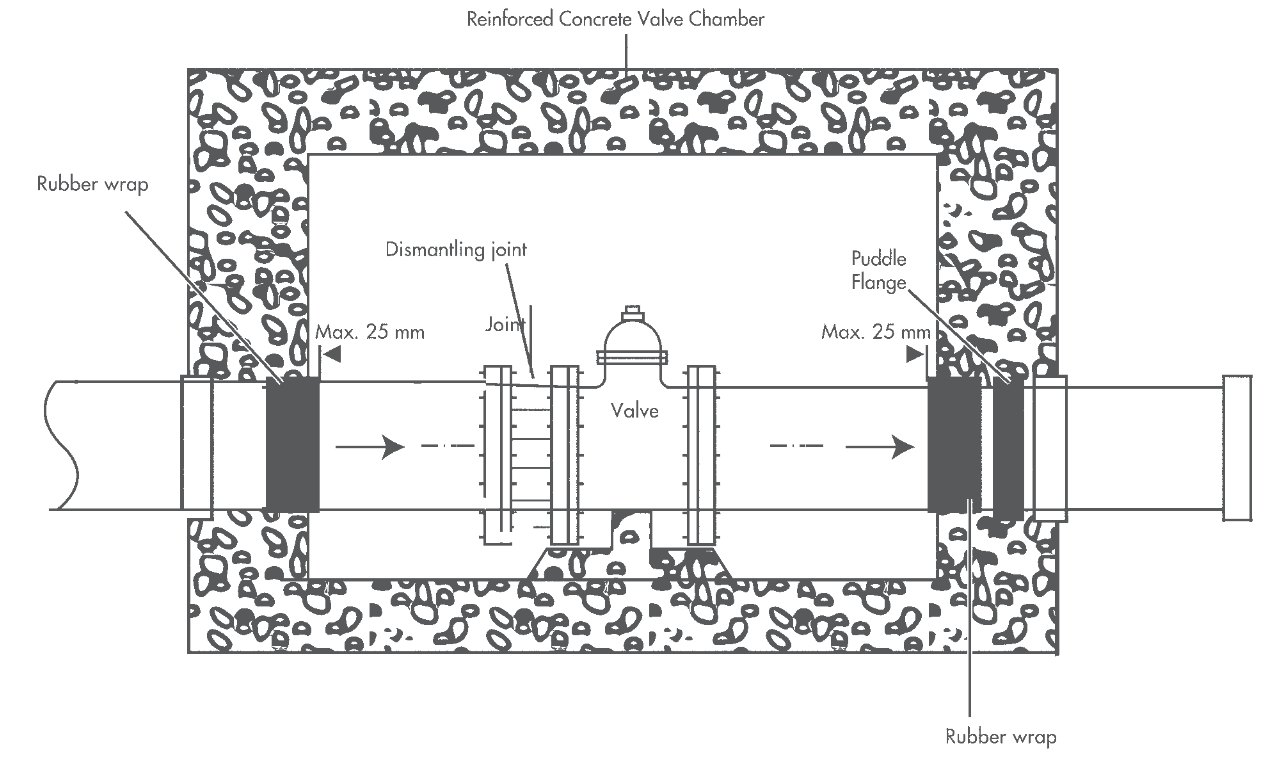


Figure 39b - Valve Chamber arrangement(s)

7. PIPELINE FIELD TESTING AND INSPECTION

7.1 Pre-test inspection

Care shall be taken to ensure that caps or other temporary blanking fittings are adequately anchored. Any temporary supports or anchorage at the ends of the test section shall not be removed until the pipeline is depressurized.

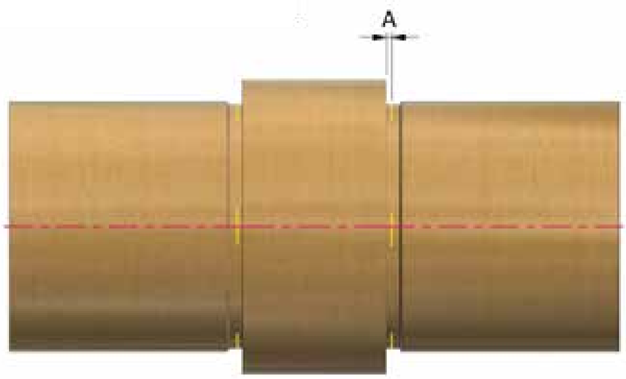
The pipeline should not be filled with water until pre-test inspection has been satisfactorily completed. In addition to the routine care, normal precautions and typical procedures, it is recommended that the following matters should be included in the pre-test inspection procedure.

Inspect the completed installation to assure that all work has been finished properly. The most critical are:

a) The quality records for the joints should be checked to verify acceptable measurements have been taken for pipe offset, coupler offset and position, joint alignment and the gap between the pipe ends.

b) Every joint should be visually inspected, position of couplers checked for movements, and spot checks should be made to verify that the quality records are correct.

c) The coupler position relative to both pipes should be marked at 4 points around the circumference see Figure 40 as reference for later checks.



A fixed distance (15 mm to 20 mm)

Figure 40 - Marking coupler positions

d) Check that rubber gaskets are correctly placed and that the gap between pipe spigot and coupler is free of concrete or other foreign inclusions.

e) Check that the cradle gives even and continuous support to the pipe and that the cradle diameter is 0.5% ± 0.25% larger than the pipe. Check the support angle is as specified with a tolerance of ± 5°.

f) The cradle support angle and cradle diameter should be checked with a template. Prefabricated cradles should be checked prior to pipe installation. For pipes supported on more than two supports, the alignment of pipe supports should be checked. Maximum allowable deviation from straight alignment is 0.1 % of the span length or the less specified in 4.4.3.3 Joint misalignment.

g) Check that the cradle liner is in place between the pipe and the cradle and ensure that there is no direct contact between cradle and pipe. Check that there is no concrete or other foreign inclusion between the pipe and the cradle liner.

h) Check that the liner is correctly positioned between the clamp and the pipe or coupler.

i) Check that there are high-friction liners at anchors and low-friction liners at guides.

j) Check the structural integrity of the supports.

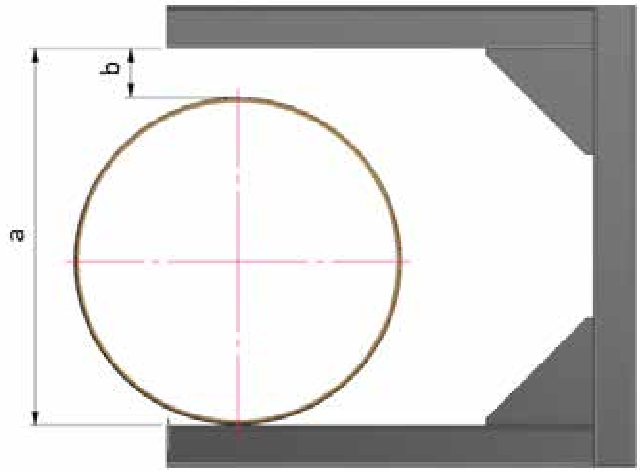
k) Mark the position of the pipe relative to the anchors, as reference for later inspection.

l) Check, if appropriate, the number and configuration of the anchor elastic elements against the specification.

m) Check the structural integrity of the steel clamp and anchor bolts.

n) Check that the steel clamp is positioned perpendicular to the pipe axis.

o) Measure and record the maximum diameter of pipes at supports, thrust blocks and other encasements that restrain the natural expansion of the pipes. The maximum deflection should be calculated as follows.
- For large diameter pipes the maximum internal diameter can be measured from the inside provided that the slope of the pipe is such that it is safe to work inside the pipe.
- For pipes that are not accessible from the inside, the maximum outer diameter may be measured by applying a rigid frame (see Figure 41).
- If the maximum deflection of the pipe at supports and encasements exceeds 1 %, contact the pipe supplier.



a frame clearance

b measured gap between frame and pipe

Actual OD = a – b

$$\text{Deflection\%} = \frac{\text{Initial } \varnothing - \text{Actual } \varnothing}{\text{Inital } \varnothing} \times 100$$

Ø can be OD or ID depending of accessibility

Figure 41 – Measuring maximum diameter of installed pipe

p) Inspect the pipes to ensure that they have not been damaged in the installation phase.

q) Check the support spacing against specifications.

r) Check system restraints (i.e. thrust blocks, and other anchors) are in place and properly cured.

s) Check flange bolting is torqued as per instructions.

t) Check that valves and pumps are anchored.

u) Check the correct support types (guides, anchors, cradle types, etc.) are in place.

7.2 Line Hydrostatic Testing

7.2.1 General

For pipeline systems with elevation variations, the required pressure should be achieved at the system lowest point. This may result in sections with large elevation variations requiring multiple test sections.

While the contractor tends to test long sections to increase his efficiency, the length of the test section should be short enough to allow an easy detection of any possible leak. It is also very difficult to fill a very long line without the risk of air entrapment.

Permanent thrust blocks or anchorages shall be constructed to withstand thrust at the test pressure. All concrete structures should be permanent constructions and concrete should be poured at least 7 days before testing.

Check whether all testing apparatus are available and operational.

The opened ends of a line must be sealed temporarily with GRP or steel/Cast iron end caps. GRP testing end caps can be purchased from the manufacturer with the pipes and fittings. All the end caps should have an inlet for water filling and an outlet for venting.

7.2.2 Bracing Test-Ends and Set-Up

Due to the thrusts occurring at the testing end-caps, temporary blocks must be used to brace the pipe end-caps in order to prevent line displacement as indicated in Figure 42.

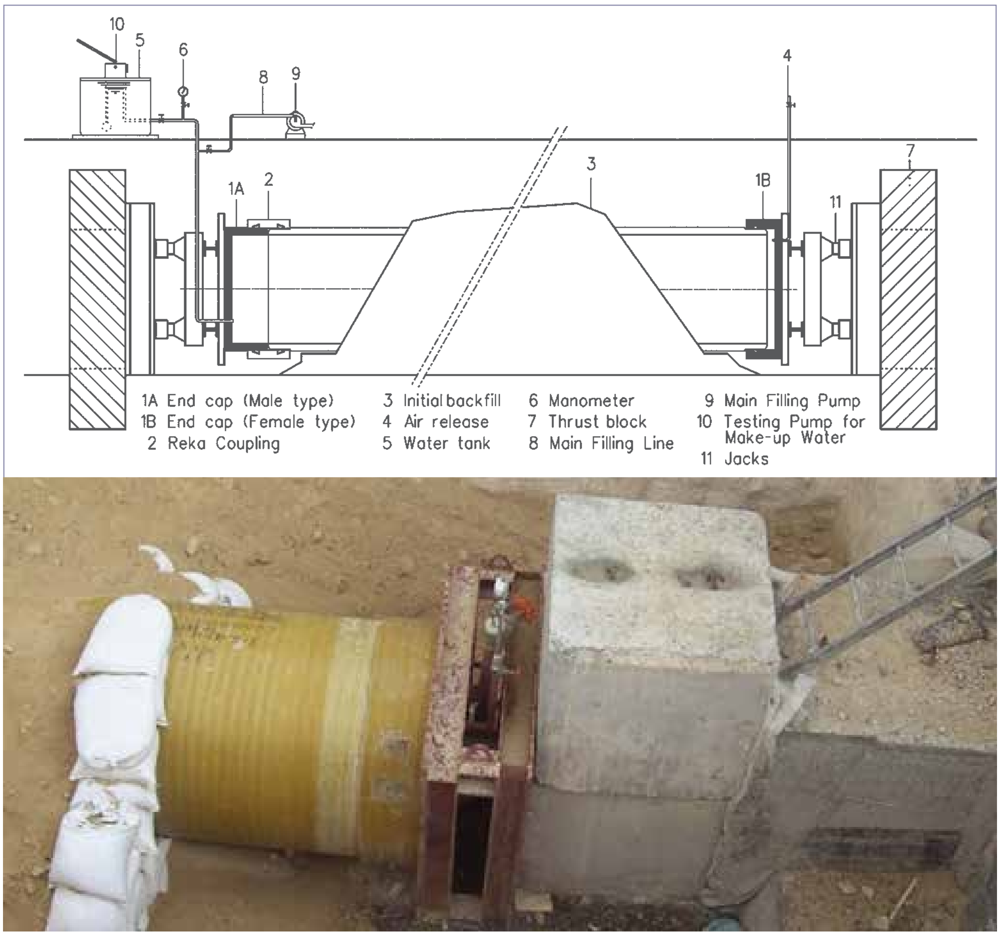


Figure 42 - Thrust blocking pipe ends and site pressure test set up

In the gap between the end of the pipeline and the block, jacks or any other method of supports shall be placed as shown in Figure 42. The last pipe length could need also to be wedged on both sides, at the top and at the bottom, in order to prevent lateral and vertical movements. Sandbags can be used for this purpose.

7.2.3 Filling the Line with Water

The line should be filled slowly and evenly with water from the lowest end point. At high points, air vents will be installed to release the entrapped air. After filling the line with water, the test section should be left for stabilization. The filling rate of the line with water should be controlled to ensure a proper venting and to keep the flow velocity below an allowable limit of 0.3 m/s.

Following the stabilization period and after expelling all the entrapped air out of the pipe test section, the release valves should be closed.

Before pressurizing the pipeline inspect the pipeline with special attention to:
a) Inspect the joints for any sign of leakage.

b) Check couplers movement relative to the marks made prior to filling the pipe. Note that the weight of fluid in the pipe will cause rotation of pipe ends (Figure 43).

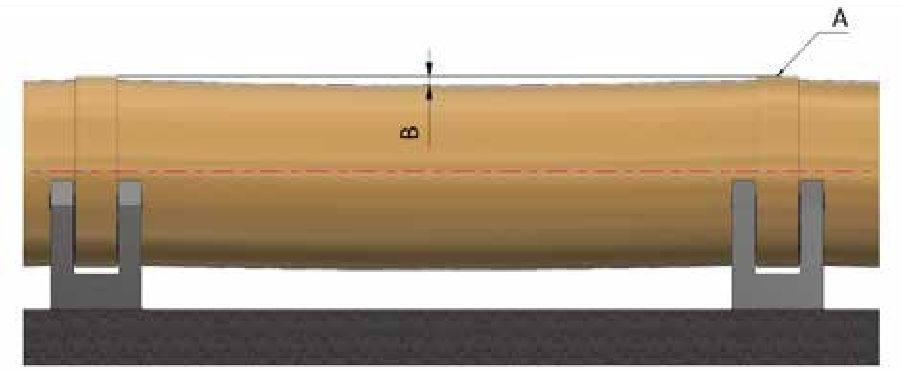


Figure 43 - Pipe deflections measurements

c) The maximum coupler to pipe offset should be checked. If there is any sign of coupler movement in excess of that which can be attributed to load induced pipe end rotation, the position of the coupler should be checked. The stability of the coupler and the pipe end supports should also be verified in an appropriate way.

d) If a coupler has moved, the new position relative to both pipes should be marked at 4 points around the circumference, see Figure 40.

e) If there is a reason to believe that supports might have settled due to the added weight, the pipe end misalignment should be checked. Pipe end misalignment should be the lesser of 0.5 % of pipe diameter and 3 mm.

f) Check the structural integrity and stability of the supports. Check if the added weight has caused settlement or deflection of supports.

g) Measure and record the maximum deflection of the pipes for each pipe span. The pipe deflection can be measured by using a tensioned string as a reference, see Figure 43.

h) If the maximum deflection at any pipe span exceeds what can be attributed to the load induced pipe deflection, the installation shall be corrected prior to pressurizing the pipe.

7.2.4 Pressurizing

After the stabilization period, the pressure shall be raised gradually until the intended test pressure at the lowest point is reached.

Unless otherwise specified by the Engineer, the test pressure shall be equal to 1.5 times the intended working pressure of the pipeline section. Once the required test pressure is reached, the pressure should be maintained for a holding period.

During the pressure test, all joints should be visually inspected, and all visual leaks should be repaired. In case the test is not satisfactory, the locations of the leaks shall be determined and rectified, and all the line re-tested in the same manner as specified above. The test section shall be accepted only after successfully passing the above leakage test.

After the field hydrostatic testing is completed, the pressure shall be decreased gradually to avoid any negative pressure (vacuum) inside the pipeline.

During the holding period, if the pressure drops, make sure that the thermal effect nor the air entrapped is not the cause.

8. REPAIR AND REPLACEMENT OF THE PIPE

The replacement of a pipe or a fitting in a Double Bell Coupler jointing system is similar to that of a closure (i.e. laying of the last length of pipe or fitting which closes or completes the line or a section of the line). In the case of the aboveground installation, due to the supporting system, replacing a pipe would mean to use a new pipe of the same length as the old one.

To replace a damaged pipe, cut out a pipe ring from its length and pull out the remaining two pipe sections from the couplers. Pull out these couplers and replace the sealing rings. Insert the new pipe as indicated below:

- Carefully measure the gap where the replacement piece has to be fitted. The replacement piece must be 32 mm shorter than the length of the gap. The pipe must be well centred, and an equal clearance of 16 mm must be left between the inserted pipe and the adjacent ones.
- Use a special pipe with long (double) machined ends especially ordered from Future Pipe Industries.
- Mount the couplers into the calibrated ends of the new pipe after abundantly lubricating the ends and the sealing rings. It will be necessary to gently help the second sealing ring over the chamfered end of the pipe to avoid rubber damage.
- After cleaning them thoroughly, lubricate the ends of the two adjacent pipes.
- Insert the pipe in its final position and pull each coupler over the adjacent pipe up to the home line.

Note 6: GRP material is chemically inert and does not have to be treated as chemical waste. Waste pipe can be disposed of similar to building material in an environment friendly manner.

9. PIPELINE COMMISSIONING

After completing the hydraulic test, the line must be thoroughly flushed out and disinfected (in case of potable water lines), as specified by the engineer or local regulations. In the absence of any such regulations, the following guidelines may be followed.

Disinfecting potable water lines is normally performed using either one of the following chemical mediums:

- Liquid Chlorine
- Sodium Hypochlorite solution
- Calcium Hypochlorite granules or tables

This application gives a solution containing at least 20 to 25 mg/l of free chlorine initially. The disinfecting period is normally 24 hours after which the residual chlorine should not be less than 10 mg/l. After the 24 hours disinfecting period, the line is flushed and filled with potable water.

When commissioning a pipeline, first ensure that all air valves are fully opened to release entrapped air. Fill the line very slowly and evenly at velocities not exceeding 0.3 m / s. Do not open valves quickly and fully during filling. After releasing all air, close air valves and hydrants and open inlet valve fully. If the line is coupled to a pump, the inlet valve should be closed when the pump starts running. Later on, the inlet valve shall be opened slowly. The discharge valve should be closed slowly before shutting down the pump.

More information is contained in AWWA C651 “Standard for disinfecting water mains”.

10. AIR IN PIPELINES, AIR VALVES AND SURGE CONTROL

Air in pressure pipelines can cause major operational problems. Typical problems induced by the presence of such air is the reduction in flow capacity because of reduced cross-sectional areas, and fluctuation in flow caused by expansion and contraction of the air pockets in the line. High surge pressures can result from the flow fluctuations, which cause sudden movements of the air from one location to another, followed by slugs of water. Also, surge (water hammer) can occur in pipelines from opening and closing valves and from the start-up and shutdown of pumps.

Air can enter a pipeline from many locations:
- Line Drains
- Negative surges (vacuum) causing air to enter at air valves in the pipeline
- Intake Source
- Release of dissolved air from the water by temperature and pressure variation
- Draining parts of the pipeline or the pipe system during normal shut-down

In the first instance, air shall be prevented from entering the line. This will reduce operational difficulties.

Suggested solutions for controlling entrapped air in pipelines are as follows:
- The intake point should be provided with low water level pump cut-off Release of air: Air dissolved in the water at the intake and released due to temperature and pressure fluctuations cannot be prevented. However, the quantities of such air are not large and provisions for releasing the air can be made by the means of air valves. Proper selection of air valves is essential.
- While draining the line, air cannot be prevented from entering the line. Large orifice air valves should be provided for exhausting the air during refilling. Long filling times will allow the complete release of air.
- Negative surges (vacuum) - Large volumes of air may be involved here and can cause serious operational problems. The best way to prevent air from entering under these conditions is by proper design to eliminate the possibility of water column separation.

Studies have shown that suddenly released entrapped air under apparently static conditions creates a situation similar to a water hammer. Generated pressures can be of the order of several times the pipeline test pressure. Any pipeline material can be seriously affected by the quick increase in the magnitude of pressure loads.

Remedial actions against entrapped air and water hammer are as follows:
1. It may be advantageous to create artificial high points by providing a small slope of around 3-4 mm per 1000m to facilitate air collection at high points. Also, for drainage, it is recommended to provide a slope of 1-2 m per 1000m.
2. Automatic continual acting air release valves should be used at all major high points. Almost all the air valve Manufacturers limit the maximum distance between air release valves to around 750meters
3. Air should be sucked out from pipeline slowly.
4. Maximum filling velocity of the pipeline is 0.3 m/s.
5. Use d/D = 1/10 to 1/15.
   d = diameter of air release valve D = pipe diameter
6. Using motorized actuated valves is an effective means of limiting positive surges to an acceptable level by controlling the rate of opening and closing the valves.
7. Flywheels on pump motors allow the pump to keep on running for a short period of time after any power shutdown, before it gradually stops.
8. Installing open or pressurized surge tanks in critical area such as near pump discharge.

Note 7: For some pumped systems where the client/owner is concerned about upset conditions or frequent start/stop of the pumps and/or frequent opening and closure of valves, a system surge analysis may be considered to insure that positive and negative pressure surges predicted are within acceptable limits for the pipe pressure and stiffness class supplied. Such surge analysis is typically performed using programs such as: Pipenet, Bosfluids, FlowMaster, HAMMER, and Hytran by specialized Engineering companies. The Young's modulus of elasticity E of pipe supplied should be requested from FPI when undertaking such surge analysis.

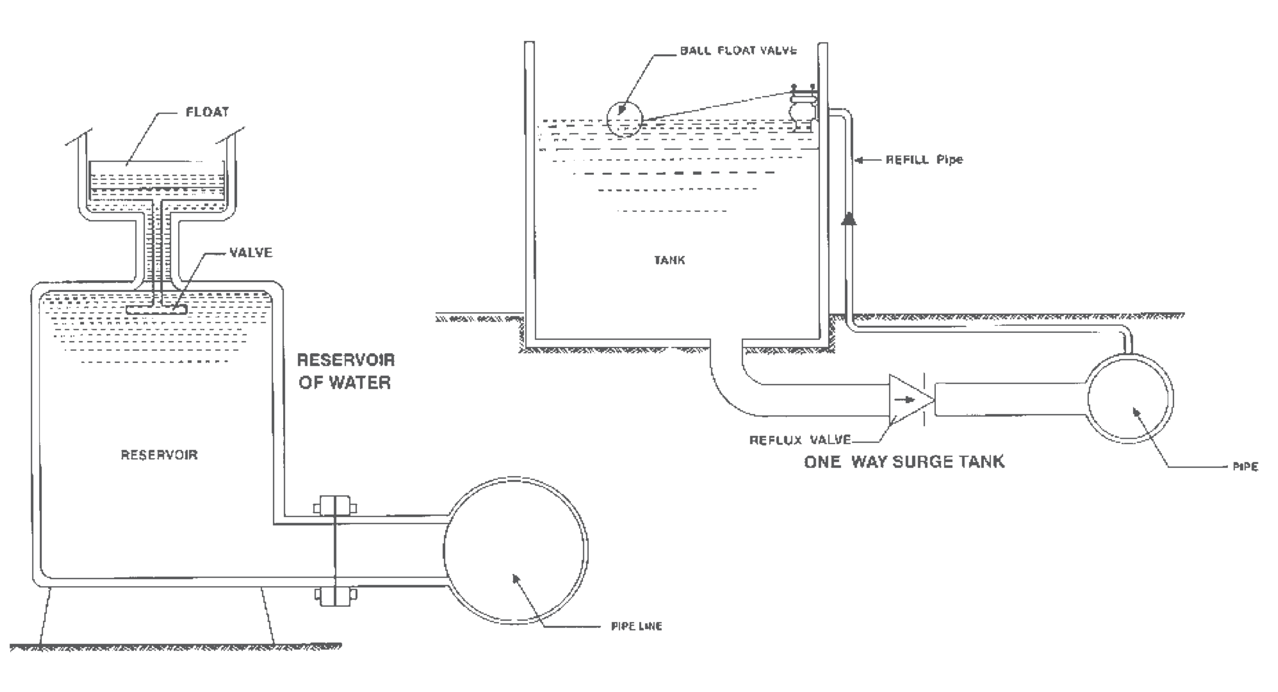


Figure 44 - Typical Surge Control Devices