PVC-O pipes:
reception, storage, installation and test instructions

Index

1. Pipe reception at work

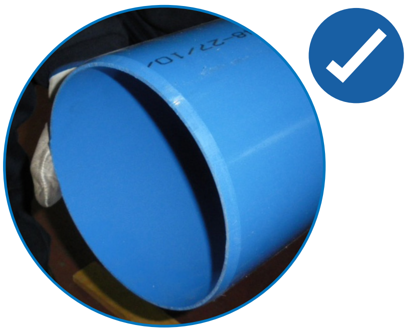
The internal and external aspect of the pipes should be checked at their reception with the aim of verifying their condition before the installation. This means that we should:

- Verify that the **mark of the pipe** corresponds to the requested one and the nominal pressure meets the requirements of each section of the piping system. The mark should include:

	N Mark	NF Mark
Manufacturer Company and Trade Mark	MOLECOR TOM ®	MOLECOR TOM ®
Product certification (1)	AENOR N 001/000857	72/01 NF
Material and Class	PVC - O 500	PVC - BO
Diameter, Wall Tickness and Nominal Diameter	200 x 4,4 - PN 16	200 PN 16 BARS
Coefficient C	C 1,4	-
Date - Hour - Batch	17/02/2019 02:55 59011	17/02/2019 02:55 59011
Reference standard	UNE-EN 17176 ISO 16422 SANS 16422	NF-T 54-948

(1) The updated certificates of the certificated references can be downloaded at www.molecor.com

- Check that the chamfer of the spigot end is in good condition.



- Check that the seals are correctly installed.

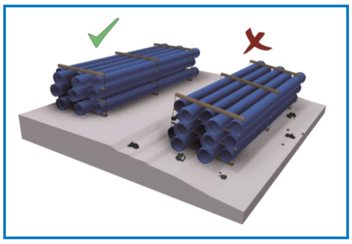
- Verify that the pipes are not damaged, paying special attention to their socket.

2. Unloading and storage

To unload and store the material it is recommended to bear in mind the following aspects:

• To unload the material from the truck flat slings should be used. On the contrary, wired devices or uncovered hooks must be avoided. Unloading must be done in such a way that pipes do not suffer any chafing, i.e, preventing the pipes from rolling on irregular surfaces and store them avoiding abrupt movements.

• Pipes should be stored horizontally on supports placed on a flat surface every 1.5 metres, thus avoiding inadequate bends.



• It is indispensable to prevent pipes from eroding with soil, especially if it consists of stone, concrete or asphalt.

• The recommended storage heights should be respected in each case (1.5 meters roughly), avoiding damaging the pipes placed at the bottom, as well as avoiding any slide caused by the wind or any other phenomenon.

• The sockets must be free, intercalating spigot ends and sockets.

• A minimum distance among the pallets must be kept, in order to guarantee a correct ventilation.

• In case of prolonged sun exposure pipes must be protected with an opaque and breathable material, being preferable the white colour since it avoids over-heating of the pipes.

• Avoid covering the pipes with black tarps without ventilation. Also, we should not store the pipes close to any heat source or in contact with metallic materials as they can transmit high temperatures to the pipes through their conductivity.

3. Pipe handling

One of the main advantages that these pipes present for the installation is their lightness. The weight can difficult the handling of the pipes, complicating consequently the installation process.

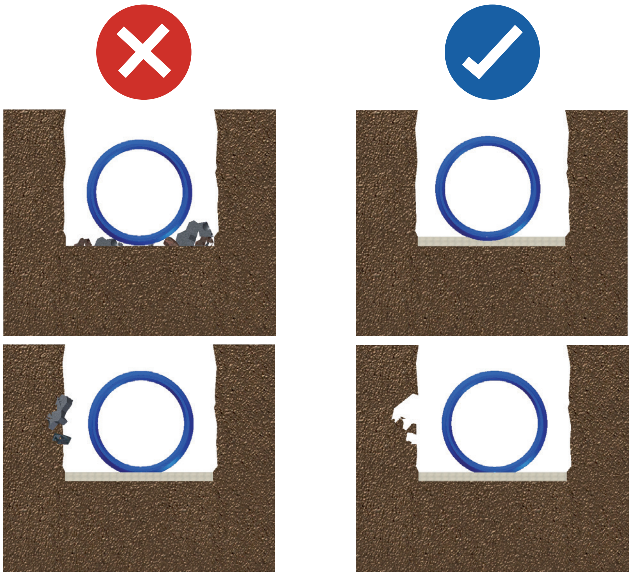
Pipes should never be dragged over the ground since this could cause the loss of material, thereby affecting their mechanical properties.

Correct ways of handling and transporting pipes

4. Trench execution

The bottom of the trench should be regular, stable and free of stones. The pipe must be leaned on granular material. The size of this granular material will depend on the groundwater height in the trench. In those installations affected by groundwater we should use thicker bedding materials without fines, from 8 to 16 mm, depending on the diameter of the pipe to be installed.

In some cases it may even be advisable the use of geotextiles and drainage pipes at the base of the trench.



The minimum width of the trench will be established according to its nominal diameter and depth.

DN (mm)	Minimum with of trench B (m)
90-250	0.60
315	0.85
355	1.10
400	1.10
450	1.15
500	1.20
630	1.35

DN (mm)	Minimum with of trench B (m)
710	1.60
800	1.65
900	1.75
1000	1.85
1100	1.95
1200	2.05

Depth of trench H (m)	Minimum with of trench B (m)
H < 1.00	0.60
1.00 < H < 1.75	0.80
1.75 < H < 4.00	0.90
H > 4.00	1.00

As a general rule, when there is no traffic, the upper generatrix of the pipe shall be at a minimum depth of 0.6 metres, extending in the case of road traffic to a minimum depth of 1 metre. In this case, it shall require verification by means of the corresponding mechanical calculation according to the most unfavourable hypothesis foreseen for its use. In any case, the installation depth of the pipe must be studied for each particular case, taking into account the burial conditions of the pipe and the external loads.

In addition, the pipes must be protected from the effects of traffic and external temperature. The principles to be taken into account when building a trench in which two pipes are to be installed are exactly the same as in the case of a trench in which only one pipe will be installed.

- Geometric factors of the trench
- Type of support of the pipe in the trench (angle of support)
- Type of soil or support and backfill material
- Degree of compaction of the backing and backfill material

The most important difference is the absence of natural soil between the pipes in the trench. For this reason, we must fill and compact the backfill in such a way that the material simulates having the same behaviour as natural soil, being able to support the pipe's lateral thrusts. This way an intolerable deformation is avoided.

When, for any reason (groundwater, lack of space...), it is impossible to achieve the necessary degree of compaction , we normally recommend the use of self-compacting materials such as sand, gravel, etc.

For compacting the filling material without damaging the pipes we should leave enough space for the compactor. The Standard **UNE 53331 IN** recommends separating the pipes 150 mm more than the size of the widest piece of the compactor. The Pressure Water Transport Pipe Technical Spanish Guide (CEDEX) recommends a distance between the pipes of 70 cm.

We recommend leaving enough distance between pipes, at least 0.4 mm, for a perfect compaction of the material. We also recommend checking any installation using the approppiate mechanical calculation according to the geotechnical data with which we are provided, guaranteeing therefore its viability.

For the correct installation of **Molecor TOM® pipes** it is recommended to follow the next steps:

1. Prepare an aligned and levelled sand bed (or other granular material) with a thickness from 10 to 15 cm before placing the pipes. In those cases in which there is too much water as a consequence of the high phreatic level, we must evacuate it from the trench by pumping or by any other procedure.
2. Lean the pipe on the bed made of granular material. Check that the bottom of the pipe rests on the bed trying to get the maximum penetration into it so that the angle of the material supporting the flanks of the pipe is as large as possible.
3. Prepare properly the bed for a correct assembly without dragging the material as this could cause problems in the union.
4. Once the pipe lies on the bed, the sides must be filled with the selected material. This material must be compacted until a density of the material superior to 95% Proctor Normal is achieved.

5. If the soil nature does not guarantee enough stability we must improve it either by compaction, replacement with other more suitable material or by singular foundations. We insist on the necessity of justifying the decision by the appropriate mechanical calculation.

6. Continue filling the trench with the selected material and compacting it laterally until the upper part of the pipe is buried at least 30 cm. Either light and mechanic vibrating compactors (0.30 kN of maximum weight when working) or light vibrating plates (1kN of maximum weight when working) can be used to achieve that level of compaction.

The structural properties of the backfill depend mainly on the type of material and the degree of compaction obtained. The degree of compaction can change with the use of different equipment or changing the number of layers.

The following table shows, according to the Standard **UNE-ENV 1046**, the maximum recommended thickness of the layers and the number of repetitions needed in order to achieve the required compaction class around the pipe for the different types of compactors and backfills. It also includes the minimum recommended coverage thickness required above the pipe before using the compaction equipment.

Equipment	Nº of repetitions needed to achieve the required class compaction		Maximum thickness of the layer in meters after compaction for each type of soil (See Annex A)				Minimum thickness above the upper part of the pipe before compaction
	Well	Moderate	1	2	3	4	m
Manual compacting: Min 15 kg	3	1	0.15	0.10	0.10	0.10	0.20
Vibrating compaction: min 70 kg	3	1	0.30	0.25	0.20	0.15	0.30
Vibrating plate:							
Min 50 kg	4	1	0.10				0.15
Min 100 kg	4	1	0.15	0.10			0.15
Min 200 kg	4	1	0.20	0.15	0.10		0.20
Min 400 kg	4	1	0.30	0.25	0.15	0.10	0.30
Min 600 kg	4	1	0.40	0.30	0.20	0.15	0.50
Vibrating roller:							
Min 15 kN/m	6	2	0.35	0.25	0.20		0.60
Min 30 kN/m	6	2	0.60	0.50	0.30		1.20
Min 45 kN/m	6	2	1.00	0.75	0.40		1.80
Min 65 kN/m	6	2	1.50	1.10	0.60		2.40
Double vibrating roller:							
Min 5 kN/m	6	2	0.15	0.10			0.20
Min 10 kN/m	6	2	0.25	0.20	0.15		0.45
Min 20 kN/m	6	2	0.35	0.30	0.20		0.60
Min 30 kN/m	6	2	0.50	0.40	0.30		0.85
Triple heavy roller: (No vibration) Min 50 kN/m	6	2	0.25	0.20	0.20		1

7. The steps 4 and 6 can be executed using the material coming from the excavation as long as:

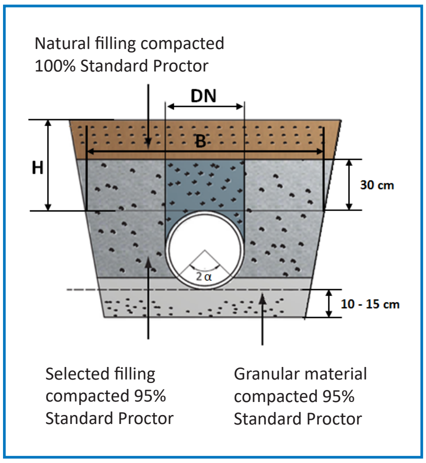
a) The material does not contain stones with a high number of edges.
b) The material does not contain particles with bigger dimensions than the ones shown in the table below.
c) The material does not contain blocks of soil twice the size of the maximum dimensions of the particles given in the table.

Maximum particle size

Nominal Diameter DN	Maximum size mm
DN < 100	15
100 ≤ DN <300	20
300 ≤ DN <600	30
600 ≤ DN	40

Any specific standard related to the filling of the trench as well as any instruction given by the Project Manager will have priority over any of the previous recommendations. Every singular case must be studied independently.

The trench must be adapted to any particular circumstance that may arise during the installation of the network: junctions, rivers and streams, gas pipelines, etc.



8. Natural soil can be used as a filler and can be compacted directly over all the surface of the trench 30 cm above the crown of the pipe.

All the necessary measures to avoid the flotation of the pipe will be taken during installation (it will also depend on the instructions given by the Project Manager).

5. Pipe assembly

The installation of the pipes should be started at those ends where the flow of each section is lower, locating preferably the sockets of the pipes upstream, although the direction of the installation is independent of the flow's one. In case of a high phreatic level it is recommended to install the trench on an up-gradient.

The nexts steps must be followed for a correct installation and assembly of the pipe.

1. Remove the protective covers if they have been supplied.

2. Verify that the pipe is clean and in good conditions paying special attention to the sockets and the spigot ends.

3. Check that the chamfer is free of imperfections and scratches.

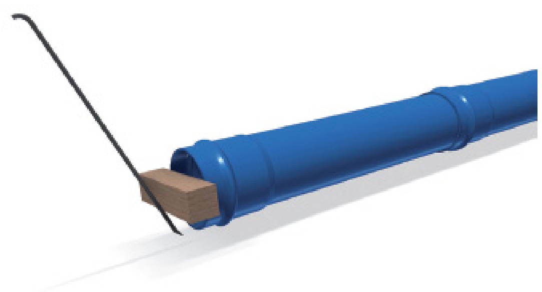
4. Check that the seal is clean, without foreign elements (stones, sand, etc.), and properly placed.

5. Lubricate the chamfer of the spigot and the seal with joint lubricant. The lubricant used in drinking water systems must be safe for human health. No greases and mineral oils can be used.

6. Align the pipe as much as possible, both horizontally and vertically.

7. Insert the chamfer edge into the socket in such a way that it is capable of supporting the pipe leaving free the rest of the pipe.

8. Give a firm and dry push to seize the inertia produced by the displacement and introduce the lip of the socket until the mark is hidden inside the socket.

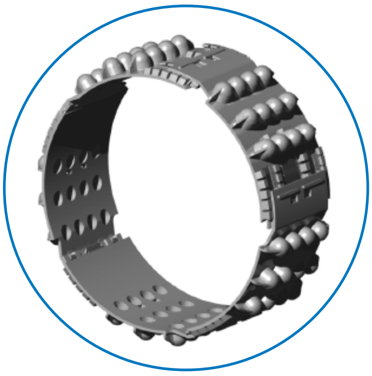


9. To join pipes of large diameters (>250mm), the help of mechanical means will be necessary using materials such as wood, tackles or slings.

The following table shows the approximate performance of 1Kg of lubricant and the number of joints per diameter:

DN (mm)	90	110	125	140	160	200	225	250	315	355	400	450	500	630	710	800	900	1000	1100	1200
Unions	87	76	65	54	46	34	32	30	25	21	17	16	14	12	11	9	8	7	7	6

10. To install TOM® PVC-O pipes with pipes of other materials it is advisable to fix the pipe with separators since they protect the pipe from scratches and avoid the movements caused by different efforts.

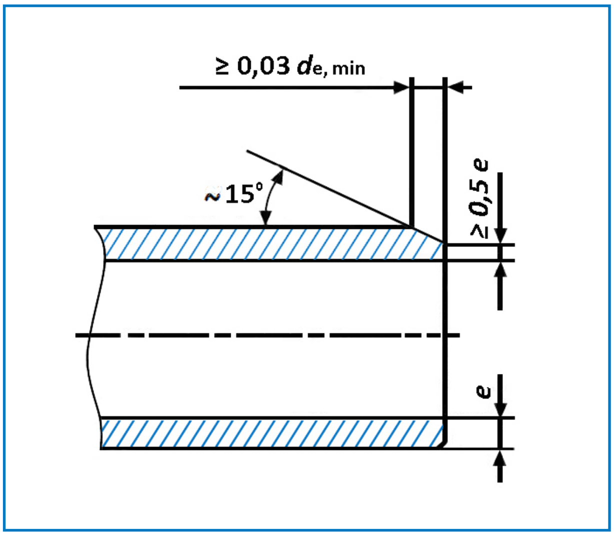


6. Pipe cutting

Pipes can be cut transversally using a circular saw or a hacksaw. The cut must be perpendicular to the pipe. For this reason it is advisable to mark the cutting line previously.

The male spigots resulting from the cut must be chamfered in order to introduce them into the socket of other fitting or pipe. The chamfer can be made with a circular saw and smoothed with a file. The chamfer should be roughly 15°.

To make these operations it is recommended to use a mask in order to avoid inhaling the dust produced during the cuts. It is also advisable to take the necessary security measures when using cutting machines.



The pipes chamfered on-site present a less precise geometry than those made at the factory, reason why they may require higher efforts or even simple mechanical means to introduce the spigot end inside the socket.

7. Special pieces, connections with other materials and reparations

The special connecting pieces will be metallic and must meet the requirements and singularities of the pipeline and the installation process.

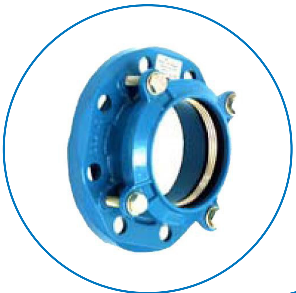
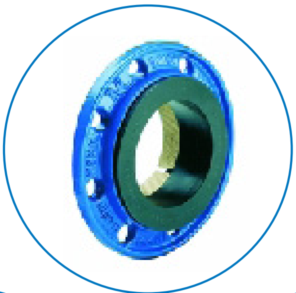
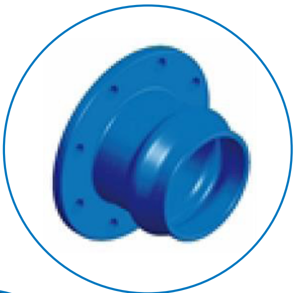
In this group of pieces we include: bends with different angles, Tees connections, flanged adaptors, tapping saddles, universal couplings, reductions...

- Socketed fittings with elastic joint

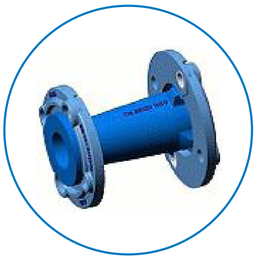




- Flanged adaptors

- Flanged fittings

- Self-locking fittings

- Saddles

• Large diameters steel fittings



The following points should be taken into consideration when selecting the fittings for TOM® pipes:

• Use fittings that meet the requirements of the Standard **UNE-EN 12842** *"Ductile fittings for PVC-U and PE systems. Requirements and test methods."* and the **UNE-EN 545** *"Ductile iron pipes, connectors and fittings and their unions for water canalizations. Requirements and test methods"*.

• Use homologated fittings.

• Install the fittings correctly following the assembly instructions given by the manufacturers.

• Use appropiate screws to avoid corrosion problems.

Joints must not be forced in order to avoid the transmission of higher stresses to the system. The piece should always be installed perpendicularly to the pipe. Flanges and other elements connected with screws will be tightened in an alternative and opposite way.

The use of full bodied tapping saddles or double screw with limit ones is recommended in order to avoid that the excess of force applied by the operators damages the pipe.



Due to the use of semi-lunar components with the same dimension as the pipes, a circumferential compression is produced along them. Consequently, pipes do not suffer any deformation.

We do not recommend using small diameters tapping saddles without limit (<250 mm) (see the picture below) because their wall is thinner than that of large diameter. This means that an excessive force applied by the operator could produce deformations and provoke leakages due to the lack of watertight.


There are different elements on the market to make the necessary reparations during the operation period. In this document we recommend some of them depending on the type of breakdown or incidence to be solved ("Guía Técnica sobre tuberías para el transporte de agua a presión - Centro de Estudios y Experimentación de Obras Públicas. Centro de Estudios Hidrográficos del CEDEX").

The **Gibault unions** are suitable to be used in unions or repairs without angulation.

For their correct installation we have to:

- Chamfer the resulting male cut ends of the pipes.

- Measure and mark the parts of the male ends that are going to be introduced so that they take up the same space inside the fitting maintaining 2 cm distance between them.


When a repair with angulation is required we will use fittings compatible with 3° joints.


Other multi-diameter fittings can be used with **TOM® pipes** whenever the manufacturer verify their compatibility.

Contact Molecor if you have any doubt about the compatibility of any fitting with TOM® pipes or about the compliance review.


When installing pressure fittings we should bear in mind that plastic pipes are flexible and compatible with fittings of the same material such as tree type repairing couplers or similar etc. as long as the assembly is performed correctly. The assembly must be performed with a dynamometric key, adjusting the torques according to the information shown in each piece or in the manufacturer technical documents.



How to connect two pipes with flanges?

It is the most common way of connecting pipes of different materials. It is also the most common way of connecting PVC-O pipes with the different elements of the hydraulic network (valves, derivations of vents, special pieces...).

Although at first sight it doesn´t seem to be a complex process, before connecting the pipes, we should take into consideration several aspects in order to attain a correct union.

- **Pipe´s section**. Is the stretch where the pipe is connected to the fitting by a saddle. Due to this we can calculate with precision the number of screws needed.

- **Channeled flow´s pressure.** This factor affects both the number of screws to be installed and the thickness of the saddle since it has to endure the stresses caused by the installed screws.

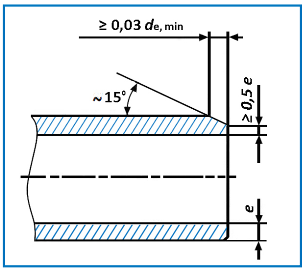
- **Pressure control key.** This tools are suitable for tightening the screws since an excessive pressure over the nuts could colapse the pipe and cause cracks in the saddle.

Procedure

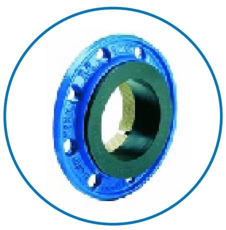
Cutting mark

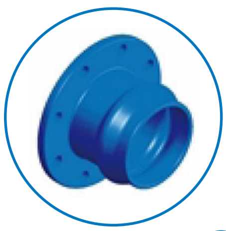
1. Cut the pipe transversely (draw the cutting line previously to ensure that the cut is perpendicular to the pipe).

2. Chamfer the male ends with a 15° inclination and a 0.03 x ED (External Diameter) length (shown in the picture) using the same saw. If the chamfers were not made, the efforts needed to introduce the male ends into the repairing fittings would be higher.



3. Choose the most suitable fitting depending on:
    - Material of the pipes
    - Hydraulic requirements
    - Angulation between pipes
    - Quality of the soil
    - ...





4. The selection of the screws, which is made according to the stresses and the aggressiveness of the soil that is going to cover the union, is as important as it is the election of a suitable fitting.
The classification of the screws based on their quality is normally specified by the Standard UNE-EN ISO 898-1. This Standard defines the following values of quality: 4.6, 5.6, 5.8, 6.8, 8.8, 10.9 and 12.9.

The **first number** multiplied by 100 represents the breaking resistance of a screw in Newtons (per square millimeter).
The resistance shown by the first number corresponds to the resistance that once is surpassed, the screw breaks. For this reason, it is not advisable to choose the screw according to its capacity, but its to **elastic limit**.

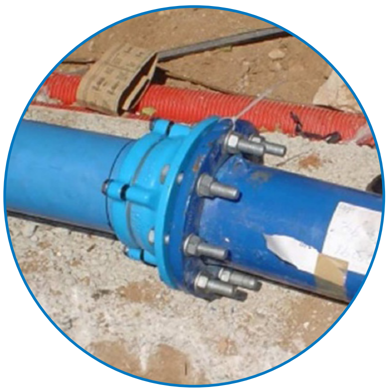
The **second number** shows what % of the breaking limit (%) is elastic limit.

- A **screw 6.8** has a resistance or breaking limit of 6 x 100 = 600 N/mm²
- A **screw .8** indicates that 80% of the breaking limit is the elastic limit. Thus, this screw elastic limit would be 600 x 0.8 = 480 N/mm²

5. Follow the fitting manufacturer instructions for its installation, depending on the material of the pipes that we want to connect. We have to respect the tightening torques defined by the manufacturer using a dynamometric key.

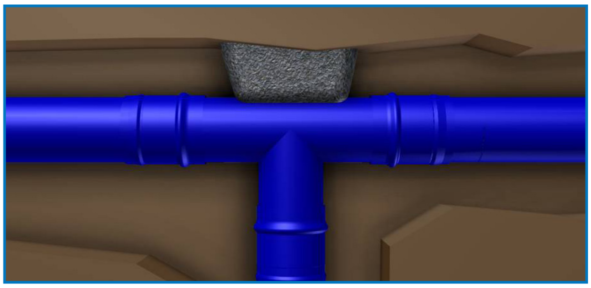
The union should not transmit stresses to the up and downstream installed pipes, mostly when we use materials that expand with changes of temperature (polyethylene). Because of this, we should respect the insertion length in the fitting and the tightening torques defined by the fitting manufacturer.

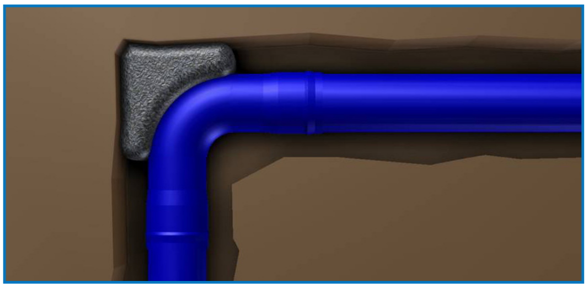
There are water management companies that in case of using polyethylene with other materials, have adopted the criteria of installing ductile intermediate fittings. These fittings are anchored to thrust blocks in order to isolate the other material from the tractions originated by the polyethylene dilatation.

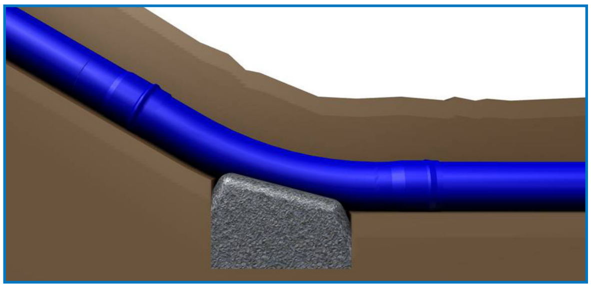


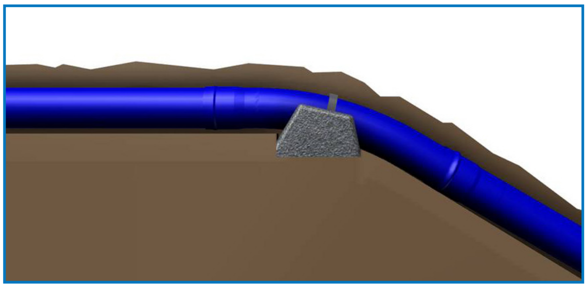
8. Anchoring

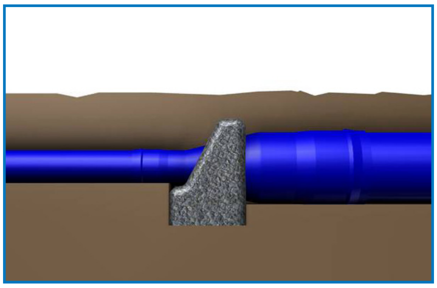
Due to the thrust forces caused by internal pressures, all the special pieces must be conveniently anchored in order to avoid their displacement. Furthermore, we should not surround the pipe completely with concrete in order to be capable of checking the installation correctly.

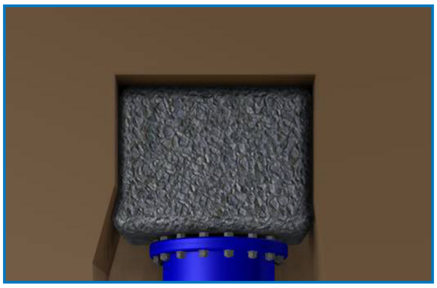












In installations with steep slopes, transverse anchors shall be used to prevent the pipeline from slipping.

The shape and size of the concrete mass will depend on the element to be anchored, the internal pressure, the resistance of the ground on which the mass will rest and the other possible stresses.

These anchorages must be dimensioned taking into account the most unfavourable case in terms of internal pressure, being aware that the STP (test pressure) may be greater than the actual pipe jacking.

Before pressure testing, all anchorages must have achieved adequate strength.

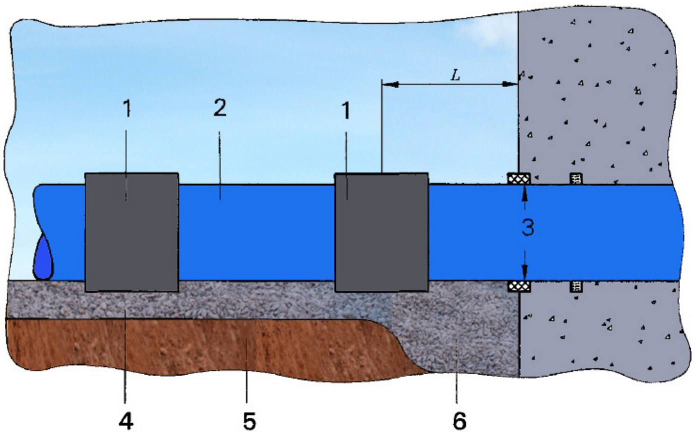
Shut-off valves, whether butterfly or gate valves, must also be anchored to withstand the maximum possible stress in the most unfavourable case during operation of the installation.

When a pipe gets inside or leaves an structure such as a building, anchor, etc. different means should be forecasted for a correct settlement. For this reason, the Standard UNE ENV-1046:2001 recommends, mostly in large diameter pipes, the installation of 2 meters long rocker pipe (nº 2 in the picture below).

The first flexible joint should be placed at the highest distance within these two values:

- L de 400 mm
- 0.5 x de (0.5 x external diameter)

Caption:
1. Flexible joint
2. Pipe section:
 - max 2 meters
 - min 1 meter
3. Rubber or asphalt
4. Pipe´s bed
5. Natural soil
6. Compacted material



9. Curvature of the pipe at environmental temperature (23°C)

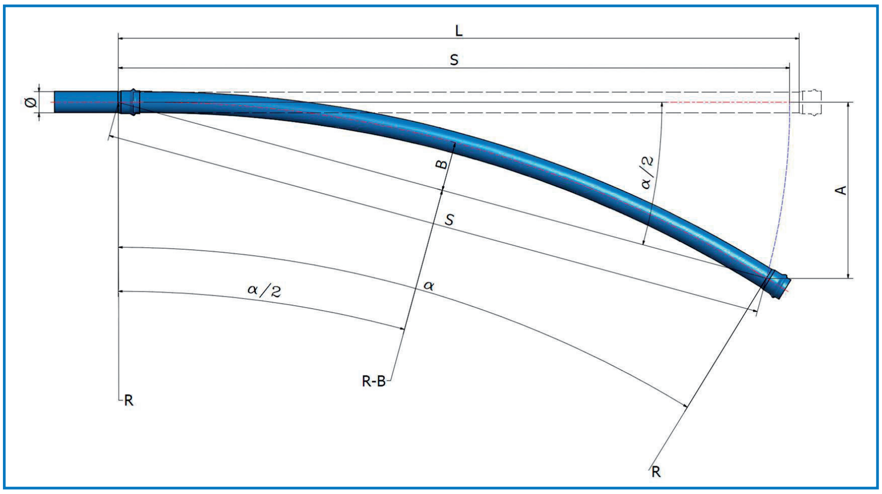
Pipes may be curved in the trench (roughly at 23°C) up to the limits defined in the table. These angular deviations should be done always in cold by manual efforts (without heating up any part of the pipe or of the socket). For pipes which DN > 250 mm, simple elements could be used for helping without damaging the geometry of the unions.

Ø= Outside Diameter, OD

- R= 200 Ø

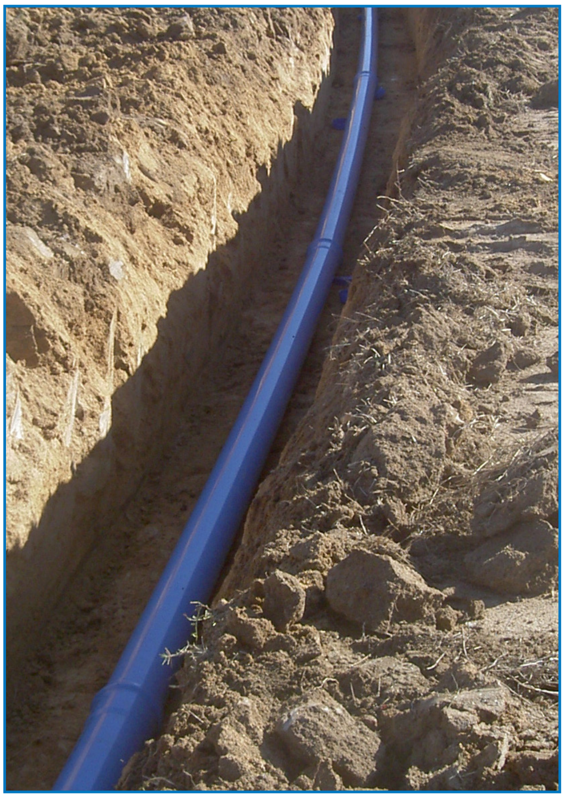
$$\alpha° = \frac{180\ L}{\pi R}$$

- $S = 2R \times \text{sen} \frac{\alpha°}{2}$
- $A = S \times \text{sen} \frac{\alpha°}{2}$
- $B = R - R \times \cos \frac{\alpha°}{2}$



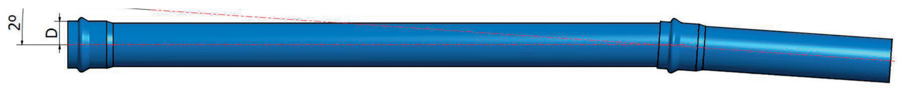
Pipes can be subjected to greater angular deviations if they are exposed to high efforts, but it is not recommendable to surpass these limits in order to avoid endangering the safety coefficients of the pipe.

		Pipe curvature			Angular deviation of the socket	Curvature + angular deviation (total angle)		
DN	L	R	α'/2	A'	angle	R'	α'/2	A'
mm	m	m	degrees	m	degrees	m	degrees	m
90	5.78	18	9.2	0.92	2	15	11.2	1.12
110	5.78	22	7.5	0.75	2	17	9.5	0.95
125	5.77	25	6.6	0.66	2	19	8.6	0.86
140	5.76	28	5.9	0.59	2	21	7.9	0.79
160	5.75	32	5.1	0.52	2	23	7.1	0.71
200	5.73	40	4.1	0.41	2	27	6.1	0.61
225	5.7	45	3.6	0.36	2	29	5.6	0.56
250	5.68	50	3.3	0.32	2	31	5.3	0.52
315	5.63	63	2.6	0.25	2	35	4.6	0.45
355	5.61	71	2.3	0.22	2	38	4.3	0.42
400	5.58	80	2	0.19	2	40	4	0.39
450	5.56	90	1,8	0.17	2	42	3.8	0.37
500	5.58	100	1.6	0.16	2	44	3.6	0.35
630	5.53	126	1.3	0.12	2	49	3.3	0.31
710	5.45	142	1.1	0.1	2	50	3.1	0.29
800	5.42	160	1	0.09	2	52	3	0.28
900	5.39	180	0.9	0,08	2	54	2.9	0.27
1000	5.39	200	0.8	0.07	2	56	2.8	0.26
1100	5.36	220	0.7	0.07	2	57	2.7	0.25
1200	5.33	240	0.6	0.06	2	58	2.6	0.24



10. Angular deviation in the socket

Besides the pipe´s curvature, an angular deviation at their union point is allowed. It is important not to exceed the established angular deviation values in the socket-spigot when performing the pipe´s curvature.



DN	Maximum angular deviation	Displacement between sockets
mm	angle (°)	D (mm)(1)
90 - 1200	2°	200

(1) Pipes of 5.95 meters total length

Pipe unions can be subjected to greater angular deviations if they are exposed to high efforts. It is not recommendable to exceed these limits in order to avoid endangering the safety coefficients of these unions subjected to pressure.

10.1. Against efforts produced as a consequence of the curvature of the pipe

Angular deviations in the pipes are allowed so that they can follow a desired line. Backpressures are produced as a consequence of these angular deviations. Under normal conditions, if the ground is compacted enough, these backpressures can be perfectly withstood. However, in those cases where the curvature is too high, the use of anchors may be necessary.

	Stresses in a curved pipe in (α/2) (2) Bar					
DN	1	5	10	15	20	25
mm	kN	kN	kN	kN	kN	kN
90	0.10	0.51	1.02	1.53	2.04	2.55
110	0.12	0.62	1.25	1.87	2.49	3.12
125	0.14	0.71	1.42	2.12	2.83	3.54
140	0.16	0.79	1.58	2.37	3.17	3.96
160	0.18	0.90	1.81	2.71	3.61	4.51
200	0.22	1.12	2.25	3.37	4.50	5.62
225	0.25	1.26	2.52	3.78	5.04	6.29
250	0.28	1.39	2.79	4.18	5.58	6.97
315	0.35	1.74	3.48	5.22	6.96	8.70
355	0.39	1.96	3.91	5.87	7.82	9.78
400	0.44	2.19	4.38	6.57	8.76	10.96
450	0.49	2.46	4.91	7.37	9.82	12.28
500	0.55	2.74	5.48	8.22	10.96	13.69
630	0.68	3.42	6.84	10.26	13.68	17.10
710	0.76	3.80	7.60	11.40	15.20	18.99
800	0.85	4.26	8.51	12.77	17.03	21.28
900	0.95	4.76	9.52	14.29	19.05	23.81
1000	1.06	5.29	10.57	15.86	21.15	26.43
1100	1.16	5.79	11.58	17.37	23.15	28.94
1200	1.25	6.27	12.55	18.82	25.09	31.37

(2) Stresses in each 5.95 meters pipe

11. Hydrostatic tests

Molecor´s recommendations at this respect are based on the Standard UNE-EN 805:2000 and on the technical team experience. To extend the information included in this section we should consult Molecor´s technical document "Hydrostatic testing pressure pipes procedure and recommendations".

The entire procedure for a pressure test shoud include:

- Preliminary test phase
- Air vent test phase
- Main test phase

We will focus on the preliminary test phase and on the recommendations given to determine the pressure test and its duration.

In the main test phase two basic testing methods are admitted:

A - Pressure drop method
B - Water loss method

A - Pressure drop method

The Standard Test Pressure (STP) is calculated on the basis of the Maximum Design Pressure (MDP). Depending on whether the water hammer has been calculated in detail or just estimated the Standard Test Pressure will be (all values in N/mm2):

- Once the water hammer is calculated the formula to be applied is:

$$STP = MDPc + 1\ Kg/cm^2$$

Where:
- STP: Standard Test Pressure
- MDP: Maximum Design Pressure

For a **PN16** pipe the maximum test pressure would be **17 atm**.
For a **PN25** pipe the maximum test pressure would be **26 atm**.

- In those cases in which the water hammer has not been calculated we will consider the lowest of the two values:

Following the previous example:

$$STP = MDPa + 5\ atm$$
$$STP = MDPa \times 1.5\ atm$$

- STP = 16 atm + 5 atm = 21 atm
  STP = 16 atm x 1,5 atm = 24 atm
- STP = 25 atm + 5 atm = 30 atm
  STP = 25 atm x 1,5 atm = 37,5 atm

The maximum test pressure established would be of 21 atm for the PN16 pipe and of 30 atm for the PN25 one.

This option should be applied only if it is considered a significant technical deficiency, since our experience has demonstrated that installations which pressures in operation surpass the MPD of the networks and which efficiency and durability are not compatible with the standard durability requirements, can be executed.

The duration of the pressure drop test should be of 1 hour, but it can be extended if the Project Manager decides so. During the test, the pressure drop Δp must show a regressive trend and at the end of the first hour it must not exceed 20 kPa.

Expertise and the available technical means allow us to design the current networks including, in most of the cases, calculations of the stresses that pipes should withstand during the explotation phase.

If the calculations are correct it will not be necessary to work in a range of pressures in which we should never work.

For this reason, the maximum test pressure should never exceed the maximum design pressure of the pipelines and of the rest of the elements of the system. This would be a mistake and a technical discrepancy that could cause an impact on the elements life expectancy, which is the main cause of additional operating costs.

B - Water loss method

Two methods may be used to measure the water loss and the volume of the evacuated and pumped water (injected). The Project Manager has to define the procedure to be followed.

At the end of the first hour of the test the water loss should not exceed the value calculated by the following formula:

$$\Delta V_{máx} = 1{,}2V.\ \Delta p[1/E_w + ID/e.E_R]$$

- ΔV_{max} admissible loss (litres)
- V volume of the stretch to be tested (litres)
- Δp admissible pressure drop during the test (20 kPa)
- Ew bulk modulus of the water (2,1 x 10^6 kPa)
- E_R modulus of ductility of the pipe´s material (kPa)
- ID internal diameter of the pipe (m)
- e nominal thickness of the pipe (m)
- 1,2: correction factor that takes into account, among other aspects, the effect of remaining air inside the pipe

12. Temperature effects

We have to take into account the loss of mechanical properties that takes place when the temperature is very high. Thus, we should avoid the following conditions during the pressure test:

- Pipe partially or fully exposed outdoors
- High external temperature
- Stagnant water inside the pipe
- Prolonged sun exposure prior to the test

All these circumstances may increase the pipe´s temperature above the operation temperature. For this reason, the overpressures of the test could damage the pipe.

Against this fact it is recommended:

- To cover the pipe once the tightness of the network is verified.
- To avoid doing the pressure test after a prolonged sun exposure of the pipes.

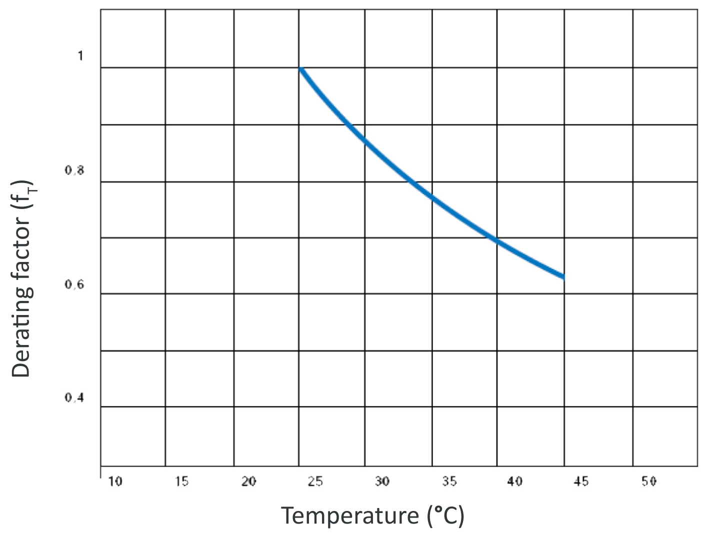
The **Allowable Operating Pressure (PFA)** of the pipe can be reduced with respect to the Nominal Pressure (NP) by high temperatures (higher than 25°C) as well as by demanding or aggressive applications.

$$PFA = PN.\int_T . \int_A$$

- The derating factor (f_t) as function of operating temperature can be obtained from the graph below.
- The derating factor (f_a) related to the application of the system must be determined by the Project Manager.

NOTE: The design of a project and the installation process are responsability of the Project Manager and of the constructor, respectively.

Temperature coefficient graph



$$PFA = PN . \int_T$$

13. Conclusions

• The performance of a mandatory test of the network via pump groups of the pump station should never exempt the partial achievement by satisfactory tests of every stretch of the network.

• The instructions given by the Project Manager and the General Technical Specifications document will prevail over any other recommendation.

• The length of the stretches to be tested should be between 500 and 1,000 meters. The same stretch should not contain pipes of different materials, working pressures, diameters or nominal stiffnesses unless the Project Manager says so.

• The designer or, in his absence, the Project Manager should specify the design pressures (DP), the maximum design pressure (MDP) and the test pressure (STP), taking into account all the suitable flow conditions.

• Thrust blocks should be correctly dimensioned bearing in mind the pressure at which the network is going to be tested (STP).

• All the security measures needed to protect the life of people involved in the process must be taken. The pressures to which the pipes and the different elements of the system will be subjected are very high, therefore all the elements must be perfectly anchored and the analyzed area isolated and protected.

• Water filling of the stretch must be carried out at the lowest point and at a speed that allows the evacuation of the existing air. Air trapped inside the pipe is one of the main reasons why pressure tests may not success.

• The pressure test may be done in phases, beginning in a filling and pressurization preliminary stage until the stabilization of the system takes place. This is followed by a phase of air venting that should ensure us that we have been capable of removing the air inside the pipe. To finish, the main phase in which the pipe is pressurized at the pressure test (STP).

• It is essential to establish the pressure test (STP). In this document, different possibilities have been shown according to the Standard UNE-EN 805, the MOPU / 1974, and even other criteria adopted by different administrations.

• Our opinion, based on our experience, is that the maximum pressure test should never exceed the maximum design pressure of the pipes and of other elements since this would be a mistake an a technical contradiction that may cause an impact on the life expectancy of these elements. This impact is the main cause of additional operating costs.

• Expertise and the available technical means allow us to design the networks including, in most of the cases, calculations of the stresses that pipes will have to endure during the explotation phase.

• If the calculations are correct it will not be necessary to work in a range of pressures in which we should never work.

• In case of testing uncovered pipes in summer or in areas with hot temperatures we should take into account the temperature´s effects on the system.

14. Legislation and bibliographic references

- **UNE-EN 805:2000** – Water supply. Specifications for systems and components outside buildings.

- **UNE-ISO 16422:2015** – Poly (vinyl chloride) Oriented (PVC-O) pipes and joints for the conveyance of water under pressure. Specifications.

- **Water pressure transport pipes Technical Guide**. Study and experimentation center for public works. **CEDEX** Hydrographic Study Center.

- **UNE 53331:1997 IN** – Unplastized poly (vinyl chloride) and high and medium density polyethylene (PE) pipes. Criteria for checking the pipes to be used in conductions with or without pressure subjected to external loads.

- **UNE-EN 1610:2016** – Construction and testing of drains and sewers.

- **UNE-ENV1046:2002** – Piping systems in plastic materials. Systems for the conveyance of water or sewage outside the structure of the buildings. Best practice for air and buried installations.

- **UNE-ENV 1452-6-2002** – Piping systems in plastic materials for the conveyance of water. Unplastized Poly (vinyl chloride) (PVC-U). Part 6: Best practice for installation (June 2002).

- **UNE-EN 12842** – Ductile iron fittings for PVC-U or PE piping systems. Requirements and testing methods.

- **UNE-EN 545:2011** – Ductile iron pipes and fittings and their unions for water systems. Requirements and testing methods.

- **UNE-EN 12842:2013** – Ductile iron fittings for PVC-U or PE systems. Requirements and testing methods.

- **UNE-EN ISO 898-1:2015** – Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread (ISO 898-1:2013)

- **197410-001 Order from 28th July 1974** by which the General Technical Specifications guide for water supply pipes is approved and by which the Standing Comission for Water Supply and Sanitation Pipelines is created”.

- Technical Manual for Network Design and Use. **Molecor** TOM® PVC-O pipes.

- Technical Manual for PVC pipes - **ASETUB** (Spanish association for manufacturers of plastic pipes and fittings).

- PVC pipes. PVC Technical Manual - **ASETUB** (Spanish association for manufacturers of plastic pipes and fittings).

- Plastic pipes installation manual. Supply, irrigation and sewage - **ASETUB** (Spanish association for manufacturers of plastic pipes and fittings).

15. Technical assistance

Molecor has available a technical assistance service for its customers in order to solve any doubt that may arise during the design and installation processes.

Our after-sales technical department will provide technical assistance on-site and will analyze all the questions that may arise from the hydraulic/mechanical calculations.